TMOS

2022 ANNUAL REPORT

The Next Generation

Contents

Centre

Message from the Director

2022 was an important year for TMOS. Firstly, interstate and overseas travel opened for us to meet and undertake many activities in person. I will never forget the enthusiasm of all students and early career researchers attending the first outreach workshop at Questacon on 9th of March. The ability to create together and the excitement to share what they'd learned was enormous. Once we ramped up the in-person activities at the Centre, we started interacting much more robustly as a team. The events culminated with the Centre's first annual conference, held this year at Murray Bridge in November 2022. It was clear that the in-person interactions are the catalyst for fruitful collaboration. These social interactions have genuinely nurtured the creative intellectual environment and brainstorming culture for innovations at the Centre. In addition, they provided the next generation of researchers with an opportunity to form networks with their peers. It is the relationships they form now, early on in their careers, that will lead to research success further down the line.

To increase the impact of our research, in June 2022, the Centre established two flagship projects linking the activities from all three research themes to accelerate industry and cross-node engagement. These flagships have been designed to provide the glue between the individual building blocks of the Centre's research program. The two flagships are 1) real-time holographic displays-cameras and 2) integrated sensors (wearable and portable). The establishment of the Centre's flagships has created a focal point for the Chief Investigators' efforts to define problems for which the new generation of meta-optics technology students can provide ground-breaking solutions.

This year, our research program has delivered stunning results. The team's research output has resulted in a total of 100 publications in refereed journals. Several of these publications were the product of cross-node collaborations and collaborations with Partner Investigators. Even with these achievements, we are still seeing the ripple effects of the COVID-19 lockdowns with cross-node outputs not where we'd initially planned. With laboratories now open and the cross-node exchange program established, we are confident that the collaborative research activities will drive a higher number of cross-node publications in 2023.

Notably, our research outputs have been directly linked to tangible outcomes. We are particularly proud of the four start-ups launched by the Centre's next generation of entrepreneurs. These include Luminere Systems, a quantum communications company spearheaded by the Centre's University of Technology Sydney; Hyrea, a sustainable energy start-up from the Australian National University (ANU); MagicWavelength, which uses new infrared technology to assist with agriculture and is led by the University of Western Australia team; and VIcolours, also by ANU researchers, which is leading the way in plasmonic colours. We are also proud to see the continued translational activities with our two industry partners, ThermoFisher Scientific and IEE.

Worldwide, we are also witnessing exciting times for our new generation of technology.

“

Worldwide, we are also witnessing exciting times for our new generation of technology.

The first meta-optic device by the Harvard start-up Metalenz has hit the consumer market. This first product, a metalens for mobile phone cameras, has shown that the technology is maturing and the market is interested. In further evidence of such, we have also seen several large companies investing in the research and development of meta-optics technologies. These companies include Apple, Google, Samsung, Meta (Facebook), Huawei, Sony, and STMicroelectronics. The key drivers for this commercial interest are the advantages of meta-optics technology, such as the miniaturisation of optical components to reduce size, weight, and power (SWaP) requirements for optical systems. Such miniaturisation is essential to progress modern consumer optoelectronic devices, drones, and space applications.

However, there are also other fundamental advantages that drive the field. First is meta-optics' ability to enable smart functions that are not readily achievable with conventional optics. These include visualising the hidden information carried by light, such as polarisation, phase, and other modalities, and integrating multiple functions in a single optical element. The second is the way nanoscale volumes of the building blocks of meta-optics offer opportunities for fast and real-time reconfigurability of the optical functions, something that, at TMOS, we are investing considerable effort in.

What does this mean for TMOS? The industry provides direction to guide our world-class research activities. The industrial applications define the open questions and the fundamental research that needs to be done to answer these questions. Their multiple needs also open new commercial opportunities for the Centre's activities. However, to capitalise on these opportunities, we need a deeper engagement with the industry and stronger collaboration between different groups in the Centre.

Finally, the next generation of technology requires a new generation of a skilled and diverse workforce. TMOS has an important role to play on this critical front, as led by IDEA Director Prof. Madhu Bhaskaran. I am proud of the work done by our early career researchers and students. It gives me great pleasure to watch them grow as researchers and earn the accolades they deserve. In particular, I want to acknowledge the achievements of Shridhar Manjunath, who was awarded the SPIE Optics and Photonics Education Scholarship; Dr Lukas Wesemann, who was awarded funding under the Australia-Germany Joint Research Co-operation Scheme, and Dr Daria Smirnova, who was the winner of the 2022 IUPAP Early Career Scientist Prize for Laser Physics and Photonics.

The Centre’s momentum over the past year has quickened. Its outcomes have been positive. I look forward to working with the team of TMOS to see the impact of our research in 2023.

Professor Dragomir Neshev
Centre Director

OUR VISION

The Australian Research Council Centre of Excellence for Transformative Meta-Optical Systems (TMOS) will develop the next generation of miniaturised optical systems with functionalities beyond what is conceivable today.

By harnessing the disruptive concept of meta-optics, we will overcome complex challenges in light generation, manipulation and detection at the nanoscale. Our research outcomes will underpin future technologies, including real-time holographic displays, artificial vision for autonomous systems to see the invisible, wearable medical devices and ultra-fast light-based Wi-Fi, meeting the evolving demands of Industry 4.0.

OUR MISSION

We will become a trans-disciplinary team of world leaders in science, technology, and engineering to deliver scientific innovations in optical systems.

We will translate research into innovative technologies in transport, health, security, defence, agriculture, entertainment and education with significant benefit to society and economic growth.

We will prepare outstanding innovators from diverse backgrounds to be future leaders for decades to come.

OUR VALUES

COLLABORATION

We work together to make a team culture that is inclusive, values diversity, strives for equity, and accessibility (you get the IDEA!) so that everyone can participate.

EDUCATION

We embrace learning and failing forward, gaining insight from each iteration of our experiments, processes and beyond.

DISCOVERY

We do research at the highest international level as an interdisciplinary team. We make the unknown knowable through the pursuit of fundamental science.

INNOVATION

We have a passion for technology innovation due to the positive impact it has on the world. Our science has a purpose.

ENGAGEMENT

Internally, we connect with each other, celebrating our wins and creating a fun and safe workplace. Externally, we engage with partners and the public to share the joy of science, and to translate our research into novel technologies.

Message from the Centre Advisory Board

Strategic investment in science and technology is Australia's path to future economic growth and national prosperity. When the Labour government came into power, Prime Minister Albanese outlined the notion of an economic future powered by science. If COVID-19 taught us anything, it is that continuing advances in science and technology research will secure our nation's health, wellbeing, and economic security.

The TMOS community will undoubtedly play a critical role in this future. Australians are resourceful and innovative; our record of invention ranges from the black box and Wi-Fi to cochlear hearing aids and vaccines to prevent cervical cancer. And having riffled through several papers and publications from TMOS scientists, I have no doubt that pioneers will similarly emerge from the field of meta-optics. I'm honoured to join the Centre Advisory Board and the world-class researchers at TMOS as the Centre evolves, focus on industry partnership and toward identifying commercial pathways for its blue-sky research toward applications that benefit society.

As a technologist straddling space and cloud computing, processing power is an everyday conversation. In the current development of electronic chips, I'm keenly aware Moore's Law is about to meet the physical limit as advanced semiconductor processes continue to approach the 3 nm process. It is becoming more and more difficult to shrink the line width of semi-conductors while the cost gets higher. The development release increases in the computing speed of electronic chips are gradually slowing; conversely, data processing grows unabated.

Photonics is already being heralded as a possible solution across the industry. Photonics that carry high-dimensional information can effectively expand the bandwidth of information operations. Optical neural network computing based on meta-optics can break through the bottleneck of electronic computing power and computing speed. Indeed, as a platform, meta-optics is so flexible it can be slipped into phones, woven into wearables, and seamlessly integrated into computers, autonomous cars, or satellites. The ability to resolve features at the subwavelength scale will revolutionize fields in biology, medicine, environmental monitoring, renewable tech, and materials science. This work is critical.

In order to undertake such highly innovative and potentially transformational research of international caliber, we must focus on skills development, extending existing capabilities, and acquiring knowledge to turn our imagination and curiosity into reality.

I don't just mean technical and scientific skills. It takes many years for individuals to acquire entrepreneurial skills and the industry content knowledge necessary to become leaders in their field. Researchers and scientists are rightly lauded for technical prowess. This focus, however, often leads to a belief that nontechnical skills are less relevant, that the behaviours that typically lead to successful academic careers do not correlate highly with those required in the corporate world. Early-career scientists often must calibrate their behaviours to align with corporate expectations to successfully get a product to market for societal impact.

This includes an appetite for interdisciplinary and collaborative approaches–to communicate, to develop relationships, network, pick up mentors, to build networks with national and international research institutions, and cultivating industry linkages. To storytell, be comfortable pitching, understand how to raise funds. To lead a team and galvanise them towards goals, to think entrepreneurially about patents, tech transfer, scaling, the applicability of product on the consumer market and crossing the chasm from scientific discovery to commercial success.

My own academic background is a medley of physiology, computer science, and technology innovation. I know from experience it is not always easy for well-trained logical heads to consider so-called soft skills. But it was soft skills that allowed me to accelerate my career and make an impact on industry. I can quote stats and literature on the importance of soft skills, but take my word for it. Professional development beyond technical skills will boost your career. Academia is a difficult career at the best of times. But so is running a business. Now think about doing both things simultaneously, because that is essentially the path you walk from research to commercialisation.

Finally, I'm delighted that TMOS as a Centre is deeply committed to inclusion and diversity. Science and engineering benefits greatly from a community that approaches problems in a variety of creative ways. A diverse community drives excellence, and is better able to generate new research methods, explanations and ideas, which can help science overcome challenging hurdles and shed new light on problems. Paradigm shifts and revolutionary thinking rarely arise in a homogenous environment. So, it's not just a moral obligation to meet equity goals and national needs, but important for the construction of knowledge and for the enterprise of science itself. In my day job, I'm a huge advocate for diversity and inclusion across space and technology just as I am passionate about leadership development, communication for impact, and collaboration for innovation success.

If these are areas of interest to you, let's chat – I welcome your connection and dialogue. And I look forward to meeting as many of you as possible over the course of the year.

Mani Thiru
Head of Space & Satellite, Asia Pacific, Amazon Web Services

> “As researchers, we bear a critical responsibility to the public. It's incumbent upon us to communicate the significance and value of our work clearly and professionally, persistently explaining what we do so that the public can grasp it. Bridging the gap between science and society is our duty, and we must strive to make the public appreciate and back scientific research. We must accomplish this task to expect the public and policymakers to provide the funds and support we require to enable the next generation of scientists and technology to thrive. Thus, let us approach this responsibility with sincerity and dedication, working towards creating a solid and supportive relationship between science and society.”
>
> - Emeritus Professor Ian Chubb AC FAA FTSE, Chairman of the Centre Advisory Board

Message from the International Scientific Advisory Committee

When thinking about the next generation, the theme of this year's TMOS annual report, my mind goes to the current Fourth Industrial Revolution, where the boundary between humans and technology is beginning to blur.

Optics will undoubtedly play an important role in next generation technology as it offers the ultimate speed of the signal propagation, high bandwidth, and lower power consumption. Importantly, most information that we get about the outside world is optical; it's through our eyes. Visual-output systems will remain central to the ways we communicate and learn about the world.

The future is all about optical and hybrid optical technologies. Flat, ultrathin optics using meta-surfaces are pushing the edge of fundamental physics and breakthrough applications in these domains. It's all going to feed into the next generation of data-driven technologies, be that free space propagation with meta-surfaces as sensors, the Internet of Things, virtual or augmented reality, smart glasses, smart windows, holographic devices, or wearable 'meta-films' compatible with the human body that are stretchable and self-healing.

Developing human-to-computer interfaces is going to be the most important development. Instead of carrying laptops or smartphones, all these technologies will be integrated with the human being and its environment. Everything will be smart and interconnected through artificial intelligence. We still have a way to go for that science fiction future to become our everyday life, but it may be closer than we think.

The first digital revolution was based on the semiconductor diode, which was invented in 1874; the first semiconductor device was patented in 1901. It took the invention of the transistor and computers for these discoveries and technologies to have a major impact, with universities contributing to the further development of the semiconductor all the while. It took time from the invention of the transistor in 1947 until materials science advances made the semiconductor industry viable in the 1960s. There was also a lag in workforce training, for the development of applications for these new devices, and for commercial and intellectual competition to drive more innovation. Eventually, it took off. George Moore, founder of Intel, in his 'Moore's Law,' predicted the doubling of the density of transistors on microchips in 1965, which has held true.

> "TMOS is all about innovation in science and technology by finding new ways to generate, manipulate and detect light. I strongly encourage the talented TMOS scientists and their teams to seek surprise along this path since true breakthroughs cannot be planned."
>
> - Professor Federico Capasso, Chair ISAC Robert Wallace Professor of Applied Physics & Vinton Hayes Senior Research Fellow in Electrical Engineering at Harvard

The situation in 2022 is very different, because companies are doing so much more R&D. Their efforts are on par with universities. This means that fundamental scientific breakthroughs that are critical for the creation of new disruptive applications are happening in parallel with remarkable developments in engineering, materials, and workforce training. Thus, the ongoing technology revolutions move much faster than previously.

Through my involvement with the Quantum Economic Development Consortium (QED-C), I see that the level of R&D in quantum technology companies and the top-notch ground-breaking research at universities are at a similar level, and that key industry players are partnering with top academic teams, thus closing the fundamental discovery/new technology loop.

No discussion of the next generation can be complete without highlighting quantum information science and technology (QIST). We are witnessing an ongoing quantum revolution, and I believe photonics is going to play a critical role simply because photons are the fastest messengers and, importantly, immune to decoherence.

Optics already plays a big role in quantum technology advancement through quantum imaging and sensing. Eventually, quantum photonics will play a big part in the human-machine world, through quantum photonic computing and unhackable, secure quantum communication systems. Meta-optics, with its ability to tailor light-matter interactions, will definitely find its way into quantum photonic systems, offering the ultimate control over the generation, control and detection of quantum states of light.

The current pace of science and technology breakthrough discoveries often happen at the intersection of different disciplines. Strong collaboration is essential, and it is very important for a Center like TMOS to make sure young people are exposed to a multi-disciplinary environment early in their career path, so that they may have the opportunity to interact with specialists from different fields.

My message to the students and researchers of TMOS is to be the best possible specialist in what you do. Always aim for the stars and never settle for incremental work. At the same time, be open to other disciplines and follow the most recent breakthroughs in science and technology. This will help you think outside of the box and never run dry of novel ideas. I don't believe any significant advances will happen without the dialogue and expertise exchange between areas of research. Being exposed to a multi-disciplinary environment and keeping abreast of changes in technology and science is very important for the next generation. They should keep a close eye on developments in quantum and big data, virtual reality and human-machine interfaces, because these areas will significantly affect their careers and change the world for the better.

The Fourth Industrial Revolution is well underway. The younger generation will be shaping it for decades to come. But I encourage them to always leave room for exploring new and unrelated ideas, because who knows what will define the next revolution and from what conversation it might spawn?

Prof. Alexandra Boltasseva,
Purdue University
ISAC Committee Member

LINKS

Meta-optics for the consumer market, F. Capasso

Read article

Three common misconceptions about the nature and nurture of research, V. Narayanamurti & J. Tsao

Read article

TMOS Launch Ceremony

The ARC Centre of Excellence for Transformative Meta-Optical Systems (TMOS) was officially launched on 28 September 2022 at the new Research School of Physics auditorium on the Australian National University (ANU) campus. The launch was a momentous occasion for the Centre, as it marked the culmination of many years of planning and collaboration, going back to 2017. TMOS formally commenced on 1 January 2021 and held out for the appropriate time to hold an in-person celebration.

The Launch Ceremony began with a Welcome to Country, provided by Uncle Paul House, Ngambri and Ngunnawal Custodian. He shared traditional music, and invited audience members to participate, including the Hon Julie Bishop, ANU Chancellor.

During the event, TMOS Director, Professor Dragomir Neshev, gave a keynote speech on the Centre's research vision and goals. He explained that TMOS is a world-leading research Centre that focuses on developing advanced meta-optical systems that can revolutionise a wide range of applications, from telecommunications to medicine and environmental monitoring. He also highlighted the collaborative nature of the Centre's research, which involves partnerships with leading international institutions and industry partners.

The Centre was formally launched by ARC CEO Ms Judith Zielke, who spoke about the importance of research and innovation, and how she was looking forward to seeing the exciting applications of TMOS research being realised. ANU Vice Chancellor Prof. Brian Schmidt, Ms Judith Zielke, and Prof. Dragomir

Neshev, shared in cutting a celebration cake to conclude the formal part of the ceremony.

The launch event featured polished poster presentations for attendees to interact with TMOS researchers and learn more about the Centre's research programs. The presentations covered a range of topics, including the development of new materials for meta-optical systems, meta-optics enabled quantum technology, and the design of advanced imaging and sensing systems.

Beyond the science, there were displays of TMOS outreach activities, including a popular simulated holographic butterfly. There was also a live demonstration of a meta-optics enabled device with collaborator Seeing Machines, which tracks eye gaze for driver fatigue monitoring. It was the first time the team trialled the setup outside the lab, providing the first field test of this groundbreaking work.

Overall, the launch event was a resounding success, demonstrating the breadth and depth of the TMOS research program and the importance of meta-optical systems research to the future of Australia's innovation and competitiveness. The Centre looks forward to continuing its work in partnership with industry and government agencies to drive transformative change across a range of sectors.

2022 Key Moments

- 1 JUN 2022 — CI Planning day
- 5 JUN 2022 — Shepparton International Day of Light Outreach event
- 20-21 JUL 2022 — inSTEM Conference
- 15 AUG 2022 — Outreach School visit at Earlwood Public School (NSW)
- 15 AUG 2022 — Outreach School visit at Turner Primary (ACT)
- 17 AUG 2022 — Outreach School visit at Fitzroy Primary (VIC)
- 19 AUG 2022 — Outreach School visit at Rosalie Primary (WA)
- 31 AUG – 1 SEP 2022 — ECR/Student conference
- 21 SEP 2022 — Chennupati Jagadish elected International Fellow into the Royal Academy of Engineering
- 28 SEP 2022 — TMOS launch
- 1 OCT 2022 — Appointment of Mani Thiru to CAB
- 1 OCT 2022 — Appointment of Prof. Alexandra Boltasseva to ISAC
- 4 OCT 2022 — Igor Aharonovich 2023 ACS Photonics Young Investigator Award
- 15 OCT 2022 — Chennupati Jagadish awarded Thomas D. Callinan Award for 2023
- 8 NOV 2022 — Outreach Science Communications Training workshop at Questacon
- 22 NOV 2022 — Outreach School visit at Rose Park Primary (SA)
- 23-25 NOV 2022 — TMOS conference
- 5 DEC 2022 — Daria Smirnova 2022 IUPAP C17 Early Career Scientist Prize "for fundamental aspects on Laser Physics and Photonics"
- 10 JAN 2023 — Chennupati Jagadish Pravasi Bharatiya Samman Award 2023

Action Items for 2023

THEME 1A – GENERATE

1. Optimising cavity design, transparent contacts, and fabrication challenges
2. Electrical injection to microring cavity
3. Develop the theoretical approaches for PT symmetry-based control of gain and loss
4. Light-emitting metasurface design and fabrication with electrical injection
5. Demonstration of NIR-to-visible conversion with coupled metamaterial and upconverting nanoparticles 0.1nW/cm2

Read the report

THEME 1B – GENERATE

1. Enhancement of nonlinear emission from 2D materials studies and their heterostructures
2. Initial characterisation of quantum dots based sources in near infrared
3. Study of second-harmonic generation in individual GaN nanowires
4. Generation of polarisation-entangled photon pairs
5. Hyper-entanglement in spatial and spectral degrees of freedom with nonlinear metasurfaces

Read the report

THEME 2A – MANIPULATE

1. Continue to explore phase change materials for optical and sensor applications
2. Fabricate and characterise electro-optic metasurface devices based on lithium niobate and expand their functionality
3. Design and develop tunable metadevices using liquid crystal through the dynamic molecular realignment
4. Explore fully controllable tunable metasurfaces in full 3D
5. Continue towards development of tunable metadevices using MEMS
6. Development of parametric metadevices for electromagnetic wave amplification

Read the report

THEME 2B – MANIPULATE

1. Fabricate and demonstrate a neuromorphic optical diffractive neural network for chemical classification
2. Characterise phase change material-sb_2se_3 and demonstrate its applications
3. Integrate nanoscale light sources/detectors with optical sensing platforms
4. Integrate focusing lenses and metasurface designs with off-shelf light sources/ detectors
5. Develop technology to scale nanowire array sensor fabrication and develop new nanowire sensors including gas and multiplexed sensors with integrated functionalities

Read the report

THEME 3A – DETECT

1. Design and validation of metamaterial-based lens for extending field of view of infrared focal plane array
2. Integration of metamaterial-based lens with infrared detector or focal plane array
3. Demonstration of single pixel polarisation sensitive nanowire array for NIR imaging
4. Demonstration of multi-pixel nanowire array for NIR to SWIR imaging

Read the report

THEME 3B – DETECT

1. Using bound-states in the continuum (BIC's) to demonstrate enhanced chemical detection with micro spectrometers
2. Demonstrate quantum ghost imaging using photon pairs generated by nonlinear-metasurfaces
3. Demonstrate electrically tunable, graphene based infrared sensing and image processing devices
4. Investigate and develop polarisation sensitive quantum well nanowire mid-infrared photodetectors

Read the report

THEME 3C – DETECT

1. Develop MBE process for growing suitable MCT layers that meet the required specifications
2. Preliminary development of fabrication process for ultra-high QE SWIR detectors and initial device testing and characterisation
3. Enhanced photodetection with plasmonic nanoparticles on ultrathin films
4. Develop flexible nanowire array SWIR photodetectors

Read the report

INDUSTRY LIAISON COMMITTEE

1. Facilitate the technical collaboration with Australian SMEs and larger corporations by mapping and making the most out of all funding and ancillary mechanisms available in the Australian landscape
2. Supporting the identification and definition of "flagship" projects across the Centre, such as portable holography and biosensing, by benchmarking with current commercially available technologies
3. Facilitate opportunities for Centre members to meet in-person with industry to present their work
4. Develop pathways to grow the TRL of Centre project IP towards patent, pilot, industry or research partnerships

Read the report

IDEA COMMITTEE

1. Leadership training for our core Centre members which also includes our Research Program Managers – with a focus on modern leadership skills
2. TMOS will play a significant role in the organisation and operations of the 2023 inSTEM Conference
3. IDEA framework and related policies will be reviewed

Read the report

EDUCATION AND PROFESSIONAL DEVELOPMENT COMMITTEE

1. Finalise the TMOS HDR student database and establish a quarterly updating mechanism
2. Deliver a professional development program based on Centre ECR and HDR's interests and needs, including the colloquium and topical workshop programs
3. Organise the 2023 Centre ECR and student mid-year conference
4. Facilitate the selection of the Centre conference program

Read the report

OUTREACH COMMITTEE

1. Collaborate with Questacon to develop a physics-themed exhibit
2. Hold another Science Communications and Training workshop in conjunction with International Day of Light outreach activities at Questacon
3. Improve on the current school workshops to make them more hands-on
4. Conduct additional public outreach activities, including school visits
5. Content development and review to ensure content being delivered is scientifically sound and topical

Read the report

INFRASTRUCTURE AND CAPABILITIES COMMITTEE

1. Add new infrastructure to the Centre's equipment register
2. Raise awareness of existing facilities within the Centre to increase cross-node collaboration
3. Support funding and access bids by Centre researchers and other researchers whose work is synergistic with Centre activities, such as the LIEF program and NCRIS funding

Read the report

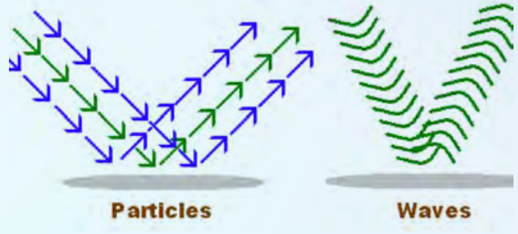
CENTRE EXECUTIVE COMMITTEE

1. Drive initiatives, events, and funding toward enhancing collaboration between the five nodes of the Centre to increase cross-node publications
2. Determine the research strategy and goals for the remainder of the Centre
3. Complete the review of all Centre governance documentation ahead of the mid-term review
4. Succession plan, inclusive of recruitment measures, to ensure a diverse meta-optics workforce beyond the life of the Centre

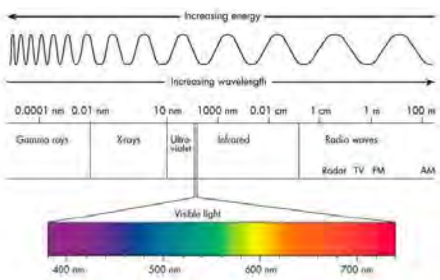
Read the report

What is light?

Light is both a wave and a particle. This is called the Quantum Theory of Light. It can bounce (reflect), bend (refract), and spread out (diffract). It can be absorbed and pass through things. Like other waves, it can interact with itself when it overlaps (interference).



Particles and wave reflected by a mirror

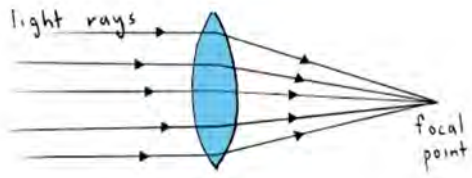


LIGHT = ENERGY

Light energy is a form of electromagnetic radiation. It comprises photons, which are produced when an object's atoms heat up. Light travels in waves. The longer the wave, the more energy it has. Light we can see is just a fraction of the light spectrum (between 450 and 800 nanometers).

WHAT DO WE KNOW ABOUT IT ALREADY?

For thousands of years, optics has revolved around the manipulation of light using a lens. Microscopes, cameras, and even your eyes all have lenses in them. Different shaped lenses created with different materials manipulate light, reflecting, refracting, and transmitting it in different ways.

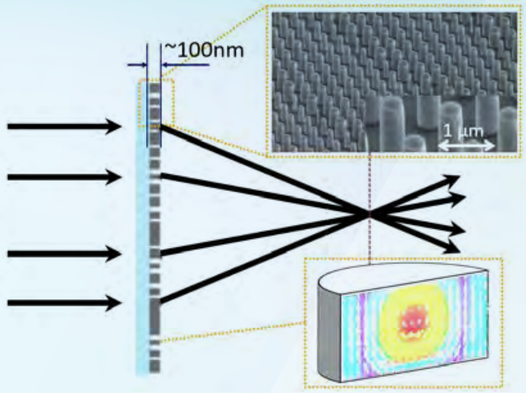


SO, WHERE'S THE PROBLEM?

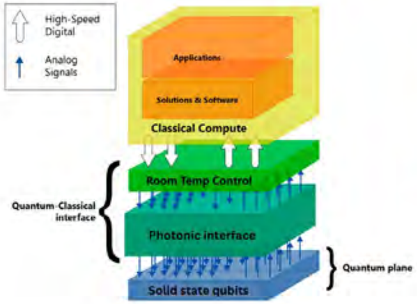
We've gotten pretty good at harnessing traditional optics to do amazing things. Fiber optics use pulses of light to transmit information, bringing us the joy that is the internet. The difficulty is, there is only so far we can push the laws of physics. The nature of light means that we've made lenses as small as they're going to get. There's no going smaller with traditional optics because light simply won't allow it.

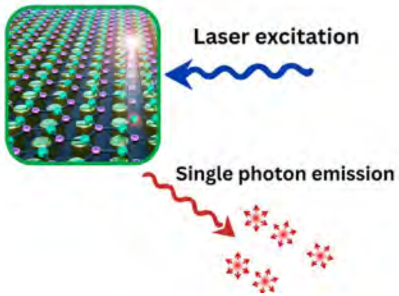
That's where meta-optics comes in...

What is meta-otpics?



Meta-optics (also known as nanophotonics) is the manipulation of light using meta-surfaces. The metasurfaces are millions of nanostructures grouped together. These nanostructures are smaller than light waves. As light passes over them, the structures can manipulate the wave, similar to how a lens does, but at a much, much, much smaller scale.





SO WHY ARE YOU TALKING ABOUT QUANTUM?

Quantum has been the next big thing in computing for a long time. In a nutshell, information is attached to sub-atomic particles and transmitted. This process relies on single photon detection and emission. The development of fully functional quantum communication technologies has been hampered by the lack of reliable quantum light sources that can encode and transmit the information. Where current quantum emitters are created using complex methods in expensive clean rooms and require cryogenic cooling, meta-optics are moving toward mass-produced emitters that work at room temperature, which will be the breakthrough quantum computing needs in order to go mainstream.

WHERE IS META-OPTICS GOING?

Because meta-surfaces are much smaller than traditional optics (only mm in size) they will be less expensive to put on drones and satellites, easier to fit into small devices and cheaper to produce in the same way an electronic chip is now. Holographic displays, night vision, wearable optical sensors, LIDAR, remote sensing and mobile medical diagnostics are just a few of the technologies to be reimagined with meta-optics.

Connect with us

INDUSTRY AND RESEARCHERS

We are interested in connecting with any researchers or potential industry partners that want to explore ways to further our research or apply it to their areas of expertise. If you're interested in having a conversation about ways we might work together, get in touch.

COMMUNITY AND EDUCATORS

The Centre is committed to the development of STEM education in Australia. If you're interested in learning more about how we support science educators through resources or in-school programs, please connect with us.

MEDIA

For all media enquiries, please contact Samara Thorn, TMOS Public Relations Specialist:

0421 276 272

@TMOS_ARC

@TMOS_MetaOptics

@arctmos

TMOS_MetaOptics

connect@tmos.org.au

People

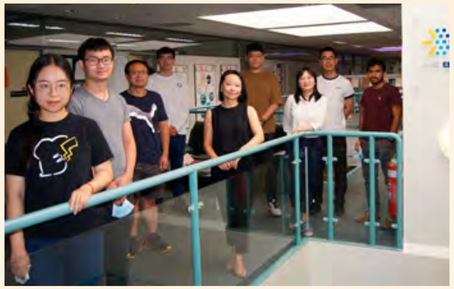
NODE OVERVIEW
Australian National University

The Centre's Australian National University node comprises several different research groups led by six chief investigators.

Its research interests include synthesising new nanoscale semiconductor structures, such as nanowires, nano-membranes and micro-rings, using metal-organic chemical vapour deposition for applications in various optoelectronic and photonics devices including lasers, LEDs, photodetectors, solar cells and bio/chemical sensors; developing fundamental solutions to the problems of creating tunable structures and their use in time-varying configurations; performing theoretical and experimental research on tailoring light-matter interactions; and testing the fundamentals of linear and nonlinear properties of optical metasurface and how they enhance light matter interactions.

The node's research spans all three of the Centre's Research Themes and contributes to each of the Centre's flagship projects. It has applications across a wide cross-section of industries, with teams working closely with industry partners in the fields of space, defence, and med-tech to develop technology that meets market needs. It has been the launching ground for two of the Centre's start-ups: Hyrea and VIColours.

As the Centre's largest node, it has a strong focus on collaboration, with regular whole-of-team in-person meetings. In 2022, it has also welcomed cross-node researchers into its labs as well as Partner and Associate Investigators.



CHIEF INVESTIGATORS:

PROFESSOR ANDREY SUKHORUKOV

Chief Investigator
The Australian National University

CI Andrey Sukhorukov is a Professor of Physics and the Theory and Modelling Coordinator at ANU. His research targets the fundamental aspects of miniaturisation of optical elements down to the micro- and nano-scale, while achieving advanced functionalities beyond the capabilities of traditional optics.

In 2016, Sukhorukov was elected Fellow of the Optical Society of America (OSA), in 2015, elected a Fellow of Optica for "pioneering contributions to nonlinear and quantum integrated photonics, including frequency conversion and broadband light manipulation in waveguide circuits and metamaterials." Prior to this, he had been awarded a Future Fellowship by the ARC in 2010 and a Queen Elizabeth II Fellowship, also from the ARC in 2007.

PROFESSOR CHENNUPATI JAGADISH

Chief Investigator

The Australian National University

PROFESSOR DRAGOMIR NESHEV

Chief Investigator

The Australian National University

CI Chennupati Jagadish is a Distinguished Professor and Head of the Semiconductor Optoelectronics and Nanotechnology Group at the ANU Research School of Physics and co-leader for Theme 1 – Generate. His research interests are based on compound semiconductor optoelectronics, nanotechnology, photovoltaics and materials science.

Jagadish served as Vice President and Secretary of Physical Sciences for the Australian Academy of Science from 2012-2016. He is currently serving as Past President of IEEE Photonics Society, Past President of Australian Materials Research Society, and Convener of Australian Nanotechnology Network. He is the Editor-in-Chief of Applied Physics Reviews and serves on editorial boards of 20 other journals. He has received Distinguished Lecturer awards from IEEE NTC, IEEE LEOS, and IEEE EDS. Jagadish has received numerous awards and recognitions. In 2016, he received Australia's highest civilian honour, Companion of the Order of Australia, for his contributions to physics and engineering, in particular nanotechnology. This year, he was given the Pravasi Bharatiya Samaan Award, the highest award given to overseas Indians by the Government of India.

CI Dragomir Neshev is Director of TMOS and Professor of Physics at ANU. Neshev has worked in the field of optics at several research centres around the world and joined ANU in 2002.

His work spans across several branches of optics, including periodic photonic structures, singular optics, plasmonics, and optical metasurfaces. Some of his most significant research achievements are in the field of dielectric meta-optics for wavefront and emission control. These include the pioneering concept of Huygens dielectric metasurfaces, which has provided a breakthrough for achieving high-efficiency transmissive meta-optics such as meta-lenses and meta-holograms and has recently been extended to highly tunable meta-devices.

Neshev's group is a leader in the field of nonlinear metasurfaces with applications in infrared imaging and up-conversion. They have pioneered the development of label-free optical sensors based on dielectric metasurfaces, demonstrating biosensors with sensitivity exceeding other portable sensing technologies. Through these activities, Neshev and a team from six ANU Colleges have recently founded the inaugural ANU Grand Challenge, Our Health in our Hands (OHIOH), a $10M multidisciplinary research program that aims to transform healthcare by developing deep personalisation of disease diagnostics and treatment.

Neshev is the recipient of numerous awards and honours, including a Highly Cited Researcher by Web of Science in 2021 and 2022 and a Queen Elizabeth II Fellowship by the ARC in 2010. He is also a Fellow of the Optical Society (OSA) and a member of SPIE and the Australia and New Zealand Optical Society.

PROFESSOR HARK HOE TAN

Chief Investigator

The Australian National University

CI Hark Hoe Tan is a Professor of Physics and the Materials and Nanofabrication Coordinator at ANU. He is Director of the ANU node for the Australian National Fabrication Facility, which provides state-of-the-art micro- and nano-fabrication facilities for the R&D communities in the fabrication of electronic and photonic devices.

His research activities cover both fundamental and applied aspects of semiconductor optoelectronics, with two distinctive contributions in (i) epitaxial growth of III-V semiconductor materials and devices and (ii) ion irradiation of compound semiconductors for optoelectronic applications. Tan is a Fellow of the IEEE “for contributions to compound semiconductor optoelectronic materials and devices.” He was the Distinguished Lecturer for IEEE Nanotechnology Council and IEEE Photonics Society in 2016 and 2017 and was named Australia’s Leading Researcher in Nanotechnology by The Australian’s Research Magazine in 2020.

PROFESSOR ILYA SHADRIVOV

Chief Investigator

The Australian National University

CI Ilya Shadrivov is Professor of Physics at the Nonlinear Physics Centre at ANU and leader of Theme 2 - Manipulate. His main research interests include metamaterials in various frequency ranges, from microwaves to Terahertz and Optics, and he leads Terahertz spectroscopy and microwave labs at the Nonlinear Physics Centre. As one of the pioneers in the field of nonlinear metamaterials, his interests are focused mostly on tunable and nonlinear structures.

Shadrivov is a Vice Chair of the OSA ‘Spotlight in Optics’ and writes highlights for some of the most exciting discoveries published in the OSA journals. He is a Fellow of Optica and of the Australian Institute of Physics. He is also the recipient of the 2016 Pawsey Medal from the Australian Academy of Science and Geoff Opatt prize from the Australian Optical Society.

PROFESSOR LAN FU

Chief Investigator

The Australian National University

CI Lan Fu is a Professor and Head of the Department of Electronic Materials Engineering at the ANU Research School of Physics and TMOS Education Director. Her main research interests include design, fabrication, and integration of optoelectronic devices such as LEDs, lasers, photodetectors, and solar cells, and chemical sensors based on low-dimensional III-V compound semiconductor structures including quantum wells, self-assembled quantum dots, and nanowires grown by metal-organic chemical vapour deposition (MOCVD).

Fu is Deputy Chair of the Australian Academy of Science National Committee on Materials Science and Engineering and Secretary of the Executive Committee of Australian Materials Research Society (AMRS). She has been the Chair of IEEE Nanotechnology Council Chapters & Regional Activities Committee since 2019, member of Editorial Board of Opto-Electronic Advances since 2019, Associate Editor of IEEE Photonics Journal since 2021, and was a member of the ARC College of Experts from 2019-2021. Fu was the recipient of the Distinguished Lecturer Award for 2021-2022.

AUSTRALIAN NATIONAL UNIVERSITY POSTDOCTORAL RESEARCHERS:

DR. ANDREI KOMAR

DR. BUDDINI KARAWDENIYA

DR. DARIA SMIRNOVA

DR. JIHUA ZHANG

DR. JINYONG MA

DR. MARIA DEL ROCIO CAMACHO MORALES

DR. MATTHEW PARRY

DR. NAIYIN WANG

DR. QUANLONG YANG

DR. TUOMAS HAGGREN

DR. VLADLEN SHVEDOV

DR. YANA IZDEBSKAYA

DR. YI ZHU

DR. ZHICHENG SU

DR. ZIYUAN LI

AUSTRALIAN NATIONAL UNIVERSITY PHD STUDENTS:


ANHA BHAT


ASWANI GOPAKUMAR SARASWATHY VILASAM


DAWEI LIU


ELIZAVETA MELIK-GAYKAZYAN


FANLU ZHANG


FEDOR KOVALEV


JINGSHI YAN


JINLIANG REN


KHOSRO ZANGENEH KAMALI


LAURA DANIELA VALENCIA MOLINA


LUYAO WANG


MARCUS CAI


MARIJN RIKERS


MATTHEW PARRY


MOHAMMAD RASHIDI


MUDASSAR NAUMAN


NEUTON LI


NIKITA GAGRANI


SARAH DEAN


SHIYU WEI


SHRIDHAR MANJUNATH


SIBO HUANGLONG


SONACHAND ADHIKARI


WEI WEN WONG


XIAOYING HUANG


YANG YU


YUE BIAN


ZAHRA AZIMI


ZIWEI YANG

NODE OVERVIEW
RMIT University

The RMIT node of TMOS supports the activities of TMOS with their materials and fabrication expertise. Many of the team's research efforts lie in the theme Manipulate - with the use of phase change materials, stretchable devices, development of fabrication techniques for next gen optical devices. The team also contributes extensively to the flagship project on Integrated Sensors.

In 2022, we continued to build on our materials and fabrication expertise with papers published on phase change materials, colour changing sensors, and impact of strain on material optical properties. We also have strong industry partners with whom we collaborate for commercialisation – one of the relevant projects is the development of wearable oximetry devices which are as thin as a bandaid - this is a fantastic example of miniaturised electronics and optics coming together.

Team members are provided leadership experiences through Research Program Manager roles as well as representing the node at various TMOS committees. They also participated in outreach activities. The team also celebrates the diversity of their members and is especially proud of the gender balance in the node membership.

CHIEF INVESTIGATORS:

PROFESSOR MADHU BHASKARAN

Chief Investigator

RMIT University

PROFESSOR SHARATH SHRIRAM

Chief Investigator

RMIT University

CI Madhu Bhaskaran is leader for the RMIT node, co-leader for Theme 2 – Manipulate, and TMOS IDEA Director. Bhaskaran is an electronics engineer and innovator with research expertise in electronic and optical materials and devices. As co-leader for the Functional Materials and Microsystems Research Group at RMIT, she utilises the unique properties demonstrated by materials at the micro- and nano-scale to create novel devices. Bhaskaran has significant experience in conformal sensors in the form of wearables and nearables, and she collaborates extensively with industry, manufacturing, and design partners to commercialise for healthcare and aged care applications.

In 2022, Bhaskaran was named a Fellow of the Australian Academy of Technological Sciences and Engineering (ATSE). As a devoted advocate for diversity and inclusion, Bhaskaran is co-chair of Women in STEMM Australia.

CI Sharath Sriram is co-leader for the Functional Materials and Microsystems Research Group at RMIT. Shriram is a science and research leader creating and delivering breakthrough technologies for nanoelectronics, sensing, imaging, and medical technologies. His research focus is on unlocking new properties in ultra-thin electronic materials to mimic brain function, sense biometric parameters, and create high-speed communication technologies, translating technology for electronics, photonics, and healthcare to bring science fiction to reality. As Director of the Discovery to Device Facility, Shriram is currently leading medical device prototyping and scale-up manufacturing initiatives.

Shriram is President-Elect of Science & Technology Australia and an active contributor to science policy with a focus on innovation and long-term strategy, early- and mid-career researchers, and diversity and inclusion. He is a former Australian Research Council Fellow, and in 2016 was named among Australia's Most Innovative Engineers by Engineers Australia. Additional recognitions include the 2016 Australian Museum 3M Eureka Prize for Emerging Leader in Science and the 2012 NMI Prize for Measurement Excellence from the National Measurement Institute, Australia.

RMIT POSTDOCTORAL RESEARCHERS:

DR. KRISHNA MURALEEDHARAN NAIR

DR. LITTY VARGHESE THEKKEKARA

DR. RAJOUR TANYI AKO

RMIT PHD STUDENTS:

MINGJIE YANG

SUVANKAR SEN

YING ZHI CHEONG

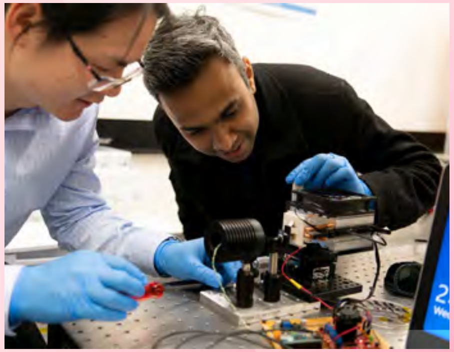
NODE OVERVIEW

University of Melbourne

The broad theme of University of Melbourne Node is on light-matter interactions on the nanoscale, with applications that range from novel forms of imaging to structural colour, new types of photodetectors, infrared chemical sensors, advanced holograms and optical nanotweezers.

2022 was a busy year in the laboratory. We published papers on imaging, structural colour, chemical detection, infrared LEDs, and on generating unusual optical beams, all based on metasurfaces.

2022 was also a busy year outside the laboratory! Node members were awarded funding from Optica to attend the Optical Student Leadership Workshop in Rochester (USA) in October 2022. We were very active in Outreach. This included organising the "Story of Light " at Shepparton Library in June 2022, that was attended by more than 100 people. We also initiated a hands-on workshop at a local primary school (with support from our RMIT colleagues) and supported a Girls in Physics Hologram Workshop.



CHIEF INVESTIGATORS:

PROFESSOR ANN ROBERTS

Chief Investigator

University of Melbourne

CI Ann Roberts is Professor of Physics at the University of Melbourne and co-leader for Theme 3 - Detect. Roberts has diverse research interests in the broad field of physical optics with a particular focus on understanding and utilising light-matter interactions on the nanoscale. She has made significant advances in the theoretical, computational, and experimental study of plasmonic devices, meta-optics, and nanoscale antennas. Roberts' research interests also include the development of novel imaging techniques and their application to the non-destructive assessment of specimens such as live cells, photonic devices, and cultural materials.

Previously Assistant Dean for Staff Equal Opportunity in the Faculty of Science at the University of Melbourne, Roberts is committed to advancing inclusion and diversity in the physical sciences and more broadly. Roberts is a Fellow of the Australian Institute of Physics, a member and former President of the Australian and New Zealand Optical Society, and a Fellow of both the SPIE and Optica. She was awarded the 2020 Alan Walsh Medal by the Australian Institute of Physics for service to industry.

PROFESSOR KENNETH CROZIER

Chief Investigator

University of Melbourne

CI Kenneth Crozier is Deputy Director for TMOS and leader for the University of Melbourne node. He joined the University of Melbourne in 2014, where he is Professor of Physics and Electronic Engineering. His research interests are in nano- and micro-optics, with an emphasis on plasmonics for surface enhanced Raman spectroscopy and optical forces, optofluidics, and semiconducting nanowires.

Crozier is a Fellow of Optica and SPIE and a member of the 2023 Fellows Class for both. In 2014, he was awarded an Innovation Fellowship from Victorian Endowment of Science, Knowledge, and Innovation (VESKI) and an ARC Future Fellowship. In 2008, he was a recipient of the CAREER Award from the National Science Foundation (USA).

UNIVERSITY OF MELBOURNE POSTDOCTORAL RESEARCHERS:


DR. JIAJUN MENG


DR. LUKAS WESEMANN


DR. NIMA SEFIDMOOYE AZAR


DR. NITU SYED


DR. SIVACARENDRAN BALENDHRAN


DR. WENDY LEE

UNIVERSITY OF MELBOURNE PHD STUDENTS:


BENJAMIN RUSSELL


DAMIAN KEITH NELSON


HAIWEI WANG


HENRY TAN


JIAJUN MENG


LAURA OSPINA ROZO


LINCOLN CLARK


MARYAM SETAREH


NIKEN PRISCILLA


PALLAVI PUNJ


SEYED SALEH MOUSAVI KHALEGHI


SHABAN SULEJMAN

NODE OVERVIEW

University of Technology Sydney

UTS node had a great 2022 year. UTS Science graduated our largest TMOS Honours cohort to date, and both Madeline Hennessey and Benjamin Whitefield will continue towards their PhDs with TMOS. Dr Tieshan Yang, ECR in TMOS, moved to develop his exciting career in industry and joined Archer.

Our postdoc John Scott received the TMOS Education award for his efforts to promote learning in TMOS. Our PhD students Ritika Ritika and Lesley Spencer explained their PhD research in an exciting Physics in the Pub night in Sydney. The FEIT/UTS group has delivered fantastic simulation results on Mid Infrared properties of the epi graphene/SiC combination to lay their foundation for dynamic tuning. This has led to the development of several key collaborations, with the UoM node (CI Roberts) on tunable phase filters, and cross CoEs with FLEET (Prof. Michael Fuhrer) regarding the experimental implementation of graphene tunability, and one with ANSTO on controlling the fundamentals of the epitaxial graphene. ECRs Dr. Iryna Khodasevychand Dr. Aiswarya Pradeepkumar are each coordinating at least one such external collaboration.

UTS node has group members across two faculties: The Science Faculty under CI Igor Aharonovich and the Faculty of Engineering and Information Technology under CI Francesca Iacopi.

CHIEF INVESTIGATORS:

PROFESSOR IGOR AHARONOVICH

Chief Investigator

University of Technology Sydney

CI Igor Aharonovich is co-leader of Theme 1 - Generate and TMOS Outreach Director.

In 2013, he established the Nanophotonics Research Group at UTS to focus on key building blocks for quantum technologies. Aharonovich's group explores new quantum emitters in wide bandgap materials and aims to fabricate quantum nanophotonic devices on a single chip for next generation quantum computing, quantum cryptography, and quantum bio-sensing. In 2016, Aharonovich led his team to discover the first quantum emitters in 2D materials that operate at room temperature based on defects in hBN. In 2020, his group, in collaboration with German Professor Dyakonov, discovered new spin defects in hBN that are promising for quantum sensing with atomic scale resolution.

Aharonovich is a fellow of OPTICA and the Royal Society of NSW. This year he was awarded the ARC Future Fellowship, as well as the 2023 ACS Photonics Young Investigator award.

PROFESSOR FRANCESCA IACOPI

Chief Investigator

University of Technology Sydney

CI Francesca Iacopi leads the Integrated Nanosystems Lab in the Faculty of Engineering and IT at the University of Technology Sydney and is Chair of the TMOS Industry Liaison Committee. With over 20 years of international industrial and academic expertise in the miniaturisation of semiconductor technologies, her research focuses on the translation of basic scientific advances in nanomaterials and device concepts into integrated technologies.

Iacopi is well known for her work in porous dielectrics for interconnects, and, more recently, graphene for on-chip applications. The latter contribution, started during her 2012 ARC Future Fellowship, has developed into a versatile scalable technology covering applications from biosensing to integrated metamaterials for mid infrared sensing and imaging.

Iacopi received the Global Innovation Award in Washington, D.C. in 2014 and was listed among the most innovative engineers by Engineers Australia in 2018. She is a Fellow of the Institution of Engineers Australia and an IEEE Distinguished Lecturer of the Electron Devices Society. She serves on several Technical and Awards Committees for the Materials Research Society and the IEEE Electron Devices Society. Iacopi is the founder of the IEEE New South Wales EDS Chapter and is an elected member of the Board of Directors of the IEEE Electron Devices Society.

PROFESSOR MILOS TOTH

Chief Investigator

University of Technology Sydney

CI Milos Toth is a Professor of Physics at the University of Technology Sydney where he leads a research group focused on electron and ion beam nanofabrication techniques.

His research is focused on the development of new nanofabrication techniques, two dimensional materials, and solid-state single photon sources and their application to quantum encryption. He works closely with industry partners to translate research to patent-protected intellectual property, leveraging seven years of experience in the high-tech industry in the United States, where he developed electron, ion, and laser beam systems used by university and government research labs, as well as high-tech industry leaders such as Intel and AMD.

UNIVERSITY OF TECHNOLOGY SYDNEY POSTDOCTORAL RESEARCHERS:

DR. AISWARYA PRADEEPKUMAR

DR. IRYNA KHODASEVYCH

DR. JOHN SCOTT

DR. MEHRAN KIANINIA

DR. PATRICK RUFANGURA

DR. TIESHAN YANG

UNIVERSITY OF TECHNOLOGY SYDNEY PHD STUDENTS:

BENJAMIN WHITEFIELD

LESLEY SPENCER

MADELINE HENNESSEY

PATRICK RUFANGURA

RITIKA RITIKA

THINH TRAN

NODE OVERVIEW

University of Western Australia

The UWA node has continued to engage via TMOS in its two flagship areas of expertise of infrared sensor and imaging technologies, and optical MEMS. This included a strong interaction with the defence and industry players, which is highlighted for example by the continuing Defence Innovation Hub project to realise Low Size, Weight and Power RF true time-delay system for radar, Electronic Warfare and communications based on optical MEMS in partnership with DST Group and L3Harris Micreo (Brisbane), a newly funded research project with L3Harris IMSA (Fremantle) in the area of MEMS-based magnetometers for undersea surveillance, and efforts supporting a local start-up company Magic Wavelength Ltd. commercialising novel sensors and instruments for non-invasive monitoring of plant health essential to improved productivity for the agricultural sector and the health of plants in the home gardening market. A significant highlight of the past year was the approval by the UWA Senate to allocate approximately $6million in funding to upgrade the clean-room fabrication facilities supporting the research of TMOS. This includes establishment of the national large-format flip-chip bonding facility arriving in 2023 as a unique capability that is not currently available in Australia.

CHIEF INVESTIGATORS:

PROFESSOR LORENZO FARAONE

Chief Investigator

University of Western Australia

CI Lorenzo Faraone is co-leader of Theme 3 - Detect. He joined the University of Western Australia in 1987. As leader of the Microelectronics Research Group (MRG) and Director of the WA Node of the Australian National Fabrication Facility (ANFF), he works on compound semiconductor materials and devices, including AlGaN/GaN HEMTs, HgCdTe-based infrared sensor technology and MBE growth, as well as optical MEMS technologies for infrared spectroscopy and imaging applications. His research activities include mobility spectrum analysis techniques for magneto-transport studies, which allow the transport properties and mobility distributions of individual carriers in multi-layer/multi-carrier semiconductor systems to be determined.

Faraone is a Member of the Order of Australia (AM) and a Fellow of the Institute of Electrical and Electronic Engineers (FIEEE), the Australian Academy of Science (FAA) and the Australian Academy of Technological Sciences and Engineering (FTSE).

PROFESSOR MARIUSZ MARTYNIUK

Chief Investigator

University of Western Australia

CI Mariusz Martyniuk is leader of the UWA node. He works with the Microelectronics Research Group and manages the Western Australian Node of the Australian National Fabrication Facility.

His primary research interests are in thin-film materials and thin-film mechanics, as well as their applications in micro-electromechanical systems and optoelectronic devices. In 2008, Martyniuk received the Inaugural Australian Museum Eureka Prize for Outstanding Science in Support of Defence or National Security. His work has resulted in 10 patents and patent applications and secured him 9 major grants spanning from 2014 through to 2026.

UNIVERSITY OF WESTERN AUSTRALIA POSTDOCTORAL RESEARCHERS:

DR. HEMENDRA KALA

DR. MICHAL ZAWIERTA

DR. NIMA DEHDASHTI

DR. WENWU PAN

UNIVERSITY OF WESTERN AUSTRALIA PHD STUDENTS:

DANIEL MORLEY

FARHAD FOROOZANDEH

OLEG BANNIK

YAN LIU

Professional Team

ALINA BRYLEVA

Centre Administrator

Australian National University

Alina joined the TMOS team for Jan-Sep 2022, bringing her experience from the two other ARC Centres of Excellence where she was employed previously. Alina enjoys helping people to solve administrative puzzles and strive for continuous self-development and learning. She has a postgraduate degree in Public Administration, in addition to Cert IV in Human Resources Management and the Foundation level Accreditation of the Research Manager from the Australasian Research Management Society.

CAMILLA GAZZANA

Outreach Officer,

Node Administrator

University of Technology Sydney

Camilla is the TMOS Outreach Officer and node administrator for UTS. She completed her undergraduate studies in Forensic Science in Applied Chemistry at the University of Technology Sydney in 2015, after which she commenced postgraduate studies in 2017, also at UTS. Her current area of research is in the field of bionanotechnology, where she is undertaking her PhD and investigating the interactions between gold nanoparticles and E. coli.

During her postgraduate studies, Camilla has undertaken a wide range of undergraduate teaching roles where her love of teaching led her to her current roles in TMOS.

EMILY SCHUSTER

Content and Engagement Officer

Australian National University

Emily is the Content and Engagement Officer for TMOS, based at ANU. Emily draws on a diverse career background in oncology research, technical writing, training development, and web support to share the amazing work being done at TMOS with internal and external audiences. Emily is passionate about effective communications. She loves helping people to tell their stories in meaningful and engaging ways and to connect with others who share their goals and values.

Emily and her family have lived in Canberra since 2021. She and her partner and their two little kids love to be outdoors and spend most weekends going for bike rides, hiking, swimming, and playing at playgrounds. When Emily gets quiet time to herself, she writes poetry and makes things out of yarn.

GALINA SHADRIVOVA

Business Coordinator

Australian National University

Galina Shadrivova is a Business Consultant for TMOS, based at ANU. She brings with her extensive experience and education in business, accounting, and research management. Galina graduated from National Research University of Electronic Technology (MIET), Russia with a double major in Economics and Information Technology with Honours. After moving to Canberra, Galina gained a CPA qualification in 2016 and worked as a practice manager and a tax agent for an accounting practice, prior to starting her career at ANU.

During her studies and work, Galina has received multiple performance recognitions, scholarships and awards, including for outstanding performance as part of the finance team at CECS, ANU.

Managing staff and clients from various backgrounds and ethnicities has been a driving force in shaping Galina's views on diversity and inclusion, which have become part of her core values. Galina is passionate about leadership, supporting people around her in growing professionally, and promoting diversity and inclusion in the workplace. She is constantly striving to make a bigger impact around her through exercising her skills and experience in managing people and processes.

GREG DENNIS

IDEA Officer

RMIT University

Greg is the Inclusion Diversity Equity and Access Officer for TMOS. He is based in Naarm (Melbourne) and works out of RMIT on the lands of the Wurundjeri and Boonwurrung people. Greg has been working within Diversity and Inclusion for three years, with previous experience in design and education. Last year, Greg completed his Graduate Certificate in Diversity and Inclusion in the Workplace from the University of Southern Queensland. He was the recipient of the 2022 TMOS Business Team Member of the Year Award.

Greg is a passionate and devoted diversity and inclusion practitioner. He is always trying to find new ways to assist people with their diversity and inclusion journey and spends a lot of his free time working within local communities to create safe spaces for the LGBTQIA+ community.

JULIE ARNOLD

Senior Administrator

Australian National University

Julie joined the TMOS Business Team in November 2022, bringing with her many years of experience working at the Australian National University. As an alumna of the School of Philosophy, Julie enjoys staying connected to ANU through her work. She excels in administration processes and loves working with people to ensure processes are completed correctly and in a timely manner.

KAREN KADER

Node Administrator

University of Western Australia

Karen Kader is the node administrator for UWA. With over 20 years of experience working as an administrative assistant in a university setting, Karen has held positions in the Department of Botany and the Department of Chemistry at University of KwaZulu-Natal in South Africa and currently in the Department of Electrical Engineering at UWA. Karen is a skilled administrator and is able to tailor her expertise to meet the individual needs of the various departments she serves.

Karen is passionate about helping people through her administrative work. She is also interested in mental health awareness and has become a Mental Health First Aid Officer at UWA. Karen is currently working on a Diploma in Community Services.

KATHY PALMER

Node Administrator

University of Melbourne

Kathy has been the node administrator for the University of Melbourne since 2021. She brings with her over 10 years of experience working with ARC Centres of Excellence and many more years of experience in financial services. Kathy has worked for the University of Melbourne since 2004, and during this time she has pursued studies in finance, accounting, and bookkeeping.

Kathy is a keen herb and native plant gardener and enjoys tending to her home, garden, and kitchen. In 2022, Kathy started living on a wholefoods plant based diet and growing her own vegetables.

KRISZTINA THURZO

Assistant Administrator

Australian National University

Krisztina began her role as the node administrator for ANU in late October 2022. In her role, Krisztina carries out administrative operations and maintains relationships with partners who are studying with, visiting, or collaborating with TMOS. She manages many of the essential day-to-day tasks that keep the ANU node running such as processing invoices, receipts, and reimbursements, and she is the first point of contact for many people who contact the Centre through email. Krisztina provides support for ongoing projects such as event management and the Annual Report.

Krisztina holds a concurrent role as a disability carer in which she accompanies disabled clients on their community involvement outings and assists with hydrotherapy and gym exercises. In her spare time, she likes to be out and about with her children and enjoys cooking family meals, playing tennis, and going on nature walks.

DR. MARY GRAY

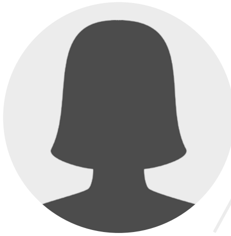
Chief Operating Officer

Australian National University

Mary has been the Chief Operations Officer of TMOS since September 2019. She leads and manages the Business Team to implement public relations, equity and diversity, events and researcher development, governance and compliance, and financial and administrative operations of the Centre. Based at ANU, Mary has had a 10-year career in research management.

She has been co-chair of the Research School of Physics Equity and Diversity Committee since 2020. She is a lifelong learner, with a PhD in Medicine (human genetics) in 2013, postgraduate certificate in creative nonfiction writing, governance credentials, and a 650-hour coaching certification, completed in December 2022.

Outside of TMOS and building her own coaching business, Mary is a member of the F45 1000 club and a well-trained mistress of two cats.



MEENA AMIRY

Administration Officer

RMIT University

Meena was the Node Administrator at RMIT from January to May. She is an experienced community and gender advocate with strong analytical and research skills in gender and security. She enjoys delivering capacity building programs to contribute to the improved health, safety and well-being of women in the community. Meena has a versatile administration background and a strong grasp on intersectional feminism from both her lived experience and studies as a Masters of International Relations student from Monash University.

SAMARA THORN

Engagement Manager

Australian National University

As the Engagement Manager at TMOS, Samara's role is to help researchers communicate their science and help businesses understand how the new field of meta-optics will transform their industry and where future opportunities for growth lie.

With close to 15 years of experience in public relations and marketing, Samara's greatest strength is understanding audiences, what motivates them, and what information they need to help them reach their goals. She specialises in taking complex scientific research and identifying who might benefit from it and how the information should be communicated, drawing on her time teaching primary and high school science, including senior physics.

Samara has an undergraduate degree in creative writing and postgraduate degrees in education and science. In her spare time, she is an award-winning novelist, and she leverages her writing skills to tell a cracking good story in her media releases.

Awards and Achievements

CHENNUPATI JAGADISH

Chief Investigator
Australian National University

AWARD: Thomas D. Callinan Award for 2023

The award is the highest recognition of our division and is based on achievements and contributions to DST science. Dielectric Science & Technology (DST) division at the Electrochemical Society (ECS)

CHENNUPATI JAGADISH

Chief Investigator
Australian National University

AWARD: International Fellow into the Royal Academy of Engineering

Fellowship of the Royal Academy of Engineering (FREng) is an award and fellowship for engineers who are recognised by the Royal Academy of Engineering as being the best and brightest engineers, inventors and technologists in the UK and from around the world, to promote excellence in engineering and to enhance and support engineering research, policy formation, education and entrepreneurship and other activities that advance and enrich engineering in all its forms.

CHENNUPATI JAGADISH

Chief Investigator
Australian National University

AWARD: Pravasi Bharatiya Samman Award 2023

The Pravasi Bharatiya Samman Award (PBSA) is the highest honour conferred on overseas Indians. PBSA is conferred by the Hon'ble President of India as part of the Pravasi Bharatiya Divas Convention on Non-Resident Indians, Persons of Indian Origin or an organisation/institution established and run by the Non-Resident Indians or Persons of Indian Origin in recognition of their outstanding achievements both in India and abroad.

DARIA SMIRNOVA

Associate Investigator/
Postdoctoral Researcher
Australian National University

AWARD: 2022 IUPAP C17 Early Career Scientist Prize "for fundamental aspects on Laser Physics and Photonics"

The IUPAP Commission on Laser Physics and Photonics runs its Young Scientist Prizes every two years, recognizing early-career researchers of the very highest level of achievements in fundamental and applied research.

IGOR AHARONOVICH

Chief Investigator
University of Technology Sydney

AWARD: 2023 ACS Photonics Young Investigator Award

This award honours the contributions of an early-career individual who is doing outstanding work in the research areas covered by ACS Photonics.

LESLEY SPENCER

PhD Student
University of Technology Sydney

AWARD: Dean's Merit List for Academic Excellence

Designed to recognise the outstanding academic performance of science students from our undergraduate and postgraduate programs.

LESLEY SPENCER

PhD Student
University of Technology Sydney

AWARD: RFG MacMillan Award

The RFG MacMillan prize was established in 1991 to award the best Honours project in the field of materials science.

NEUTON LI

PhD Student
Australian National University

AWARD: Vice Chancellor's HDR Travel Grant for travel to CLEO San Jose

The VC HDR Travel Grant allows students to develop relationships within the international research community and allows them to access international research facilities and equipment to conduct research activities.

SHABAN SULEJMAN

PhD Student
University of Melbourne

AWARD: Dixson Scholarship in Experimental Physics

The Dixson Scholarship is awarded to UoM Faculty of Science students within the Schools of Chemistry, Physics or Mathematics & Statistics based on outstanding academic merit.

SHABAN SULEJMAN

PhD Student
University of Melbourne

AWARD: Rural & Regional Enterprise Scholarship from QTAC

The RRES program supports Australian students from regional and remote areas to access and maintain their higher education.

SHRIDHAR MANJUNATH

PhD Student
Australian National University

AWARD: SPIE Optics and Photonics Education Scholarship

SPIE Optics and Photonics Education Scholarship awarded in education scholarships to 78 outstanding individuals for their potential long-range contribution to optics, photonics, or other related fields.

Partner Investigators

DISTINGUISHED PROFESSOR ANDREA ALU

Partner Investigator

City University of New York, USA

PROFESSOR ANDREI FARAON

Partner Investigator

California Institute of Technology, USA

PROFESSOR ANDREW WEE

Partner Investigator

National University of Singapore

DR. AURELIEN BOTMAN

Partner Investigator

Thermo Fisher Scientific, USA

ASSOCIATE PROFESSOR CHENGWEI QIU

Partner Investigator

National University of Singapore

PROFESSOR DEMETRIOS CHRISTODOULIDES

Partner Investigator

University of Central Florida, Orlando, USA

DR. HANNAH JOYCE

Partner Investigator

University of Cambridge, UK

PROFESSOR HARRY ATWATER

Partner Investigator

California Institute of Technology, USA

PROFESSOR ISABELLE STAUDE

Partner Investigator

Friedrich Schiller University of Jena, Germany

PROFESSOR LAURA HERZ

Partner Investigator

University of Oxford, UK

PROFESSOR MICHAEL JOHNSTON

Partner Investigator

University of Oxford, UK

DR. NORBERT HERSCHBACH

Partner Investigator

IEE, Luxembourg

PROFESSOR SANJAY KRISHNA

Partner Investigator

The Ohio State University, USA

PROFESSOR TERI ODOM

Partner Investigator

Northwestern University, USA

PROFESSOR WILLIE PADILLA

Partner Investigator

Duke University, USA

PROFESSOR YESHAIAHU (SHAYA) FAINMAN

Partner Investigator

University of California San Diego, USA

Associate Investigators

PROFESSOR ALEXANDER KHANIKAEV

Associate Investigator

City College of New York, USA

PROFESSOR ALI JAVEY

Associate Investigator

University of California, Berkeley

PROFESSOR AMPALAVANAPILLAI (ALIAS 'THAS') NIRMALATHAS

Associate Investigator

University of Melbourne

PROFESSOR ANDREY MIROSHNICHENKO

Associate Investigator

University of New South Wales

PROFESSOR ANTONIO TRICOLI

Associate Investigator

University of Sydney

DISTINGUISHED PROFESSOR ARNAN MITCHEL

Associate Investigator

RMIT University

ASSOCIATE PROFESSOR ARTI AGRAWAL

Associate Investigator

University of Technology Sydney

PROFESSOR CHRISTINA LIM

Associate Investigator

University of Melbourne

ASSOCIATE PROFESSOR DANIEL GOMEZ

Associate Investigator

RMIT University

DR. DARIA SMIRNOVA

Associate Investigator

Australian National University

DR. DAVID POWELL

Associate Investigator

University of New South Wales

PROFESSOR DILUSHA SILVA

Associate Investigator

University of Western Australia

DR. FRANK SETZPFANDT

Associate Investigator
Friedrich Schiller University
Jena, Germany

DR. GILBERTO UMANA-MEMBRENO

Associate Investigator
University of Western Australia

DR. HAORAN REN

Associate Investigator
Macquarie University

ASSOCIATE PROFESSOR JAREK ANTOSZEWSKI

Associate Investigator
University of Western Australia

DR. JEFFERY ALLEN

Associate Investigator
Air Force Research Laboratory, USA

DR. JENNY JIANG

Associate Investigator
Univeristy of Cambridge

DR. JIAWEN LI

Associate Investigator
University of Adelaide

PROFESSOR KISHAN DHOLAKIA

Associate Investigator
University of Adelaide

DR. KYLIE DUNNING

Associate Investigator
University of Adelaide

ASSOCIATE PROFESSOR MARTIN HILL

Associate Investigator
University of Western Australia

PROFESSOR MOHSEN RAHMANI

Associate Investigator
Nottingham Trent University

DR. MONICA ALLEN

Associate Investigator
Air Force Research Laboratory, USA

ASSOCIATE PROFESSOR RANJITH RAJASEKHARAN UNNITHAN

Associate Investigator

University of Melbourne

DR. SEJEONG KIM

Associate Investigator

University of Melbourne

PROFESSOR SUMEET WALIA

Associate Investigator

RMIT University

PROFESSOR THOMAS PERTSCH

Associate Investigator

Friedrich Schiller University Jena, Germany

DR. TIM DAVIS

Associate Investigator

University of Melbourne

DR. VICTORIA COLEMAN

Associate Investigator

National Measurement Institute

PROFESSOR WEN LEI

Associate Investigator

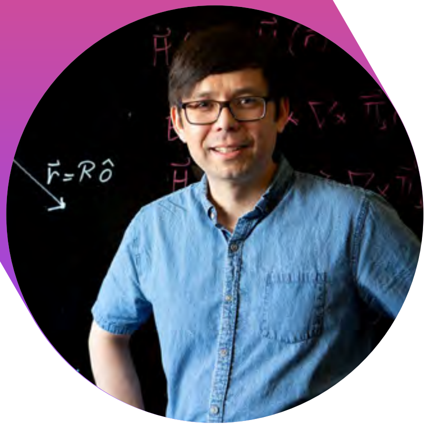
University of Western Australia

PROFESSOR YUERUI LU

Associate Investigator

The Australian National University

Research



Message from the Deputy Director

One of the striking things about meta-optics is how quickly it is transitioning from the laboratory into real-world applications. This represents a precious opportunity for Australia. As it is a new area, we can compete on a more level playing field. We have the chance to become an important player with new homegrown companies. How can the Centre contribute? Some people may think it's by making scientific breakthroughs, but in our view, it is even more important for us to nurture the next generation of scientists and engineers, to develop not only their research skills but also their leadership skills.

Let me say a few words about how we are supporting Centre students and Early Career Researchers (ECRs) to develop leadership skills and the results that we are seeing.

TMOS students and ECRs find many opportunities to develop their leadership skills. The Centre's main decision-making body, the Centre Executive Committee (CEC), includes a PhD student representative and an ECR representative. Their input is essential to the Centre's decision making because it provides an important perspective that complements that of the Chief Investigators.

All Centre PhD students receive supervision from their primary supervisor and also an external supervisor from a different node. These individuals often provide helpful guidance on leadership development that adds to advice from their primary supervisors.

The Centre's ECR Committee drives initiatives to support ECRs, including the organisation of workshops, professional development opportunities, and the Centre's mentoring program. The Committee also provides leadership opportunities to those ECRs serving on it. The Centre's mentoring program has a strong emphasis on leadership and provides each TMOS ECR with the opportunity to join with a mentor, who is usually a Chief Investigator from another node.

Lastly, the Research Program Manager (RPM) scheme provides the opportunity for Centre ECRs to lead, coordinate, and implement project management of the research programs within each of the Centre's

> "The Centre achieved a lot in 2022, but none of it was as gratifying as the steps our Centre members took towards becoming tomorrow's leaders.

three scientific themes. They do so under the guidance and mentorship of the Theme Leaders. They have a number of duties and expectations, ranging from organising and planning workshops, to tracking scientific progress and reporting. Indeed, we had several in-person Chief Investigator planning days during 2022, led by the RPMs. Each event had important outcomes, both tangible, such as actions items to follow up on, and intangible, such as Chief Investigators' improved understanding of the Centre's work. It is pretty clear that the success of these meetings was largely a result of the efforts of the Research Program Managers.

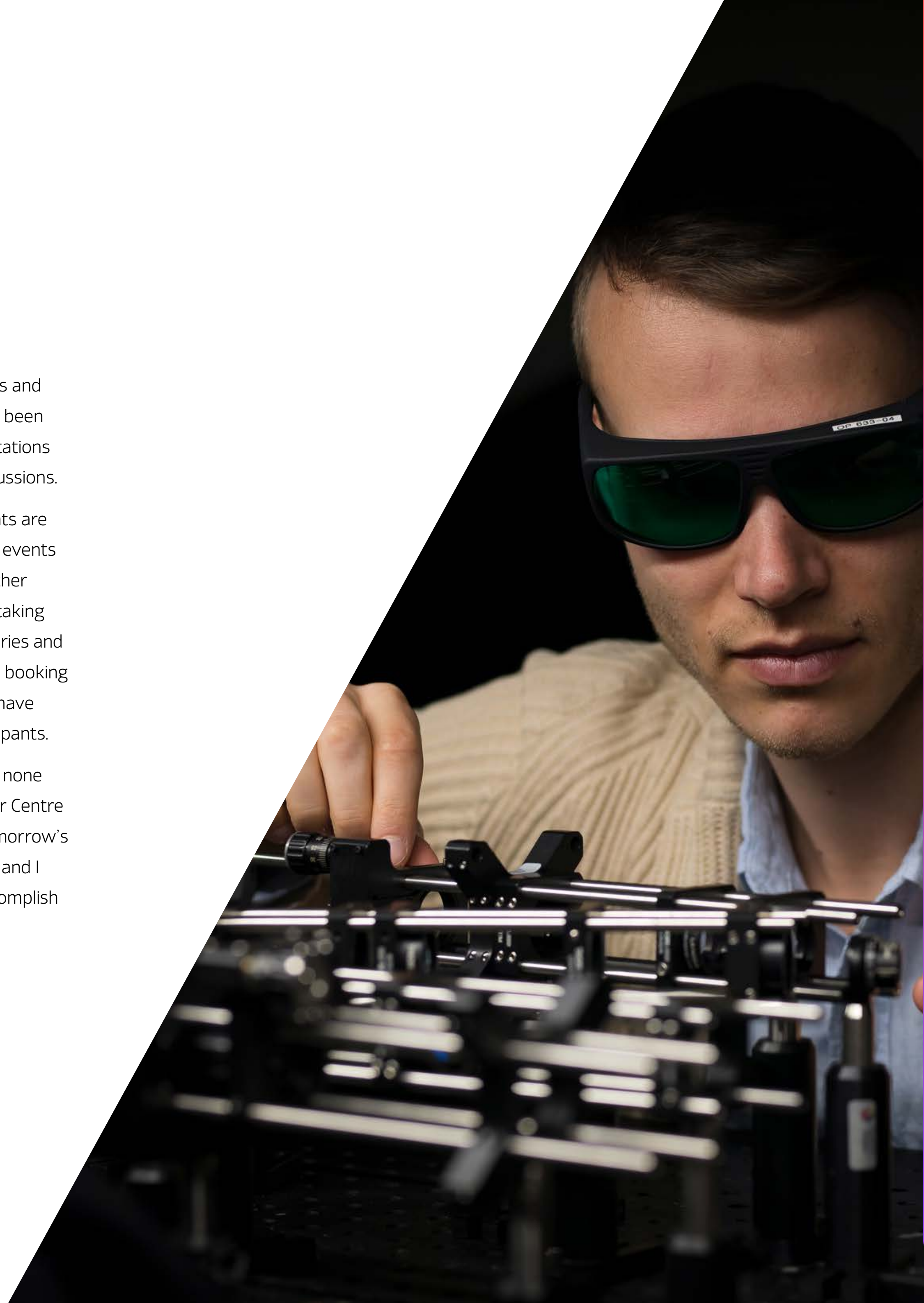
It is encouraging to see the emergence of the fruits of these efforts to foster leadership. Many readers will have attended the Centre's annual conference. Those same individuals may not realise that highly successful TMOS ECR and student conferences have also been held in those years. These have been wholly organised and attended by ECRs and students. Indeed, TMOS Chief Investigators are largely "banned" from these meetings, with a few notable exceptions. These meetings are clearly "by ECRs and students for ECRs and students"! By all accounts, these have been highly successful events, with presentations of a high standard and extensive discussions.

Furthermore, Centre ECRs and students are taking the lead in organising outreach events through our Outreach Committee. Rather than being just participants, they are taking the initiative. They are contacting libraries and schools in their local communities and booking engagements. Some of these events have attracted more than a hundred participants.

The Centre achieved a lot in 2022, but none of it was as gratifying as the steps our Centre members took towards becoming tomorrow's leaders. For that, I congratulate them, and I look forward to seeing what they accomplish in 2023.

Professor Kenneth Crozier

Centre Deputy Director



Research Overview

Our research excellence in meta-optics enables us to overcome complex scientific and engineering challenges in light generation, manipulation, and detection at the nanoscale. We lead internationally esteemed innovations, inspiring others, and creating positive impacts on society.

Our research outcomes underpin future technologies, including real-time holographic displays, artificial vision for autonomous systems to see the invisible, wearable medical devices and ultra-fast light-based Wi-Fi, meeting the evolving demands of Industry 4.0. The Centre has a visible impact on technology beyond the seven-year timeframe of its research program.

Our Centre has three Research Themes and our goals for each are to:

GENERATE

Prepare for next-generation optical systems by developing miniaturised, energy-efficient laser-light nano-emitters.

MANIPULATE

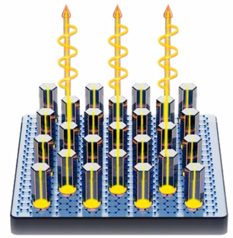
Cater for the exponential growth of image-processing data and emerging exascale problems by developing photonic problem-specific processors.

DETECT

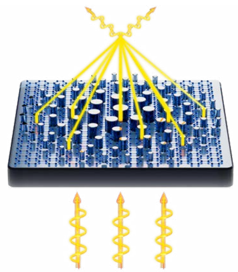
Realise access to currently unavailable optical information by integrating metasurfaces into photodetectors to expand their functionality.

In addition, our research program will provide the Centre with capabilities and infrastructure that supports and expedites research.

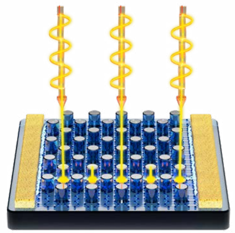
Find out more about our themes on our website



GENERATE



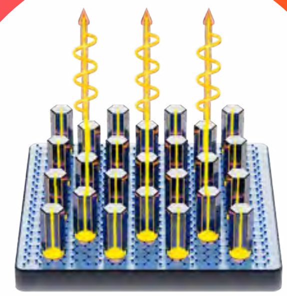
MANIPULATE



DETECT

THEME ONE
Generate

Light emitting diodes (LEDs) and semiconductor lasers are pervasive in our daily lives in applications such as high efficiency low-power lighting, traffic lights, displays, Playstations®, Xboxes® and optical fibre links for the internet. As good and efficient as these devices are now, it is expected that the next-generation optical systems would be integrated onto micro/nano-electronic platforms with added functionalities. As such, miniaturised, highly compact and energy-efficient light sources are needed. To obtain added functionalities, the properties of the emitted beams must also be easily manipulated in terms of colour (frequency), coherence, polarisation, directions and spatial profile.



THEME LEADERS:

PROFESSOR IGOR AHARONOVICH
University of Technology Sydney

PROFESSOR CHENNUPATI JAGADISH
The Australian National University
(Until May 2022)

PROFESSOR HOE TAN
The Australian National University
(from May 2022)

2022 has been the first year where our theme gathered together face-to-face post COVID-19 pandemic. This enabled us to come up with common strategic goals, and align our efforts to synergically contribute to TMOS vision. Our aims for this theme continue to focus on developing novel meta-optical light emitters to be the brightest and most efficient miniaturised classical and quantum light sources. Towards this vision, we have achieved the first room-temperature optically detected magnetic resonance of single defects in hexagonal boron nitride. This was done via collaboration between the UTS and the ANU node, in partnership with our friends in Cambridge. The work was enabled by the excellent material grown by ANU and the characterisation capabilities at UTS and Cambridge.

The UTS team has also delivered the first ultra bright source of single photons, with purity exceeding 99%, packaged into a portable box. This was demonstrated to NSW Chief Scientist as a new capability developed entirely in Australia, and led by the TMOS team.

The ANU team demonstrated efficient nonlinear sum-frequency generation in multiresonant GaP metasurfaces. By varying the input pump beam polarisation, it is possible to direct the emission

to different diffraction orders, opening up new opportunities for nonlinear light sources and infrared to visible light conversion. The ANU team developed a tiny quantum light source with spatial spooky features using nonlinear metasurfaces. This device has flexible tunability in wavelength and emission angle and does not need temperature control. The device's practical qualities will make it a valuable component for future micro-quantum technology.

In nanolasers, the ANU team has developed both building blocks for nanolasers as well as controllable emission in different nanolaser systems. The building blocks include GaN nanopillar arrays with controllable dimensions and thin-film semiconductor LEDs that form a basis for electrical metasurface lasers. In tailorable nanolasers, the ANU team has developed the selective area growth of micro-ring cavities with atomically flat side facets and demonstrated micro-ring lasers coupled with nanoantennas for directional emission, as well as the first nanowire laser array with simultaneous Fabry-Perot and random lasing modes, where the dominant mode can be controlled by temperature.

KEY ACHIEVEMENTS

- First portable single photon source, based on a 2D material (hBN)
- New generation of quantum emitters at the blue spectral range
- First demonstration of spin-photon interface, at room temperature, of a quantum emitter in hBN
- New method for nonlinear frequency conversion with high efficiency
- First demonstration of spatially entangled photon pairs with metasurfaces

KEY MILESTONES FOR 2023

1. Realisation of coupled emitter–cavity system
2. Initial characterisation of QD based sources in near infrared
3. Study of second-harmonic generation (SHG) in individual GaN nanowires
4. Study of non-linear topological protected modes in Si nanostructures
5. Industry engagement with Sony Europe B.V: Nonlinear Imaging via sum-frequency generation
6. Industry engagement with L3Harris Technologies: ANU-TMOS SWIR Upconverter
7. Hyper-entanglement in spatial and spectral degrees of freedom with nonlinear metasurfaces
8. Electrically injected micro-ring lasers
9. Light-emitting metasurface fabrication

GENERATE

Subprograms

This theme supports two sub-programs aimed and developing new meta-optical light emitters.

1A. NANOSCALE LASERS AND LASER ARRAYS

In Theme 1A, our aims include electrical nanolasers, tailorable emission and coupled nanolaser arrays. These aspects are critical in practical devices and in many applications such as holograms and optical sensing. In 2022 we have progressed in many areas including fundamental nanolaser building blocks, nanolaser arrays and controllable emission.

In the nanolaser building blocks, uniform GaN nanopillar arrays were grown with precise control on dimensions and with smooth crystal facets on sidewalls. GaN material is conducive for UV and blue emitters, while the nanopillar geometry simultaneously forms a nanoscale Fabry-Perot cavity to enable lasing.

In another development, a transfer process and device fabrication scheme were developed for ultrathin semiconductor films, with a successful fabrication of a 230 nm-thick LED emitting at an optical communications wavelength of 1550 nm. In future work, such film can be modified to create an electrical metamaterial laser that can enable tailoring of emission properties such as direction, polarisation wavelength etc.

In nanolaser arrays, a unique hybrid system was demonstrated, where Fabry-Perot and random lasing modes coexist at the same time. Furthermore, by changing the operating temperature, the dominating mode could be selected, and thereby the emission properties as well. These lasers were made of GaAs nanowires, where a random array enabled random lasing and the nanowire dimensions enabled Fabry-Perot lasing.

Finally, controllable emission direction was demonstrated in microring lasers. In a typical case, microring lasers emit light in-plane, which is useful in photonic integrated circuits, for example. By coupling the microrings to nanoantennas, directional, out-of-plane emission was achieved, which can be exploited in optical sensing, LIDARs and holograms among other applications. Overall, the year 2022 was productive in Theme 1A with many exciting demonstrations and opportunities for future developments.

ACTION ITEMS 2023

- Optimising cavity design, transparent contacts, and fabrication challenges
- Electrical injection to microring cavity
- Develop the theoretical approaches for PT symmetry-based control of gain and loss
- Light-emitting metasurface design and fabrication with electrical injection
- Demonstration of NIR-to-visible conversion with coupled metamaterial and upconverting nanoparticles 0.1nW/cm2

PUBLICATIONS

1. Characteristics and Thermal Control of Random and Fabry-Pérot Lasing in Nanowire Arrays
2. Nonpolar AlxGa1- xN/AlyGa1- yN multiple quantum wells on GaN nanowire for UV emission
3. Selective Area Growth of GaN Nanowire: Partial Pressures and Temperature as the Key Growth Parameters
4. Directional Lasing in Coupled InP Microring/ Nanowire Systems
5. Effective Passivation of InGaAs Nanowires for Telecommunication Wavelength Optoelectronics

INTERVIEW

RESEARCH PROGRAM MANAGER: Tuomas Haggren

How long have you been a researcher and what is your particular field of interest?

The first research project I carried out was my masters thesis in 2011 that encompassed six months of experimental research. The thesis was on the field of nanoscience and nanofabrication. The field still remains in the core of my research interests, which I apply to optoelectronics and metamaterials in my current research.

What is it about meta-optics research that excites you?

The field is still relatively new and it has enormous potential in many directions. This itself is exciting, and as an added bonus, it gives plenty of room for creative thinking and research.

When did you first decide that you wanted to be a physicist? What inspired you?

Already as a kid I was intrigued by the possibilities that science and technology offer, particularly in the long term. I believe that science is the best bet for enhancing the lives of everyone on the planet, as well as the planet itself.

Why did you choose to take on the role of Research Program Manager?

The Research Program Manager role offered interesting opportunities to enhance leadership skills, to interact more broadly with the centre researchers, and to get insights and contribute to the organisation and the management of the centre.

What has been the biggest challenge of taking on the role of Research Program Manager?

Time allocation.

What has been the greatest joy in taking on the role of Research Program Manager?

Working with other enthusiastic Program Managers and researchers.

How have the Chief Investigators supported you in your new role?

They have been very accommodating in providing knowledge and support whenever needed.

How do you feel this role is going to benefit your future career? In 20 years, where do you see yourself?

The leadership and organisational experiences will be definitely beneficial in future.

What advice do you have for young people beginning their career in science research?

Think positive and look for research topics you're motivated about.

What is the one big thing that you think meta-optics is going to change in society? How do you think it will benefit the next generation?

I believe there will be numerous things that meta-optics will change. Among them, one of the bigger things is likely imaging where meta-optics enables flat lenses and the possibility to see properties of light that are difficult to see by conventional means.

Finish this sentence. In 50 years the world will... be a better place and more advanced than we can imagine, as science and technology progress at ever-accelerating pace.

TUOMAS HAGGREN

Research Fellow

Australian National University

Tuomas Haggren is a Research Fellow at ANU and Research Program Manager for Nanolasers and Laser Arrays at TMOS.

Haggren graduated from Aalto University School of Electrical Engineering in 2016 with his PhD thesis focusing on epitaxy and nanofabrication of III-V semiconductors. He has published over 30 peer-reviewed journal articles and one patent. He worked as a postdoctoral researcher at Aalto University School of Science from 2017-2018 and subsequently secured his own funding to carry out a research project at the Australian National University from 2019-2021. His postdoctoral research topics encompassed epitaxial lift-off (ELO) and nanoscale devices, with applications focusing on solar cells, lasers, and other optoelectronics.

1B. ADVANCED AND QUANTUM LIGHT SOURCES

Advanced and quantum light sources are essential to optical imaging and various quantum applications. A two-dimensional surface with nanoscale thickness, known as a metasurface, shows a huge potential to facilitate the miniaturisation of advanced optical devices with added functionalities. This research program aims to explore the efficient conversion of light colour, emission of quantum light, and generation of spooky photons using metasurfaces, developing the next generation of ultra-compact light sources with functionalities beyond what is conceivable today. Towards this vision, we have made exceptional achievements in the past year and will briefly introduce the exciting research below.

Efficient conversion of light colour. The ANU team presented a novel approach to achieve effective nonlinear sum-frequency generation in multi-resonant GaP metasurfaces. The research shows potential in controlling the emission to various diffraction orders by changing the polarisation of the input pump beam, creating new possibilities for infrared to visible light conversion with nonlinear light sources.

Quantum emitters. The UTS team produced the first ultrabright source of single photons packaged into a portable box, with purity exceeding 99%. This was presented to the NSW Chief Scientist as a novel capability that was totally Australian-developed and was led by the TMOS team. The team has also achieved a new generation of quantum emitters at the blue spectral range and the first demonstration of the room-temperature spin-photon interface of a quantum emitter in hBN.

Generation of spooky photons. For the first time, the ANU team used nonlinear metasurfaces to produce a nanometre-thickness quantum light source with spatial entanglement. This device does not require temperature control and allows flexible tuning of photon wavelength and emission angle. The practical features of the device will make it an important part of upcoming micro-quantum technologies.

ACTION ITEMS 2023

- Enhancement of nonlinear emission from 2D materials studies and their heterostructures
- Initial characterisation of quantum dots based sources in near infrared
- Study of second-harmonic generation in individual GaN nanowires
- Generation of polarisation-entangled photon pairs
- Hyper-entanglement in spatial and spectral degrees of freedom with nonlinear metasurfaces

PUBLICATIONS

1. J. Yan, Q. Ou, M. A. Vincenti, C. De Angelis, Q. Bao, and D. N. Neshev, Nonlinear Microscopy of Lead Iodide Nanosheets, Opt. Express 30, 4793 (2022).
2. R. Camacho-Morales, L. Xu, H. Zhang, S. T. Ha, L. Krivitsky, A. I. Kuznetsov, M. Rahmani, and D. Neshev, Sum-Frequency Generation in High-Q GaP Metasurfaces Driven by Leaky-Wave Guided Modes, Nano Lett. 22, 6141 (2022).
3. H. L. Stern et al., Room-Temperature Optically Detected Magnetic Resonance of Single Defects in Hexagonal Boron Nitride, Nat Commun 13, 618 (2022).
4. A. Gale, C. Li, Y. Chen, K. Watanabe, T. Taniguchi, I. Aharonovich, and M. Toth, Site-Specific Fabrication of Blue Quantum Emitters in Hexagonal Boron Nitride, ACS Photonics 9, 2170 (2022).
5. J. Zhang, J. Ma, M. Parry, M. Cai, R. Camacho-Morales, L. Xu, D. N. Neshev, and A. A. Sukhorukov, Spatially Entangled Photon Pairs from Lithium Niobate Nonlocal Metasurfaces, Sci. Adv. 8, eabq4240 (2022).

INTERVIEW

RESEARCH PROGRAM MANAGER: Jinyong Ma

How long have you been a researcher and what is your particular field of interest?

I started my research journey with my Master's study in 2012. My research interest includes experiments and theory in nano-structured metasurfaces, quantum nano-photonics, quantum optomechanics, optical levitation, photothermal effects, and nonlinear optics.

What is it about meta-optics research that excites you?

Meta-optics is an excellent platform for miniaturising various quantum devices with added functionalities.

When did you first decide that you wanted to be a physicist? What inspired you?

I have dreamt of being a physicist since I was a kid. My curiosity about so many fascinating phenomena in nature drives me to study physics and explore the universe.

Why did you choose to take on the role of Research Program Manager?

As a program manager, I would be able to meet many new people in different fields, which may initiate broad and interesting collaborations. Additionally, I would like to launch my research group in the future. The leadership skills I will develop in the position of a program manager will be essential for my future career.

What has been the biggest challenge of taking on the role of Research Program Manager?

The researchers at TMOS working on the advanced and quantum light sources come from different universities. It was very challenging to coordinate all researchers and facilitate collaborations.

What has been the greatest joy in taking on the role of Research Program Manager?

I got to know a lot of new people from different research fields and universities.

How have the Chief Investigators supported you in your new role?

The Chief Investigators reported detailed progress of research projects in this research program and provided some suggestions on potential collaborations.

How do you feel this role is going to benefit your future career? In 20 years, where do you see yourself?

As I have mentioned earlier, I would like to launch my research group in the future. The leadership skills I obtain from the role of a program manager will be beneficial for my future career.

What advice do you have for young people beginning their career in science research?

My advice is: stay motivated and be responsible; don't be afraid to ask colleagues or supervisor for help; develop independent research skills; learn techniques important to your research field.

What is the one big thing that you think meta-optics is going to change in society? How do you think it will benefit the next generation?

The use of quantum technologies based on meta-optics will become people's daily life. For example, we can monitor our health with an ultrasensitive quantum biosensor, communicate securely with quantum communication techniques, and achieve low-dose and high-resolution imaging with quantum imaging.

Finish this sentence. In 50 years the world will... be dominated by meta-optics. You will see meta-optics in nearly all devices in our daily life.

JINYONG MA

Research Fellow

Australian National University

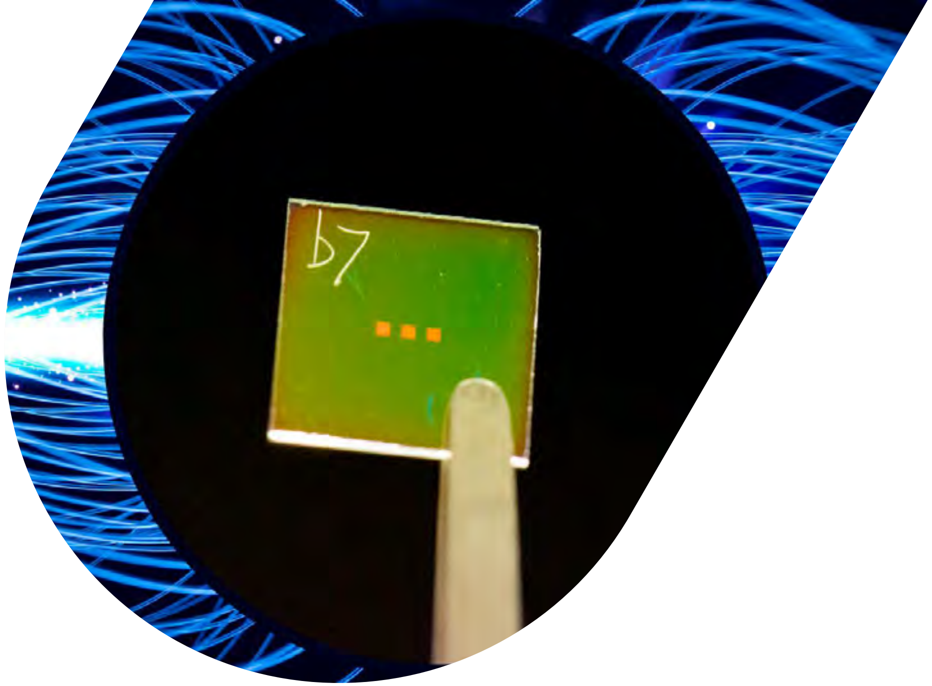
Jinyong Ma is a Research Fellow in Professor Andrey Sukhorukov's group at ANU and Research Program Manager for Advanced and Quantum Light Sources at TMOS.

After completing his PhD at ANU in 2020, Jinyong became a postdoctoral associate at Yale University until 2021, before returning to ANU in 2022. He has many first-author publications in prestigious journals including *Science Advances, Optica,* and *Communication Physics*. He is a reviewer of research journals for *Photonics Research, ACS Photonics, APL Photonics, Optics Letters,* and *Optics Express.*

Ma's research interests include both experiments and theory on nano-structured metasurfaces, quantum nano-photonics, nonlinear optics, quantum optomechanics, optical levitation, photothermal effects, etc.

GENERATE CASE STUDY

Spooky but tiny: grating boosts nanostructured quantum light source



A key element for future quantum technology is a step closer with the unveiling of a tiny quantum light source, less than one hundredth the diameter of a strand of human hair.

The device's practical qualities will make it a valuable component for future micro-quantum technology, says TMOS Chief Investigator Professor Andrey Sukhorukov.

"The device is small enough to fit on a silicon chip, and operates at room temperature with a tunable wavelength, which are big advantages over existing technology," he says.

The quantum light source takes energy from an input laser and creates two entangled photons. Quantum entanglement means that the photons' properties remain linked, even when far apart, a phenomenon that Einstein thought implausible, dubbing it "spooky action at a distance."

The link between such separate entities can be used to create unbreakable quantum encryption, or to reveal incredibly faint or inaccessible data using quantum imaging.

However, existing quantum light sources each have their own limitations, in frequency of operation, direction of emission or temperature requirements.

The new source, described in Science Advances boasts not only small size, room temperature operation and wavelength tunability, but also emits two entangled photons that leave the device in different directions – distinguishing them from existing quantum light sources in waveguides, whose photon pairs travel efficiently inside a waveguide circuit but are not easily extracted into free space.

Team member Dr Jinyong Ma performed the quantum characterisation, showing that the photons are spookily linked no matter how far they are separated.

> In fact, it is impossible to find a pair of photons in the same place!" he said. "This type of light source will underpin free-space quantum communications and quantum imaging."
>
> \- Jinyong Ma

SPOTLIGHT

Jihua Zhang

Early Career Researcher

Jihua won the TMOS Early Career Researcher of the Year Award in 2022 and is part of the Australian National University team.

SPOTLIGHT

Jinyong Ma

Early Career Researcher

Jinyong is a Research Program Manager for the Centre's Generate Theme and is an Early Career Researcher at the Australian National University.

"In fact, it is impossible to find a pair of photons in the same place!" he says. "This type of light source will underpin free-space quantum communications and quantum imaging,"

A second unique feature of the nano-grating is its ability to support optical resonances at different wavelengths depending on the emission angle of the light.

This allows efficient control of wavelength and quantum behaviour of the generated photons by simply tuning the wavelength of the input laser – a major advantage over crystal sources which require careful temperature control to operate at different wavelengths.

"Controlling the temperature is inconvenient in everyday devices – mobile phones for example need to operate in a range of environments," said Dr Zhang.

As well as operating at different frequencies, the phenomenon can be reversed in the device, says team member Dr Rocio Camacho Morales. "The device can combine two photons into one. This is useful in generating new colours of light, which would be useful for night vision cameras," said Dr Rocio, who confirmed this effect in an experiment.

The Director of TMOS, Professor Dragomir Neshev, was thrilled with the results. "This exciting work is a firm step towards the goal of TMOS in realising miniaturised optical systems for end-user applications."

Spatially entangled photon pairs from lithium niobate nonlocal metasurfaces

SCIENCE ADVANCES 29/07/22

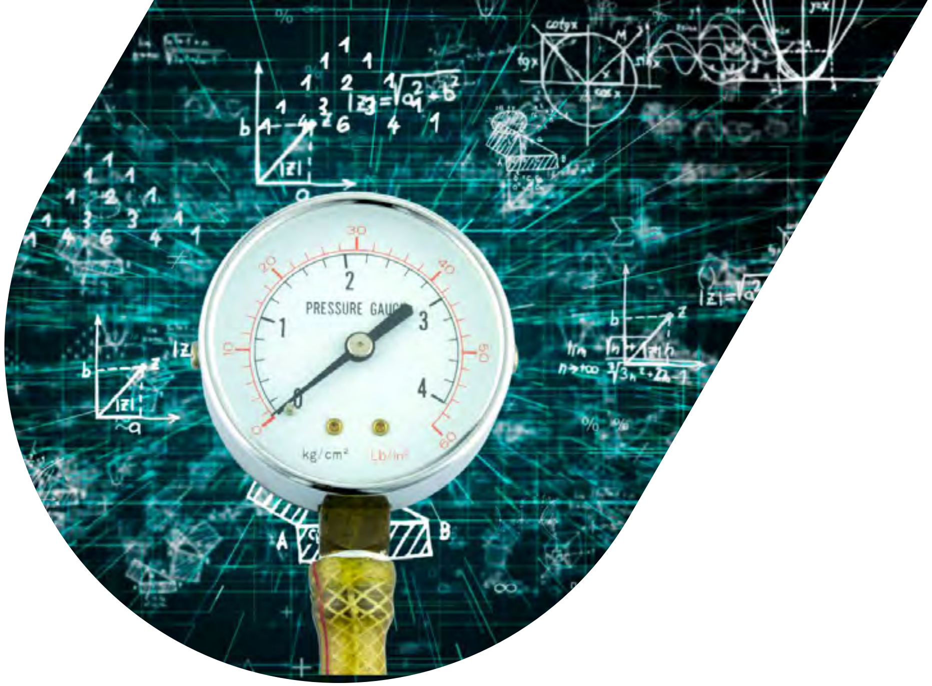
Jihua Zhang, Jinyong Ma, Matthew Parry, Marcus Cai, Rocio Camacho-Morales, Lei Xu, Dragomir Neshev, Andrey Sukhoruov

Metasurfaces consisting of nanoscale structures are underpinning new physical principles for the creation and shaping of quantum states of light. Multiphoton states that are entangled in spatial or angular domains are an essential resource for many quantum applications; however, their production traditionally relies on bulky nonlinear crystals. We predict and demonstrate experimentally the generation of spatially entangled photon pairs through spontaneous parametric down-conversion from a metasurface incorporating a nonlinear thin film of lithium niobate covered by a silica meta-grating. We measure the correlations of photon pairs and identify their spatial antibunching through violation of the classical Cauchy-Schwarz inequality, witnessing the presence of multimode entanglement. Simultaneously, the photon-pair rate is strongly enhanced by 450 times as compared to unpatterned films because of high-quality-factor resonances. These results pave the way to miniaturization of various quantum devices by incorporating ultrathin metasurfaces functioning as room temperature sources of quantum-entangled photons.

Read the full article

GENERATE CASE STUDY

UV LEDS: a new formula for safer drinking water



It has been over a decade since the UN General Assembly recognised continuous access to safe, affordable drinking water and sanitation as a human right, yet still almost a quarter of the world's population don't have access to a safely managed water source, resulting in hundreds of thousands of deaths per year.

One method of treating dirty water is using ultraviolet (UV) lamps to kill microorganisms such as bacteria, viruses, and parasites. The lamps are installed in water filtration systems where microorganisms are exposed to UV-C radiation in a process called UV disinfection.

The difficulty is, UV lamps in their current form present their own risk. They are bulky, fragile and made of mercury, a toxic metal that can cause serious health problems if a person is exposed to it in significant amounts. Mercury poisoning can also affect plant and animal life. Since the Minamata Convention of Mercury came into effect five years ago, countries have been working together to reduce the use, emission and release of mercury.

TMOS researchers are working on safe UV-LEDs to replace UV lamps made of mercury.

Current LEDs that can be found in the average home or office use bulk Gallium Nitride (GaN)-based semiconductors and operate in the visible wavelength. The reason they're so popular is because they have an efficiency of more than 80%. Such success has yet to be had with LEDs that operate at UV wavelengths, with efficiencies maxing out at approximately 20% as the addition of aluminium (AlGaN) is required for UV emission, creating material quality issues in the AlGaN layers. These issues become worse as more Al is incorporated in order to reach deep UV (UV-C) range.

The TMOS team at the Australian National University are working to develop GaN-

> "Nanostructures can create highly efficient UV LEDs because we can improve the quality of the AlGaN layers required for UV-C emission. Hopefully, the work we are doing will lead to cheaper, safer, more accessible drinking water for those in need."
>
> - Hark Hoe Tan

SPOTLIGHT

Sonachand Adhikari

PhD Student

Sonachand studied with the Centre's Australian National University team and completed his PhD at the end of 2022.

AlGaN nanowires instead of bulk devices. Due to the unique properties afforded by the inherent nanowire geometry, the material quality of AlGaN layer on the nanowires is improved, creating solid-state UV LEDs with high efficiency that could one day replace mercury-based UV lamps. The challenge they've faced until now has been achieving consistency in nanowire growth as there are a large number of variables to be controlled, such as temperature, pressure, flow rates and the choice of carrier gas.

Chief Investigator Hark Hoe Tan and his team are overcoming this challenge by taking a unifying approach to metal organic chemical vapour deposition parameters. Rather than considering parameters such as flow rate of precursors and the carrier gas individually, they studied partial pressure as an overall unit of measurement that, combined with growth temperature, governed the regular and controllable growth of GaN-AlGaN nanostructures.

Lead author and PhD student Sonachand Adhikari says "Having a single formula that controls all of the variables for GaN nanowire growth allows for understanding the deviation in nanostructure shapes and sizes, and hence it can be tuned to achieve consistent results and reproducibility between each batch. This will be essential for mass production of highly efficient UV LEDs. The exciting thing is this formula is likely to be applicable to other semiconductor materials we use to grow nanowires."

Chief Investigator Tan says "Nanostructures can create highly efficient UV LEDs because we can improve the quality of the AlGaN layers required for UV-C emission. Hopefully, the work we are doing will lead to cheaper, safer, more accessible drinking water for those in need."

Selective Area Growth of GaN Nanowire: Partial Pressures and Temperature as the Key Growth Parameters

ACS: CRYSTAL GROWTH & DESIGN 8 AUGUST 2022

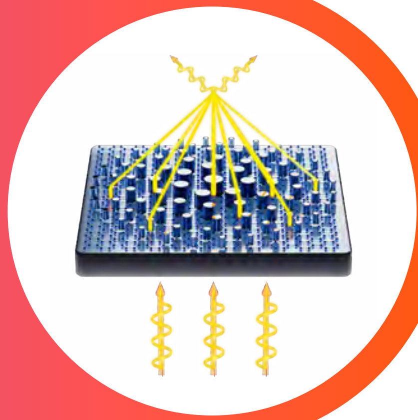
Sonachand Adhikari, Mykhaylo Lysevych, Chennupati Jagadish, and Hark Hoe Tan

Selective area growth of Ga-polar GaN nanowires by metal organic chemical vapor deposition provides a path to achieve arrays of uniform nanowires with controllable dimensions. A systematic investigation on the growth parameters of GaN nanowires demonstrates that although a low V/III ratio and low precursor flows are necessary, V/III ratio is not a sufficient parameter to determine the morphology of GaN nanowires. Partial pressures of the constituent gases, on the other hand, can be used as a single parameter, at a particular growth temperature, to explain the resulting morphology. By correlating the partial pressures of precursors and H2 in the carrier gas with the morphology of the nanowires, we can then determine the flow rates for precursors and hence the range of V/III ratios required for achieving the growth of GaN nanowires.

THEME TWO

Manipulate

Vision is a key sense for humans, so it is not surprising that we have so many static pictures and devices around us displaying images. This is being done not only for our entertainment but also for productive purposes. Over the course of human history, the ability to create images evolved from still to the dynamic pictures that we enjoy now in the form of videos, with an ever increasing quality of these images. The limitation of all these visuals is that they only give a flat representation of our volumetric world. In other words, we see 2D images of 3D objects. This limits the usability of these images, as we are not able to see the real depth of the objects or see them from different angles. The desire to show 3D pictures led to the invention of static holograms almost half a century ago. Making dynamic holograms, a true 3D video, is an extremely sought-after ability that will revolutionise many areas of human life, including education, health and entertainment. Artificial surfaces created for manipulating light, or metasurfaces, give us the concept for solving this problem, and this is one of the main motivations behind Research Theme 2 of the Centre.



THEME LEADERS:

PROFESSOR ILYA SHADRIVOV
The Australian National University

PROFESSOR MADHU BHASKARAN
RMIT University

Manipulate is logically placed between the Generate and Detect themes. In any optical system light needs to be manipulated after it is generated and/or before it is detected. In fact, to create *any* functional device using light that will, for example, form an image or transfer data, we need to appropriately change the light properties.

Many optical systems rely on classical optical components controlling light in free space. In compact devices where space and weight are critical factors, conventional optical components can hinder the functionality and efficiency of the device. For instance, in satellites, every gram of weight and every cubic centimetre of space counts, as it directly impacts the launch cost and overall design of the satellite. Similarly, in drones, night-vision goggles, and endoscopes, the need for compact, lightweight and efficient devices is essential.

Traditional optical components, such as glass or plastic lenses with mechanical parts, are not practical in these devices as they are often bulky and take up valuable space. Additionally, the mechanical parts in tunable optical systems can be prone to wear and tear and can impact the performance of the device over time. For example, changing focus to see clearly typically requires physically moving a lens, by tilting, sliding, or otherwise shifting the lens, usually with the help of mechanical parts that add to the bulk of microscopes and telescopes.

Therefore, replacing these conventional optical components with alternative, more compact solutions is critical in ensuring that these devices are able to function effectively and efficiently. This could include the use of metasurfaces that are lightweight, space-saving, and offer improved performance compared to traditional optical components.

At TMOS, we create tunable metadevices – flat arrays of nano-antennas or resonators with multi-functionalities triggered by various external stimuli that can be controlled and programmed in real time. By exploiting these resources, optical elements can be highly miniaturised and various optical applications have been implemented, such as tunable beam splitters, absorbers, metalenses, metaholograms, selective thermal emitters, detecting devices as well as sensors. They have been widely applied to a range of scenarios, including imaging, solar energy harvesting, optoelectronic detection, and more.

Our tunable metasurfaces control the properties of light dynamically in time without changes to their physical position or shape. In this way, tunable "metalens" could focus on objects at multiple depths without tilting, moving or using mechanical elements and thus, could allow miniature zoom lenses for more nimble optical devices, such as miniature heat scopes for drones, ultra-compact cameras for mobile devices including medical equipment.

We explore various materials that may be suitable for creation of metasurfaces that change response under external stimuli, including liquid crystals, ferroelectrics, phase change materials and others.

KEY ACHIEVEMENTS

- Demonstrated tunability of metasurfaces with liquid crystals through applied magnetic field.
- Initiated the studies of vanadium dioxide use in tunable metasurfaces.
- Demonstrated phase-only tuning of Huygens metasurfaces.
- Studied properties of electro-optic metasurfaces.
- Reviewed surface functionalisation and texturing of optical metasurfaces for sensing applications.
- Developed nanowire array gas sensor for dynamic NO_2 monitoring.

KEY MILESTONES FOR 2023

1. Experimentally demonstrate electro-optic metasurface devices based on lithium niobate and continue theoretical works on expanding the functionality of such devices.
2. Study phase change materials for optical and sensor applications.
3. Develop tunable metadevices with liquid crystals incorporating several control mechanisms.
4. Continue fabrication of tunable metadevices using MEMS.
5. Demonstrate diffractive neural network for chemical classification.
6. Develop integrated platform with nanoscale light sources/detectors and optical sensors.
7. Develop new scalable designs for sensor applications.

MANIPULATE
Subprograms

2A. DYNAMICALLY TUNABLE METAOPTICS

This research program aims to create tunable metadevices where the properties of light can be controlled and programmed dynamically in real time for image processing applications. Action items for 2022 were achieved by using a variety of approaches for making tunable metasurfaces and achieving their practical functionality.

We have further investigated phase-change materials to realise tunable metasurfaces. Alongside using pure vanadium dioxide that undergoes insulator-to-metal transition, we have demonstrated that tailored nanostructuring of vanadium dioxide can dramatically enhance optical transmission modulation, which is two times larger than the previous modulation achieved.

Continuing to explore liquid crystal as tunable material, we have developed a new type of dynamic control of metasurfaces infiltrated with liquid crystal by applying an external magnetic field. This method opens novel opportunities for realising switchable metadevices without the usual limitations imposed by boundary conditions of liquid crystal cells and external voltage. Furthermore, a new method for realising 2π-dynamic phase tuning in transmissive dielectric metasurfaces has been proposed, which can be implemented by controlling the bias voltage and changing the temperature of the surrounding liquid crystal. We are also continuing to investigate and design liquid crystal metalens with adjustable focal lengths to replace bulky, curved traditional lenses.

We have designed electro-optic metadevices based on lithium niobate and studied their amplitude and phase tunability. We also have proposed metadevices with the possibility of controlling light polarisation.

Electrically tunable metasurfaces were developed for beam-shaping applications. It was designed and fabricated with four individual metasurface pixels that can be controlled separately. By applying an asymmetric driving voltage, flash heating was achieved, leading to 90% transmission modulation depth and switching time <625 ms.

We have developed tunable metasurface filters for long-wavelength infrared range using a micro-electro-mechanical system (MEMS). Furthermore, we have proposed a new approach for realising parametric metadevices for electromagnetic wave amplification. A significant gain was demonstrated in the case of small incident microwave radiation power.

ACTION ITEMS 2023

- Continue to explore phase change materials for optical and sensor applications
- Fabricate and characterise electro-optic metasurface devices based on lithium niobate and expand their functionality
- Design and develop tunable metadevices using liquid crystal through the dynamic molecular realignment
- Explore a fully controllable tunable metasurfaces in full 3D
- Continue towards development of tunable metadevices using MEMS
- Development of parametric metadevices for electromagnetic wave amplification

PUBLICATIONS

1. Device Geometry Insights for Efficient Electrically Driven Insulator-to-Metal Transition in Vanadium Dioxide Thin-Films
   https://doi.org/10.1002/aelm.202100428
2. Magnetic tuning of liquid crystal dielectric metasurfaces
   https://doi.org/10.1515/nanoph-2022-0101
3. Electro-optic metasurfaces
   https://doi.org/10.1364/OE.469647
4. Phase-Only Tuning of Extreme Huygens Metasurfaces Enabled by Optical Anisotropy
   https://doi.org/10.1002/adom.202101893
5. Fundamental Limits for Transmission Modulation in VO_2 metasurfaces
   https://doi.org/10.1364/PRJ.474328

INTERVIEW

RESEARCH PROGRAM MANAGER: Yana Izdebskaya

How long have you been a researcher and what is your particular field of interest?

I have more than 10 years' experience in research, and my current interest is in developing dynamically tunable dielectric metasurfaces by using liquid crystals.

What is it about meta-optics research that excites you?

Some future applications of metasurfaces are very inspiring. Shrinking optical devices, such as cameras, telescopes, and microscopes to ultra-thin metadevices with high-resolution opens new perspectives in image-processing and medical applications. I believe that in the near future, people will benefit greatly from metadevices that help them in different areas, including health care and security.

When did you first decide that you wanted to be a physicist? What inspired you?

I was always fascinated with science, and how things worked. I had an opportunity to visit a university, have a lab tour and talk to real scientists, which made me excited to learn more beyond our lessons at school. After that tour, I decided to take courses in the physics department. What inspires me about being a physicist is that I have an opportunity to explore the world as we know it and satisfy my curiosity for the advancement of humankind.

Why did you choose to take on the role of Research Program Manager?

I took on this role of planning and overseeing projects to contribute to TMOS and achieve our common goals in developing tunable metasurfaces. I believe such metasurfaces, whose functionalities can be actively tunable, can significantly expand capabilities of metadevices for a wide range of applications. By fulfilling this role and participating in the projects I am excited to see how this technology can positively impact the different industries and change people's lives.

What has been the biggest challenge of taking on the role of Research Program Manager?

Collaboration is one of the most important parts of our work. However, due to travel restrictions during COVID-19, we had some challenges developing our cross-node collaborative projects. Nevertheless, due to the organisation of our regular online meetings and then the successful holding of the first TMOS conference, we have overcome these challenges, settled up our goals and objectives and started new exciting collaborative projects.

What has been the greatest joy in taking on the role of Research Program Manager?

As a project manager, I feel rewarded when I keep the projects and our schedules on track, meet the objectives, and collaborate with colleagues to ensure everything runs efficiently. I love making projects happen and getting tasks completed when they contribute to the overall goal.

How have the Chief Investigators supported you in your new role?

We have great support from our Chief Investigators via our regular meetings and discussions. They always provide timely and helpful advice and constructive feedback that helps me grow in this role.

How do you feel this role is going to benefit your future career? In 20 years, where do you see yourself?

This role gives me a great opportunity to develop my management and communication skills. I'm learning how to plan research projects and effectively communicate with others to achieve our goals. In 20 years, I hope to advance within this role and continue to learn and grow in science research.

What advice do you have for young people beginning their career in science research?

Networking and collaboration are the most powerful tools you can use in scientific research. Expand your network with your peers and researchers from another field. Networking enables shared learning, the transfer of technology, and the chance to collaborate on projects.

What is the one big thing that you think meta-optics is going to change in society? How do you think it will benefit the next generation?

I believe the realisation of dynamic full-colour 3D meta-holograms will significantly affect our daily lives, as they would be able to produce realistic high-resolution 3D images. Such holograms could one day be used for many different purposes, including security, the entertainment industry and medical uses. For example, 3D dynamic projections would be very useful in planning and carrying out treatments and surgeries.

Finish this sentence. In 50 years the world will… likely be highly dominated by artificial intelligence (AI) where machines will outperform humans in most activities. Nearly all data will become digitised, and robots and AI will take over the manufacturing, delivery, design, and marketing of most goods. AI is likely to be used for most decision-making and optimizations of technology.

YANA IZDEBSKAYA

Research Fellow

Australian National University

Yana Izdebskaya is a Research Fellow at ANU and Research Program Manager for Tunable Metadevices at TMOS.

Izdebskaya received her PhD in the field of Optics and Laser Physics from Taurida National University in Ukraine before moving to Australia and taking up a variety of research positions at ANU. She is the recipient of several grants and fellowships, including an Australian Postdoctoral Fellowship and ARC Discovery Project.

Her research focuses on the development of dynamically tunable metadevices for efficient light manipulation, and she recently initiated an experimental project working on the magnetic field tuning of dielectric metasurfaces infiltrated with liquid crystals. In recognition of Izdebskaya's research contributions to this field, she was invited to present these results at the Australian and New Zealand Conference on Optics and Photonics in 2022 and joined the ANZCOP 2022 Technical Program Committee. She has been selected as an expert reviewer for the European Commission of Research and Innovation Programmes.

> “I believe the realisation of dynamic full-colour 3D meta-holograms will significantly affect our daily lives, as they would be able to produce realistic high-resolution 3D images. Such holograms could one day be used for many different purposes, including security, the entertainment industry and medical uses.

2B. OPTICAL SENSING

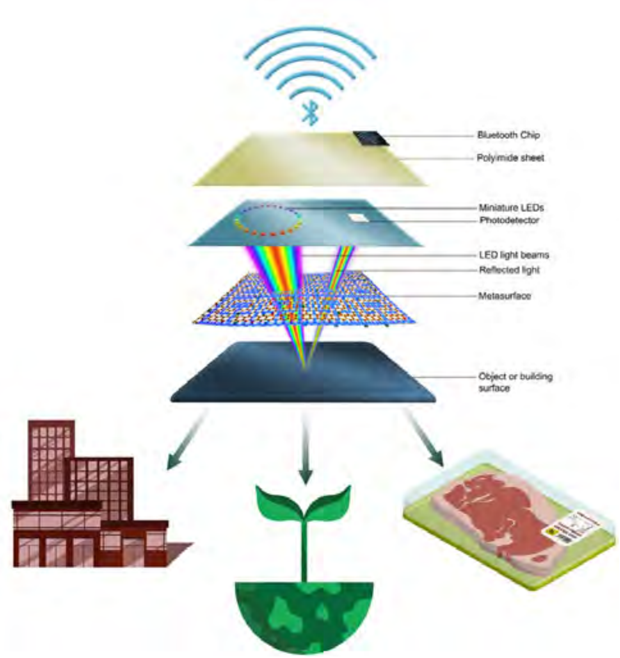
We live in an era that is going through global challenges around health and climate. Besides, we are merging into a world of artificial intelligence and space exploration. In the changing world, research under TMOS theme 2B addresses challenging problems for the present and future world, such as health care monitoring of vital functions, environmental sensing for pollutants, global warming, agriculture monitoring, and food and air quality using optical technologies. Furthermore, we envisage the development of non-invasive wearable, nearable, and portable sensing devices, energy harvesting technologies, and data transfer technologies using our expertise in materials designing and device fabrication techniques.

The limitations of the current sensing devices include sensitivity and selectivity in the identification of analytes, which leads to the lowering of accuracy in the quantification and classification, speed in the information processing and data transfer, robustness, and comfort level of using the device. Further, the cost-effectiveness and competitiveness of the integrated sensors are significant factors to be considered. However, we envisage that combining thin films, nanoscale optical components, and metasurfaces can potentially overcome the aforementioned problems.

In 2022, our research focused on the following areas: 1) Developing phase change materials for the visible and infrared regions. 2) Nanoscale materials and structures for gas sensing. 3) Nanoscale devices (light sources and detectors) and integration for gas sensing. 4) Embedded components for electronics and optics. 5) Metasurfaces for molecule detection. 6) Neural networks for wavelength classification. Among those studies, we wish to highlight the development of the InP nanowire array devices for self-powered environmental sensing based on the photovoltaic effect, particularly for NO_2 gas sensing, led by Prof. Lan Fu's group at ANU with Ms. Shiyu Wei., a Ph.D. student as the lead author. The developed gas sensors achieve an 84% sensing response to 1 ppm NO_2 and record a limit of detection down to the sub-ppb level, with little dependence on the incident light intensity, even under <5% of 1 sun illumination. The sensor is successfully integrated into a commercial microchip interface for on-field dynamic environmental monitoring of NO_2 level from motor vehicle exhaust.

FLAGSHIP INITIATIVE

In addition, we are now commencing a TMOS Flagship project involving the development of integrated sensors, which will aim to be a product to be projected as a collaborative effort of our research community.



JOURNAL PUBLICATIONS

1. Buddini I. Karawdeniya, Adam M. Damry, Krishnan Murugappan, Shridhar Manjunath, Y. M. Nuwan D. Y. Bandara, Colin J. Jackson, Antonio Tricoli, and Dragomir Neshev. *Chemical Reviews* **2022** 122 (19), 14990-15030.
2. Wei, S., Li, Z., Murugappan, K., Li, Z., Zhang, F., Saraswathyvilasam, A. G., Lysevych, M., Tan, H. H., Jagadish, C., Tricoli, A., Fu, L . *Adv. Mater.* **2022**, 2207199.
3. Sruthi Kuriakose, Aminuddin Bin Ahmad Kayani, Mahta Monshipouri, Shubhendra Kumar Jain, Edwin L. H. Mayes, Taimur Ahmed, Sharath Sriram, Madhu Bhaskaran, and Sumeet Walia. *ACS Applied Nano Materials* **2022** 5 (12), 18553-18560.
4. Peter Francis Mathew Elango, Sumaiya Kabir, Ponnappa Kechanda Prasanna, Mei Xian Low, Mingjie Yang, Sudip Chakraborty, Sumeet Walia, Sharath Sriram, and Madhu Bhaskaran. *ACS Applied Electronic Materials* **2022** 4 (11), 5456-5467.
5. Mei Xian Low, Sherif Abdulkader Tawfik, Salvy P. Russo, Sharath Sriram, Madhu Bhaskaran, and Sumeet Walia, *ACS Applied Nano Materials* **2022** 5 (9), 12189-12195.
6. Sumaiya Kabir, Dan Yang, Aminuddin Bin Ahmad Kayani, Huihui Zhang, Shruti Nirantar, Sharath Sriram, Sumeet Walia, and Madhu Bhaskaran. *ACS Applied Nano Materials* **2022** 5 (8), 10280-10291.
7. Xiaojing LV, Rajour Tanyi Ako, Madhu Bhaskaran, Sharath Sriram, Christophe Fumeaux, and Withawat Withayachumnankul. *IEEE Transactions on Terahertz Science and Technology* 12.3 **2022**: 257-266.
8. Sumayia Kabir, Shruti Nirantar, Mahta Monshipouri, Mei Xian Low, Sumeet Walia, Sharath Sriram, Madhu Bhaskaran. *Adv. Electron. Mater.* **2022**, 8, 2100428.

ACTION ITEMS 2023

1. Fabricate and demonstrate a neuromorphic optical diffractive neural network for chemical classification
2. Characterise phase change material-sb_2se_3 and demonstrate its applications
3. Integrate nanoscale light sources/detectors with optical sensing platforms
4. Integrate focusing lenses and metasurface designs with off-shelf light sources/ detectors
5. Develop technology to scale nanowire array sensor fabrication and develop new nanowire sensors including gas and multiplexed sensors with integrated functionalities

INTERVIEW

RESEARCH PROGRAM MANAGER: Litty Thekkekara

How long have you been a researcher, and what is your particular field of interest?

My field of interest understands light-matter interactions and their effective utilisation for developing applications that can later be translated into real-life applications.

What is it about meta-optics research that excites you?

The miniaturisation of the technology, along with the artificial designs that meta-optics allow, is the exciting part for me in this research.

When did you first decide that you wanted to be a physicist? What inspired you?

I was born in a place where light is integral to our life in various forms, and as a child, I always wondered what makes the differences in light to form different colours. When I grew up, I decided to study the phenomenon of light in more detail and became fascinated to see how light can contribute to technology to make life easier and still studying to see how light can contribute more to society.

Why did you choose to take on the role of Research Program Manager?

I choose the role because it allows me to develop and coordinate programs across the centre to develop light technologies for practical applications like sensing.

What has been the biggest challenge of taking on the role of Research Program Manager?

Bringing together people for a common goal by forming a plan and considering opinions and indifferences is the biggest challenge for the role of research program managers.

What has been the greatest joy in taking on the role of Research Program Manager?

The role will allow you to dream of an achievable goal that can change society.

How have the Chief Investigators supported you in your new role?

Chief Investigators in TMOS offer support by nurturing the young generation of researchers. Their timely advice is helping a lot in the formation of plans, taking, and coordinating the actions and smooth on-going of the program.

How do you feel this role is going to benefit your future career? In 20 years, where do you see yourself?

In 20 years, I will advocate for science, technology, and commercialisation, even though it might be through multiple roles.

What advice do you have for young people beginning their career in science research?

Nowadays, one who wishes to pursue a career in science has several options instead of the traditional concept of becoming a 'Professor' in academia or moving to industries. Try to identify the area of your passion and strength for science as you go through your studies and take practical steps at your earliest convenience to move into it.

What is the one big thing that you think meta-optics will change in society? How do you think it will benefit the next generation?

Holograms/Stereoscopic vision for the metaverses will be the big thing meta-optics will change in society. Miniaturisation and portability are the most significant advantages of meta-optics compared to other technologies.

Finish this sentence. In 50 years the world will... be more sustainable and user-friendly.

LITTY THEKKEKARA

Research Fellow

RMIT University

Litty Thekkekara is a Research Fellow at RMIT and Research Program Manager for Functional Materials and Microsystems at TMOS.

Thekkekara completed a Masters in Business Law, before undertaking her PhD in Applied Physics at RMIT University. She is a current member of Optica, SPIE and IEE. Before joining TMOS, she was a Co-Founder and Chief Technology Officer of a graphene manufacturing company, Benchwise Solutions. Her research work has resulted in several non-disclosure agreements with leading industries within the optics field. Her academic interests include light-matter interactions, energy harvesting, sensing, science policy and commercialization.

MANIPULATE CASE STUDY

Protecting children and pets: Innovative metasurface prevents cars from overheating

Every year in Australia, more than 5000 children are rescued after being left unattended in a car. Not all of those children are saved before they succumb to death by heatstroke, with at least 10 Australian children dying in the past five years after being left inside a hot car. The number of animal deaths has not been recorded but according to the RSPCA, is likely to significantly exceed the number of human deaths. A dog can overheat in six minutes inside a car during an Australian summer.

Researchers from the Centre's RMIT team are working to eliminate these tragedies by developing a meta-surface coating that can be sprayed on to existing car windows and windshields at room temperature. This coating, as reported on in ACS Applied Nano Materials, is made from vanadium dioxide (VO_2), a thermochromic material with optical properties that change as it changes in temperature. The VO_2 coating transmits both visible light and the infrared waves responsible for much of the sun's heat. Once the coating reaches a certain temperature, its properties change. It still transmits visible light but once it switches from a semiconductor to a metal, it reflects infrared, preventing most of the heat from passing through the window into the car.

Previous attempts to solve the problem of overheating cars using light filters have had moderate success. There are some electrochromic glasses on the market that can switch between being transparent and opaque by applying voltage. This requires an electric charge, and it blocks all light, not just infrared. The Centre's VO_2 coating is solar powered so needs no connection to an electricity source and it allows for the user to see through the glass while the heat is being reflected.

Earlier versions of thermochromic coatings were applied to substances using a process called annealing, which heats the substance to a very high temperature in a vacuum environment before slowly letting it cool, an expensive process that might work for new car windows and windshields but doesn't solve the problem of overheating in the almost 15 million passenger cars currently on the road in Australia.

In addition, these earlier coatings corroded over time when exposed to oxygen, making them impractical for everyday use. This new VO_2 coating includes other polymers that give the coating added stability against oxidation and greater uniformity, which improves performance.

Lead researcher Sumaiya Kabir says "This is a huge step in the development of a glass coating that reflects heat while still transmitting visible light. The threshold for

SPOTLIGHT

Sumaiya Kabir

PhD Student

Sumaiya completed this research at RMIT as part of her PhD project. She graduated at the end of 2022.

the transition from infrared-transmitting semiconducting insulator to infrared-reflective metal is currently 68 degrees and the next step in the research is to lower that temperature threshold by combining it with other materials."

Chief Investigator Madhu Bhaskaran says, "This metasurface coating has a wide range of applications beyond smart windows. It could be used for smart wearables and reconfigurable electronics also. The strength of it is in its compatibility with different scalable manufacturing processes such as dip coating, drop casting, and screen printing, offering great feasibility for further scaling up."

For more information about this research, please email connect@tmos.org.au

Solution-Processed VO_2 Nanoparticle/Polymer Composite Films for Thermochromic Applications

ACS APPLIED NANO MATERIALS, 20 JULY 2022

Sumaiya Kabir, Dan Yang, Aminuddin Bin Ahmad Kayani, Huihui Zhang, Shruti Nirantar, Sharath Sriram, Sumeet Walia, and Madhu Bhaskaran

Thin films composed of vanadium dioxide (VO_2), a well-known thermochromic material with reversible insulator-to-metal-transition near room temperature, are intriguing for intelligent and energy-efficient heat-blocking applications. However, the conventional vacuum-based deposition methods often involve a high-temperature annealing process, and oxidation of VO_2 under air exposure further limits their practical applications. In this work, we demonstrate a room-temperature solution process to prepare VO_2-based thermochromic thin films using a smart ink composed of crystalline VO_2 nanoparticles. To enhance their chemical stability against oxidation and assist in the uniform deposition of the VO_2 thin films, polymers were used as both capping agents and for surface modification of the VO_2 nanocrystals. Specifically, the concentration of VO_2 nanocrystals, the type of polymers, and the molar ratio between VO_2 and polymers are systematically tailored, and their effects on the thermochromic performance are also explored. It is revealed that the inclusion of optimum polymers enhanced the thermochromic performance with an almost 4-fold increase in IR switching with a visible luminous transmittance of 86% and a solar modulation of 17.61%. In addition, the inks are compatible with an array of scalable manufacturing processes. We demonstrate uniform films on different substrates, both rigid and flexible, by dip coating, drop casting, and screen printing, offering great feasibility for further scaling up.

Read the full article

MANIPULATE CASE STUDY

New nanowire sensors are the next step in the Internet of Things

A new miniscule nitrogen dioxide sensor could help protect the environment from vehicle pollutants that cause lung disease and acid rain.

Researchers from TMOS, the Australian Research Council Centre of Excellence for Transformative Meta-Optical Systems have developed a sensor made from an array of nanowires, in a square one fifth of a millimetre per side, which means it could be easily incorporated into a silicon chip.

In research published in Advanced Materials, PhD scholar at the Centre's Australian National University team and lead author Shiyu Wei describes the sensor as requiring no power source, as it runs on its own solar powered generator.

Wei says, "As we integrate devices like this into the sensor network for the Internet of Things technology, having low power consumption is a huge benefit in terms of system size and costs. The sensor could be installed in your car with an alarm sounding and alerts sent to your phone if it detects dangerous levels of nitrogen dioxide emitted from the exhaust."

Co-lead author Dr. Zhe Li says "This device is just the beginning. It could also be adapted to detect other gases, such as acetone, which could be used as a non-invasive breath test of ketosis including diabetic ketosis, which could save countless lives."

Existing gas detectors are bulky and slow, and require a trained operator. In contrast, the new device can quickly and easily measure less than 1 part per billion, and the TMOS prototype used a USB interface to connect to a computer.

Nitrogen dioxide is one of the NOx categories of pollutants. As well as contributing to acid rain, it is dangerous to humans even in small concentrations. It is a common pollutant from cars, and also is created indoors by gas stoves.

The key to the device is a PN junction – the engine of a solar cell – in the shape of a nanowire (a small hexagonal pillar with diameter about 100 nanometres, height 3 to 4 microns) sitting on a base. An ordered array of thousands of nanowire solar cells, spaced about 600 nanometres apart formed the sensor.

The whole device was made from indium phosphide, with the base doped with zinc to form the P part, and the N section at the tip of the nanowires, doped with silicon. The middle part of each nanowire was undoped (the intrinsic section, I) separating the P and N sections.

SPOTLIGHT

Shiyu Wei

PhD Student

Shiyu is part of the Australian National University team, working with senior researchers to commercialise her work.

Light falling on the device causes a small current to flow between the N and P sections. However, if the intrinsic middle section of the PN junction is touched by any nitrogen dioxide, which is a strong oxidiser that sucks away electrons, this will cause a dip in the current.

The size of the dip allows the concentration of the nitrogen dioxide in the air to be calculated. Numerical modelling by Dr Zhe Li, a postdoctoral fellow in EME, showed that the PN junction's design and fabrication are crucial to maximising the signal.

The characteristics of nitrogen dioxide – strong adsorption, strong oxidation – make it easy for indium phosphide to distinguish it from other gases. The sensor could also be optimised to detect other gases by functionalising the indium phosphide nanowire surface.

TMOS Chief Investigator Professor Lan Fu, leader of the research group says "The ultimate aim is to sense multiple gases on the one small chip. As well as environmental pollutants, these sensors could be deployed for healthcare, for example, for breath tests for biomarkers of disease.

"The tiny gas sensor is easily integratable and scalable. This, combined with meta-optics, promises to achieve multiplexing sensors with high performance and multiple functionalities, which will enable them to fit into smart sensing networks. TMOS is a network of research groups across Australia dedicated to progressing in this field.

"The technologies we develop will transform our life and society in the coming years, with large-scale implementation of Internet of Things technology for real-time data collection and autonomous response in applications such as air pollution monitoring, industrial chemical hazard detection, smart cities, and personal healthcare."

For more information about this research, please email connect@tmos.org.au

A Self-Powered Portable Nanowire Array Gas Sensor for Dynamic NO_2 Monitoring at Room Temperature

ADVANCED MATERIALS. 10 DECEMBER 2022

Shiyu Wei, Zhe Li, Krishnan Murugappan, Ziyuan Li, Fanlu Zhang, Aswani Gopakumar Saraswathyvilasam, Mykhaylo Lysevych, Hark Hoe Tan, Chennupati Jagadish, Antonio Tricoli, Lan Fu

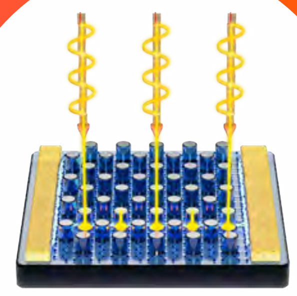
The fast development of the Internet of Things (IoT) has driven an increasing consumer demand for self-powered gas sensors for real-time data collection and autonomous responses in industries such as environmental monitoring, workplace safety, smart cities, and personal healthcare. Despite intensive research and rapid progress in the field, most reported self-powered devices, specifically NO_2 sensors for air pollution monitoring, have limited sensitivity, selectivity, and scalability. Here, a novel photovoltaic self-powered NO_2 sensor is demonstrated based on axial p–i–n homojunction InP nanowire (NW) arrays that overcome these limitations. The optimised innovative InP NW array device is designed by numerical simulation for insights into sensing mechanisms and performance enhancement. Without a power source, this InP NW sensor achieves an 84% sensing response to 1 ppm NO_2 and records a limit of detection down to the sub-ppb level, with little dependence on the incident light intensity, even under <5% of 1 sun illumination. Based on this great environmental fidelity, the sensor is integrated into a commercial microchip interface to evaluate its performance in the context of dynamic environmental monitoring of motor vehicle exhaust. The results show that compound semiconductor nanowires can form promising self-powered sensing platforms suitable for future mega-scale IoT systems.

Read the full article

THEME THREE

Detect

Optical detection is central to modern information acquisition and processing technology. The increasing demands for the miniaturisation of electronic devices requires ultra-compact efficient, multimodal optical and infrared detectors using meta-optics. The Detect Theme will develop devices that will create new opportunities for novel optics in Industry 4.0.



THEME LEADERS:

PROFESSOR LORENZO FARAONE
The University of Western Australia

PROFESSOR ANN ROBERTS
University of Melbourne

Ultra-compact, efficient, multimodal optical and infrared detection is essential for meeting the increasing demands placed on the miniaturisation of mobile electronic devices for applications ranging from sensing, through to three-dimensional imaging and enhancing visibility through fog and bushfire smoke.

Detectors used for infrared light are critical for defence, medical and other major applications integral to Industry 4.0. Their relative inefficiency at room temperatures, however, is a significant barrier to reducing system size and precludes their use in drones and space applications where weight is critical. New methods for infrared detection using semiconductor nanowires and the integration of sub-wavelength elements into mercury cadmium telluride detectors will massively lower barriers to their adoption. Furthermore, light carries knowledge about objects beyond the intensity recorded by conventional detectors, and there is a significant demand for a range of detectors operating in different spectral regions that have the capacity to extract polarisation, phase, and other information from electromagnetic waves.

Excellent progress was made toward completing the 2022 action items with some continuing to device optimisation and finalisation in

early 2023. Highlights include the development of several different nanowire based photo-detection devices operating in different regions of the spectrum. A top-down etched broadband Si nanowire array photodetector has been shown to exhibit broadband sensitivity from the visible to the short-wave infrared. Novel InGa/As/InP quantum well nanowire mid-IR photodetectors and InAs devices with a photo response at wavelengths up to 3 μm have also been demonstrated.

Furthermore, in an ANU/Melbourne collaboration, GaAsSb nanowire based multi-pixel array photodetectors have been fabricated and their implementation in a spectrometer is currently under development. Significant progress has also been achieved in the design of meta-optics for the characterisation of two-photon distinguishability with experimental demonstrations due for completion in 2023. Moreover, novel polarising elements with a > 50% conversion efficiency of unpolarised to polarised light have been investigated and demonstrated.

Looking forward, meta-surfaces will be integrated into the new and enhanced detectors that have been demonstrated, to permit novel functionality and ultimately enabling orders-of-magnitude miniaturisation of devices. Furthermore, merging the outcomes of the Manipulate program we will create individual photodetectors and imaging arrays with a tunable sensitivity to different properties of light, or permit extraction of multiple dimensions of information from an optical field from the visible through to the mid-infrared region of the spectrum.

KEY MILESTONES FOR 2023

1. Development of broadband nanowire array-based spectrometers (visible to SWIR)
2. Demonstration of chemical detection using mid-IR spectral filters
3. Experimental realisation of two-photon distinguishability characterisation using a topology-optimized meta-surface
4. Demonstration of single-pixel nanowire array imaging from the NIR to SWIR
5. Investigate meta-material-based polarisation and spectrally selective element compatible with a 2x2 pixel element for IR imaging
6. Demonstration of polarization sensitive imaging using a GaAsSb nanowire array integrated with a meta-surface
7. Realisation of mid-infrared bound state in the continuum spectral filters
8. Develop a meta-material microlens technology suitable for on-pixel hybridisation with an IR imaging array

DETECT
Subprograms

3A. ADVANCED IMAGING

Detectors used for infrared light are critical for defence, medical and other major applications in Industry 4.0. The relative inefficiency of existing infrared detectors at room temperatures, however, is a major roadblock to miniaturisation and precludes their use in drones and space applications where weight is critical. New approaches to infrared detection using semiconductor nanowires and the integration of subwavelength elements into mercury cadmium telluride detectors will enable the miniaturisation and lowering of cost of portable electronic devices for applications such as LIDAR, imaging through bushfire smoke, and enhanced night vision, among others. This technology will greatly lower barriers to the widespread adoption of infrared detection technology and expand the capacity to extract information from electromagnetic waves.

The key achievements of 2022 included:

- Demonstration of dual (visible and NIR) GaAsSb Nanowire Array multiwavelength photodetectors along with their application to RGB colour imaging.
- Demonstration of a InGaAs/InP multi-QW photoconductive photodetector with high room temperature responsivity (14.5 A/W @1550 nm).
- Demonstration of highly uniform multiple QW nanowire growth which is critical for NW-QWIP fabrication.
- Demonstration of a device that can discriminate between different angles of incidence on a metasurface and its application to phase contrast imaging of optical wavefields and microscopy of biological cells.

ACTION ITEMS 2023

- Design and validation of metamaterial-based lens for extending field of view of infrared focal plane array
- Integration of metamaterial-based lens with infrared detector or focal plane array
- Demonstration of single pixel polarisation sensitive nanowire array for NIR imaging
- Demonstration of multi-pixel nanowire array for NIR to SWIR imaging

PUBLICATIONS

1. Self-Powered InP Nanowire Photodetector for Single-Photon Level Detection at Room Temperature, Zhu, Y., Raj, V., Li, Z., Tan, H. H., Jagadish, C., Fu, L., Self-Powered InP Nanowire Photodetector for Single-Photon Level Detection at Room Temperature. Adv. Mater. 2021, 33, 2105729. https://doi.org/10.1002/adma.202105729
2. Investigation of light–matter interaction in single vertical nanowires in ordered nanowire arrays, Li, Z., Li, L., Wang, F., Xu, L., Gao, Q., Alabadla, A., ... & Fu, L. (2022). Investigation of light–matter interaction in single vertical nanowires in ordered nanowire arrays. Nanoscale, 14(9), 3527-3536.
3. Design of InAs nanosheet arrays with ultrawide polarization-independent high absorption for infrared photodetection, Zuo, X., Li, Z., Wong, W.W., Yu, Y., Li, X., He, J., Fu, L., Tan, H.H., Jagadish, C. and Yuan, X., 2022. Design of InAs nanosheet arrays with ultrawide polarization-independent high absorption for infrared photodetection. Applied Physics Letters, 120(7), p.071109.
4. Phase contrast imaging with meta-optics, L. Wesemann, J. Rickett, J. Song, J. Lou, E. Hinde, T. J. Davis, and A. Roberts, "Phase contrast imaging with meta-optics," in Imaging and Applied Optics Congress 2022 (3D, AOA, COSI, ISA, pcAOP), Technical Digest Series (Optica Publishing Group, 2022), paper ITu3E.3.
5. Large area van der Waals epitaxy of II–VI CdSe thin films for flexible optoelectronics and full-color imaging, Pan, W., Liu, J., Zhang, Z. et al. Large area van der Waals epitaxy of II–VI CdSe thin films for flexible optoelectronics and full-color imaging. Nano Res. 15, 368–376 (2022). https://doi.org/10.1007/s12274-021-3485-x

INTERVIEW

RESEARCH PROGRAM MANAGER: Hemendra Kala

How long have you been a researcher and what is your particular field of interest?

I have been working as a researcher for the past six years and my field of interests include infrared detectors, microelectromechanical systems (MEMS) and meta-optics.

What is it about meta-optics research that excites you?

Meta-optics has the potential to enable a wide variety of applications that previously could not be implemented in mobile platforms such as drones and hand-held devices.

When did you first decide that you wanted to be a physicist? What inspired you?

I was inspired to become an engineer at age 12 when I saw the intel advertisements featuring people working inside cleanrooms in bunny suits.

Why did you choose to take on the role of Research Program Manager?

I chose to take on the role of a Research Program Manager as this would allow me to interact with and learn from leading researchers in the field of meta-optics, while also allowing me to improve my communication and management skills.

What has been the biggest challenge of taking on the role of Research Program Manager?

The biggest challenge of this role has been to try and figure out how to get efficient and useful collaborations started between researchers from diverse backgrounds, locations, and time-zones.

What has been the greatest joy in taking on the role of Research Program Manager?

The greatest joy of this role has been getting to meet, interact and learn from both world-leading researchers and students from all over Australia.

How have the Chief Investigators supported you in your new role?

The Chief Investigators have been extremely helpful in providing information related to the role as well as valuable feedback on how to proceed with contacting researchers, formulating the research plan, and preparing progress reports.

How do you feel this role is going to benefit your future career? In 20 years, where do you see yourself?

I believe that this role will help me improve my communication, organisational and management skills which are extremely critical for a research career.

What advice do you have for young people beginning their career in science research?

Try and find a mentor who will guide you in establishing your career in scientific research.

What is the one big thing that you think meta-optics is going to change in society? How do you think it will benefit the next generation?

I believe that meta-optics will enable erstwhile 'exotic' technologies such as night vision, advanced spectroscopy, LIDAR, and holography, to become mainstream and be available to everyone in society.

Finish this sentence. In 50 years the world will... Run on electro-optics technology.

HEMENDRA KALA

Research Fellow

The University of Western Australia

Hemendra Kala is a Research Fellow at UWA and is Research Program Manager for Advanced Imaging at TMOS.

Kala obtained his bachelor's degree in Electronics & Communications Engineering from the Birla Institute of Technology Ranchi, India in 2007. Following this he moved to Perth, WA in 2008 to pursue a master's degree in Microelectronics Engineering at the UWA. In 2016, he graduated with a doctorate degree for the study of electronic carrier transport phenomenon in narrow band semiconductors.

Since 2016, he has been working as a research associate at the WA node of the Australian National Fabrication Facility (ANFF) where his primary research work involved the development, fabrication, and characterisation of mercury cadmium telluride (HgCdTe) based infrared detectors and focal plane arrays. From 2017 to 2021 he was a co-investigator on the Defence Science and Technology Group (DSTG) Counter Improvised Threats Grand Challenge Grant for developing unmanned airborne imaging and infrared spectroscopy for detection and identification of improvised threats. This work involved the development of microelectromechanical systems (MEMS) based infrared filters for multispectral and hyperspectral infrared detection.

3B. SEEING THE INVISIBLE WITH NANOTECHNOLOGY

The second sub-theme of Theme 3 'multimodal detection' focuses on research that uses nanotechnology to extract information from light. Light carries a vast amount of 'hidden' information that is crucial for applications such as agriculture, pharmaceutical production, medical diagnostics, environmental monitoring and machine vision. Unfortunately, conventional light detection technology makes it challenging to access some of these properties of light in a compact and efficient way. In this subtheme, TMOS creates meta-optical systems that permit accessing and measuring these properties of light. Many of the scientific questions around the technologies needed for these systems remain unanswered – and at TMOS we are working hard to find these answers. The ultra-compact systems we develop could be used in future devices, including small-scale sensors for industry 4.0 and smartphone cameras, to enable them to see and detect more than is possible today.

For example, the 'brightness' of light is relatively simple to detect, while other properties of light, such as the precise combination of colours contained in it, or a property called polarisation, are much harder to extract. Two examples of work performed in this subtheme in 2022 illustrate our work towards nanotechnology enabled light detection applications.

Identifying chemicals based on the way they interact with light is a fundamental enabler in important fields including food production, pharmaceutical manufacturing, and environmental monitoring. In 2022 we have engineered a micrometre sized device able to perform this analysis by leveraging nanotechnology and artificial intelligence algorithms. These 'micro spectrometers' could enable low-cost and mobile chemical detection in future handheld devices.

- An important application of polarisation detection is distinguishing an object from its surroundings in complex imaging situations. Highly compact photodetectors that can efficiently determine the polarisation of light in an image in the infrared spectral region are challenging to create. We have numerically demonstrated that nanometer sized sheets of InAs semiconductor can successfully achieve this task. We are currently working on the experimental implementation of these structures.
- In conclusion, we plan to develop nanotechnology-based light detection methods into practical devices that will have a real-world impact in the foreseeable future.

ACTION ITEMS 2023

- Using bound-states in the continuum (BIC's) to demonstrate enhanced chemical detection with micro spectrometers
- Demonstrate quantum ghost imaging using photon pairs generated by nonlinear-metasurfaces
- Demonstrate electrically tunable, graphene based infrared sensing and image processing devices
- Investigate and develop polarisation sensitive quantum well nanowire mid-infrared photodetectors

PUBLICATIONS

1. Meng, J., Weston, L., Balendhran, S., Wen, D., Cadusch, J.J., Rajasekharan Unnithan, R. and Crozier, K.B., 2022. Compact Chemical Identifier Based on Plasmonic Metasurface Integrated with Microbolometer Array. **Laser & Photonics Reviews, 16(4), p.2100436.**
2. Tan, H., Cadusch, J.J., Meng, J. and Crozier, K.B., 2022. Genetic optimization of mid-infrared filters for a machine learning chemical classifier. **Optics Express, 30(11), pp.18330-18347.**
3. Khodasevych, I., Rufangura, P. and Iacopi, F., 2022. Designing concentric nanoparticles for surface-enhanced light-matter interaction in the mid-infrared. **Optics Express, 30(13), pp.24118-24131.**
4. Wesemann, L., Rickett, J., Davis, T.J. and Roberts, A., 2022. Real-time phase imaging with an asymmetric transfer function metasurface. **ACS Photonics, 9(5), pp.1803-1807.**
5. Jun, H., Huang, Z., Li, Z., Wong, W.W., Yu, Y., Huang, L., Li, X., Fu, L., Tan, H.H., Jagadish, C. and Yuan, X., 2022. Design of InAs nanosheet arrays for high-performance polarization-sensitive infrared photodetection. **Journal of Physics D: Applied Physics.**

INTERVIEW

RESEARCH PROGRAM MANAGER: Lukas Wesemann

How long have you been a researcher and what is your particular field of interest?

I've been involved in scientific research since 2014. My field of interest is optics and photonics with a specific focus on ultrathin metamaterials. I investigate how we can use those in future imaging systems that could support medical diagnostics.

What is it about meta-optics research that excites you?

The most fascinating part for me is that we are working at the cutting edge of what's possible today with nanotechnology and light, while still aiming to solve very applied problems.

When did you first decide that you wanted to be a physicist? What inspired you?

When I was about 10 years old, an older friend of mine was building radio transmitters at home and I helped him solder the components onto a circuit board. When we managed to transmit a song to a radio next door with this DIY transmitter that we just built in his garage, that really got me.

Why did you choose to take on the role of Research Program Manager?

I've always enjoyed being involved in strategic planning activities and learning about new research from other fields. TMOS is a very large research centre and I believe that good planning and management, spotting opportunities and connecting the right people can really have a significant impact.

What has been the biggest challenge of taking on the role of Research Program Manager?

Especially in the beginning, organising ourselves within the Research Program Manager (RPM) team, getting an overview of a large number of sub-projects as well as the networking required to build relationships with each researcher all had to start in parallel. This was really challenging but also a lot of fun! We had to prioritise a lot, develop standardised systems, and get feedback from the Chief Investigators.

What has been the greatest joy in taking on the role of Research Program Manager?

That we can already see the results of our hard work this year – I'm really proud that we could help TMOS grow continuously and that research collaborations across nodes are happening right now because of our work.

How have the Chief Investigators supported you in your new role?

The Chief Investigators were extremely supportive, we often received constructive feedback on our roles as RPM's and could always pitch new ideas for management processes, cross node collaborations and workshops.

How do you feel this role is going to benefit your future career? In 20 years, where do you see yourself?

I think I could write a whole page on this question. In essence I think being an RPM has significantly expanded my skill set beyond what I learned from being a researcher. A lot of it comes down to high-level project management and keeping an overview of a broad range of research activities at the same time. I'm sure this will greatly benefit me during my career and will open doors into many types of management positions in academia and industry where strategic planning and identifying new opportunities is crucial. Another aspect that I think massively benefits anyone taking up an RPM role within TMOS is that you meet a lot of interesting people. I talk to the CI's in my research theme every other week and through this process I have grown my professional network more than at any other time in my career. In 20 years from now I would like to be involved in transforming new optical technology into real-life applications.

What advice do you have for young people beginning their career in science research?

Talk to a lot of researchers and try a lot of different things – something will be just right for you!

Also, don't be scared and travel the world – science research opens many doors.

What is the one big thing that you think meta-optics is going to change in society? How do you think it will benefit the next generation?

It's very hard to pick just one! But If I have to, I'd say meta-optics in virtual and augmented reality technology will probably create possibilities that we can't even imagine at this stage. We might be able to replace a lot of the bulky technology like monitors, smartphones and cameras that we are so used to today, with miniaturised equipment that we wear as glasses or contact lenses. I imagine this would change society at least as much as the arrival of the smartphone did. It could provide us with new ways to stay connected with friends, family and colleagues and make it easier to access and exchange information. "Do you remember back in 2022 when we had to pick up our phone to check for new messages or make a video call?".

Finish this sentence. In 50 years the world will... be a lot more meta!

LUKAS WESEMANN

Research Fellow

The University of Melbourne

Lukas Wesemann is a Postdoctoral Research Fellow at UoM and Research Program Manager for Multimodal Detection at TMOS.

As Research Program Manager, Wesemann is responsible for planning and coordinating research activities across five universities, identifying collaboration opportunities, and leading IDEA initiatives. He is the 2022 TMOS Leadership Award winner.

Wesemann received his PhD from the University of Melbourne in 2021 in the field of optical metasurfaces for image processing applications. Prior to that, he worked in nonlinear optics and femtosecond laser writing during his MSc at the University of Muenster, Germany.

His current research focuses on meta-optical devices that miniaturise optical computation and image processing, with a special focus on applications in bioimaging. These devices have the potential to be used in future mobile medical equipment, as well as attachments to camera lenses and compact virtual reality equipment.

Outside of work, he enjoys playing the violin and going camping in the beautiful national parks around Melbourne.

"... meta-optics in virtual and augmented reality technology will probably create possibilities that we can't even imagine at this stage.

3C. DETECTING INFRARED LIGHT FOR IMAGING

Infrared imaging and sensing technology has a variety of applications in strategic areas of astronomy, security & surveillance, agriculture, night vision, remote sensing and medical imaging. NASA James Webb space Telescope (JWST) has much better resolution compared to Hubble thanks to its enhanced infrared imaging array.

Increasing the resolution/sensitivity of infrared imaging devices, along with reducing the size, weight and power (SWaP) is the key motivation for space and technology development due to the increase in efficiency and decrease in energy requirements, leading to economic advantages.

Further technological advancement in imaging in infrared is limited by the fundamental physics of material and light. TMOS aims to break these limits by exploring the integration of current technologies with meta-optics to enhance the imaging performance and hence reducing the size and weight of cameras. We aim to push the frontier of infrared imaging even further by combining imaging arrays with meta-materials, micro-lenses, and engineering the material properties.

We want to explore novel materials and smart engineering of the detectors to create novel devices. In 2022, our projects include sensing with nanowires and improving spectroscopy with IR filters.

Our recent plasmonic research is aimed at enhancing mid-infrared nanophotonics by fabricating emerging nanostructures such as III-V nanowire quantum well detectors. We have combined experimental methods and computer simulations to demonstrate enhanced infrared absorption at shortwave spectral band employing such structures. This is possible thanks to the advancement of nanowire synthesis techniques by employing MOCVD machine at Australian National University.

We have also developed tiny infrared resonators for remote thermal sensing and imaging utilising metamaterials. These are fixed or electrically tunable structures which will only pass a specific wavelength of light just before entering the photodetector or imaging array. The aim is to achieve Mercury-Cadmium-Telluride (MCT) imaging arrays with lower cross-talk, improved modulation transfer function (MTF), and higher operating temperature (HOT). As a result in 2022, both design and simulation have been completed for an on-pixel aligned metalens array that is compatible with MCT mid-wave infrared (MWIR) imaging array technology.

Since merging the two different technologies is a challenging task, our aim for 2023 is to finalise designs for hybridisation of metalens array with MCT imaging array. Simultaneously, we will have our initial fabrication and technology development of metalens array, and optical characterization of them, which is essential for the success of the project. We will develop an initial fabrication technology for integrating metalens array with MCT imaging array which has been never done before. The integration will be a joint effort by UWA and ANU.

ACTION ITEMS 2023

- Develop MBE process for growing suitable MCT layers that meet the required specifications
- Preliminary development of fabrication process for ultra-high QE SWIR detectors and initial device testing and characterisation
- Enhanced photodetection with plasmonic nanoparticles on ultrathin films
- Develop flexible nanowire array SWIR photodetectors

PUBLICATIONS

1. Design Principles for High QE HgCdTe Infrared Photodetectors for eSWIR Applications, ND Akhavan, GA Umana-Membreno, R Gu, J Antoszewski, L Faraone, *J. Electron. Mater.* **51**, 4742–4751 (2022). https://doi.org/10.1007/s11664-022-09809-y

2. Electron mobility distribution in FD-SOI MOSFETs using a NEGF-Poisson approach, ND Akhavan, GA Umana-Membreno, R Gu, J Antoszewski, L Faraone, S Cristoloveanu, Solid-State Electronics, Volume 193, 2022, https://doi.org/10.1016/j.sse.2022.108283.

3. Emerging opportunities for SWIR sensing and imaging, ND Akhavan, GA Umana-Membreno, R Gu, J Antoszewski, L Faraone, Freiburg Infrared Colloquium 2023, Freiburg, 16-17 May 2023.

4. High performance HgCdTe detectors for emerging SWIR sensing and imaging applications, ND Akhavan, GA Umana-Membreno, R Gu, J Antoszewski, L Faraone, WOCSDICE-EXMATEC 2023, Palermo (Italy), 21-25 May 2023

5. Ultimate performance of n-on-p infrared photodetectors fabricated by RIE process, ND Akhavan, GA Umana-Membreno, R Gu, J Antoszewski, L Faraone, 2022 US Workshop on the Physics & Chemistry of II-VI Materials, Tampa, FL, USA.

6. High performance Infrared Photodetectors for Sensing Applications, ND Akhavan, GA Umana-Membreno, R Gu, J Antoszewski, L Faraone, the 2022 Conference on Optoelectronic and Microelectronic Materials and Devices (COMMAD), 11th - Friday 16th December 2022, Adelaide, Australia.

INTERVIEW

RESEARCH PROGRAM MANAGER: Nima Dehdashtiakhavan

How long have you been a researcher and what is your particular field of interest?

I received my Ph.D. degree in Microelectronics from the Tyndall National Institute, University College Cork, Ireland, in 2011 with a speciality in silicon nanowire devices for ultimate scaling. In 2012, I moved to Australia and has been part of the research staff with the Microelectronics Research Group at the University of Western Australia, where I have been involved in modelling, growth and characterisation of mercury cadmium telluride infrared detectors, and quantum transport in nanostructures. I have to mention that this was a completely new material system and technology from what I studied during my PhD.

What is it about meta-optics research that excites you?

Light interaction with material has always fascinated me and the ability of humans to manipulate/detect and therefore extract such a vast amount of information from an invisible ray of light is dazzling.

When did you first decide that you wanted to be a physicist? What inspired you?

I wanted to become an engineer/scientist since I was in elementary school. I grew up in a family environment where most people around me were engineers or scientists. Furthermore, I used to watch sci-fi movies with human-machine interface via electronics and they were fascinating to me. For example, 'The Terminator' with Arnold Schwarzenegger as an actor with a chip in his head.

Why did you choose to take on the role of Research Program Manager?

Delivering a high-quality research outcome is a whole-of-team work, and I have been interacting with several staff and students in our group in order to meet our scientific goals. As a mid-career researcher, the Centre's research program manager position was a good opportunity to formally act as a coordinator between different people and institutes in order to achieve a set of research deliverables.

What has been the biggest challenge of taking on the role of Research Program Manager?

The role of research program manager not only involves local research activities but also interaction with other universities across Australia. The role started during COVID lockdown era and due to lack of face-to-face communication, it was really hard to find out what was actually going on in our research node and in other nodes. It also took a while to understand the duties. Furthermore, being in Perth and the increase in travel costs has made it very difficult to travel to other nodes which, definitely has had an adverse impact on the performance and experience.

What has been the greatest joy in taking on the role of Research Program Manager?

Working with great people all around the Australia. I have met many new people from academia whose name I have heard before, however I have never had the chance to do a scientific collaboration with them.

How have the Chief Investigators supported you in your new role?

The Chief Investigators in the Centre are absolutely great people. I mostly work with Lorenzo Faraone and Ann Roberts. Both of them are, firstly, great friends but also then mentors, mangers, and scientists. The input and advice of Chief Investigators helped a lot in properly laying down a road map in order to have a clear path of achieving the assigned research activities.

How do you feel this role is going to benefit your future career? In 20 years, where do you see yourself?

The main objective of this role is to organize the research activity of individual people and small groups in order to achieve a final goal. Therefore, it has trained me how to manage research projects and contracts of the similar sizes as I advance in my career. Well, 20 years is a long time away. I would like to see a translation of science to technology to real-world in my area of research within the next five years.

What advice do you have for young people beginning their career in science research?

There are always endless possibilities when you start a scientific career. You will always have a choice of what to do in your life, because you have a scientific knowledge. I also recommend young researchers do research in different areas of science, which widens their knowledge and experience.

What is the one big thing that you think meta-optics is going to change in society? How do you think it will benefit the next generation?

Apart from the scientific achievements, which will be achieved by incorporating meta-optics, I hope that people will realise the importance of light as an information medium in their day-to-day life. I would also like to see a larger opto-electronic or optical industry in general be created or supported in Australia.

Finish this sentence. In 50 years the world will be… more automated.

DETECT CASE STUDY

From Dark Nights to Safe Highways: New Infrared technology delivering 360-degree vision on the road

Anyone whose rearview camera has saved them from a broken bumper knows the value of eyes in the back of your head. That's why new cars come complete with rear-facing visible cameras, RADAR and near-infrared LiDAR sensors that will tell you when something is getting too close. LiDAR is currently the workhorse of automated driving; its ability to sense the distance of objects is why it can perform the perfect parallel park.

But LiDAR has its limitations. It can sense the distance of an object, but not what an object is. It can tell that something is standing by the side of the road but it doesn't know if that thing is a kangaroo. If LiDAR could make that distinction, the car's automation system could prepare for a sudden impact.

Infrared (IR) detectors are able to determine what an object is based on its unique thermal signatures. It can tell a rubbish bin from a child. The military uses it to determine if a floating structure is a ship or organic material. The most expensive consumer car brands, such as Audi, have included IR detectors in their vehicles but even they are limited to IR detectors made from Silicone-based CMOS* technology and/or III-V Indium Gallium Arsenide (InGaAs), which only detect wavelengths in the range of near-infrared to short-wave infrared, require a light source, frequent replacement of IR illuminators, and have limited sensitivity.

IR detectors made from Mercury Cadmium Telluride (MCT) are far superior, detecting a much wider range of wavelengths with greater sensitivity and less noise in a faster time frame. They are the detector of choice for the military. They are also incredibly expensive, far beyond what commercial car manufacturers can include in their products, and in order to provide the necessary 360 degree vision, they require bulky, complex optics or multiple sensors to achieve a wide field of view.

Conventional flat IR detectors distort the edges of an image due to the way light passes through a lens and lands on the sensor. To correct this problem, high-end IR cameras use multiple lens elements to flatten the focusing plane, but these systems can be large, bulky, and expensive. Using a curved sensor instead of a flat one reduces edge distortion. With a curved imaging plane, you only need one lens, which makes this technology smaller, lighter and cheaper.

Researchers at TMOS are working on curved/flexible MCT detectors, as published in Advanced Materials Interfaces. These detectors are orders of magnitude smaller, decreasing the cost of production

SPOTLIGHT

Wenwu Pan

PhD Student

In addition to his research contributions, Wenwu is the University of Western Australia representative on the Centre's Outreach Committee.

significantly. Because they are so thin and are grown on a 2D material with a weak bonding between the sensor and the substrate, they can be peeled off, bent, and placed on a curved plane that mimics the retina of our eyes. This increases the sensor's field of view without the need for additional optics.

Lead author Wenwu Pan says "We have discovered a way to grow high-quality MCT thin films IR detectors using a method called van der Waals epitaxy on 2D layered substrates. This creates weak bonds, which allows us to lift the thin film off the substrate so that we can shape it into a curved IR imaging array. This could lead to simpler lenses, wider field of view, and better imaging quality in comparison to conventional flat IR detectors."

TMOS Chief Investigator Lorenzo Faraone says "The integration of MCT detectors with optical metasurfaces has the potential to improve IR detection and provide new functionality. In addition to the application in curved imaging sensors, a free-standing MCT thin film offers even more design flexibility and fabrication options for realising these integrated structures. For instance, these MCT device layers can be transferred or integrated onto various optical platforms using metamaterial layers, creating more complex and versatile optical systems, including higher performance imaging devices for long-range imaging and advanced sensors with polarisation sensitivity for enhanced target identification."

For more information about this research, please contact connect@tmos.org.au

** CMOS stands for Complementary Metal–Oxide–Semiconductor*

Van der Waals Epitaxy of HgCdTe Thin Films for Flexible Infrared Optoelectronics

ADVANCED MATERIALS. 10 DECEMBER 2022

Wenwu Pan, Zekai Zhang, Renjie Gu, Shuo Ma, Lorenzo Faraone, Wen Lei

Van der Waals epitaxial (vdW) growth of semiconductor thin films on 2D layered substrates has recently attracted considerable attention since it provides a potential pathway for realising monolithically integrated devices and flexible devices. In this work, direct growth of epitaxial HgCdTe (111) thin films on 2D layered transparent mica substrates is achieved via molecular beam epitaxy. The full width at half maximum of the ω-mode X-ray diffraction peak is measured to be around 306 arc sec. Mid-wave infrared photoconductors based on the as-grown HgCdTe thin films have been demonstrated and the self-heating effect has been evaluated. A peak responsivity at the wavelength of around 3500 nm is measured to be about 110 V W^{-1} at 80 K and 8 V W^{-1} at room temperature under a bias of 25 V cm^{-1}. Twinning defects are observed, limiting the crystallinity and mobility-lifetime product in HgCdTe/mica. Benefiting from the vdW epitaxial growth, an etch-free layer transfer process for lifting off the HgCdTe from the mica substrate has been demonstrated, leading to large area free-standing HgCdTe thin films.

Read the full article

DETECT CASE STUDY

A smartphone could spell the end for malaria and other infectious diseases

Scientists are about to turn your smartphone into a tool that can diagnose diseases such as malaria, making mobile medical diagnostics affordable and accessible to remote areas such as third world countries and outback Australia.

Currently, disease diagnostics usually require chemical staining of cells and bulky and expensive microscopes that perform a process referred to as phase imaging. These microscopes cost thousands of dollars, putting them out of reach of remote medical practices. As a result, early stage detection is often not possible, leading to more severe illness and increased death rates. In 2020, there were an estimated 627,000 deaths caused by malaria, with 96% of those coming from the African region, where advanced medical diagnostics is hard to come by.

Research published in ACS Photonics by researchers at the University of Melbourne and TMOS, an Australian Research Council-funded research centre, is helping to miniaturise technology that makes invisible aspects of biological cells visible using metasurfaces, which are only a few hundred nanometres thick and thus small enough to be included in the lens of a smartphone. This future technology would allow mobile devices such as a smartphone to investigate biological specimens in a way not possible previously.

In addition to providing resources for remote medical practices, this new technology could one day lead to at-home disease detection, where the patient could obtain their own specimen through saliva or a pinprick of blood, and then transmit an image to a laboratory anywhere in the world. The lab could then analyse and diagnose the illness.

Lead researcher, Lukas Wesemann, says "making medical diagnostic devices smaller, cheaper and more portable will help disadvantaged regions gain access to healthcare that is currently only available to first world countries. This is why we go into science—to help change the world."

TMOS Chief Investigator Ann Roberts says "This is an exciting breakthrough in the field of phase-imaging and just the tip of the iceberg in terms of how metasurfaces will completely reimagine conventional optics and lead to a new generation of miniaturised devices."

> "This is why we go into science—to help change the world."
>
> \- Lukas Wesemann

SPOTLIGHT

LUKAS WESEMANN

Research Program Manager

Lukas Wesemann is a Research Program Manager for the Detect theme and is part of the Centre's University of Melbourne team.

Real-Time Phase Imaging with an Asymmetric Transfer Function Metasurface

The conversion of phase variations in an optical wavefield into intensity information is of fundamental importance for optical imaging including the microscopy of biological cells. Recently, meta-optical devices have demonstrated all-optical, ultracompact image processing of optical wavefields but are limited by their symmetric optical response to amplitude and phase gradients. In this article, we describe a metasurface that exploits photonic spin–orbit coupling to create an asymmetric optical transfer function for real-time phase imaging. We demonstrate experimentally the effect of the asymmetry with the generation of high contrast pseudo-3D intensity images of phase variations in an optical wavefield without the need for post-processing. This non-interferometric method has potential applications in biological live cell imaging and real-time wavefront sensing.

DETECT CASE STUDY

Saving lives by seeing through the smoke

When a building is on fire, every second counts. It can mean life or death for trapped victims and no emergency responder wants to be slowed down because they can't see through walls of smoke. But firefighters can't run headlong into every situation. When there's a likelihood that toxic substances are present, they need to consult hazardous material databases, slowing them down, or rely on their own visual identification, which comes with human fallibilities. Victims' lives and responders' health are put at risk when this happens.

What is needed is an accurate, portable spectrometer that can identify toxic substances quickly and from safe distances. That is why researchers at TMOS are working on lightweight, portable spectrometers that could one day be integrated into firefighter's body armour, much in the way that thermal cameras now are.

Every substance has its own unique thermal signature—the wavelengths at which it absorbs and emits photons. spectrometers can measure these thermal signatures to determine the chemical composition of something; this is how we know that the sun is made of hydrogen and helium, with smaller amounts of carbon, nitrogen and oxygen.

Traditionally, infrared spectroscopic instruments are limited to laboratory use due to their excessive size and fragile nature. Their operation often requires complex sub-sampling systems in air-conditioned shelters or lengthy fiberoptics. In addition, common environmental factors such as vibration, dust and temperature changes can have a detrimental impact on their performance. This makes them unsuitable for use in a field portable system such as mobile firefighting tool.

The University of Western Australia team is working to change this, having created tiny infrared spectral filters for remote thermal sensing and imaging utilising microelectromechanical systems (MEMS). MEMS is set to disrupt the current spectroscopic industry with its small size,

> "These miniaturised on-chip lightweight and small size devices are being seen as futuristic solutions towards simple and low-cost miniature spectroscopic remote systems..."
>
> - Marius Martyniuk

SPOTLIGHT

Gurpreet Singh Gill

PhD Student

Gurpreet is part of the Centre's UWA node and is currently working towards his PhD.

lightweight, minimal power requirements and robust construction, enabling spectroscopy applications never before imagined.

Chief Investigator Marius Martyniuk says, "These miniaturised on-chip lightweight and small size devices are being seen as futuristic solutions towards simple and low-cost miniature spectroscopic remote systems operating in the very important thermal infrared emission band of the electromagnetic spectrum, where minimising weight, size and power requirements is of most critical importance, such as on firefighter headsets.

Lead author Gurpreet Singh Gill says, "We have designed and built an electrically tunable surface micromachined Fabry-Perot filter using Ge and BaF_2 optical layers — the first time this has been successfully manufactured utilising low-index BaF_2 thin-films. This filter could one day be integrated into thermal cameras on a firefighter's headset, enabling immediate identification of toxic substances, giving firefighters the ability to move quickly and safely."

For more information about this research, please contact connect@tmos.org.au

Large-area narrowband Fabry–Pérot interferometers for long-wavelength infrared spectral sensing

JOURNAL OF OPTICAL MICROSYSTEMS, 19 MAY 2022

Gurpreet Singh Gill, Michal Zawierta, Dhirendra Kumar Tripathi, Adrian Keating, Gino Putrino, Konkaduwa Kamala Mesthrige Buddhika Dilusha Silva, Lorenzo Faraone, Mariusz Martyniuk

This paper presents a proof-of-concept for microelectromechanical system (MEMS)-based fixed cavity Fabry–Pérot interferometers (FPIs) operating in the long-wavelength infrared (LWIR, 8 to 12 μm) region. This work reports for the first time on the use of low-index BaF2 thin films in combination with Ge high-index thin films for such applications. Extremely flat and stress-free ~3-μm-thick free-standing distributed Bragg reflectors (DBRs) are also presented in this article, which were realized using thick lift-off of a trilayer structure fabricated using Ge and BaF2 optical layers. A peak-to-peak flatness was achieved for free-standing surface micromachined structures within the range of 10 to 20 nm across large spatial dimensions of several hundred micrometers. Finally, the optical characteristics of narrowband LWIR fixed cavity FPIs are also presented with a view toward the future realization of tunable wavelength MEMS-based spectrometers for spectral sensing. The measured optical characteristics of released FPIs agree with the modeled optical response after taking into consideration the fabrication-induced imperfections in the free-standing top DBR such as an average tilt of 15 nm and surface roughness of 25 nm. The fabricated FPIs are shown to have a linewidth of ~110 nm and a suitable peak transmittance value of ~50 %, which meets the requirements for their utilization in tunable MEMS-based LWIR spectroscopic sensing and imaging applications requiring spectral discrimination with narrow linewidth.

Read the full article

Infrastructure and Capabilities Committee Chair Report

ICC Chair, Professor Kenneth Crozier

Our committee aims to ensure that each Centre researcher can realise their ideas by being able to make or measure something. At first glance, this might not seem like a lofty goal. But meta-optical systems are technologically advanced, and thus sophisticated computational and experimental infrastructure is needed for their development. The objective of the Infrastructure and Capabilities Committee is to ensure that Centre members have access to this infrastructure. We do this in several ways:

1. We host an equipment register on the Centre website.
2. We coordinate submissions to the Linkage Infrastructure Equipment Facilities (LIEF) program of the ARC.
3. We organise regular meetings in which Chief Investigators can discuss unmet infrastructure needs.
4. We support Centre researchers in submissions to Australian and international government-funded facilities.
5. We serve as a contact point with ANFF, NCI, and Microscopy Australia.

2022 was a good year for the Infrastructure and Capabilities Committee. We added new capabilities to the equipment register and we supported successful bids to the Linkage Infrastructure Equipment Facilities (LIEF) program of the ARC. These successful bids were developed partly in response to feedback from Chief Investigators on unmet infrastructure needs. We supported a successful submission for computing time from the National Computational Infrastructure (NCI), Australia's leading high-performance data, storage and computing organisation. The Infrastructure Committee also maintained its close contact with bodies such as ANFF. Chief Investigator Hoe Tan and Mariusz Martyniuk are in the leaderships of the ACT and Western Australia ANFF nodes, respectively. We also continued our strong linkages with Microscopy Australia.

In 2023, we look forward to continuing to support Centre research however we can. New infrastructure will be added to TMOS as a result of successful grant applications, including the LIEF program, and this will be reflected in our equipment register. We will continue to raise awareness of existing facilities within the Centre, which should help increase cross-node collaboration. We will support Centre researchers to lead bids to the LIEF program and to join bids led by non-TMOS researchers that are synergistic with Centre activities. We will continue to support our researchers in bids to Australian and international facilities, and we will continue to serve as a contact point for ANFF, NCI and Microscopy Australia. Indeed, we are working with our ANFF colleagues, in particular the ACT and WA Nodes, to request fabrication tools relevant to the Centre in the next round of NCRIS funding for enhanced capability as identified by the 2021 National Research Infrastructure Roadmap.

On behalf of the Committee, we extend our best wishes to all TMOS members for their experiments and simulations in 2023.

Professor Kenneth Crozier
Infrastructure Committee Chair

ACTION ITEMS FOR 2023

1. Add new infrastructure to the Centre's equipment register.
2. Raise awareness of existing facilities within the Centre to increase cross-node collaboration.
3. Support funding and access bids by Centre researchers and other researchers whose work is synergistic with Centre activities, such as the LIEF program and NCRIS funding.

COMMITTEE MEMBERS:

PROFESSOR FRANCESCA IACOPI

Chief Investigator

UTS

PROFESSOR HOE TAN

Chief Investigator

ANU

KATHY PALMER

UoM (Secretary)

PROFESSOR KEN CROZIER

Chief Investigator

UoM (Infrastructure Chair)

ASSOCIATE PROFESSOR MARIUSZ MARTYNIUK

Chief Investigator

UWA

PROFESSOR SHARATH SRIRAM

Chief Investigator

RMIT

Engagement & Culture

Early-Career Researcher Committee Report

Early-Career Researcher Committee Co-Chairs, Professor Sharath Sriram and Dr. Nima Dehdashtiakhavan

WHO IS AN ECR?

An early-career researcher (ECR), as the name indicates, is a person at the start of their research career.

The ECR stage is typically the first five years after PhD graduation, accounting for career interruptions.

This phase is when an ECR finds their first employment, with the opportunities and support provided defining their career for years to come. Unlike many professions, research performance is cumulative, which is why career interruptions impact more significantly.

THE TMOS ECR COMMITTEE'S ROLE

The ARC Centre of Excellence for Transformative Meta-Optical Systems (TMOS) will create technology for the optical revolution. This effort will be driven by a core Centre membership of Early-Career Researchers (ECRs) and Doctor of Philosophy (PhD) candidates.

The ECR Committee will lead initiatives to support ECRs within the Centre. Core activities include:

- Representing the needs of ECRs in all decision-making processes of the Centre
- Design and support the implementation of the ECR Mentoring Program
- Facilitate networking opportunities for ECRs in the Centre and in related disciplines
- Coordinate support for ECRs across IDEA and Education Committees
- Organising workshops and career/ professional development opportunities for ECRs
- Surveying TMOS ECRs where the need arises

WHAT DO ECRS WANT AND NEED?

This is the question our ECR Committee is interested in answering. Every ECR working within TMOS has different needs and wants when it comes to their experience working within the Centre. The ECR committee has conducted numerous Centre-wide surveys to find out what these needs and wants are. This will be an ongoing process as needs evolve with changes to the sector.

The Committee is in the process of designing our mentoring program, we have been doing a lot of research on the best way to run it across our five participating universities. This has been a large undertaking and we are looking forward to rolling out the mentoring program in 2023.

> "The TMOS ECR Committee's vision is to empower our emerging researchers with skills, capabilities, exposure, and networks to establish successful careers in academia and beyond.

As a Committee we have also been instrumental in organising our second ECR conference! This is an amazing opportunity for our ECRs to share their work among each other and to create a network of peers to collaborate, support, and develop with.

CENTRE-WIDE SURVEY

The ECR committee will continually survey our members to make sure we are always up-to-date with our ECRs' needs.

Our most recent survey was to determine the additional professional development the ECRs wanted. The results told us that they want to learn:

- “How to be successful with grant applications”,
- ”Different career paths in and out of academia”, and
- “Start-up company formation”

MENTORING

Mentoring from independent experts and peers can increase opportunities, networks, and exposure for our ECRs. With this in mind, the ECR Committee has been researching the best way to create an inter-node mentoring program. We have engaged with Mentorloop to discuss the best approach for TMOS. We implemented roll out in November 2022, with plans to join a multi-Centre network in 2023.

COMMITTEE WIND DOWN

It was decided that 2022 would be the final year of the committee, with many functions of the ECR committee now being performed by the Education Committee (to be renamed Education and Professional Development Committee), and eventually the interest groups feature in Mentorloop. Through the various sub-committees, the Research Program Managers into the Centre Executive Committee, and more in-person gatherings means there are ample opportunities for leadership development and representation in 2023. We will always have the option to bring it back, if we drive it ourselves.

We would like to thank our committee members for their hard work during 2022!

Professor Sharath Sriram and Dr. Nima Dehdashtiakhavan
ECR Committee Co-Chairs

COMMITTEE MEMBERS:

GREG DENNIS

RMIT

PROFESSOR ILYA SHADRIVOV

Chief Investigator
ANU

DR. IRYNA KHODASEVYCH

ECR Representative
UTS

DR. JIAJUN MENG

ECR Representative
UoM

DR. KRISHNA MURALEEDHARAN NAIR

ECR Representative
RMIT

DR. NIMA DEHDASHTIAKHAVAN

UWA (Chair)

PROFESSOR SHARATH SRIRAM

Chief Investigator
RMIT (Chair, Co-chair & Secretary)

DR. TUOMAS HAGGREN

ECR Representative
ANU

INTERVIEW

ECR OF THE YEAR: Jihua Zhang

Dr. Jihua Zhang is currently researching quantum metasurfaces. With the support of TMOS, he aims to use metasurfaces for generation, manipulation, and detection of quantum optical states at ultrathin scale. His goal is to develop miniaturised quantum optical devices and systems for applications in quantum imaging and communications. In 2022, he and his collaborators demonstrated a spatially entangled quantum optical source based on a nonlinear lithium niobate metasurface, which has a thickness of only 500 nanometers. This work was published in *Science Advances*.

What were the highlights of 2022 for you?

Winning the Centre's Early Career Researcher of the Year Award was definitely a highlight. In 2022, I also gave my first invited talk and the first lecture. These are milestones of my career.

What challenges did you face in your research? How did the Centre support you in this?

My current research is to realise metasurface quantum sources. The challenge is that the efficiency is too low for practical applications. One solution to improve the efficiency is to etch the nonlinear material based on our theoretical study, but the etching process is not that easy and could take a long time for me to develop the recipe. Last year, we began collaborating with Igor Aharonovich and Milos Toth at the Centre's UTS node. Their group can etch the nonlinear material nicely. This kind of cross-node collaboration is always supported and encouraged by TMOS.

What opportunities did being a member of TMOS give you? How have you gotten involved in the Centre?

The biggest opportunity was to meet, talk, and work with all the prestigious Chief and Partner Investigators. They are the top professors in the field and the best mentors. As an early career researcher, I learnt a lot and obtained valuable advice from them. Last year, I had the opportunity to help organise the Centre's ECR/Student conference as one of the organising committee members.

When did you first know that you wanted to be a physicist?

In high school, when I heard the stories of famous physicists like Albert Einstein and then started to understand that everything can be explained by physics.

What career challenges have you encountered since embarking on your PhD?

As an experimental researcher, the biggest career challenge I faced was the COVID-19 lockdown. Not being able to do the fabrication and experiment in the lab strongly delayed the progress of my project. Especially because this happened when I had just joined ANU.

Where do you think you'll be in five years? How are you going to get there?

In five years, I hope to become a Partner Investigator and lead a research group. To make myself prepared for this role, I will need to do my best to publish more papers, improve my skills in attracting funding and supervising students, and broaden my network in my research field. Fortunately, TMOS is one of the best places to achieve these goals.

Do you have any advice for young people thinking of a career in research?

Keep the desire for knowledge and work hard. The achievement of research is proportional to the effort.

JIHUA ZHANG

Research Fellow

Australian National University

Jihua Zhang has been a Research Fellow at ANU since July 2021.

Zhang obtained his BS degree from Huazhong University of Science and Technology in 2011 and dual PhD degrees from University Paris-Saclay and Huazhong University of Science and Technology in 2016. Before joining TMOS, he worked as a Postdoctoral Associate in The Institute of Optics at University of Rochester from 2016-2020.

His current research is focused on design, nanofabrication, and characterisation of nanostructured metasurfaces for nonlinear and quantum photonics. This research aims to explore metasurfaces for frequency conversion of light, generation of entangled photon pairs, manipulation, and detection of quantum photon states, which will facilitate the development of miniaturised and new-function quantum optical elements and devices for applications in quantum imaging and free-space quantum communication.

Zhang was awarded the 2022 TMOS ECR of the Year Award. In his spare time, he likes to spend time with family and friends exploring the beautiful nature of Australia.

Education and Colloquia Committee Chair Report

Education and Colloquia Committee Co-Chairs, Professor Lan Fu and Professor Milos Toth

The Education and Colloquia Committee (ECC) aims to develop a multidisciplinary, dynamic, interactive, and collaborative culture fostering the next generation of leaders who display academic excellence and are equipped with transferable skills to take on any career they choose. The committee strives to provide an outstanding educational experience for the Higher Degree Research (HDR) students within the Centre and to promote engagement in activities across all nodes to maximise collaboration and networking between teams. The committee:

- designs strategies for HDR recruitments in collaboration with node universities
- develops, implements and monitors the Centre HDR program
- coordinates the delivery of seminars, workshops, events, and training courses that support the goals of collaboration, education and development in alignment with the IDEA Framework
- coordinates the HDR-Partner Investigator student exchange program
- coordinates the Centre HDR/ECR and annual conferences, including monitoring expenditure and the design of the conference program
- is a forum to support HDR candidates and best practice HDR supervision

In 2022, the main activities led and carried out by the ECC included:

- organisation of the second mid-year Early Career Researcher (ECR) and student conference. This was a two-day hybrid-mode conference organised by Centre ECRs and students featuring around 50 participants, including 41 ECR and student oral and poster presentations as well as four invited talks from young rising stars and experienced professors discussing their recent research and career pathways
- organised and hosted a series of internal seminars as part of the Centre's Science Tuesday program. Topics were selected based on feedback from students and ECRs and included Chief Investigator Hot Seats (Lan Fu, Francesca Iacopi, Milos Toth and Lorenzo Faraone), an introduction of basic numerical simulation techniques (Dr. Arti Agrawal, UTS), and entrepreneurship (Dr. Simon Poole, Cylite)
- developed the program for the inaugural Centre conference and assisted with conference logistics
- planned and coordinated the 2021 Centre Colloquium program
- initiated bi-monthly ECR/HDR meetings to foster collaboration and provide opportunities for peer support

After a successful 2022 supporting and growing the industry's future leaders as researchers, academics and people, we are looking forward to 2023 and the opportunity to help them deepen their knowledge and widen their network of collaborators. To this end we are re-naming our committee in 2023 to better reflect our support for both ECRs and students as the Education and Professional Development Committee.

Professor Lan Fu and Professor Milos Toth
Education and Colloquia Committee Co-Chairs

ACTION ITEMS FOR 2023

- Finalise the TMOS HDR student database and establish a quarterly updating mechanism.
- Deliver a professional development program based on Centre ECR/ HDR's interests and needs, including the colloquium and topical workshop programs.
- Organise the 2023 Centre ECR and student mid-year conference and the Centre conference.

COMMITTEE MEMBERS:

DR. AISWARYA PRADEEPKUMAR

ECR Representative

UTS

EMILY SCHUSTER

(Secretary)

DR. FARHAD FOROOZANDEH

HDR representative

UWA

DR. JINYONG MA

ECR Representative

ANU

DR. JOHN SCOTT

ECR Representative

UTS

PROFESSOR LAN FU

Chief Investigator

ANU (Chair)

PROFESSOR MILOS TOTH

Chief Investigator

UTS (Chair)

NIKEN PRISCILLA

HDR representative

UoM

SAMARA THORN

(Engagement Manager)

SHIYU WEI

HDR representative

ANU

SUVANKAR SEN

HDR representative

RMIT

INTERVIEW

EDUCATION AWARD 2023: John Scott

John Scott, an Early Career Researcher from the University of Technology Sydney was awarded the 2023 Education Award for his work leading the ECR & Student conference working party, mentoring junior researchers as well as supervising Honours and PhD students. He is an active member of the Education and Colloquia Committee, having organised and chaired several of the Centre's Colloquia.

What are three things organising the student conference taught you?

Previously this I had no experience in organising events like this. Firstly, I learned how and where to ask for help. There were plenty of people within the Centre who could either provide guidance or accomplish the required task. It was just a matter of contacting them and asking for help.

Secondly, communication. It was essential that each person involved knew what was required of them and when it had to be completed. We had to create safe and comfortable spaces for all volunteers to express their ideas and concerns.

Finally, adaptability and flexibility when faced with unexpected challenges. Many unexpected events occurred that required effective handling. With flexible planning, we could quickly apply changes to ensure a successful conference.

How did it all go? What do you think people got out of it?

The conference was a big success. Whilst improvements can be made next year, I am very proud of the work that the committee did. What is most exciting is that many of the Centre's newest researchers were given a platform to share their work and also had exposure to incredible, field-leading scientists in an interactive environment.

You are also an active member of the colloquium committee. Can you describe what you think the importance of the colloquium program is?

For me, one of the most rewarding parts of working as a researcher is hearing truly brilliant scientists discussing their work. It helps me with my own research on so many levels including: project ideas, setting research goals, the presentation of data, building well-structured and supported arguments, effective communication and more. TMOS is truly a Centre of might and influence that can attract brilliant scientists to discuss their work. Two personal highlights for me last year were chairing the colloquiums with Prof. Andrea Alu and Prof. Mathieu Kociak.

How has the TMOS professional development program impacted you as a researcher? What skills has it helped to develop? How do you see it benefiting your career?

What I've learned since finishing my PhD is that a career in research is so much more than being an outstanding scientist. Transitioning into team leadership roles demands many skills beyond data collection, analysis and presentation. For many researchers, there hasn't been the opportunity to learn and gain feedback on these skills before they enter leadership positions. TMOS provides these opportunities. With the incredible network and support I've received, I feel as if my professional development is ahead of many of my peers. I am confident in my ability to transition to team leadership roles in the next stage of my career.

If you had any advice for new researchers coming into an organisation like TMOS, what would it be?

Communicate with your peers: Attend and contribute at conferences and workshops, join societies, and engage with your TMOS peers.

Don't give up: Research is often a long and difficult process, it is important to stay persistent and not give up when faced with obstacles.

Be open-minded and flexible: Research can take unexpected turns, so be open to new ideas and be willing to change your approach if necessary.

INTERVIEW

STUDENT OF THE YEAR 2022: Shiyu Wei

Shiyu has been working on III-V semiconductors nanowire-based gas sensors, which have several industrial applications, including environmental monitoring and healthcare. In 2022, she published a referee journal article in *Advanced Materials*, the top journal in the field of chemical and materials engineering. The article covered her work with self-powered InP nanowires NO_2 sensors, which have proven to be capable of vehicle exhaust measurement.

What were the highlights of 2022 for you?

My highlights mainly involve TMOS. I took the lead in the ANU node organization of the 2022 TMOS ECR & student conference and I took part in the Centre's conference, winning the Student of the Year Award. I also took part in the three-minute thesis competition in ANU and made it into the top 10 finalists.

What challenges did you face in your research? How did the Centre support you in this?

I needed to do a lot of lab experiments, nanostructured semiconductor device fabrication and characterisation. This process is very complicated and challenging. The Centre offered opportunities for collaboration and co-supervision to get the critical guidance and support needed to overcome these challenges.

What opportunities did being a member of TMOS give you? How have you gotten involved in the Centre?

I had opportunities to be involved in events and learned a lot about their organisation and working across groups and nodes. Also, my background in the optical and photonic field is minimal. The Centre has expertise from across the world. By becoming familiar with its leading projects during the Centre's seminars and conferences, I absorbed many Frontiers theories and principles.

When did you first know that you wanted to be a physicist?

In my childhood, I learned that a plastic rubber scratched on hair will lift small pieces of paper in a short distance. At that time, I thought this phenomenon was amazing, and I wanted to know why. Then, I chose to study electronic materials during my master's degree, and I realized that I like to solve the problems and issues that occur during research. That made me realize I wanted to become a physicist.

What career challenges have you encountered since embarking on your PhD?

I was not good at writing and oral presentations when I started my PhD. However, these two tasks are inevitable to become a real PhD. So, I have done a lot of practice for the writing and rehearsals for presentations. My supervisor Prof. Lan Fu also helped me to improve my writing and speaking skills, especially in the academic fashion.

Where do you think you'll be in five years? How are you going to get there?

First, I need to complete the rest of my project and get the dissertation done for my PhD in the next 10 months. Then, I plan to find a position in school to continue my research and apply for my own grants and funding based on my research output.

Do you have any advice for young people thinking of a career in research?

I think those who consider research as their career could apply for some short-term program during their undergraduate semesters to see if they really like this and which kind of research field they would like to work on. Then, they can search for the institutions or groups with good reputations in those research fields and reach out to those Chief Investigators to find out about what requirements there are. They may need to consider the platform and supervisors in there at the same time. It would be the best if they can connect to someone who has already studied there to get more information.

SHIYU WEI

PhD Candidate

Australian National University

Shiyu Wei is a PhD Candidate in Electronic Materials Engineering at ANU, supervised by Professor Lan Fu.

Wei received her Master's Degree from Hefei University of Technology in 2019 and Bachelor's Degree from Hefei University of Technology in 2016. Her research interests focus on the III-V semiconductor nanowires-based gas sensors.

Wei has published three papers as first author in prestigious international journals on the topics of conjugated polymer nanowire sensors and photodetectors. In 2022, she received the TMOS Student of the Year award.

Student Recruitment Campaign

TMOS-wide Higher Degree Research (HDR) student recruitment had been slow in 2020 and 2021, in particular because of the difficulties in getting international students to Australia. The Centre needed to recruit a significant number of students in order to reach the critical mass required to meet its research objectives. In particular, more women and diverse people were needed.

AUDIENCES

Two target audiences were chosen;
1) international students and 2) domestic students. Some of the challenges faced included:

INTERNATIONAL STUDENTS

- They must secure scholarships. One for the university fees and the stipend to cover their living costs.
- We do not get top tier students as their preference is to attend universities such as Cambridge and Oxford, despite the high rankings of the Centres Go8 universities.

DOMESTIC STUDENTS

- In the past, these have come via an undergraduate pathway, however there are an insufficient number of students who've taken the required photonics courses. Undergraduate students focus on quantum physics.
- Domestic students have a stronger interest in fundamental research.

CAMPAIGN GOALS

1. Frame meta-optics as a field of research that is exciting and impactful due to the way it straddles the gap between fundamental and applied research.
2. Position the centre as the leading research body in the field, highlighting the academic rankings of its centre universities.

STRATEGY

1. A landing page on the website that highlights the prestige of our Chief Investigators and outlines the various projects PhD students could work on.
2. A paid social media campaign that features students and highlights the impact meta-optics could have on multiple industries, as well as a "Day in the life" video that shows the benefits of doing a PhD at the Centre.
3. Instagram profile development that shows the people and facilities you'll be working with.
4. Email provided to the Centre for members to send to their networks as well as given to all node admins to forward to the physics departments of their universities as well as physics departments of other Australian and New Zealand universities.

905
Unique landing page visitors

52
Applications

Visit

Visit

Visit

2022 Early Career Researcher & Student Conference

ECR & Student Conference Lead, John Scott

The 2022 ECR & Student Conference was held from 31 August – 1 September in hybrid mode, meaning students and ECRs at each node gathered in a conference room for the event with a live and interactive feed shared between the centre's nodes. Importantly, speakers at each node could present to an in-person audience. RMIT University and the University of Melbourne held a joint event, with each node hosting one day of the conference. This hybrid format was the first event of its kind for the Centre.

> "It was a very well organised conference that enabled the TMOS community to come together and share our research. It was a great platform to begin discussing collaborations, which are now just coming to fruition."
>
> – Neuton Li

Based on feedback from the previous year's conference, there were fewer ECR and student speakers, with each allocated a slightly longer time slot of 15 minutes to present their work. Each session was chaired by a node representative, giving our team valuable experience. There were 22 oral presentations, nine posters, conference break activities and four keynote talks. Centre Director Dragomir Neshev provided opening remarks.

Keynote speakers included:

- TMOS Associate Investigator Prof. Arnan Mitchell
- Associate Prof. Noushin Nasiri
- Associate Prof. Arka Majumdar
- Prof. Judith Dawes

The Centre's Chief Investigators were excluded from the event to encourage discussions between students and ECRs.

The primary objectives of the conference were to:

- generate research collaborations within the centre
- develop communication skills of the centre's ECRs and students
- share research conducted within the centre and
- expose ECRs and students to cutting edge research from field leading scientists

After calling for volunteers through the TMOS newsletter, we quickly amassed a team of 13 committee members. Our challenges included balancing conference tasks with busy research obligations for all committee members and organising a full speaking schedule across five nodes in different time zones, including an international keynote talk. Scheduling required an adaptable mindset, with changes being required in the days leading up to the conference.

This was a fantastic experience for all involved. We learnt to work with a diverse team of researchers to help accomplish tasks for which we had very limited prior experience. The execution of a successful conference was a result of constant and productive collaboration between committee members. Feedback from conference attendees and presenters both have been positive, and we consider the conference objectives met. On reflection, we feel that including Chief Investigators in future years could be beneficial.

The ECR & Student conference was the first event of this nature that I have personally led. I received incredible support and direction from the professional team, the Education & Colloquia Committee Co-Chairs CIs Lan Fu and Milos Toth, and the previous year's conference committee members, Litty Thekkekara, Wendy Lee and Niken Priscilla.

I want to thank everyone who contributed to making this event a success and I look forward to working with and supporting next year's team.

Dr. John Scott
ECR & Student Conference Lead

"The ECR & Student Conference was an excellent opportunity to come together in a professional, yet accommodating setting. Organised exceptionally well by John and the organising committee, the conference enabled local nodes to meet in-person, such as RMIT and UoM in Melbourne, and cross nodes virtually. We came out of the conference with an increased knowledge of each other's work and with ideas for future collaborations."

– Shaban Sulejman

AWARDS

Best Poster:

Ying Zhi Cheong

Best Speaker:

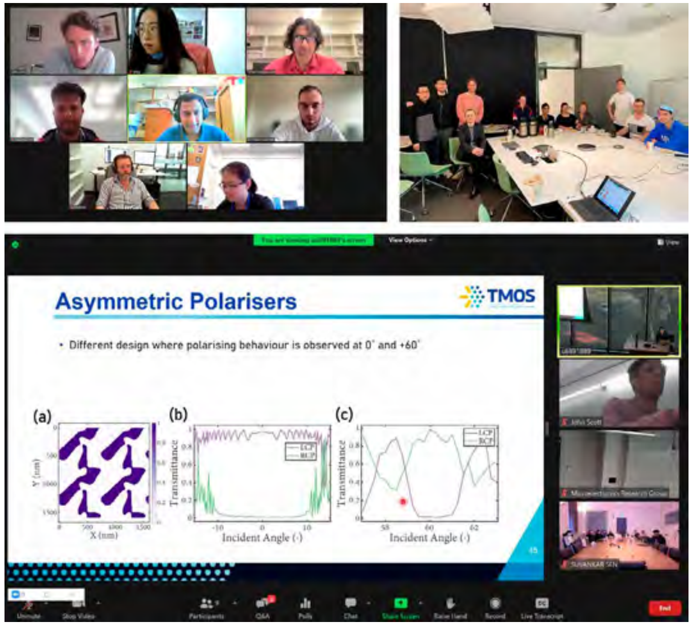
Neuton Li

"Through this event, we could better engage with TMOS and had the chance to understand the projects by different groups, which is critical for collaboration. The social activities were difficult to organise cross-node, but the trivia and online lab tours were very interesting and creative."

– Shiyu Wei

STUDENT CONFERENCE COORDINATORS

- John Scott, Early Career Researcher (UTS)
- Hemendra Kala, Early Career Researcher (UWA)
- Jihua Zhang, Early Career Researcher (ANU)
- Michal Zawierta, Early Career Researcher (UWA)
- Nima Dehdashti, Early Career Researcher (UWA)
- Henry Tan, PhD Student (UoM)
- Farhad Foroozandeh, PhD Student (UWA)
- Matthew Parry, PhD Student (ANU)
- Niken Priscilla, PhD Student (UoM)
- Shaban Sulejman, PhD Student (UoM)
- Shiyu Wei, PhD Student (ANU)
- Suvankar Sen, PhD Student (RMIT)
- Karen Kader, Node Admin (UWA)



Testing the Webinar link with ECR/ Student Conference committee members. UTS node ECR/ Student Conference gathering and a screenshot of a student's presentation during the conference.

Colloquiums

CENTRE COLLOQUIUM

20-JAN-22 / Prof. Michael Johnston

Nanowire-based devices for THz polarimetry

10-FEB-22 / Prof. Mathieu Kociak

Nanooptics in the electron microscope

06-APR-22 / Prof. Rachel Grange

Nonlinear and electro-optic metal-oxides for sensing and telecom devices

22-JUN-22 / Dr. Andrea Alù

Extreme Control of Light and Sound with Metasurfaces

04-JULY-22 / A/Prof. Patrick Parkinson

A needle in a needlestack – exploiting functional inhomogeneity as a tool for optimized nano-optoelectronics

04-JULY-22 / Prof. Hannah Joyce

Growth, characterisation and device integration strategies for III-V nanowires

06-JULY-22 / Prof. Isabelle Staude

Active metasurfaces empowered by two-dimensional materials

08-JULY-22 / Prof. Stefan Maier

Enhanced light harvesting and emission via disordered plasmonic metasurfaces – and a few other topics

07-SEP-22 / Dr. Andrei Faraon

Passive and tunable dielectric metasurfaces

18-OCT-22 / A/Prof. Niels Quack

Integrating MEMS in Silicon Photonics

07-DEC-22 / Nobel Laureate, Prof. Donna Strickland.

Generating High-Intensity, Ultrashort Optical Pulses

IDEA Committee Chair Report

IDEA Committee Chair, Professor Madhu Bhaskaran

2022 was a year in which we focussed on embedding IDEA principles more firmly in the operations of TMOS.

For 2022 the IDEA committee had outlined the following key action items:

- Create a pilot culture survey (to become an annual survey) to understand what is working and receive feedback from the team.
- Establish the Centre's wellbeing and family policies.
- Indigenous training for all core Centre members.

We launched our first culture survey in September with a response rate of 75% of our Centre. As this was our first culture survey, we needed to establish our baseline standard. To achieve this we asked a broad range of questions ranging from "TMOS is a diverse and inclusive organisation" to "My supervisor provides regular and constructive feedback through performance discussions?" We are delighted with the time and energy our members put in to give us a better understanding of how we are operating. As we analyse the information from this survey, this is offering us insights into where we are exceeding as a Centre and the few areas in which we can improve. We were overwhelmed by the positive responses of our members and this feedback has galvanised us as a committee to continue the important work we are doing within our Centre.

The other action item which was completed was the introduction of the Centre wellbeing and family policies. While working on these policies we realised they needed to be reshaped into the Participation and Inclusion Policy. Under this policy we have also created the Carers Scholarship Program; this program has been established to support our members who have caring responsibilities. This program will support our members financially to allow them to participate fully. The purpose of this policy is to provide expectations and guidance for Centre leadership and members on the minimum standards for ensuring that we reduce the barriers to workplace participation and inclusion and build community in alignment with the Centre IDEA Framework. Within this policy are guidelines for our members to adhere to such as inclusive meeting planning and checking D&I practices when attending conferences.

By introducing this policy in November, we are now able to provide support and guidance for all our Centre members.

With Indigenous training, the consensus was that the members will benefit more from participating in in-person workshops offered in their own node organisations which will provide stronger local cultural awareness. TMOS core members will endeavour to do this in 2023.

We have worked on creating a standardised Acknowledgement of Country for our Centre, by compiling those from our participating universities, creating an acknowledgement that is genuine and meaningful.

Throughout 2022, numerous educational pieces were created and shared within the Centre. These include monthly IDEA newsletters featuring an interview discussing a different IDEA topic, the topics discussed/ celebrated were International Women's Day, World Autism Awareness Day, International Day of Families, Pride Month, International Youth Day, International Equal Pay day, Mental Health Month, LGBTQIA+ STEM Day and Transgender Awareness Week. This continual discussion and education around IDEA has had a wonderful response from our team. We also took part in the inaugural InSTEM conference which is a networking and careers advice conference for marginalised and underrepresented people within STEM.

The committee will continue to encourage and support our members throughout their IDEA journey.

Professor Madhu Bhaskaran
IDEA Committee Chair

ACTION ITEMS FOR 2023

- Leadership training for our core Centre members which also includes our Research Program Managers – with a focus on modern leadership skills
- TMOS will play a significant role in the organisation and operations of the 2023 inSTEM Conference
- IDEA framework and related policies will be reviewed

Proffessor Chennupati Jagadish at the InSTEM Conference. Photo credit: Matthew Dahlitz, Dahlitz Media

COMMITTEE MEMBERS:

PROFESSOR ANN ROBERTS
Chief Investigator
UoM (Deputy Chair)

PROFESSOR DRAGOMIR NESHEV
Centre Director
ANU

GREG DENNIS
IDEA Officer (2022)
RMIT

PROFESSOR MADHU BHASKARAN
Chief Investigator
RMIT (Chair)

MARCUS CAI
HDR Representative
ANU

DR. MARY GRAY
Chief Operating Officer
ANU

YAN LIU
HDR Representative
UWA

Inclusion, Diversity, Equity and Access – Impact

Inclusion, Diversity, Equity and Access Officer, Greg Dennis

In late 2021 I was appointed the TMOS IDEA Officer and created and implemented numerous different strategies to further educate our team in 2022. In 2021 the focus within IDEA was making sure our governance and structure were set up to support the education of our members. In 2021 TMOS engaged Symmetra, an online training program to begin the education of our members in IDEA. With this groundwork completed it allowed 2022 to be a proactive year to engage our team.

At the beginning of 2022 I realised that the two major issues facing TMOS within IDEA were, firstly members of our team needed further basic understanding of IDEA was, after one member asked what does IDEA mean? The second was a lack of team culture within TMOS, due to the Centre being established during COVID-19 lockdowns each node was operating essentially independently, this meant that building a culture of inclusivity would be near impossible straight away.

To continue the education of our members I created a 12-month plan for 2022. One of the major parts of the IDEA plan for 2022 was the introduction of a monthly IDEA newsletter. Creating a monthly newsletter allowed me to cover the basics of "What is IDEA?", which was delivered by creating a series of five short videos breaking down IDEA. These videos were between two and four minutes to allow for easy consumption.

Each newsletter also contained an interview focusing on a different topic within IDEA coinciding with a day, week or month celebrating that topic. Throughout the year the topics that were covered were: International Women's Day, Autism Awareness Day, International Day of Families, Pride Month, International Youth Day, International Equal Pay Day, Mental Health Awareness Month, LGBTQIA+ STEM Day, Transgender Awareness Week and IDEA in business. These interviews have been received exceptionally well and have been shared outside our Centre.

This year also saw our Centre conduct its first culture survey. This is a very important tool for us as previously we have had no indication of our cultural climate or a baseline to measure the impact of IDEA work we have been doing. The results were predominantly positive with a few issues being raised that we need to work on in a more local capacity. Our culture survey will be conducted each year to give us more measurable data to understand how we are improving year on year as a Centre.

One of the other major events of 2022 was TMOS participating and assisting in the organisation of InSTEM. InSTEM is a networking and career development conference for people from marginalised or underrepresented groups in STEM, and their allies. It is an initiative of the STEM-focused ARC Centres of Excellence. 2022 was the first year that InSTEM was organised and I was on the Steering Committee as well as the chair of the Planning Committee. This event was a great success and TMOS is looking forward to having a larger role within InSTEM in 2023.

2022 was a big year for IDEA within our centre and 2023 is looking to be even bigger. With more targeted education and greater outreach work in the pipeline, stay tuned.

Thanks

Greg Dennis (He/Him)

Inclusion, Diversity, Equity and Access Officer

InSTEM Conference by the Centres of Excellence

The 2022 inSTEM Conference was an initiative by STEM based ARC Centers of Excellence to support underrepresented and marginalised groups in STEM and their allies. TMOS was a Bronze partner of this event, which was led by EQuS. TMOS had four members as part of the organising committee, including Dr. Mary Gray, Greg Dennis, Dr. Buddini Karawdeniya and Marcus Cai.

The 2022 inSTEM Conference was an initiative by STEM based ARC Centers of Excellence to support underrepresented and marginalised groups in STEM and their allies. TMOS was a Bronze partner of this event, which was led by EQuS. TMOS had four members as part of the organising committee, including Dr. Mary Gray, Greg Dennis, Dr. Buddini Karawdeniya and Marcus Cai.

The inSTEM Conference was designed to provide support and advice on career progression in addition to networking opportunities for underrepresented and marginalised groups in STEM and their allies, in a 2 full-day program that included multiple talks, panel discussions, workshops, and one-on-one feedback sessions. These sessions were designed to discuss and acknowledge the challenges faced by marginalised and underrepresented groups in the STEM fields and how to overcome them to reach both career and life goals.

Many attendees took advantage of the on-site accommodation that provided convenience and extra time to get to know people and build new networks. This inaugural event was held on campus at the University of Queensland, Brisbane with over 100 participants on 20-21st July 2022. Multiple TMOS members attended the conference and found the event highly useful and relevant. The next inSTEM Conference in 2023 will be led by TMOS and we are looking forward to it!

Find out more about InSTEM

Photo credit: Matthew Dahlitz, Dahlitz Media













INTERVIEW

IDEA AWARD 2023: Marcus Cai

Marcus has been an IDEA Committee member since its inception, taking an active role in its initiatives. In particular, he was on the Steering Committee for the inSTEM Conference, a networking and social conference for marginalised and underrepresented groups in STEM. He is also a strong advocate for all things IDEA within the ANU Optics Student Chapter and informally with friends and colleagues.

What has contributing to the Centre's IDEA initiatives taught you in 2022?

1. Visibility matters. Even wearing a pin or a lanyard with an IDEA theme could make others in marginalised and underrepresented groups feel safe and not isolated.
2. The importance of listening to others. When someone comes to me because they want to talk about their frustration, it's important for me to listen to them and be empathetic, instead of giving advice that they don't really need, unless they specifically ask for it.

What has been the most challenging aspect of IDEA in the past couple of years?

COVID-19 stopped us from physically interacting with others. We could not host events in person. Interacting online only also makes it harder to connect to people. People, especially from marginalised and underrepresented groups, felt more isolated and were more easily affected by negative emotions.

What has been your favourite moment of IDEA in the past couple of years?

Contributing to the inSTEM Conference. It was my first in-person conference since COVID-19, and it was very empowering to see the conference run smoothly. Participants were having a good time, gaining a better understanding of IDEA in STEM while building connections with other underrepresented and marginalised scientists. I very much look forward to the inSTEM Conference in 2023, which will be led by the Centre.

Why is IDEA so important to you?

As a member of the LGBTQIA+ community, IDEA allows me to feel included and to express my opinions without fear. It helps me maintain a healthier mindset.

What IDEA work would you like to see TMOS doing in the future?

I would really like to see TMOS somehow get involved with different pride festivals and promote science/optics in them, maybe a booth at the fair day at the SpringOut Festival in Canberra, sponsoring or even forming a float at Mardi Gras in Sydney. We have so many pride festivals in Australia, which are all excellent opportunities to promote ourselves.

While doing a PhD, you also hold down a full-time job in government. How do you see the IDEA work that's done at TMOS apply in non-research organisations?

I am also in the Pride Network in my government agency. I have been able to pass on my learnings from TMOS to my agency and vice versa. Given my agency has a bigger designated team to work on IDEA and members from different marginalised, underrepresented groups, I think the agency is probably more mature regarding IDEA compared to TMOS.

> "Visibility matters. Even wearing a pin or a lanyard with an IDEA theme could make others in marginalised and underrepresented groups feel safe and not isolated.

Although this might not work in the government agency setting, it would be helpful for non-research organisations to have carer scholarships to cover the extraordinary financial costs of attending organisational events that are remote to the recipient's usual place of work, as the Centre does. It lowers the pressure for full-time workers who are also carers.

If you had any advice for marginalised persons wanting to choose a career in research, what would it be?

Please, don't hesitate to speak up. If you are discriminated against or undermined, escalate the issue in a peaceful and professional manner. If you have done something awesome, don't be shy to promote it and gain visibility for your work and for yourself.

If you had advice for senior academics or industry personnel who haven't experienced any marginalisation, what would it be?

Please don't dismiss someone's feelings or opinions. As a senior, your actions could have a strong influence on others, especially when there's a power imbalance. Please be a good leader and help others grow.

MARCUS CAI

PhD Student

Australian National University

As the 2022 TMOS IDEA Award winner and a TMOS IDEA committee member, PhD student Marcus is passionate about promoting IDEA on various occasions, especially in STEM. With a broad interest in optics, Marcus is studying light frequency up- and down-conversion using dielectric nanostructures. As the co-president of the ANU Optica and SPIE Student Chapter for the last two years, Marcus enjoys organising various events and seeing other people grow. Marcus also works as a project management officer at the Australian Bureau of Statistics to develop his professional skills so he will become a more well-rounded researcher when he graduates.

Outreach Committee Report

Igor Aharonovich, Outreach Director, Samara Thorn, Engagement Manager and Camilla Gazzana, Outreach Officer

The Outreach Committee began the year with a three-day workshop with our partners at Questacon. Not only did we develop our science communication skills, we workshopped ideas for teaching optics, expanded our repertoire of hands-on science demonstrations, and got to engage with the public to practise what we'd learned. It was a fun, high-energy few days that set us up for our primary goal of the year: developing and implementing school workshops.

Our three new workshops have been designed to entertain and engage young audiences, encouraging them to become our future leaders and innovators in STEM careers. Our workshops are:

- The Story of Light
- Discovering Diffraction, and
- How-to Holograms.

Each workshop is aimed at Year 5 primary students, addressing key content descriptors from the Australian National Curriculum to introduce our young audience to the science behind optics and the exciting world of meta-optics!

Our workshops include hands-on demonstrations and connections between the learning material and real-life examples to solidify the concepts being taught and to offer a different learning style and opportunity for students to better engage with the content.

Committee members across all nodes got involved in our Outreach program in 2022. As a result, our Centre interacted regularly with the community and formed relationships with schools and educational systems as an organisation. By bringing our knowledge and resources to the classroom, not only did we increase interest in science and physics, we helped our committee members grow as science communicators and educators while increasing the reputation of TMOS for being known as the go-to for meta-optics.

> "By bringing our knowledge and resources to the classroom, not only did we increase interest in science and physics, we helped our committee members grow as science communicators and educators while increasing the reputation of TMOS for being known as the go-to for meta-optics.

In 2022, we reached five schools across five states and territories:

- Earlwood Public School (NSW)
- Fitzroy Primary School (VIC)
- Rosalie Primary School (WA)
- Turner Primary School (ACT)
- Rose Park Primary School (SA)

We're looking forward to an equally successful 2023 and the opportunity to reach even more primary students with the story of light.

Igor Aharonovich, Outreach Director,
Samara Thorn, Engagement Manager &
Camilla Gazzana, Outreach Officer

ACTION ITEMS FOR 2023

1. Collaborate with Questacon to develop a physics-themed exhibit
2. Hold another Science Communications and Training workshop in conjunction with International Day of Light outreach activities at Questacon
3. Improve on the current school workshops to make them more hands-on
4. Conduct additional public outreach activities, including school visits
5. Content development and review to ensure content being delivered is scientifically sound and topical

COMMITTEE MEMBERS:

CAMILLA GAZZANA

Outreach Officer

UTS

PROFESSOR IGOR AHARONOVICH

Chief Investigator

UTS (Chair)

LESLEY SPENCER

HDR Representative

UTS

DR. LITTY THEKKEKARA

ECR Representative

RMIT

A/PROF. MARIUSZ MARTYNIUK

Chief Investigator

UWA (Deputy Chair)

SAMARA THORN

Engagement Manager

ANU

DR. WENDY LEE

ECR Representative

UoM

DR. WENWU PAN

ECR Representative

UWA

School Workshops

TMOS's school workshop program has been designed to entertain and engage young Australians, encouraging them to be future leaders and innovators in STEM careers. Through our workshops, we introduce our audiences to the science behind the optics and help them understand the new industrial revolution - Industry 4.0.

Three new workshops have been designed to address key content descriptors from the Australian National Curriculum and include hands-on demonstrations and real-life examples to build connections between the learning material and everyday life to solidify the concepts being taught. Each workshop is aimed at Year 5 primary school students, offering an alternate learning opportunity for students to better engage with the content.

The three new workshops include:

1. **The Past, Present and Future of Light:** The audience is introduced to The Story of Light - from antiquity to the future of meta-optics. Learn about the sun, fire, lenses, electromagnetism, refraction, diffraction, interference, photons, lasers and the exciting world of meta-optics. Hands-on demonstrations include being able to replicate some of the historical experiments which led to some of the biggest discoveries in light and learning how to physically demonstrate these exciting concepts at home!

   Key content descriptors addressed:

   - Labelled ray diagrams
   - Comparing shadows from point and extended light sources
   - Classification of materials as transparent, opaque or translucent
   - Recognising colour of objects depends on their properties and the colour of the light source
   - Using mirrors to demonstrate reflection of light
   - Recognising refraction of light at surfaces of transparent materials
   - Investigating the use of solar panels
   - Understanding the behaviour of light by making observations of its effects
   - Exploring reflection, absorption and refraction of light using mirrors, sunglasses and prisms
   - Discussing the use of electricity and conservation of sources of energy

2. **How-to Holograms:** Holograms - how and where they are used in everyday life. Learn about the fascinating light concepts behind the formation of holograms, including reflection, refraction, diffraction and interference! Hands-on demonstrations include the use of a laser pointer to visualise the light principles of reflection, refraction and diffraction, see hologram printing in action and take home a pair of your own diffraction glasses!

   Key content descriptors addressed:

   - Labelled ray diagrams
   - Classification of materials as transparent, opaque or translucent
   - Recognising colour of objects depends on their properties and the colour of the light source
   - Using mirrors to demonstrate reflection of light
   - Recognising refraction of light at surfaces of transparent materials
   - Understanding the behaviour of light by making observations of its effects
   - Exploring reflection, absorption and refraction of light using mirrors, sunglasses and prisms

3. **Discovering Diffraction:** Learn about the concepts behind diffraction and where we can observe diffraction in nature and our day-to-day lives. Hands-on demonstrations include the use of torchlights, CDs and plastic prisms to demonstrate how light can be diffracted, learn how to use multi-coloured LED finger-lights and diffraction glasses to see diffraction in action and make your own spectrometer with a mini DIY kit!

Key content descriptors addressed:

- Recognising colour of objects depends on their properties and the colour of the light source
- Recognising refraction of light at surfaces of transparent materials
- Developing an understanding of the behaviour of light by making observations on its effects

ROSE PARK PRIMARY SCHOOL

EARLWOOD PUBLIC SCHOOL

ROSALIE PRIMARY SCHOOL

“STORY OF LIGHT " WORKSHOP AT SHEPPARTON LIBRARY

INTERVIEW

OUTREACH AWARD 2023: Wendy Lee

2022 was a busy year for Wendy. It started with a Questacon bootcamp to learn more about science communication, was followed by a road trip to Shepparton where she supported fellow Outreach Committee member Shaban Sulejman in a library workshop with over 100 attendees, and ended with six workshops in a single day at Rose Park Primary School. In amongst all of that, she developed the Centre's Discovering Diffraction workshop, visited Fitzroy Primary School, assisted at the University of Melbourne's Girls in Physics Day and hosted many, many lab tours. Somewhere in amongst all of that outreach, she got some research done.

What are three things this outreach work has taught you?

Patience, versatility, and the ability to adapt on the fly.

What has been the most challenging aspect of outreach in the past couple of years?

It's always more helpful to learn new things through a combination of observation and hands-on activity. When COVID-19 struck, a lot of the hands-on activities were removed, and this affected learning tremendously. Post-COVID-19, there are still several challenges regarding face-to-face interaction and some schools are still not very keen on it.

How has the TMOS team supported you with this?

TMOS has provided me the needed training as part of its partnership with Questacon, the kits and material, and Camilla Gazzana, the coolest Outreach Officer. That has made everything so much easier.

What has been your favourite moment of outreach in the past couple of years?

When I was in Fitzroy Primary School, a student came up to me afterwards and said he would like to be an engineer when he grows up and hopes he'll be in one of my classes at the University of Melbourne.

Why is working in schools to teach optics so important to you?

I think it's important for the kids/students to see that we (the engineers and physicists) are just ordinary people. Teachers mostly cover what's in the curriculum, whereas having someone in the field come in and talk about the same thing in a different way makes it more relatable. Building the connection between what one learns in class and the outside world creates links that can't easily be forgotten.

Part of the reason you are selected was the level of assistance you provide to others who are undertaking outreach work. How would you describe the outreach team and the way you work together?

I think the team is awesome. I feel that we are a synergistic team that enables every team member to be their full selves! Our unique life experiences, perspectives, talents, and communication styles make every workshop enjoyable and keeps you on your toes.

“Building the connection between what one learns in class and the outside world creates links that can't easily be forgotten.

What Outreach work would you like to see TMOS doing in the future?

I'd like to do regional road trips to visit schools and teach them about lasers and optics. I also have started working on a new workshop that is aimed at High School students, as most workshops we have are at the Year 5-6 level.

If you had any advice for school students wanting to be engineers or physicists, what would it be?

From personal experience, you do not have to be the top of your class to get into physics or engineering. Passion is the main thing that will help you overcome the many obstacles in your career, then mix it together with focus and perseverance!

If you had any advice for new researchers coming into a PhD program, what would it be?

Embrace the chaos. A PhD journey is full of challenges and hurdles that will knock you down over and over again. Building a good support network is key to making it to graduation. Ask all the questions! Don't be afraid to be wrong, no one knows everything! Imposter syndrome is real!

WENDY LEE

Postdoctoral Researcher

University of Melbourne

Wendy's research focuses on the engineering meta-atoms to manipulate incoming electromagnetic waves to suit a predetermined purpose. An array of these meta-atoms form a metasurface, which is a two-dimensional planar variant that is suitable for integration with on-chip devices. Currently she is investigating incorporating metasurfaces with upconverting nanoparticles for enhanced emissions and tunable metasurfaces for imaging with vanadium dioxide. Wendy received her PhD in Electrical Engineering from the University of Adelaide with Dean's Commendation for Doctoral Thesis Excellence where she remained as a lecturer and Postdoctoral Research Assistant prior to the position at the University of Melbourne.

Industry Liaison Committee Chair Report

Industry Liaison Committee Director, Francesca Iacopi

"The Centre has the ambitious goal of achieving true technological and societal impact and working with industry forms a key pillar of our strategy to meet that.

The Industry Liaison Committee (ILC) works in partnership with local and international industry to facilitate the translation of the Centre's scientific work. In particular, it engages with defence, space and medtech research and development institutions. The Centre has the ambitious goal of achieving true technological and societal impact and working with industry forms a key pillar of our strategy to meet that.

2022 has been an important year for the Committee, as it was the first year after the COVID-19 restrictions and most in-person meetings could finally resume. Face-to-face interaction helps to build solid and meaningful translational partnerships.

The ILC facilitates industrial and techno-societal engagement opportunities, tracks engagement within the Centre and plans large-scale translational initiatives. In addition, the ILC educates the Centre team about alternative technical careers to academia, from industrial R&D to entrepreneurship paths, to technical advisory roles within government and government-related organisations and initiatives. In this context, the ILC fosters long-term relationships with relevant Australian and overseas industry as some of those companies may hire Centre alumni. This is yet another path through which the Centre's legacy will be endurably embedded in society.

Looking back on the past year, the ILC Committee has worked towards growing our industry network by engaging with the space industry at the Australian Space Summit, an event that led to several further conversations with members from Lockheed Martin and EOS about the future impact of meta-optics and how the Centre could support these companies develop their workforce in this field.

In addition, we further nurtured our relationships with Barajah, Evident Scientific, Defense Science & Technology, and Seeing Machines by bringing them on as contributors at our Centre launch and conference.

Another focus for 2022 has been on technology start-ups. Start-ups are an area where the next generation of leaders/entrepreneurs can leave a legacy, hence it is a key part of the Centre's strategy. This year, two start-ups were formed: Luminere Systems, a quantum communications company spawning from work done at the Centre's UTS node and Magic Wavelength which was formed by Centre members from our UWA node and is focussed on agricultural technology, in particular, sensors for non-invasive monitoring of plant health.

Part of the Centre's early success in the start-up arena is because of the training we've provided our team. We put those who were interested through the Cruxes BASE program, where they could identify their potential partners and develop a pitch that summarised the potential business opportunities related to their research. In addition, we've held translation talks featuring three experts in technical entrepreneurship: Kevin Finn, Managing Director of Magic Wavelength; Murray Hurps, Head of Entrepreneurship at UTS and former CEO of Fishburners, Australia's largest start-up incubator; and Simon Poole, serial entrepreneur in optics/photonics in Australia.

The Centre's ILC looks forward to building further lasting impact and legacy together in the meta-optics field!

Francesca Iacopi
Industry Liaison Director

ACTION ITEMS FOR 2023

- Facilitate the technical collaboration with Australian SMEs and larger corporations by mapping and making the most out of all funding and ancillary mechanisms available in the Australian landscape.
- Supporting the identification and definition of “flagship” projects across the Centre, such as portable holography and biosensing, by benchmarking with current commercially available technologies.
- Facilitate opportunities for Centre members to meet in-person with industry to present their work.
- Develop pathways to grow the TRL of Centre project IP towards patent, pilot, industry or research partnerships.

COMMITTEE MEMBERS:

DR. ANDREI KOMAR

ECR Representative

ANU

PROFESSOR ANN ROBERTS

Chief Investigator

UoM

PROFESSOR DILUSHA SILVA

Associate Investigator

UWA

PROFESSOR DRAGOMIR NESHEV

Centre Director

ANU

PROFESSOR FRANCESCA IACOPI

Chief Investigator

UTS (Industry Liaison Director)

DR. IRYNA KHODASEVYCH

ECR Representative

UTS

KAREN JACKSON

Strategic Projects & Partnership

ANU

KAREN KADER

Secretary

UWA

PROFESSOR LORENZO FARAONE

Chief Investigator

UWA (Industry Liaison Deputy Director)

DR. MARY GRAY

Chief Operations Officer

ANU

SAMARA THORN

Engagement Manager

ANU

PROFESSOR SHARATH SRIRAM

Chief Investigator

RMIT

INTERVIEW

INDUSTRY AWARD 2022: Rocio Camacho Morales

In 2022, Rocio worked with Centre Director Dragomir Neshev to lead an industry partnership with US defence contractor L3Harris® Technology. This stemmed from work she did to promote her recent research into night vision instruments and sensor devices. She wrote a piece for *The Conversation* that was translated into other languages and that generated enquiries from multiple potential industry partners about the possibility of tailoring her studies towards an application of their interest. It was from one of these discussions that a partnership with L3Harris® Technologies to study nonlinear imaging via sum-frequency generation was born.

What are three things you've learned about research translation and working with industry in 2022?

1. Industries are interested in research that can develop new technologies.
2. Universities can attract the interest of industries and work together when there is an effective media promotion of their research.
3. Companies plan their projects carefully. For them, time is also an investment.

What was the process of developing a relationship with L3Harris®? Did any of it make you nervous before you started? What was the best moment?

The process was like many of the research collaborations I had been part of before. Both parties wanted to help each other and collaborate to get the best possible outcome.

A major difference was the time required to formally obtain an agreement between the university and the industry. The best moment was when we started discussing the details of our research. The questions asked by L3Harris® showed they were engaged and they understood the complexity of our research.

What has been the biggest challenge of this industry relationship in 2022?

Following the timeline and keeping all the team members of ANU updated, while also keeping them committed and engaged with the industry project.

How has the TMOS team supported you during this process?

The TMOS team helped me from the very beginning of the process. When the research paper was ready to be published, they advised us on the different strategies we could use to maximise the media promotion of our research. This was key in promoting our work, allowing us to reach an audience of close to four million people. The successful media coverage generated conversations with several companies and the TMOS team helped us to identify the best opportunity for us.

How has working with L3Harris® affected your research? Has it helped your research grow or has your research slowed down a little while you work on this project?

The research has been slower since our primary goal in this case is not publications. However, once we complete the project, we expect publications to accelerate as we'll be using results already obtained.

“The process was like many of the research collaborations I had been part of before. Both parties wanted to help each other and collaborate to get the best possible outcome.

What does 2023 look like for you? What industry engagement will you be doing?

For the moment, I will only focus on maintaining our relationship with L3Harris® and delivering our project on time, which might lead to future projects with them.

Any chance of a trip overseas to meet your collaborators in person?

That would be ideal and an excellent path to growing the relationship!

If you could give advice to a young researcher looking to translate their work, what would that advice be?

Be proactive and look for opportunities to communicate your research to audiences outside academia. This will not be helpful only in terms of research translation, but will also enhance your communication skills.

ROCIO CAMACHO-MORALES

Postdoctoral Fellow

Australian National University

Rocio Camacho-Morales is a Postdoctoral Fellow at ANU.

She received her Bachelor's Degree in Physics from the National Autonomous University of Mexico, her MSc Degree from the Ensenada Centre for Scientific Research and Higher Education, Mexico, and her PhD in Physics from ANU.

Her research interests are in the fields of nanophotonics, optical meta-surfaces, and nonlinear frequency generation.

In 2022, Camacho-Morales was named the ANU Research School of Physics winner of the Neville Fletcher Early Career Researcher Award. Also this year, she received the 2022 TMOS Industry Award, for her excellent work in industry.

Creating a start-up is a bold and courageous act. We celebrate three of our startup founders

PROFESSOR ILYA SHADRIVOV
The Australian National University

DR. VLADLEN SHVEDOV
The Australian National University

VI COLOURS | HYERA

Prof. Ilya Shadrivov and Dr. Vladlen Shvedov, the Australian National University

So why did you choose to do two start-ups? And whose influence was that?

"We had two ideas." (Vlad)

"They are two very different companies, different in scale and different timelines in terms of growth. It's good to diversify too, as starting a business is highly challenging. It was definitely Vlad's influence to do both." (Ilya)

"It's also such a gamble doing this. If one or both or neither of them will become successful, we just don't know."

What is success to you?

"Profitable."

"If the company grows to financial success and makes an impact in the real world."

Tell me more about the companies and their differences.

"HYERA (https://www.hyrea.com.au/) is in the green hydrogen sector. It has much more potential to scale into a large company but it will take a long time to get there. There's quite a lot of R&D to be done, different stages to go through, and it requires more financial investment every step of the way as it's developing a new technology."

"It's also solving a high-impact problem that is very relevant to Australia. Being part of the green energy industry and the possibility of treating the environment better on such a scale helps keep the motivation strong."

"VI Colours (https://www.linkedin.com/company/vi-colours/), is our other company. The work we do is laser engraving to modify the surfaces of metals or other substances. We made the meta-surface keyrings for the TMOS launch, and have interest from government agencies, start-ups, and even artists. It's been easier to start this company as we are working with existing tools and can see how this company can start bringing income. It's exciting as we are doing things that were considered impossible with the tools we use."

"I didn't know those things were impossible. Our laser engraving makes beautiful things, some maybe useful things too, and we have done many interesting things scientifically in the process. There is quite a bit of know-how and trade secrets involved now."

"This is also the limiting factor though. What we do is not very patentable unless we get really specific on some of the technical aspects involved. This limits our options quite a bit so we are still working out what we want to do with this company."

You mentioned that you had been learning, tell me more about that.

"We have been doing the Griffin Accelerator through CBRIN. It's a full-on commercialisation training with mentors who are highly successful people in various industries. I've got quite a lot out of it, mostly the ability to ask ourselves the right questions about the business and how to develop it. It doesn't mean we have the answers to all those questions though! We expanded our network in the business community in Canberra and in Australia."

> Being part of the green energy industry and the possibility of treating the environment better on such a scale helps keep the motivation strong.

"I have a new appreciation for how businesses work. I've also got to meet people with many great ideas and skills that I wouldn't have had the chance to do so just within a university. It's really eye opening and refreshing."

You mentioned that it will take a long time to get there with HYERA. Could you explain more about that?

"Every single step of this business will take substantial time. For example, usually when you publish a paper it can take a few years before it gets much interest, such as citations and people contacting you for collaborations or information. People need to see something, and see it, over again before they make a decision. Commercialisation is quite a bit like that but higher stakes."

"It will take four or five years to get the progress and visibility we want. We need to create different stages of prototypes and solve problems at different scales along the way as we make these prototypes. We know in theory what to expect. Now we need to measure everything and collect data, to be proven. Later we will need to get investment and industry partners to keep developing so we need them to see us, see our data, and see our growth."

Any messages for Centre members wanting to do a start-up or two?

"You need to be patient and creative, and be willing to try again even if it doesn't work out. But that's how physics can be too."

"You can still be a scientist at any career stage and give it a go. I didn't think of myself as an entrepreneur but doing this means I am one. You can be both."

HELEN ZENG
University of Technology Sydney

LUMINERE SYSTEMS

Helen Zeng, PhD Student, University of Technology Sydney

What is your elevator pitch for your start-up?

Defence, finance, and government agencies require the utmost in cybersecurity, with a need to further enhance their data protection to adapt to the ever-evolving threat of hacking, data breach, and quantum computing.

So, we know cybersecurity is a fast-evolving concern for many sectors such as defence, finance, telecommunications industries and government agencies, currently there is a need to further enhance data protection in order to adapt to ongoing threat of hacking, data breaches and to secure quantum computing.

As a solution, our product utilises quantum processes to guarantee information security against even the most powerful adversaries. Our photonic solution is a paradigm shift in the cyber defence sector, which uses proven technology to encode sensitive information into unclonable light packets, providing a truly unhackable encryption scheme.

Our integrated design can be fitted to upgrade existing cyber infrastructure, and is robust, compact, and can secure a wide range of communication data, including transactions, video, and voice.

The impact of this means that we can truly guarantee total security of sensitive data transmissions today, and long into the future.

When did you realise what you were working on had commercial potential?

We were working on enhancing single photon sources for quantum applications as part of a project funded by Defence Innovation Network, as we were conducting the research, we realised that the techniques and methods we were developing had potential applications beyond just academic research. We were able to create a more efficient and effective way to generate single photons using a solid-state material called hexagonal boron nitride. Single photon source is a critical component for various quantum technologies such as quantum communication and quantum computing.

We identified a gap in the market for a more cost-effective and scalable approach to producing single photons. This realisation led us to explore the commercial potential of our technology, and we began to investigate the feasibility of starting a company based on our research and so we began to take steps towards starting Luminere Systems (http://www.lumineresystems.com/) .

How has this impacted your PhD research?

Starting a quantum tech startup company has had both positive and negative impacts on my PhD research. On the positive side, the startup has allowed me to further develop and apply the skills and knowledge that I am gaining through my PhD program to real-world applications. Along with my co-founder Dr Minh Nguyen, we have had the opportunity to collaborate and work on cutting-edge research and collaborate with other experts in the field of quantum technologies.

On the other hand, the startup has also required a significant amount of time and effort, which has sometimes been challenging to balance with my PhD research. Juggling the two commitments has been a balancing act, on top of that, I have chronic health conditions that also take up time and ongoing management, and so I have had to manage my time carefully to ensure that all endeavours receive the attention they require.

Overall, it has been both positive and challenging, but I believe that the experience has been valuable in enhancing my research skills and preparing me for a career in academia and industry.

What have you learned so far about research and start-ups?

So far, I have learned a lot about both research and entrepreneurship. Collaboration is key. In research, collaboration can lead to new ideas and insights, and in startups, collaboration can help to develop a stronger and more comprehensive business plan. This ties in with communication, which is a crucial skill that academics can often struggle in, having clear communication can ensure that everyone is on the same page and working towards the same goal. Effective communication is necessary for building relationships with investors, partners, and customers. You also need to be flexible and adapt to new information and changing circumstances, everything from adjusting experimental designs or changing the product offering based on customer feedback.

Lastly, persistence is essential. Research and startups need resilience, in research oftentimes we do not yield the desired results and in startups setbacks and challenges are not uncommon. It is important to stay motivated and focus on long-term goals.

There are many commonalities with research and startups, the skills and knowledge are transferable and can be applied from one to the other. By combining knowledge from both aspects, we can create innovative technologies.

Do you have any advice for other students looking at commercial pathways for their research?

I would suggest the first thing to do is to seek out mentorship and guidance. Starting a startup can be a daunting task, but you don't have to do it alone. The first things we did was seek mentorship and guidance from our UTS TMOS CIs and from there we started to access start-up incubators like DSTG and Cicada Innovations who can put you in contact with experienced entrepreneurs, investors, or industry experts. They can offer valuable insights and help you avoid common pitfalls.

Build a strong team of talented and passionate individuals who share your vision and complement your skills. This will not only make your start-up stronger but also make it more attractive to investors. As mentioned earlier, also be prepared to juggle multiple priorities.

Also, don't be afraid to fail, starting a start-up is risky, and failure is always a possibility. However, failure can also be a valuable learning experience. Embrace the possibility of failure and use it as an opportunity to learn, grow, and pivot your approach if necessary.

Anything else you would like to share?

Commercialising your research requires a combination of market research, mentorship, team building, time management, and a willingness to take risks. With the right approach and mindset, you can turn your research into a successful startup that makes a positive impact on society.

Lastly, embrace the journey and remember to celebrate the little wins along the way.

Outreach: Digital Media

In 2022 we explored new channels and developed new audiences, with a focus on attracting young people via TikTok and Instagram. We had a lot of fun doing so, especially creating content for our recruitment campaign. By featuring our students and early career researchers heavily on our social media pages, we increased internal engagement with the Centre and made our organisation and research more accessible to the next generation. 60% of our website traffic came from users 35 years and under.

At the inaugural Centre conference we held a mini workshop on the role profile building and social media plays in creating impact from research. The message and the memes that it delivered were heard loud and clear with a significant increase in engagement from our Centre members.

In 2023, we plan to continue working with our junior researchers to help build their careers by increasing our promotion of their research, drawing them into our existing social media channels, and profiling them in new and exciting ways. The next generation is our future. It's time to hear all about them.

Samara Thorn
Engagement Manager

52,243
Website page views

MOST POPULAR PAGE

List of Chief Investigators

17,688
Unique website visitors

TOP 5 VISITOR COUNTRIES

India
Australia
South Korea
United States
China

35
Posts on the TMOS website in 2022

TOP 3 POSTS

1. Colloquium registration: Nanowire-based devices for THz polarimetry
2. Media release: TMOS researchers' paper on GaN nanowires featured as ACS Editors' Choice
3. Colloquium registration: Nonlinear and Electro-Optic Metal-Oxides for Sensing and Telecom Devices

SOCIAL MEDIA

1318 (396 new)
TWITTER FOLLOWERS

1169 (434 new)
LINKEDIN FOLLOWERS

45 (45 new)
TIKTOK FOLLOWERS

76 (76 new)
INSTAGRAM FOLLOWERS

84 (51 new)
YOUTUBE SUBSCRIBERS

32
YOUTUBE VIDEOS

3,635
YOUTUBE VIEWS

Governance

Message from the Chief Operations Officer

This year, I've been thinking quite a bit about what we need to do as a Centre as we head toward our mid-term review.

All Centres of Excellence are reviewed by the Australian Research Council (ARC) at their mid-point to ensure that they are meeting their goals, and are operating in alignment with the proposal and the Commonwealth funding agreement. This isn't a scary thing but a great opportunity to reflect on what we are doing and how we are doing it – and importantly what our gaps are so we can finish strong. It is certainly stressful though, a bit like having a rental house inspection but it's a great push to do a spring clean!

The Centre of Excellence professional community is a friendly and collaborative group, so I was fortunate to be able to get a hold of a copy of the CE17 review terms, and ASTRO3D even published their review document and strategy that they provided to the ARC. We know each year the expectations on what Centres achieve beyond research are raised, which is reflected in the contract we have between the ANU and the ARC.

With that in mind, the Centre has work to do to be in the best possible position for the mid-term review. We want feedback from the ARC that enhances our program to make the most of the opportunity – rather than things we can see ourselves.

To this end, I have led the following improvement processes.

The International Scientific Advisory Committee (ISAC) and Centre Advisory Board (CAB) are key bodies for the Centre that, when used effectively, guide strategic direction on research objectives and non-research objectives respectively. Given their importance, I sought to change the composition of these bodies to better reflect the make-up of our team and our desire for engagement. Our two new board members give the 2022 ISAC and CAB messages at the introduction to this report. Along similar lines, we have also continued to be conscious of our Associate Investigators (AI), ensuring that for any new man there is at least one new woman brought into our team. This has meant we have more exciting emerging

> "For the Centre's research to have any impact the world needs to know about the work we do and our people.

leaders of all genders across the world involved in our Centre as AIs.

The Centre executive and sub-committees are how we make decisions for the whole team. These need to be groups that an outside auditor could understand their function in the Centre and see the value they provide. Some changes were as simple as a new name to reflect their activities, through to folding a committee. One important change was to the executive to ensure that the Research Program Managers (RPMs) could be part of the decision-making processes in an appropriate way. We also wanted to talk more about research, so the executive was divided into research (where the RPMs join), and management, where we can discuss at times more confidential matters. I'm looking forward to seeing how this plays out in 2023.

Another domain that is important, and agreed by our CAB, is public relations and communications. For the Centre's research to have any impact the world needs to know about the work we do and our people. I have re-structured the Business Team to enable our resources to focus on this important aspect of what we do. Marketing and communications is a critical function of TMOS to build relationships, and ideally build our industry engagement and translation opportunities for our researchers. As part of this, we are doing a major refresh of our website so that we are talking to the public and people in the private sector, instead of just to ourselves.

Staffing is another domain that is very important to me. Given the scope of our funding and our strategic plans, I have firmed up the roles of the Business Team for the duration of the Centre. For the researchers, we also need to take this approach to retaining our key talent and ensuring that we meet our obligations to building a diverse future workforce. It's also important that we reflect on the impact of COVID-19 on the careers of our postdoctoral researchers, who were at times unable to access lab facilities for up to 12 months of their contracts, have been limited in their ability to build their network, and some remain unable to travel internationally due to ongoing visa processing issues. I see resolving this as part of the key work of the executive during 2023, to develop an appropriate succession plan and pathway to support the critical mass of researchers the Centre is training.

Dr Mary Gray
Chief Operations Officer

Image – word cloud from the TMOS planning day Nov 2022, showing the keywords on everyone's mind for the vision and priorities for TMOS in 2023.

TMOS Chief Investigators and Research Program Managers gathered at the planning day Nov 2022.

Governance: CAB and ISAC

CENTRE ADVISORY BOARD:

DR. GREG J CLARK AC

IBM Australia (former Director)

PROFESSOR IAN CHUBB
AC FAA

Australian Chief Scientist (former)
(Chair)

MANI THIRU

Amazon Web Services

DR. SIMON POOLE
AO FAA FTSE

Finisar Australia (Director of New Business Opportunties)

INTERNATIONAL SCIENTIFIC ADVISORY COMMITTEE:

PROFESSOR ALEXANDRA BOLTASSEVA

Purdue

PROFESSOR CONNIE CHANG-HASNAIN

UC Berkley

PROFESSOR DIN-PING TSAI

Academia Sinica (Director)

PROFESSOR FEDERICO CAPASSO

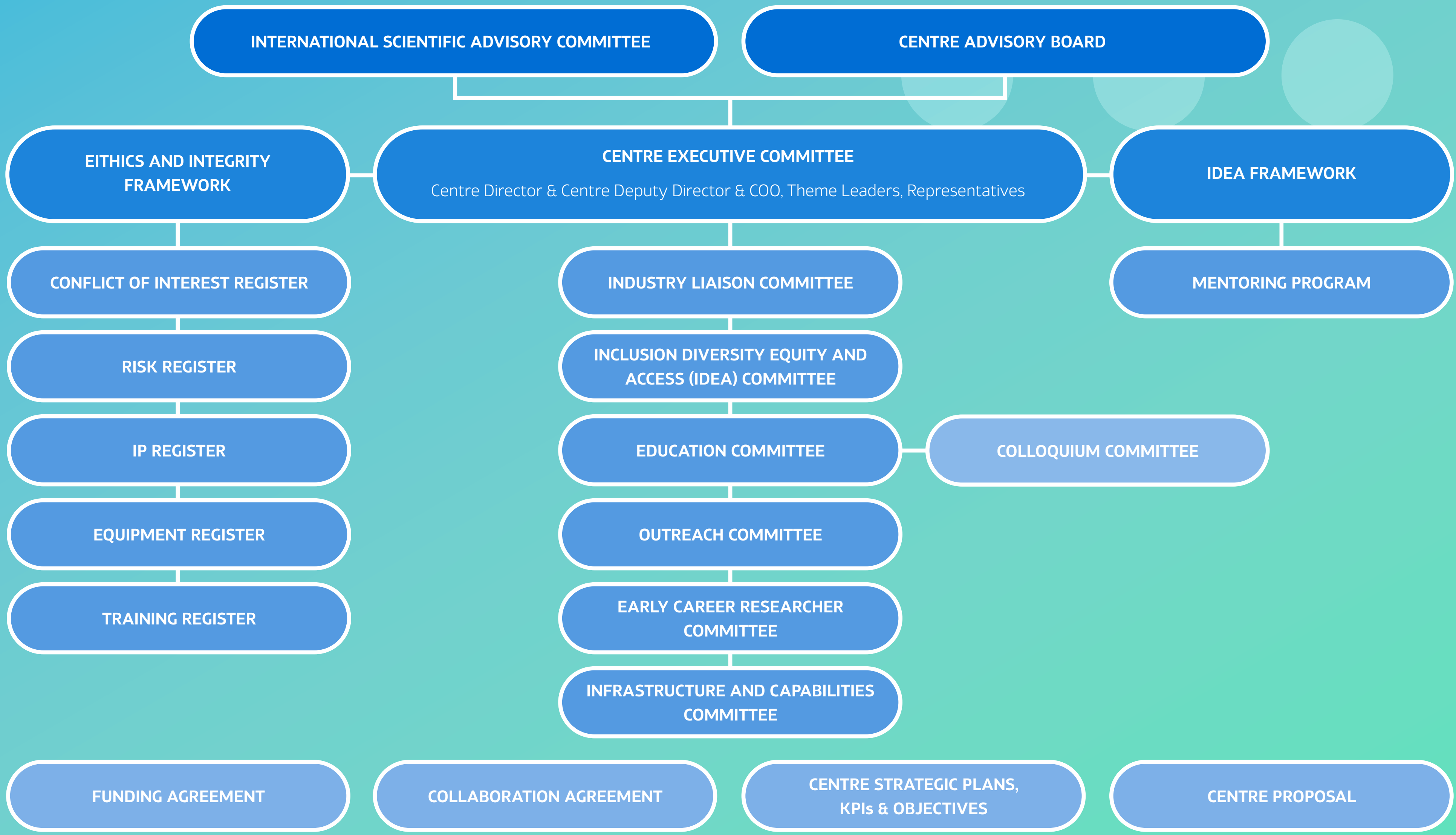
Harvard, Bell Labs (former Director)

(Chair)

PROFESSOR MARK BRONGERSMA

Stanford University

Governance: Structure



Centre Executive Committee Directorate Report

The Centre Executive Committee (CEC) met 19 times in 2022 to discuss, debate, approve, and action various matters.

We are pleased to report on our 2022 Action Items:

1. Development of our inspiring flagship research goals
2. Completion of the Centre's on-boarding process and induction modules
3. Completion of the Centres Operation Manual and KPI reporting system
4. Development of the Centre's succession plan
5. Consolidate and finalise the Centre's Code of Conduct.

The Centre has agreed on two Flagship Projects – real-time holographic displays and cameras, and integrated sensors (wearable and portable). These flagships are designed to bridge the three research themes to provide a focus for applications of our research.

The Centre's on-boarding process was developed by the Chief Operations Officer into a 12-week email journey with an associated workbook. All current Centre members are on this email induction journey, including the Chief Investigators. In 2023, the induction process will be enhanced to make it seamless for new members and include an induction journey for Associate Investigators.

The operation manual was converted into a resource centre within the project management program Trello. Individual standard operating procedures are presented in the form of cards with checklists and links to specific resources. It is being continuously added to and is a place where continuous improvement can be documented. The KPI reporting system in Smartsheet was further established as a single form for all Centre members to report their activities. Uptake is incentivised through a monthly prize draw. There is still significant progress to be made in creating a culture of proactive reporting.

The Centre is without a succession plan. This critical document will be developed in 2023 with input from the Research Program Managers. This document will scope how we aim to maintain critical mass in meta-optics beyond the life of the Centre.

The Centre's Code of Conduct was developed by the IDEA Officer, Greg Dennis, and agreed on by members as part of their attendance of the 2022 Centre Conference. The next step for improvement is to incorporate this into the revision of the Centre's IDEA Framework, which is part of the work plan for the IDEA Committee in 2023.

The CEC made several changes to be implemented for 2023. These changes aim to provide more leadership opportunities for early career researchers and focused time to discuss research, collaboration, and management issues. The CEC will have two streams, the first is the CEC – Research Meeting, of which all Research Program Managers are members. The committee oversees the Cross-Node Travel Award, the Infrastructure Committee, and research strategy and implementation. Importantly, the Research Program Managers have a slot every meeting for quizzing the Chief Investigators, in addition to being able to request agenda items. The CEC – Management Meeting is where the bulk of the policy matters are taken and non-research strategy. For example, recruitment, culture, events, professional development, and translation are discussed.

Many of the Centre's governance documentation, such as policies and frameworks were developed in 2020/21 so are due for renewal in 2023. This is timely, as the Centre will be preparing for the mid-term review, which is an audit of all the Centre's activities. In preparation, we have made changes to sub-committees, and have ended the Early Career Researcher Committee to focus our efforts.

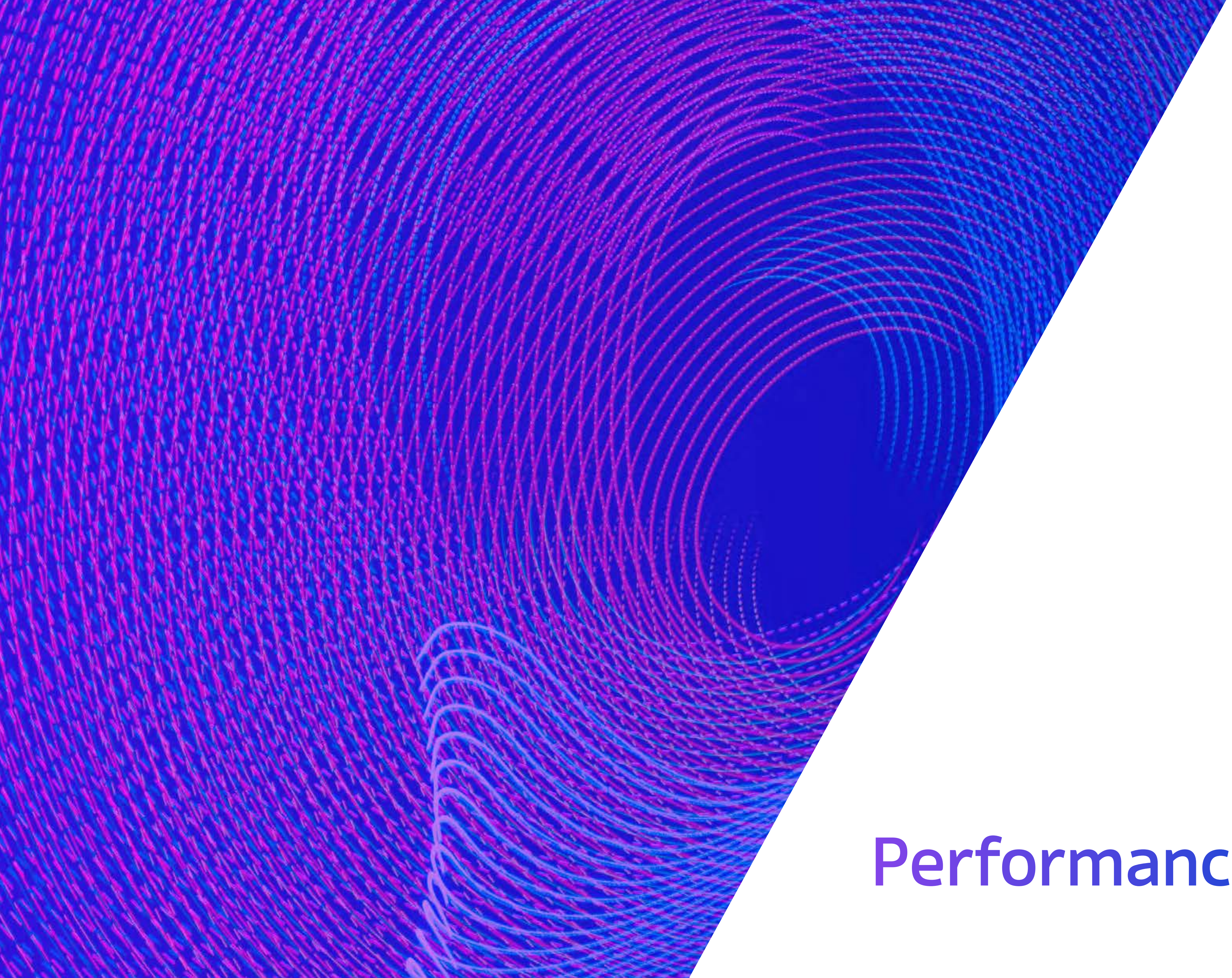
We are happy to share any of our documentation, induction program, or more with the Centre community. Please get in touch.

Warmly, the Directorate Team

Professor Dragomir Neshev, Professor Ken Crozier, and Dr Mary Gray

ACTION ITEMS FOR 2023

1. Drive initiatives, events, and funding toward enhancing collaboration between the five nodes of the Centre to increase cross-node publications
2. Determine the research strategy and goals for the remainder of the Centre
3. Complete the review of all Centre governance documentation ahead of the mid-term review
4. Succession plan, inclusive of recruitment measures, to ensure a diverse meta-optics workforce beyond the life of the Centre



Performance

Key Performance Indicators

Performance Measure		Actual Y0 2020	Actual Y1 2021	Target Y2 2022	Actual Y2 2022	Perform. rate 2022
Number of research outputs	Journal articles	91	87	65	100	154%
	Book chapters[1]	1	1	3	0	0%
	Patents (filing provisional patents and higher)[2]	1	1	5	2	40%
Quality of research outputs	Cross-node publications[3]	2	2	20	4	20%
	Publications with PIs[4]	3	2	10	4	40%
	High impact publications (in top 10% in the field, e.g. IF>9)	17	20	10	28	280%
	Top-impact publications (in top 3% of the field, e.g. Nature/Science family)	10	7	3	5	167%
Number of workshops/ conferences held/ offered by the Centre	Centre annual workshop (conference)	0	0	1	2	200%
	Conference facilitation	0	4	2	8	400%

1. Book chapters are low volume outputs in physics and engineering so we expect these numbers to fluctuate annually but over the course of the Centre meet the total target.
2. We have been slow to commercialse research via patents due to the fundamental nature of the majority research, however we are pleased to report we have exceeded our start-up target.
3. We are still feeling the impact of COVID-19, with many teams persuing local area solutions to problems. Addressing this is the focus of 2023.
4. The impact of COVID-19 has limited international collaboration. However, we are pleased to report that we have co-authored 27 journal articles with Associate Investigators this year.

Performance Measure		Actual Y0 2020	Actual Y1 2021	Target Y2 2022	Actual Y2 2022	Perform. rate 2022
Number of training courses held/offered by the Centre	Professional development courses	0	3	3	4	133%
	Topical workshops and courses	0	19	3	11	367%
	Centre-wide Seminar Program, number of presentations	0	18	20	21	105%
Number of additional researchers working on Centre research	Postdoctoral researchers (new)	3	15	2	5	250%
	Honours and undergraduate students (new)[5]	1	6	6	1	17%
	TMOS HDR students (PhD and Masters new)	0	11	5	16	320%
	Masters by coursework students (new)[6]	0	0	6	0	0%
	Associate Investigators (new)[7]	0	0	2	1	50%
Number of postgraduate completions	Women HDR completions (percentage of the cohort)	0	0	20	31	155%
Number of mentoring programs offered by the Centre	Industry internships (any level longer than 1 month)[8]	0	0	2	0	0%
	PI-Student Exchange Program[9]	0	0	5	0	0%
	Mentors within the Centre[10]	0	0	20	19	95%
	Number of mentees[11]	0	0	30	21	70%

5. We have focused on recruting PhD students as this is a more attractive path to many of our prospective students.
6. We have focused on recruting PhD students as this is a more attractive path to many of our prospective students.
7. We reviewed our AIs annually and have made several new appointments that commence in January 2023.
8. The Industry Liasion Committee and Education Committees jointly agreed to not pursue a Centre-based program due to the new National Industry PhD Program.
9. This program was on pause due to COVID-19 and the rising cost of international travel. The program will be reinstated in mid-2023.
10. In late 2022 we launched mentoring via the Mentorloop program, with plans for exansion in 2023.
11. In late 2022 we launched mentoring via the Mentorloop program, with plans for exansion in 2023.

Performance Measure		Actual Y0 2020	Actual Y1 2021	Target Y2 2022	Actual Y2 2022	Perform. rate 2022
Number of presentations/ briefings	To the public (Outreach/public engagement events, public lectures)	4	4	10	14	140%
	To government (parliamentarians and department/agencies at both State and Federal level)[12]	1	0	3	0	0%
	To industry/business/end users (documented) incl. DSTG, CSIRO	3	5	5	1	20%
	To non-government organisations	1	3	3	6	200%
	School visits[13]	2	4	8	6	75%
Number of new organisations collaborating with, or involved in, the Centre	Academic collaborations (new)	4	6	3	10	333%
	Industry and end user partnerships (new)	4	10	3	7	233%
Number of female research personnel	Women and diverse gender, % (double the discipline mean)	33	25	35	36	104%

12. We did not interact with government but did request opportunities, including through invitations to the Centre Launch.
13. School visits have picked up in the centre with the launch of our three workshops, which we aim to deliver more in 2023.

Performance Measure		Actual Y0 2020	Actual Y1 2021	Target Y2 2022	Actual Y2 2022	Perform. rate 2022
Centre-specific KPIs						
Research	Plenary talks at international conferences	2	3	3	12	400%
	Keynote and Invited talks at international conferences	21	41	40	41	102%
	Awards and fellowships to CIs, ECRs and AIs	11	10	10	14	140%
	Additional research income secured by Centre staff ('000)	4,410	19,749	1,000	5,957	596%
Equity and Diversity	Unconscious bias training, % of Centre personnel (CIs)[14]	100	0	100	0	0%
	Inclusion training, % of Centre personnel[15]	0	100	100	90	90%
IP uptake by end-users	Start-up companies	0	1	0	2	infinity
	IP uptake by end-users[16]	0	0	1	0	0%
	Number of TMOS alumni employed in industry	0	0	0	6	infinity

14. We did not undertake specific unconcious bias training with the CIs, we can report that CIs completed IDEA training as captured by the 'inclusion training' KPI.
15. We were unable to deliver our previous years' communications drive at the end of 2022 to push to 100% completion.
16. We have started several new relationships with end-users but this has not converted to IP-uptake, yet.

Performance Measure		Actual Y0 2020	Actual Y1 2021	Target Y2 2022	Actual Y2 2022	Perform. rate 2022
Centre-specific KPIs						
Education	Associate TMOS HDR students (PhD and Masters, new)[17]	16	26	5	1	20%
	Centre-member attendees at training workshops (total)	0	0	90	129	143%
	Non-Centre member attendees at training workshops[18]	0	0	20	16	80%
	HDRs visiting PIs[19]	1	0	10	3	30%
Outreach	Media releases[20]	2	10	20	13	65%
	Media mentions	38	170	20	20	100%
	Twitter followers (new)	477	445	100	396	396%
	Outreach hours[21]	22	26	1,000	59	6%

17. We have several associated students through MetaActive, which is an international program, not captured by this KPI.
18. Our first in-person training events have focused on building internal team collaboration in 2022.
19. We have not activated our PI exchange program due to COVID-19 and the increased costs of international travel.
20. Due to resourcing allocation in the Business Team we had reduced capacity in this space as we focused on delivering several events. The team resourcing is allocated toward increasing public relations and marketing for 2023.
21. The Outreach team will be further increasing their outreach hours in 2023 as we grow this important program. We will request a re-calibration of this KPI with the ARC in 2023.

Finance

REPORTING PERIOD	2022	2023
	Actual ($)	Forecast ($)
Opening Balance (total funds)	**9,213,087**	
INCOME		
ARC[1]	5,227,481	5,399,946
Australian National University	1,842,053	437,911
The University of Melbourne	52,999	159,011
RMIT University	212,526	220,477
University of Technology Sydney	210,000	404,857
The University of Western Australia	159,725	159,725
Partners' contributions	-	4,820
Consultancies	19,364	19,580
TOTAL INCOME	**7,724,147**	**6,806,327**

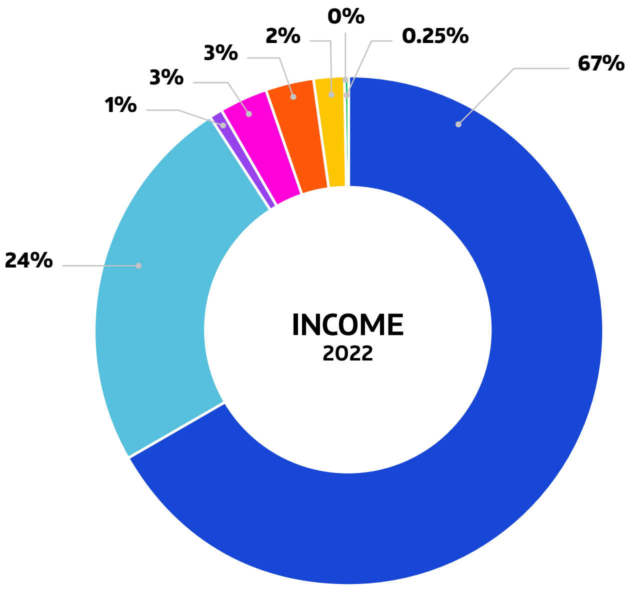
REPORTING PERIOD	2022	2023
EXPENDITURE	Actual ($)	Forecast ($)
Personnel	3,531,132	3,635,257
Equipment	156,801	585,748
Scholars Expenses	482,810	641,516
Travel	490,573	631,574
Other[2]	831,164	1,312,233
TOTAL EXPENDITURE	**5,492,479**	**6,806,327**
CARRY FORWARD (TOTAL)	**11,444,755**	
CARRY FORWARD TO 2023	**4,994,634**	
CARRY FORWARD TO 2027[3]	**6,450,121**	

REPORTING PERIOD	2022	2023
	Actual ($)	Commitment ($)
IN-KIND		
Australian National University	1,128,468	1,121,068
The University of Melbourne	713,212	391,390
RMIT University	584,870	334,870
University of Technology Sydney	370,836	370,836
The University of Western Australia	317,968	317,968
Partners' contributions	736,629	736,629
TOTAL INCOME	**3,851,982**	**3,272,761**

Notes on the Financial Statement:

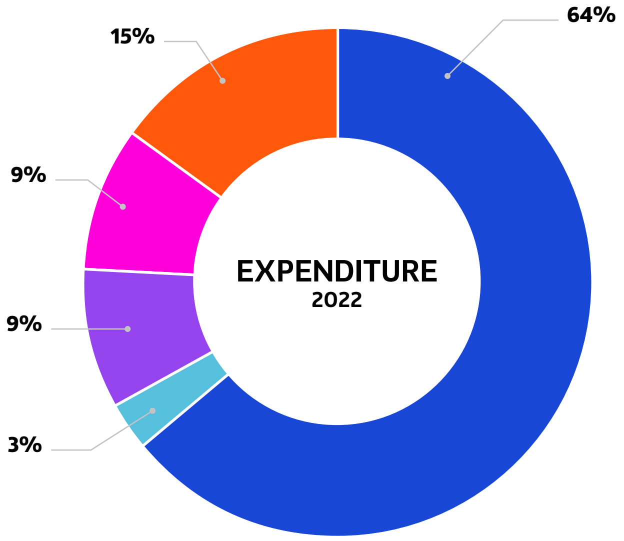
1) includes indexation and 2022 ARC funding
2) incl Materials, R&M, Branding, Outreach, Consultancies, Recruitment, Administrative support, Strategic Initiatives
3) unspent balance from 2020 reserved for 2027 (year 7) operations

CASH INCOME SOURCES 2022:



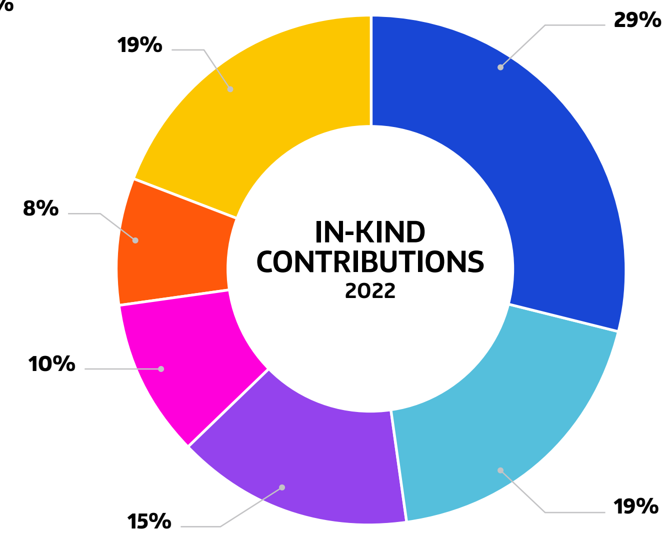
- ARC[1] **67%**
- Australian National University **24%**
- The University of Melbourne **1%**
- RMIT University **3%**
- University of Technology Sydney **3%**
- The University of Western Australia **2%**
- Partners' contributions **0%**
- Consultancies **0.25%**

EXPENDITURE 2022:



- Personnel **64%**
- Equipiment **3%**
- Scholars Expenses **9%**
- Travel **9%**
- Other **15%**

IN-KIND CONTRIBUTIONS 2022:



- Australian National University **29%**
- The University of Melbourne **19%**
- RMIT University **15%**
- University of Technology Sydney **10%**
- The University of Western Australia **8%**
- Partners' contributions **19%**

Notes on the Financial Statement:

1) includes indexation and 2022 ARC funding

Publications

1. Adhikari, Sonachand, Olivier Lee Cheong Lem, Felipe Kremer, Kaushal Vora, Frank Brink, Mykhaylo Lysevych, Hark Hoe Tan, and Chennupati Jagadish. 'Nonpolar AlxGa1−xN/AlyGa1−yN Multiple Quantum Wells on GaN Nanowire for UV Emission'. *Nano Research* 15, no. 8 (August 2022): 7670–80. https://doi.org/10.1007/s12274-022-4403-6

2. Adhikari, Sonachand, Mykhaylo Lysevych, Chennupati Jagadish, and Hark Hoe Tan. 'Selective Area Growth of GaN Nanowire: Partial Pressures and Temperature as the Key Growth Parameters'. *Crystal Growth & Design* 22, no. 9 (7 September 2022): 5345–53. https://doi.org/10.1021/acs.cgd.2c00453

3. Aghamiri, Neda Alsadat; Guangwei Hu, Alireza Fali, Zhen Zhang, Jiahan Li, Sivacarendran Balendhran, Sumeet Walia, Sharath Sriram, James H. Edgar, Shriram Ramanathan, Andrea Alù, Yohannes Abate. 'Reconfigurable Hyperbolic Polaritonics with Correlated Oxide Metasurfaces'. *Nature Communications* 13, no. 1 (3 August 2022): 4511. https://doi.org/10.1038/s41467-022-32287-z

4. Aharonovich, Igor, Fadis F. Murzakhanov, Georgy Vladimirovich Mamin, Sergei Borisovich Orlinskii, Uwe Gerstmann, Wolf Gero Schmidt, Timur Biktagirov, Andreas Gottscholl, Andreas Sperlich, Vladimir Dyakonov, Victor A. Soltamov. 'Electron–Nuclear Coherent Coupling and Nuclear Spin Readout through Optically Polarized V_B^- Spin States in HBN'. *Nano Letters* 22, no. 7 (13 April 2022): 2718–24. https://doi.org/10.1021/acs.nanolett.1c04610

5. Aharonovich, Igor, Toshiyuki Tashima, Hideaki Takashima, Andreas W. Schell, Toan Trong Tran, and Shigeki Takeuchi. 'Hybrid Device of Hexagonal Boron Nitride Nanoflakes with Defect Centres and a Nano-Fibre Bragg Cavity'. *Scientific Reports* 12, no. 1 (December 2022): 96. https://doi.org/10.1038/s41598-021-03703-z

6. Aharonovich, Igor, Jean-Philippe Tetienne, and Milos Toth. 'Quantum Emitters in Hexagonal Boron Nitride'. *Nano Letters* 22, no. 23 (14 December 2022): 9227–35. https://doi.org/10.1021/acs.nanolett.2c03743

7. Akhavan, N. D., G. A. Umana-Membreno, R. Gu, J. Antoszewski, and L. Faraone. 'Design Principles for High QE HgCdTe Infrared Photodetectors for ESWIR Applications'. *Journal of Electronic Materials* 51, no. 9 (September 2022): 4742–51. https://doi.org/10.1007/s11664-022-09809-y

8. Azimi, Zahra, Aswani Gopakumar, Amira S. Ameruddin, Li Li, Thien Truong, Hieu T. Nguyen, Hark Hoe Tan, Chennupati Jagadish, and Jennifer Wong-Leung. 'Tuning the Crystal Structure and Optical Properties of Selective Area Grown InGaAs Nanowires'. *Nano Research* 15, no. 4 (April 2022): 3695–3703. https://doi.org/10.1007/s12274-021-3914-x

9. Bandres, Miguel A., Oded Zilberberg, and Andrey Sukhorukov. 'Special Topic on Synthetic Gauge Field Photonics'. *APL Photonics* 7, no. 5 (1 May 2022): 050401. https://doi.org/10.1063/5.0093334

10. Bera, Kousik, Dipankar Chugh, Hark Hoe Tan, Anushree Roy, and Chennupati Jagadish. 'Non-Thermal and Thermal Effects on Mechanical Strain in Substrate-Transferred Wafer-Scale HBN Films'. *Journal of Applied Physics* 132, no. 10 (14 September 2022): 104303. https://doi.org/10.1063/5.0102617

11. Budnik, Garrett, John A. Scott, Chengge Jiao, Mostafa Maazouz, Galen Gledhill, Lan Fu, Hark Hoe Tan, and Milos Toth. 'Nanoscale 3D Tomography by In-Flight Fluorescence Spectroscopy of Atoms Sputtered by a Focused Ion Beam'. *Nano Letters* 22, no. 20 (26 October 2022): 8287–93. https://doi.org/10.1021/acs.nanolett.2c03101

12. Butson, Joshua D., Astha Sharma, Hongjun Chen, Yuan Wang, Yonghwan Lee, Purushothaman Varadhan, Mihalis N.Tsampas, Chuan Zhao, Antonio Tricoli, Hark Hoe Tan, Chennupati Jagadish, and Siva Karuturi. 'Surface-Structured Cocatalyst Foils Unraveling a Pathway to High-Performance Solar Water Splitting'. *Advanced Energy Materials* 12, no. 1 (January 2022): 2102752. https://doi.org/10.1002/aenm.202102752

13. Cadusch, Jasper J., Jiajun Meng, Dandan Wen, Vivek Raj Shrestha, and Kenneth B. Crozier. 'Compact, Lightweight, and Filter-Free: An All-Si Microspectrometer Chip for Visible Light Spectroscopy'. *ACS Photonics* 9, no. 2 (16 February 2022): 474–81. https://doi.org/10.1021/acsphotonics.1c01187

14. Camacho-Morales, Rocio, Lei Xu, Haizhong Zhang, Son Tung Ha, Leonid Krivitsky, Arseniy I. Kuznetsov, Mohsen Rahmani, and Dragomir Neshev. 'Sum-Frequency Generation in High-Q GaP Metasurfaces Driven by Leaky-Wave Guided Modes'. *Nano Letters* 22, no. 15 (10 August 2022): 6141–48. https://doi.org/10.1021/acs.nanolett.2c01349

15. Chen, Disheng, Johannes E. Fröch, Shihao Ru, Hongbing Cai, Naizhou Wang, Giorgio Adamo, John Scott, Fuli Li, Nikolay Zheludev, Igor Aharonovich, and Weibo Gao. 'Quantum Interference of Resonance Fluorescence from Germanium-Vacancy Color Centers in Diamond'. *Nano Letters* 22, no. 15 (10 August 2022): 6306–12. https://doi.org/10.1021/acs.nanolett.2c01959

16. Ding, Lei, Xuchen Shan, Dejiang Wang, Baolei Liu, Ziqing Du, Xiangjun Di, Chaohao Chen, Mahnaz Maddahfar, Ling Zhang, Yuzhi Shi, Peter Reece, Benjamin Halkon, Igor Aharonovich, Xiaoxue Xu, and Fan Wang. 'Lanthanide Ion Resonance-Driven Rayleigh Scattering of Nanoparticles for Dual-Modality Interferometric Scattering Microscopy'. *Advanced Science*, 17 August 2022, 2203354. https://doi.org/10.1002/advs.202203354

17. Faisal, Shaikh Nayeem, and Francesca Iacopi. 'Thin-Film Electrodes Based on Two-Dimensional Nanomaterials for Neural Interfaces'. *ACS Applied Nano Materials* 5, no. 8 (26 August 2022): 10137–50. https://doi.org/10.1021/acsanm.2c03056

18. Fedotova, Anna, Luca Carletti, Attilio Zilli, Frank Setzpfandt, Isabelle Staude, Andrea Toma, Marco Finazzi, Costantino De Angelis, Thomas Pertsch, Dragomir N. Neshev, and Michele Celebrano. 'Lithium Niobate Meta-Optics'. *ACS Photonics*, 9 November 2022, acsphotonics.2c00835. https://doi.org/10.1021/acsphotonics.2c00835

19. Fröch, Johannes E., Chi Li, Yongliang Chen, Milos Toth, Mehran Kianinia, Sejeong Kim, and Igor Aharonovich. 'Purcell Enhancement of a Cavity-Coupled Emitter in Hexagonal Boron Nitride'. *Small* 18, no. 2 (January 2022): 2104805. https://doi.org/10.1002/smll.202104805

20. Gagrani, Nikita, Kaushal Vora, Lan Fu, Chennupati Jagadish, and Hark Hoe Tan. 'Flexible InP–ZnO Nanowire Heterojunction Light Emitting Diodes'. *Nanoscale Horizons* 7, no. 4 (2022): 446–54. https://doi.org/10.1039/D1NH00535A

21. Gagrani, Nikita, Kaushal Vora, Chennupati Jagadish, and Hark Hoe Tan. 'Thin $Sn_xNi_yO_z$ Films as p-Type Transparent Conducting Oxide and Their Application in Light-Emitting Diodes'. *ACS Applied Materials & Interfaces* 14, no. 32 (17 August 2022): 37101–9. https://doi.org/10.1021/acsami.2c04890

22. Gale, Angus, Chi Li, Yongliang Chen, Kenji Watanabe, Takashi Taniguchi, Igor Aharonovich, and Milos Toth. 'Site-Specific Fabrication of Blue Quantum Emitters in Hexagonal Boron Nitride'. *ACS Photonics* 9, no. 6 (15 June 2022): 2170–77. https://doi.org/10.1021/acsphotonics.2c00631

23. Gill, Gurpreet Singh, Christopher Jones, Dhirendra Kumar Tripathi, Adrian Keating, Gino Putrino, K. K. M. B. Dilusha Silva, Lorenzo Faraone, and Mariusz Martyniuk. 'Correction to: Mechanical Properties of Thermally Evaporated Germanium (Ge) and Barium Fluoride (BaF2) Thin-Films'. *MRS Communications* 12, no. 2 (April 2022): 284–284. https://doi.org/10.1557/s43579-022-00156-x

24. Gill, Gurpreet Singh, Christopher Jones, Dhirendra Kumar Tripathi, Adrian Keating, Gino Putrino, K. K. M. B. Dilusha Silva, Lorenzo Faraone, Mariusz Martyniuk. 'Mechanical Properties of Thermally Evaporated Germanium (Ge) and Barium Fluoride (BaF2) Thin-Films'. *MRS Communications* 12, no. 1 (February 2022): 112–18. https://doi.org/10.1557/s43579-021-00149-2

25. Gupta, Bikesh, Md. Anower Hossain, Asim Riaz, Astha Sharma, Doudou Zhang, Hark Hoe Tan, Chennupati Jagadish, Kylie Catchpole, Bram Hoex, and Siva Karuturi. 'Recent Advances in Materials Design Using Atomic Layer Deposition for Energy Applications'. *Advanced Functional Materials* 32, no. 3 (January 2022): 2109105. https://doi.org/10.1002/adfm.202109105

26. Gupta, Niharika, Hyungjin Kim, Nima Sefidmooye Azar, Shiekh Zia Uddin, Der-Hsien Lien, Kenneth B. Crozier, and Ali Javey. 'Bright Mid-Wave Infrared Resonant-Cavity Light-Emitting Diodes Based on Black Phosphorus'. *Nano Letters* 22, no. 3 (9 February 2022): 1294–1301. https://doi.org/10.1021/acs.nanolett.1c04557

27. Haggren, Tuomas, Vidur Raj, Anne Haggren, Nikita Gagrani, Chennupati Jagadish, and Hark Hoe Tan. 'CuI as a Hole-Selective Contact for GaAs Solar Cells'. *ACS Applied Materials & Interfaces*, 16 November 2022, acsami.2c16033. https://doi.org/10.1021/acsami.2c16033

28. He, Jun, Zhiwei Huang, Ziyuan Li, Wei Wen Wong, Yang Yu, Longsibo Huang, Xi Li, Lan Fu, Hark Hoe Tan, Chennupati Jagadish, and Xiaoming Yuan. 'Design of InAs Nanosheet Arrays for High-Performance Polarization-Sensitive Infrared Photodetection'. *Journal of Physics D: Applied Physics* 55, no. 1 (22 December 2022): 015105. https://doi.org/10.1088/1361-6463/ac9fe1

29. Horder, Jake, Simon J.U. White, Angus Gale, Chi Li, Kenji Watanabe, Takashi Taniguchi, Mehran Kianinia, Igor Aharonovich, and Milos Toth. 'Coherence Properties of Electron-Beam-Activated Emitters in Hexagonal Boron Nitride Under Resonant Excitation'. *Physical Review Applied* 18, no. 6 (8 December 2022): 064021. https://doi.org/10.1103/PhysRevApplied.18.064021

30. Huang, Lujun, Alex Krasnok, Andrea Alú, Yiling Yu, Dragomir Neshev, and Andrey E. Miroshnichenko. 'Enhanced Light–Matter Interaction in Two-Dimensional Transition Metal Dichalcogenides'. *Reports on Progress in Physics* 85, no. 4 (1 April 2022): 046401. https://doi.org/10.1088/1361-6633/ac45f9

31. Iacopi, Francesca, and Chin-Teng Lin. 'A Perspective on Electroencephalography Sensors for Brain-Computer Interfaces'. *Progress in Biomedical Engineering* 4, no. 4 (1 October 2022): 043002. https://doi.org/10.1088/2516-1091/ac993d

32. Izdebskaya, Yana V., Ziwei Yang, Mingkai Liu, Duk-Yong Choi, Andrei Komar, Dragomir N. Neshev, and Ilya V. Shadrivov. 'Magnetic Tuning of Liquid Crystal Dielectric Metasurfaces'. *Nanophotonics* 11, no. 17 (23 August 2022): 3895–3900. https://doi.org/10.1515/nanoph-2022-0101

33. Jiang, Yifan, Rui Shen, Tong Li, Jiamin Tian, Shuo Li, Hark Hoe Tan, Chennupati Jagadish, and Qing Chen. 'Enhancing the Electrical Performance of InAs Nanowire Field-Effect Transistors by Improving the Surface and Interface Properties by Coating with Thermally Oxidized Y_2O_3'. *Nanoscale* 14, no. 35 (2022): 12830–40. https://doi.org/10.1039/D2NR02736D

34. Karawdeniya, Buddini I., Adam M. Damry, Krishnan Murugappan, Shridhar Manjunath, Y. M. Nuwan D. Y. Bandara, Colin J. Jackson, Antonio Tricoli, and Dragomir Neshev. 'Surface Functionalization and Texturing of Optical Metasurfaces for Sensing Applications'. *Chemical Reviews*, 10 May 2022, acs.chemrev.1c00990. https://doi.org/10.1021/acs.chemrev.1c00990

35. Karuturi, Siva, Chennupati Jagadish, and Sudip Chakraborty. 'Advances in Low-Dimensional and Nanostructured Materials for Sustainable Energy Conversion and Storage'. *The European Physical Journal Special Topics* 231, no. 15 (September 2022): 2915–17. https://doi.org/10.1140/epjs/s11734-022-00646-y

36. Katzmarek, David A, Aiswarya Pradeepkumar, Richard W Ziolkowski, and Francesca Iacopi. 'Review of Graphene for the Generation, Manipulation, and Detection of Electromagnetic Fields from Microwave to Terahertz'. *2D Materials* 9, no. 2 (1 April 2022): 022002. https://doi.org/10.1088/2053-1583/ac59d1

37. Kaushik, Shuchi, Subhajit Karmakar, Ravendra Kumar Varshney, Hardhyan Sheoran, Dipankar Chugh, Chennupati Jagadish, Hark Hoe Tan, and Rajendra Singh. 'Deep-Ultraviolet Photodetectors Based on Hexagonal Boron Nitride Nanosheets Enhanced by Localized Surface Plasmon Resonance in Al Nanoparticles'. *ACS Applied Nano Materials* 5, no. 5 (27 May 2022): 7481–91. https://doi.org/10.1021/acsanm.2c01466

38. Khodasevych, Iryna, Patrick Rufangura, and Francesca Iacopi. 'Designing Concentric Nanoparticles for Surface-Enhanced Light-Matter Interaction in the Mid-Infrared'. *Optics Express* 30, no. 13 (20 June 2022): 24118. https://doi.org/10.1364/OE.462117

39. Kianinia, Mehran, Zai-Quan Xu, Milos Toth, and Igor Aharonovich. 'Quantum Emitters in 2D Materials: Emitter Engineering, Photophysics, and Integration in Photonic Nanostructures'. *Applied Physics Reviews* 9, no. 1 (March 2022): 011306. https://doi.org/10.1063/5.0072091

40. Kumar, Pawan, Sina Saravi, Thomas Pertsch, Frank Setzpfandt, and Andrey A. Sukhorukov. 'Nonlinear Quantum Spectroscopy with Parity–Time-Symmetric Integrated Circuits'. *Photonics Research* 10, no. 7 (1 July 2022): 1763. https://doi.org/10.1364/PRJ.450410

41. Lee, Yonghwan, Bikesh Gupta, Hark Hoe Tan, Chennupati Jagadish, Jihun Oh, and Siva Karuturi. 'Protocol on the Fabrication of Monocrystalline Thin Semiconductor via Crack-Assisted Layer Exfoliation Technique for Photoelectrochemical Water-Splitting'. *STAR Protocols* 3, no. 1 (March 2022): 101015. https://doi.org/10.1016/j.xpro.2021.101015

42. Lee, Yonghwan, Bikesh Gupta, Hark Hoe Tan, Chennupati Jagadish, Jihun Oh, and Siva Karuturi. 'Ultrathin Transparent Metal Capping Layer on Metal Oxide Carrier-Selective Contacts for Si Solar Cells'. *The European Physical Journal Special Topics* 231, no. 15 (September 2022): 2933–39. https://doi.org/10.1140/epjs/s11734-022-00544-3

43. Li, Ziyuan, Li Li, Fan Wang, Lei Xu, Qian Gao, Ahmed Alabadla, Kun Peng, Kaushal Vora, Haroldo T.Hattori, Hark Hoe Tan, Chennupati Jagadish, Lan Fu. 'Investigation of Light–Matter Interaction in Single Vertical Nanowires in Ordered Nanowire Arrays'. *Nanoscale* 14, no. 9 (2022): 3527–36. https://doi.org/10.1039/D1NR08088A

44. Liu, Hongwei, Noah Mendelson, Irfan H. Abidi, Shaobo Li, Zhenjing Liu, Yuting Cai, Kenan Zhang, Jiawen You, Mohsen Tamtaji, Hoilun Wong, Yao Ding, Guojie Chen, Igor Aharonovich, and Zhengtang Luo. 'Rational Control on Quantum Emitter Formation in Carbon-Doped Monolayer Hexagonal Boron Nitride'. *ACS Applied Materials & Interfaces* 14, no. 2 (19 January 2022): 3189–98. https://doi.org/10.1021/acsami.1c21781

45. Low, Mei Xian, Sherif Abdulkader Tawfik, Salvy P. Russo, Sharath Sriram, Madhu Bhaskaran, and Sumeet Walia. 'Strain Modulation of Optoelectronic Properties in Nanolayered Black Phosphorus: Implications for Strain-Engineered 2D Material Systems'. *ACS Applied Nano Materials*, 27 July 2022, acsanm.2c02909. https://doi.org/10.1021/acsanm.2c02909

46. Mao, Haifeng, Xianshan Dong, Yihui Liu, Dilusha Silva, and Lorenzo Faraone. 'Cryogenic Mid-Wave Infrared Hyperspectral Fabry-Perot Filter Based on a Tensile-Strained Single-Layer Subwavelength Grating Mirror'. *Optics Express* 30, no. 24 (21 November 2022): 44071. https://doi.org/10.1364/OE.475649

47. Mao, Haifeng, Xianshan Dong, Yihui Liu, K. K. M. B. Dilusha Silva, and Lorenzo Faraone. 'Investigation and Process Control of the Grating Fill-Factor and Sidewall Angle Impacts on 2-D Metamaterial Infrared Mirrors'. *Optical Materials Express* 12, no. 11 (1 November 2022): 4199. https://doi.org/10.1364/OME.471630

48. Martyniuk, Mariusz, K. K. M. B. Dilusha Silva, Gino Putrino, Hemendra Kala, Dhirendra Kumar Tripathi, Gurpreet Singh Gill, and Lorenzo Faraone. 'Optical Microelectromechanical Systems Technologies for Spectrally Adaptive Sensing and Imaging'. *Advanced Functional Materials* 32, no. 3 (January 2022): 2103153. https://doi.org/10.1002/adfm.202103153

49. Maryam, W, H H Tan, C Jagadish, J M Dawes, B Zhao, and Wz Wan Ismail. 'A Hybrid Random Laser Using Dye with Self-Organized GaN Nanorods'. *Semiconductor Science and Technology* 37, no. 2 (1 February 2022): 025009. https://doi.org/10.1088/1361-6641/ac3b3a

50. Mazzanti, Andrea, Matthew Parry, Alexander N. Poddubny, Giuseppe Della Valle, Dragomir N. Neshev, and Andrey A. Sukhorukov. 'Enhanced Generation of Angle Correlated Photon-Pairs in Nonlinear Metasurfaces'. *New Journal of Physics* 24, no. 3 (1 March 2022): 035006. https://doi.org/10.1088/1367-2630/ac599e

51. Mendelson, Noah; Ritika Ritika, Mehran Kianinia, John Scott, Sejeong Kim, Johannes E.Fröch, Camilla Gazzana, Mika Westerhausen, Licheng Xiao, Seyed Sepehr Mohajerani, Stefan Strauf, Milos Toth, Igor Aharonovich, and Zai-Quan Xu. 'Coupling Spin Defects in a Layered Material to Nanoscale Plasmonic Cavities'. *Advanced Materials* 34, no. 1 (January 2022): 2106046. https://doi.org/10.1002/adma.202106046

52. Meng, Jiajun, Luke Weston, Sivacarendran Balendhran, Dandan Wen, Jasper J. Cadusch, Ranjith Rajasekharan Unnithan, and Kenneth B. Crozier. 'Compact Chemical Identifier Based on Plasmonic Metasurface Integrated with Microbolometer Array'. (Laser Photonics Rev. 16(4)/2022). *Laser & Photonics Reviews* 16, no. 4 (April 2022): 2270016. https://doi.org/10.1002/lpor.202270016

53. Mu, Zhao, Hongbing Cai, Disheng Chen, Jonathan Kenny, Zhengzhi Jiang, Shihao Ru, Xiaodan Lyu, Teck Seng Koh, Xiaogang Liu, Igor Aharonovich, and Weibo Gao. 'Excited-State Optically Detected Magnetic Resonance of Spin Defects in Hexagonal Boron Nitride'. *Physical Review Letters* 128, no. 21 (27 May 2022): 216402. https://doi.org/10.1103/PhysRevLett.128.216402

54. Nair, Rajesh V., Fan Wang, Xusan Yang, and Chennupati Jagadish. 'Photonic Materials: From Fundamentals to Applications'. *The European Physical Journal Special Topics* 231, no. 4 (May 2022): 583–87. https://doi.org/10.1140/epjs/s11734-022-00541-6

55. Neshev, Dragomir N., Andrey A. Sukhorukov, Jihua Zhang, Jinyong Ma, Matthew Parry, Marcus Cai, Rocio Camacho-Morales, and Lei Xu. 'Spatially Entangled Photon Pairs from Lithium Niobate Nonlocal Metasurfaces'. *Science Advances* 8, no. 30 (29 July 2022): eabq4240. https://doi.org/10.1126/sciadv.abq4240

56. Nonahal, Milad, Chi Li, Febiana Tjiptoharsono, Lu Ding, Connor Stewart, John Scott, Milos Toth, Son Tung Ha, Mehran Kianinia, and Igor Aharonovich. 'Coupling Spin Defects in Hexagonal Boron Nitride to Titanium Dioxide Ring Resonators'. *Nanoscale* 14, no. 40 (2022): 14950–55. https://doi.org/10.1039/D2NR02522A

57. Ospina-Rozo, Laura, Ann Roberts, and Devi Stuart-Fox. 'A Generalized Approach to Characterize Optical Properties of Natural Objects'. *Biological Journal of the Linnean Society* 137, no. 3 (22 October 2022): 534–55. https://doi.org/10.1093/biolinnean/blac064

58. Pan, Wenwu, Shimul Kanti Nath, Shuo Ma, Renjie Gu, Zekai Zhang, Lan Fu, Lorenzo Faraone, and Wen Lei. 'Non-Invasive and Non-Destructive Characterization of MBE-Grown CdZnTe/CdTe Superlattice-Based Dislocation Filtering Layers'. *Journal of Applied Physics* 131, no. 20 (28 May 2022): 205304. https://doi.org/10.1063/5.0091573

59. Pankov, Artem V., Ilya D. Vatnik, and Andrey A. Sukhorukov. 'Optical Neural Network Based on Synthetic Nonlinear Photonic Lattices'. *Physical Review Applied* 17, no. 2 (3 February 2022): 024011. https://doi.org/10.1103/PhysRevApplied.17.024011

60. Potočnik, Teja, Peter J. Christopher, Ralf Mouthaan, Tom Albrow-Owen, Oliver J. Burton, Chennupati Jagadish, Hark Hoe Tan, Timothy D. Wilkinson, Stephan Hofmann, Hannah J. Joyce, and Jack A. Alexander-Webber. 'Automated Computer Vision-Enabled Manufacturing of Nanowire Devices'. *ACS Nano*, 26 September 2022, acsnano.2c08187. https://doi.org/10.1021/acsnano.2c08187

61. Priscilla, Niken, Dan Smith, Enrico Della Gaspera, Jingchao Song, Lukas Wesemann, Timothy James, and Ann Roberts. 'Optical Janus Effect in Large Area Multilayer Plasmonic Films'. *Advanced Photonics Research* 3, no. 5 (May 2022): 2100333. https://doi.org/10.1002/adpr.202100333

62. Qin, Jiayi, Giovanni Guccione, Jinyong Ma, Chenyue Gu, Ruvi Lecamwasam, Ben C. Buchler, and Ping Koy Lam. 'Cancellation of Photothermally Induced Instability in an Optical Resonator'. *Optica* 9, no. 8 (20 August 2022): 924. https://doi.org/10.1364/OPTICA.457328

63. Raj, Vidur, Tuomas Haggren, Wei Wen Wong, Hark Hoe Tan, and Chennupati Jagadish. 'Topical Review: Pathways toward Cost-Effective Single-Junction III–V Solar Cells'. *Journal of Physics D: Applied Physics* 55, no. 14 (7 April 2022): 143002. https://doi.org/10.1088/1361-6463/ac3aa9

64. Rashidi, Mohammad, Tuomas Haggren, Chennupati Jagadish, and Hark Hoe Tan. 'Characteristics and Thermal Control of Random and Fabry–Pérot Lasing in Nanowire Arrays'. *ACS Photonics* 9, no. 11 (16 November 2022): 3573–83. https://doi.org/10.1021/acsphotonics.2c00960

65. Revuri, Praveen Kumar, Konrad Walus, Vincent P. Wallace, K. K. M. B. Dilusha Silva, Adrian Keating, Lorenzo Faraone, and Mariusz Martyniuk. '3D Printed Fabry–Pérot Filters for Terahertz Spectral Range'. *Journal of Infrared, Millimeter, and Terahertz Waves*, 16 November 2022. https://doi.org/10.1007/s10762-022-00887-x

66. Rocco, Davide, Rocio Camacho Morales, Lei Xu, Attilio Zilli, Vincent Vinel, Marco Finazzi, Michele Celebrano, Giuseppe Leo, Mohsen Rahmani, Chennupati Jagadish, Hark Hoe Tan, Dragomir N. Neshev, and Costantino De Angelis. 'Second Order Nonlinear Frequency Generation at the Nanoscale in Dielectric Platforms'. *Advances in Physics: X* 7, no. 1 (31 December 2022): 2022992. https://doi.org/10.1080/23746149.2021.2022992

67. Russell, Benjamin J., Jasper J. Cadusch, Jiajun Meng, Dandan Wen, and Kenneth B. Crozier. 'Mid-Infrared Spectral Reconstruction with Dielectric Metasurfaces and Dictionary Learning'. *Optics Letters* 47, no. 10 (15 May 2022): 2490. https://doi.org/10.1364/OL.448858

68. Saraswathy Vilasam, Aswani Gopakumar, Ponnappa Kechanda Prasanna, Xiaoming Yuan, Zahra Azimi, Felipe Kremer, Chennupati Jagadish, Sudip Chakraborty, and Hark Hoe Tan. 'Epitaxial Growth of GaAs Nanowires on Synthetic Mica by Metal–Organic Chemical Vapor Deposition'. *ACS Applied Materials & Interfaces* 14, no. 2 (19 January 2022): 3395–3403. https://doi.org/10.1021/acsami.1c19236

69. Schaeper, Otto, Ziwei Yang, Mehran Kianinia, Johannes E. Fröch, Andrei Komar, Zhao Mu, Weibo Gao, Dragomir N. Neshev, and Igor Aharonovich. 'Monolithic Silicon Carbide Metalenses'. *ACS Photonics* 9, no. 4 (20 April 2022): 1409–14. https://doi.org/10.1021/acsphotonics.2c00178

70. Schaeper, Otto, Ziwei Yang, Mehran Kianinia, Johannes E. Fröch, Andrei Komar, Zhao Mu, Weibo Gao, Dragomir N.Neshev, and Igor Aharonovich. 'Monolithic Silicon Carbide Metalenses'. *ACS Photonics* 9, no. 4 (20 April 2022): 1409–14. https://doi.org/10.1021/acsphotonics.2c00178

71. Schefer, Thomas A., Ryszard Narkowicz, Kilian Lenz, Fabian Ganss, Malcolm P. Roberts, Olav Hellwig, Mariusz Martyniuk, Jürgen Lindner, and Mikhail Kostylev. 'Application of a Microfabricated Microwave Resonator in a Co- Pd –Based Magnetic Hydrogen-Gas Sensor'. *Physical Review Applied* 18, no. 2 (4 August 2022): 024015. https://doi.org/10.1103/PhysRevApplied.18.024015

72. Scott, John A., James Bishop, and Milos Toth. 'Suppression of Surface Roughening during Ion Bombardment of Semiconductors'. *Chemistry of Materials* 34, no. 19 (11 October 2022): 8968–74. https://doi.org/10.1021/acs.chemmater.2c02391

73. Soo, Joshua Zheyan, Bikesh Gupta, Asim Riaz, Chennupati Jagadish, Hark Hoe Tan, and Siva Karuturi. 'Facile Substrate-Agnostic Preparation of High-Performance Regenerative Water Splitting (Photo) Electrodes'. *Chemistry of Materials* 34, no. 15 (9 August 2022): 6792–6801. https://doi.org/10.1021/acs.chemmater.2c00932

74. Stern, Hannah L., Qiushi Gu, John Jarman, Simone Eizagirre Barker, Noah Mendelson, Dipankar Chugh, Sam Schott, Hark Hoe Tan, Henning Sirringhaus, Igor Aharonovich, and Mete Atatüre. 'Room-Temperature Optically Detected Magnetic Resonance of Single Defects in Hexagonal Boron Nitride'. *Nature Communications* 13, no. 1 (December 2022): 618. https://doi.org/10.1038/s41467-022-28169-z

75. Tan, Henry, Jasper J. Cadusch, Jiajun Meng, and Kenneth B. Crozier. 'Genetic Optimization of Mid-Infrared Filters for a Machine Learning Chemical Classifier'. *Optics Express* 30, no. 11 (23 May 2022): 18330. https://doi.org/10.1364/OE.459067

76. Tan, Qinghai, Jia-Min Lai, Xue-Lu Liu, Dan Guo, Yongzhou Xue, Xiuming Dou, Bao-Quan Sun, Hui-Xiong Deng, Ping-Heng Tan, Igor Aharonovich, Weibo Gao, and Jun Zhang. 'Donor–Acceptor Pair Quantum Emitters in Hexagonal Boron Nitride'. *Nano Letters* 22, no. 3 (9 February 2022): 1331–37. https://doi.org/10.1021/acs.nanolett.1c04647

77. Toth, Milos, Igor Aharonovich, Simon J. U. White, Tieshan Yang, Nikolai Dontschuk, Chi Li, Zai-Quan Xu, Mehran Kianinia, and Alastair Stacey. 'Electrical Control of Quantum Emitters in a Van Der Waals Heterostructure'. *Light: Science & Applications* 11, no. 1 (December 2022): 186. https://doi.org/10.1038/s41377-022-00877-7

78. Toth, Milos, Chennupati Jagadish, Vidur Raj, Aswani Gopakumar, Gayatri Vaidya, John Scott, and Vini Gautam. 'High-Density Individually Addressable Platinum Nanoelectrodes for Biomedical Applications'. *Discover Materials* 2, no. 1 (December 2022): 6. https://doi.org/10.1007/s43939-022-00027-1

79. Tu, Chia-Wei, Masoud Kaveh, Martin Fränzl, Qian Gao, Hark Hoe Tan, Chennupati Jagadish, Heidrun Schmitzer, and Hans Peter Wagner. 'Unique Reflection from Birefringent Uncoated and Gold-Coated InP Nanowire Crystal Arrays'. *Optics Express* 30, no. 3 (31 January 2022): 3172. https://doi.org/10.1364/OE.440891

80. Wang, Luyao, and Ilya Shadrivov. 'Electro-Optic Metasurfaces'. *Optics Express* 30, no. 20 (26 September 2022): 35361. https://doi.org/10.1364/OE.469647

81. Wei, Shiyu, Zhe Li, Alishba John, Buddini I. Karawdeniya, Ziyuan Li, Fanlu Zhang, Kaushal Vora, Hark Hoe Tan, Chennupati Jagadish, Krishnan Murugappan, Antonio Tricoli, and Lan Fu. 'Semiconductor Nanowire Arrays for High-Performance Miniaturized Chemical Sensing'. *Advanced Functional Materials* 32, no. 5 (January 2022): 2107596. https://doi.org/10.1002/adfm.202107596

82. Weissflog, Maximilian A., Marcus Cai, Matthew Parry, Mohsen Rahmani, Lei Xu, Dennis Arslan, Anna Fedotova, Giuseppe Marino, Mykhaylo Lysevych, Hark Hoe Tan, Chennupati Jagadish, Andrey Miroshnichenko, Giuseppe Leo, Andrey A. Sukhorukov, Frank Setzpfandt, Thomas Pertsch, Isabelle Staude, and Dragomir N. Neshev. 'Far-Field Polarization Engineering from Nonlinear Nanoresonators'. *Laser & Photonics Reviews*, 10 October 2022, 2200183. https://doi.org/10.1002/lpor.202200183

83. Wen, Dandan, Kai Pan, Jiajun Meng, Xuanguang Wu, Xuyue Guo, Peng Li, Sheng Liu, Dong Li, Bingyan Wei, Xin Xie, Dexing Yang, Jianlin Zhao, and Kenneth B. Crozier. 'Broadband Multichannel Cylindrical Vector Beam Generation by a Single Metasurface'. *Laser & Photonics Reviews* 16, no. 10 (October 2022): 2200206. https://doi.org/10.1002/lpor.202200206

84. Wesemann, Lukas, Jon Rickett, Timothy J. Davis, and Ann Roberts. 'Real-Time Phase Imaging with an Asymmetric Transfer Function Metasurface'. *ACS Photonics* 9, no. 5 (18 May 2022): 1803–7. https://doi.org/10.1021/acsphotonics.2c00346

85. White, Simon J. U., Tieshan Yang, Nikolai Dontschuk, Chi Li, Zai-Quan Xu, Mehran Kianinia, Alastair Stacey, Milos Toth, and Igor Aharonovich. 'Author Correction: Electrical Control of Quantum Emitters in a Van Der Waals Heterostructure'. *Light: Science & Applications* 11, no. 1 (18 July 2022): 226. https://doi.org/10.1038/s41377-022-00917-2

86. Wong, Wei Wen, Chennupati Jagadish, and Hark Hoe Tan. 'III–V Semiconductor Whispering-Gallery Mode Micro-Cavity Lasers: Advances and Prospects'. *IEEE Journal of Quantum Electronics* 58, no. 4 (August 2022): 1–18. https://doi.org/10.1109/JQE.2022.3151082

87. Wong, Wei Wen, Naiyin Wang, Chennupati Jagadish, and Hark Hoe Tan. 'Directional Lasing in Coupled InP Microring/Nanowire Systems'. *Laser & Photonics Reviews*, 18 December 2022, 2200658. https://doi.org/10.1002/lpor.202200658

88. Xu, Lei, Daria A. Smirnova, Rocio Camacho-Morales, Rifat Ahmmed Aoni, Khosro Zangeneh Kamali, Marcus Cai, Cuifeng Ying, Ze Zheng, Andrey E. Miroshnichenko, Dragomir N. Neshev, and Mohsen Rahmani. 'Enhanced Four-Wave Mixing from Multi-Resonant Silicon Dimer-Hole Membrane Metasurfaces'. *New Journal of Physics* 24, no. 3 (1 March 2022): 035002. https://doi.org/10.1088/1367-2630/ac55b2

89. Yan, Jingshi, Qingdong Ou, Maria Antonietta Vincenti, Costantino De Angelis, Qiaoliang Bao, and Dragomir N. Neshev. 'Nonlinear Microscopy of Lead Iodide Nanosheets'. *Optics Express* 30, no. 4 (14 February 2022): 4793. https://doi.org/10.1364/OE.451214

90. Yang, Tieshan, Han Lin, Keng-Te Lin, David Mesa Saldarriaga, Guoliang Yang, Chunsheng Guo, Huihui Zhang, Jie Zhang, Scott Fraser, Alan Kin-Tak Lau, Tianyi Ma, and Baohua Jia. 'Single-Shot Production of Janus Graphene Thin Film for Solar Steam Generation with 94.5% Efficiency'. *Carbon* 199 (October 2022): 469–78. https://doi.org/10.1016/j.carbon.2022.07.030

91. Yang, Tieshan, Noah Mendelson, Chi Li, Andreas Gottscholl, John Scott, Mehran Kianinia, Vladimir Dyakonov, Milos Toth, and Igor Aharonovich. 'Spin Defects in Hexagonal Boron Nitride for Strain Sensing on Nanopillar Arrays'. *Nanoscale* 14, no. 13 (2022): 5239–44. https://doi.org/10.1039/D1NR07919K

92. Yang, Ziwei, Mingkai Liu, Andrei Komar, Lei Xu, and Dragomir N. Neshev. 'Phase-Only Tuning of Extreme Huygens Metasurfaces Enabled by Optical Anisotropy'. *Advanced Optical Materials* 10, no. 2 (January 2022): 2101893. https://doi.org/10.1002/adom.202101893

93. Yi, Ruixuan, Xutao Zhang, Chen Li, Bijun Zhao, Jing Wang, Zhiwen Li, Xuetao Gan, Li Li, Ziyuan Li, Fanlu Zhang, Liang Fang, Naiyin Wang, Pingping Chen, Wei Lu, Lan Fu, Jianlin Zhao, Hark Hoe Tan, and Chennupati Jagadish. 'Self-Frequency-Conversion Nanowire Lasers'. *Light: Science & Applications* 11, no. 1 (December 2022): 120. https://doi.org/10.1038/s41377-022-00807-7

94. Yi, Ruixuan, Xutao Zhang, Fanlu Zhang, Linpeng Gu, Qiao Zhang, Liang Fang, Jianlin Zhao, Lan Fu, Hark Hoe Tan, Chennupati Jagadish, and Xuetao Gan. 'Integrating a Nanowire Laser in an On-Chip Photonic Waveguide'. *Nano Letters* 22, no. 24 (28 December 2022): 9920–27. https://doi.org/10.1021/acs.nanolett.2c03364

95. Zeng, Helen ZhiJie, Minh Anh Phan Ngyuen, Xiaoyu Ai, Adam Bennet, Alexander S. Solntsev, Arne Laucht, Ali Al-Juboori, Milos Toth, Richard P. Mildren, Robert Malaney, and Igor Aharonovich. 'Integrated Room Temperature Single-Photon Source for Quantum Key Distribution: Publisher's Note'. *Optics Letters* 47, no. 9 (1 May 2022): 2161. https://doi.org/10.1364/OL.460614

96. Zha, Jiajia, Mingcheng Luo, Ming Ye, Tanveer Ahmed, Xuechao Yu, Der-Hsien Lien, Qiyuan He, Dangyuan Lei, Johnny C. Ho, James Bullock, Kenneth B. Crozier, and Chaoliang Tan. 'Infrared Photodetectors Based on 2D Materials and Nanophotonics'. *Advanced Functional Materials* 32, no. 15 (April 2022): 2111970. https://doi.org/10.1002/adfm.202111970

97. Zhang, Fanlu, Xutao Zhang, Ziyuan Li, Ruixuan Yi, Zhe Li, Naiyin Wang, Xiaoxue Xu, Zahra Azimi, Li Li, Mykhaylo Lysevych, Xuetao Gan, Yuerui Lu, Hark Hoe Tan, Chennupati Jagadish, and Lan Fu. 'A New Strategy for Selective Area Growth of Highly Uniform InGaAs/InP Multiple Quantum Well Nanowire Arrays for Optoelectronic Device Applications'. *Advanced Functional Materials* 32, no. 3 (January 2022): 2103057. https://doi.org/10.1002/adfm.202103057

98. Zhang, Zekai, Wenwu Pan, Mariusz Martyniuk, Shuo Ma, Lorenzo Faraone, and Wen Lei. 'Nanoindentation of Hg0.7Cd0.3Se Prepared by Molecular Beam Epitaxy'. *Infrared Physics & Technology*, November 2022, 104446. https://doi.org/10.1016/j.infrared.2022.104446

99. Zheng, Ze, Lei Xu, Lujun Huang, Daria Smirnova, Peilong Hong, Cuifeng Ying, and Mohsen Rahmani. 'Boosting Second-Harmonic Generation in the LiNbO 3 Metasurface Using High- Q Guided Resonances and Bound States in the Continuum'. *Physical Review B* 106, no. 12 (12 September 2022): 125411. https://doi.org/10.1103/PhysRevB.106.125411

100. Zuo, Xinrong, Ziyuan Li, Wei Wen Wong, Yang Yu, Xi Li, Jun He, Lan Fu, Hark Hoe Tan, Chennupati Jagadish, and Xiaoming Yuan. 'Design of InAs Nanosheet Arrays with Ultrawide Polarization-Independent High Absorption for Infrared Photodetection'. *Applied Physics Letters* 120, no. 7 (14 February 2022): 071109. https://doi.org/10.1063/5.0066507

Awards, Honours and Prizes

Awardee Name	Details
Chennupati Jagadish	International Fellow into the Royal Academy of Engineering
Chennupati Jagadish	Thomas D. Callinan Award for 2023; The award is the highest recognition of our division and is based on your achievements and contributions to DST science. Dielectric Science &Technology (DST) division at the Electrochemical Society (ECS)
Madhu Bhaskaran	ATSE Fellowship
Igor Aharonovich	2023 ACS Photonics Young Investigator Award
Sharath Sriram	Science & Technology Australia's new President
Daria Smirnova	Winner of the 2022 IUPAP C17 Early Career Scientist Prize "for fundamental aspects on Laser Physics and Photonics"
Neuton Li	Vice Chancellor's HDR Travel Grant for travel to CLEO San Jose
Shridhar Manjunath	SPIE Optics and Photonics Education Scholarship awarded in education scholarships to 78 outstanding individuals for their potential long-range contribution to optics, photonics, or other related fields
Wei Wen Wong	IUMRS-ICYRAM 2022 Travel Award, which was a cash prize award of JPY 90000 to fund my travel to Fukuoka, Japan, to attend the conference
Wei Wen Wong	Jim Williams Award, a joint departmental award by the Department of Material Physics and Department of Electronic Materials Engineering at the Research School of Physics, ANU
Shaban Sulejman	Dixson scholarship in experimental physics in August by the School of Physics at UoM
Shaban Sulejman	Rural & Regional Enterprise scholarship from QTAC
Lesley Spencer	Dean's Merit List for Academic Excellence for their outstanding performance in 2021
Lesley Spencer	RFG MacMillan Award This prize was established in 1991 to award the best Honours project in the field of materials science

Awarded Funding

TMOS Member	Title of Funding Scheme	Project ID	Total Amount (AUD)	Collaborators	Funding Source
Andrey Sukhorukov	LIEF 2023: A cryogenic multifunctional multiscale material characterisation facility .	LE230100024	$ 909,754	Professor Yun Liu; Dr Teng Lu; Associate Professor Danyang Wang; Professor Zhenxiang Cheng; Professor Shujun Zhang; Dr Srikanth Mateti; Dr Qiran Cai; Professor Ying Chen; Professor Amanda Ellis; Associate Professor Alexey Glushenkov; Dr Zi (Sophia) Gu; Professor Deanna D'Alessandro; Professor Cameron Kepert; Professor Baohua Jia; Professor Andrey Sukhorukov	Australian Research Council
Ann Roberts	Discovery Project 2023: Nature's advanced optical materials and their role in thermal management	DP230100207	$ 529,373	Professor Devi Stuart-Fox, Professor Nanfang Yu	Australian Research Council
Lan Fu	LIEF 2023: Cryogenic Near-Field Imaging and Spectroscopy Facility at the 10-nm-Scale.	LE230100113	$ 970,000	Professor Yuerui Lu; Professor Ping Koy Lam; Professor Liming Dai; Professor Ian Petersen; Professor Lan Fu; Dr James Bullock; Dr Dan Liu; Professor Dewei Chu; Associate Professor Deepak Dubal; Dr Hidehiro Yonezawa; Associate Professor Yan Jiao; Associate Professor Jianzhen Ou; Professor Elena Ostrovskaya; Professor Brian Abbey	Australian Research Council
Lorenzo Faraone	LIEF 2023: National Facility for Performance Characterisation of Infrared Technologies.	LE230100019	$ 690,000	Professor Lorenzo Faraone; Professor Michael Tobar; Professor Paul Low; Associate Professor Gilberto Umana-Membreno; Associate Professor Wen Lei; Professor Kenneth Crozier; Professor Dragomir Neshev; Professor Hark Tan; Associate Professor William Rickard; Associate Professor Simone Ciampi; Dr Nadim Darwish; Professor Dzung Dao	Australian Research Council

TMOS Member	Title of Funding Scheme	Project ID	Total Amount (AUD)	Collaborators	Funding Source
Madhu Bhaskaran	LIEF 2023: Facility for growth and characterisation of advanced materials and devices.	LE230100065	$ 1,310,536	Professor Alexander Hamilton; Dr Julie Karel; Professor Nagarajan Valanoor; Professor Madhu Bhaskaran; Associate Professor Lan Wang; Professor Kiyonori Suzuki; Dr Karina Hudson; Dr Golrokh Akhgar; Dr Feixiang Xiang; Associate Professor Ajay Karakoti; Professor Jared Cole; Associate Professor Nikhil Medhekar; Associate Professor Neeraj Sharma	Australian Research Council
Mariusz Martyniuk, Willie Padilla (PI)	Discovery Project 2023: Micro-electromechanical technology for harnessing terahertz waves.	DP23010381	$ 553,728	Vincent Wallace, Martin Saunders, Willie Padilla	Australian Research Council
Ann Roberts, Lukas Wesemann	Australia-Germany Joint Research Co-operation Scheme		$ 24,400	Prof. Ann Roberts, Dr. Tim Davis, Prof. Harald Giessen, Dr. Mario Hentschel, PhD students from both nodes to-be-named	Universities Australia in collaboration with the DAAD (German Academic Exchange Service)
Ilya Shadrivov, Vladlen Shvedov	ICEDS Seed Funding 'Hydrogen Generation from Widely Available Inorganic Materials'		$ 20,000		ANU Institute for Climate, Energy & Disaster Solutions
Ilya Shadrivov, Vladlen Shvedov	College of Science Research Translation and Engagement Primer Funds 'Generation and storage green hydrogen using solid inorganic materials'		$ 25,000		College of Science Research Translation and Engagement Primer Funds, Australian National University
Dragomir Neshev, Hoe Tan, Chennupati Jagadish	SONY Europe, Nonlinear Imaging via sum-frequency generation (SFG)		$ 46,017		Sony Corporation
Mariusz Martyniuk	DelivAssure-A novel monitoring device to detect hypoxia during childbirth.		$ 483,050		Department of Industry, Science and Resources (Australia)
Dragomir Neshev, Hoe Tan, Chennupati Jagadish	L3 Harris, Supply a prototype SWIR upconversion film		$ 96,217		L3 Harris (US)

TMOS Member	Title of Funding Scheme	Project ID	Total Amount (AUD)	Collaborators	Funding Source
Mariusz Martyniuk	A compact non-cryogenic high-precision magnetic field sensor for maritime surveillance		$ 150,000		WA State Government's Department of Jobs, Tourism, Science and Innovation (JTSI) Defence Science Centre Collaborative Research Grant
Mariusz Martyniuk	Advanced Fabrication of Cold Atom Traps for an Australian Portable Quantum Optical Clock		$ 149,300		WA State Government's Department of Jobs, Tourism, Science and Innovation (JTSI) Defence Science Centre Collaborative Research Grant
TOTAL			**$ 5,957,375**		

TMOS
ARC CENTRE OF EXCELLENCE FOR
TRANSFORMATIVE META-OPTICAL SYSTEMS

tmos.org.au
connect@tmos.org.au

Australian Government
Australian Research Council