ISSUE 04,2024

OPTICA
Advancing Optics and Photonics Worldwide

Optical Fabrication and Testing

NEWSLETTER

FUSION IGNITION'S OPTICAL BREAKTHROUGH

FACILITY FOCUS: THE MIRROR LAB!

SPOTLIGHT: JAMES WEBB's NIRcam INSIGHTS

INFOPTICA CHALLENGE: BRIDGING ART & SCIENCE

COVER ARTWORK BY CATALIN FLOREA, LOCKHEED MARTIN

F O R E W O R D

Chris Holmes, Chair
Associate Professor
University of Southampton

C O N T E N T S

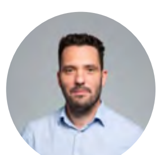
We are thrilled to welcome you to the inaugural edition of our newly formatted newsletter – a glossy, engaging insight designed to highlight our ongoing activity seeing to promote the area of optical fabrication and testing. I feel this edition is not just a testament to our commitment to excellence and innovation but also a celebration of the diverse and groundbreaking work that defines our field.

In this issue, we are excited to bring you a wide breadth and depth of our technical group's interests and expertise. From an overview of our latest webinars, which are a cornerstone of our group's ongoing efforts through to our new initiatives including Facility Focus and Infoptica challenge that aim to engage in new ways with our members.

A special highlight of this edition is an exclusive article on the James Webb Space Telescope, with a particular focus on the NIRCam – a marvel of optical engineering that promises to expand our understanding of the universe. This piece is the second in a three part instalment that offers a glimpse into a cutting-edge optical system and collaborative effort that is pushing humanity forward.

It is important to note that the success of this newsletter and all our events would not be possible without the dedication, passion, and expertise of our committee. I extend my deepest gratitude for their unwavering commitment and valuable contributions. As we embrace this new format, I hope you find the contents of this newsletter both enlightening and inspiring. We are a unique group, united by our passion for pushing the boundaries of what is possible in optical fabrication and testing. Let us continue to explore, innovate, and lead. Thank you for your continued support and engagement.

Meet The Team



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University of Southampton

Catalin Florea
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Lockheed Martin

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Facility Focus Coordinator
University of Arizona

Debasmita Banerjee
Student Engagement Lead
University of Central Florida

Hesham Sakr
Webinar Officer
Microsoft

Sarika Joshi
Newsletter Editor
IIT Bombay & Monash University

Shobha Shukla
Newsletter Editor
IIT Bombay

webinar

Tayyab Suratwala presented a talk titled 'Optic Technologies enabling Fusion Ignition at the National Ignition Facility' on 4th October. Tayyab is a program director of Optics and Materials Science & Technology at Lawrence Livermore National Laboratory. On December 5, 2022, Lawrence Livermore National Laboratory's (LLNL) National Ignition Facility (NIF) made history, demonstrating fusion ignition for the first time in a laboratory setting. NIF produced 3.15 megajoules (MJ) of fusion energy output using 2.05 MJ of laser energy delivered to the target, demonstrating the fundamental science basis for inertial fusion energy. The webinar highlighted optical technologies contributing towards progress in Laser output which in turn enabled successful demonstration of inertial fusion energy. The talk can be accessed here.

We welcome your suggestions of theme/speakers for the group activities. Please contact Hesham at heshamab@microsoft.com

Facility Focus

Our Technical Group supports the diverse interests of its members, spanning optical fabrication and testing at scales ranging from the atomic to the astronomical. The Facility Focus feature seeks to highlight and celebrate the cutting-edge research capabilities in photonics centers, all around the world. This initiative is led by Dr. Kim Daewook, Associate Professor of Optical Sciences and Astronomy, Univ. of Arizona.

In this first Facility Focus Video of the 2024 series, we introduce you to the Richard F. Caris Mirror Laboratory (RFCML) at the University of Arizona, a pioneering hub where science meets innovation in extremely large optics manufacturing. The RFCML team of dedicated scientists, engineers, and technicians is revolutionizing the field of astronomical mirrors.

They've broken away from traditional solid-glass mirrors, creating large, lightweight mirrors with unparalleled surface accuracy. These innovative mirrors feature a unique honeycomb structure, crafted from low thermal expansion glass. This design is achieved through an intricate process of melting the glass into a honeycomb mold while spin casting in a specially designed rotating oven. The result is a new generation of extremely large telescopes that explore the universe. The RFCML team is shaping the future of astronomical space exploration here.

Please contact Dr. Daewook Kim at dkim@optics.arizona.edu to feature your lab facilities here.

The NIRCam

Catalin Florea

Optics On Duty: A Closer Look at the James Webb Telescope

Part B

In the first installment of this series, we introduced the Near Infrared Camera (NIRCam) – Webb's primary imager that operates in the wavelength ranges 0.6 – 2.3 microns ("short wave", SW channel) and 2.3 – 5.0 microns ("long wave", LW channel) [1]. The NIRCam's layout and its main components are illustrated in Figure 1 [2]. The multiple functionalities of the NIRCam's are achieved via a dichroic splitter (to separate short and long wave channels), occulting masks and Lyot stops, as well as multiple bandpass filters selectively accessed via filter wheel assemblies dedicated to each channel.

One of the capabilities of the NIRCam is that of a coronagraph , meaning that it can take high-contrast images of faint features around bright point sources. Coronagraphy is the technique that enables collecting images of the Sun corona or stellar coronas, for studies of atmosphere and circumstellar disks, or the detection of exo-planets around a given star. The technique, introduced in 1931 by French astronomer Bernard Lyot (1897 – 1952), relies on using an occulting mask that blocks the central portion of the star's image. Given that the intensity contrast between a star and its corona is many orders of magnitude, it took progress in many areas (detectors, baffles and absorbing materials, glass and lens fabrication) to allow the evolution from a Solar coronagraph to a stellar coronagraph as the one enabled on James Webb.

Figure 1. Diagram of the main subassemblies of the NIRCam's instrument.

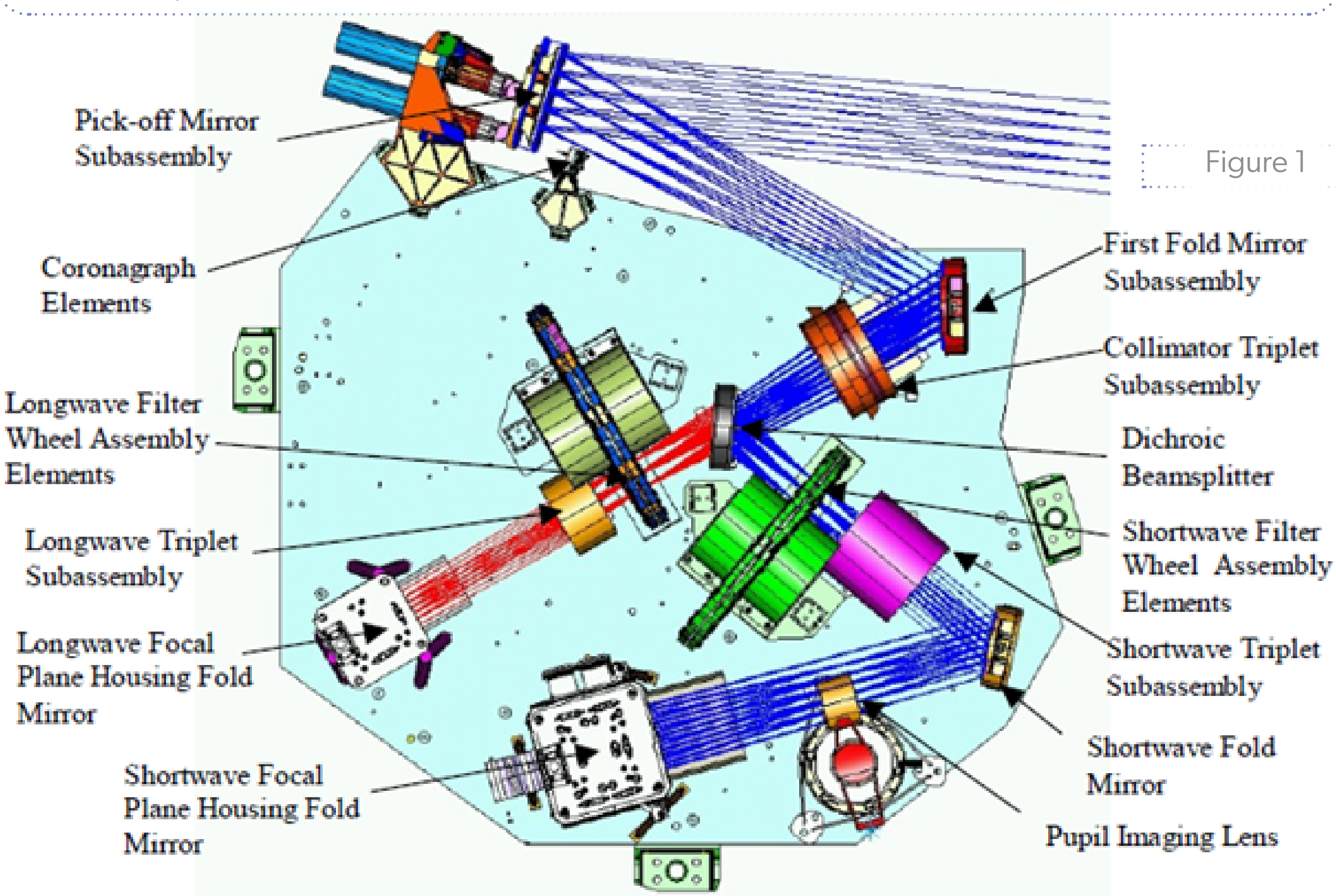

Figure 1

[1]Other instruments on board (such as the Mid-Infrared Instrument, MIRI) are also capable of operating in coronagraph mode.

Lyot's original design [3] is illustrated in Figure 2. The occulting disk blocks the Sun image at the field lens (F1) and the set of Lyot stops at the imaging objective (O2) blocks or traps the diffracted light generated by the lens edges and the occulting disk. The Lyot stops are therefore providing an "apodized" light field downstream toward the image plane. With this approach Lyot was able record impressive, for the time (1935), live video of Sun's corolla and its solar flares. The video was published in 1957 by the French National Centre for Scientific Research (CNRS) and is available to be viewed online [4]

The combination of occulting mask and Lyot stops is what enables the Webb telescope to provide imaging capable of up to 10^(-6) intensity contrast at a source separation of 1". The Lyot stops are metallic patterns deposited onto wedge-shaped substrates. Given that Webb has two spectral channels, different materials are used accordingly: Si for the LW channel and BaF_2 for the SW channel.

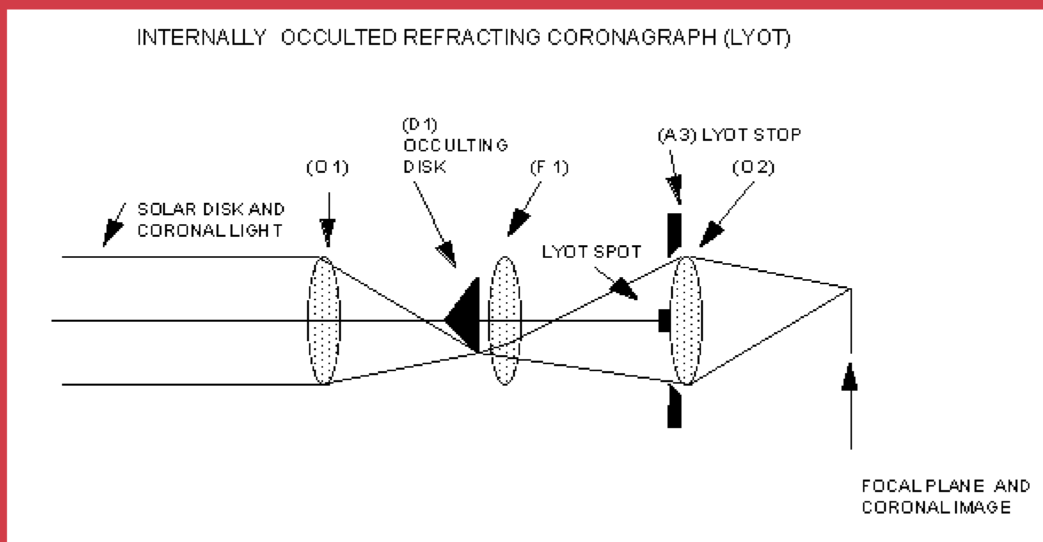

Figure 2. Optical layout and ray diagram for the original Lyot coronagraph design (from [5])

Each channel has 3 round and 2 bar occulters which are masks consisting of binary half-tone patterns composed of individual squares such as to approximate greyscale transmission (see Figure 3). They are lithographically etched from a chrome-on-aluminum coating deposited atop a multilayer, anti-reflection (AR) coated sapphire substrate that is the basis of the coronagraph optical mount (COM). Also located along the edges of the COM substrate are 5′′ × 5′′ and 2.5′′× 2.5′′ squares of nichrome with an optical density of ~3, the larger set of which serve as neutral density (ND) filters for bright target acquisition.

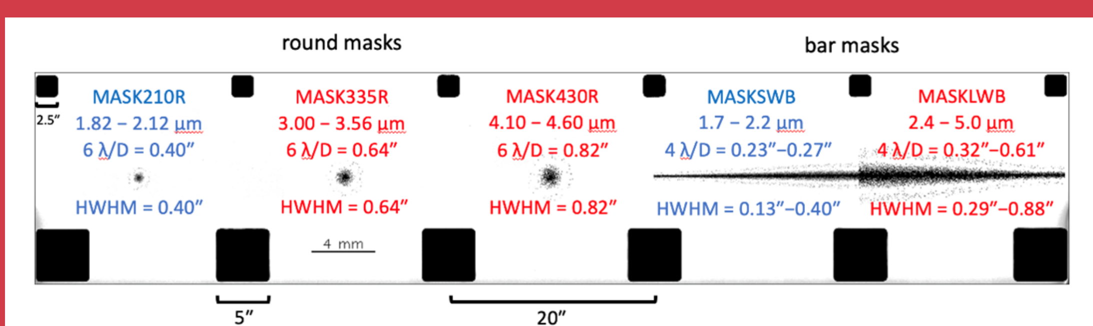

Figure 3. (a) Occulting masks along and neutral density filters on the COM

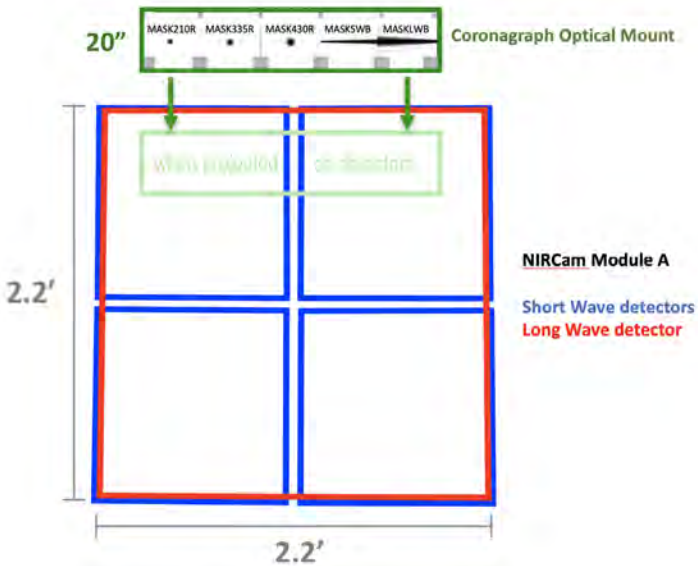

Figure 3. (b) COM projection onto SW and LW detectors

It is important to note that the performance of the AR coating (see Figure 5) dictates what spectral filters can be used in coronagraph mode. It is obvious that the SW channel is limited to wavelengths above 1.8um. A detailed coronagraphic imaging guide is provided elsewhere [6]. Finally, an insightful simulation is illustrated in Figure 5, which shows the diffraction patterns and the nominal locations of the Lyot stops as seen from the focal plane [6]. To achieve the optimum intensity contrast a delicate and intricate process is necessary where the right combination of optics and exposure parameters needs to be selected along with fine tuning of the telescope pointing as to place the target image at the optimal location on the occulting mask [8]. An example of an exoplanet observed through the NIRCam in coronagraph mode at 3.0um and 4.4um is illustrated in Figure 6 [9].

Each occulting mask has a specific transmission profile (in each of the two spectral bands) that allows sub-arcsec control in the transmission values. We show in Figure 4 only the transmission profile for the round occulting masks [5]. The transmission profile is an important system variable given the extremely small angular extent of the light sources considered.

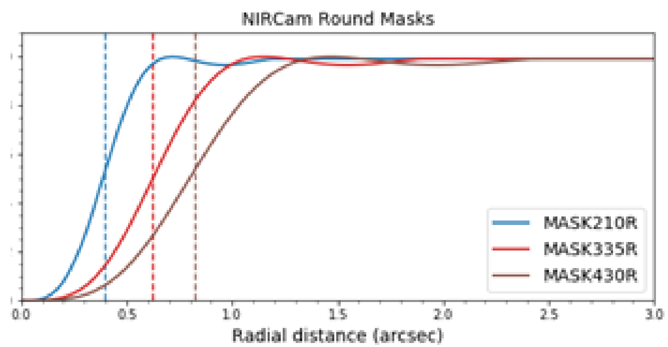

Figure 4. Transmission profile for the round occulting masks.

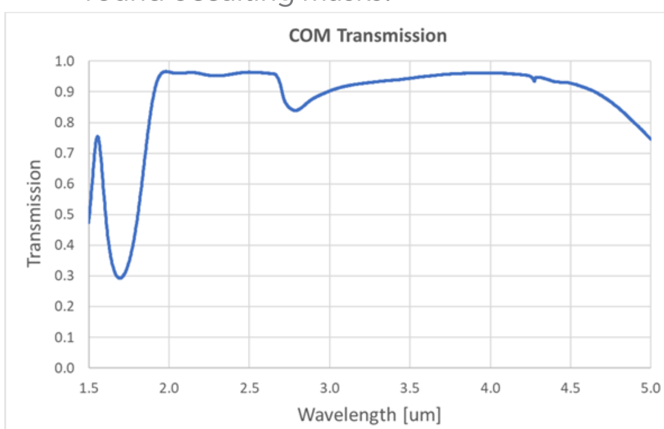

Figure 5. The AR coating performance on the sapphire substrate of the COM

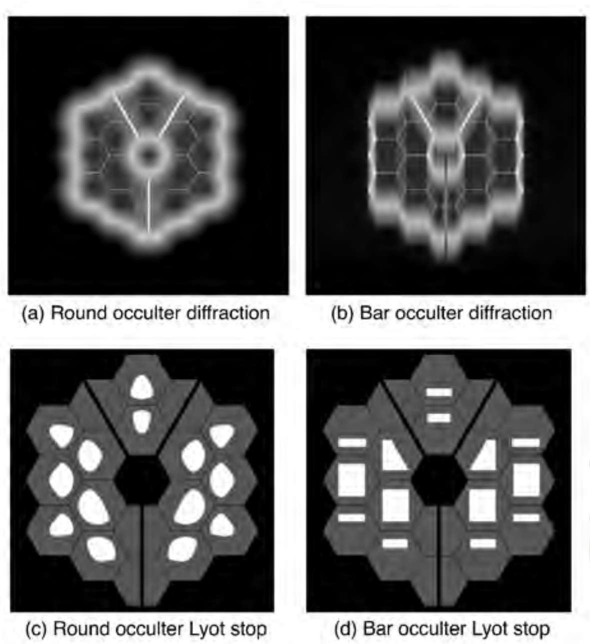

Figure 6. Simulation of diffraction patterns from the (a) round and (b) bar occulters, and the illuminated regions of the JWST pupil transmitted through holes in the Lyot stops designed for the (c) round and (d) bar occulters.

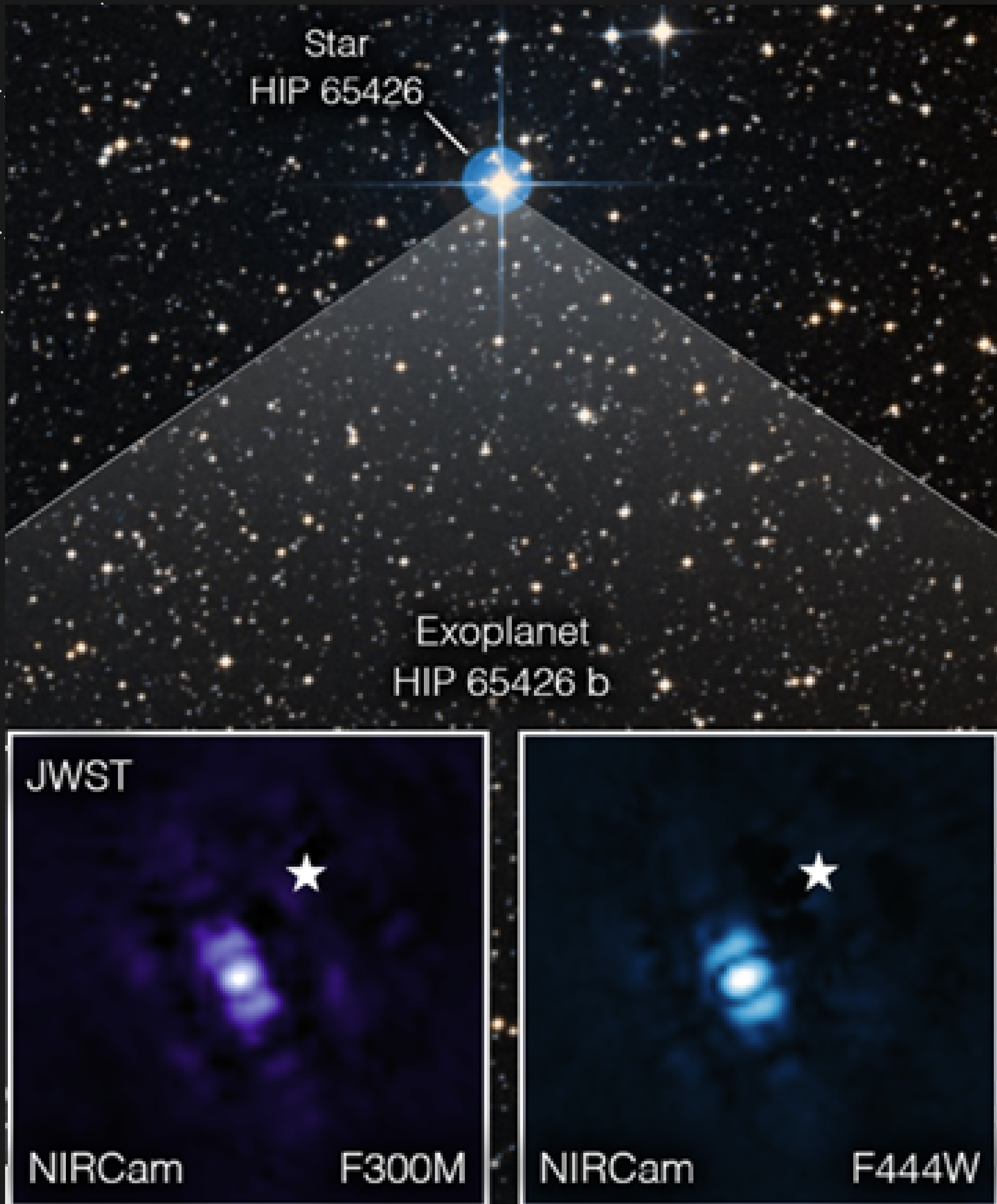

Figure 6. Images of the exoplanet HIP 65426 b from NIRCam at 3.00um (purple) and 4.44 um (blue). The small white star in each image marks the location of the host star HIP 65426, which has been subtracted using the coronagraphs and image processing. The bar shapes in the NIRCam images are artifacts of the bar Lyot stops.

About the author: *Catalin Florea is a senior research scientist at Lockheed Martin and an active OF&T group member*

[1] https://jwst.nasa.gov/content/observatory/instruments/nircam.html.
[2] All images provided in this article have been obtained from NASA's online, public-access documentation.
[3] https://umbra.nascom.nasa.gov/spartan/coronagraphs.html
[4] https://images.cnrs.fr/video/1348
[5]https://jwst-docs.stsci.edu/jwst-near-infrared-camera/nircam-instrumentation/nircam-coronagraphic-occulting-masks-and-lyot-stops
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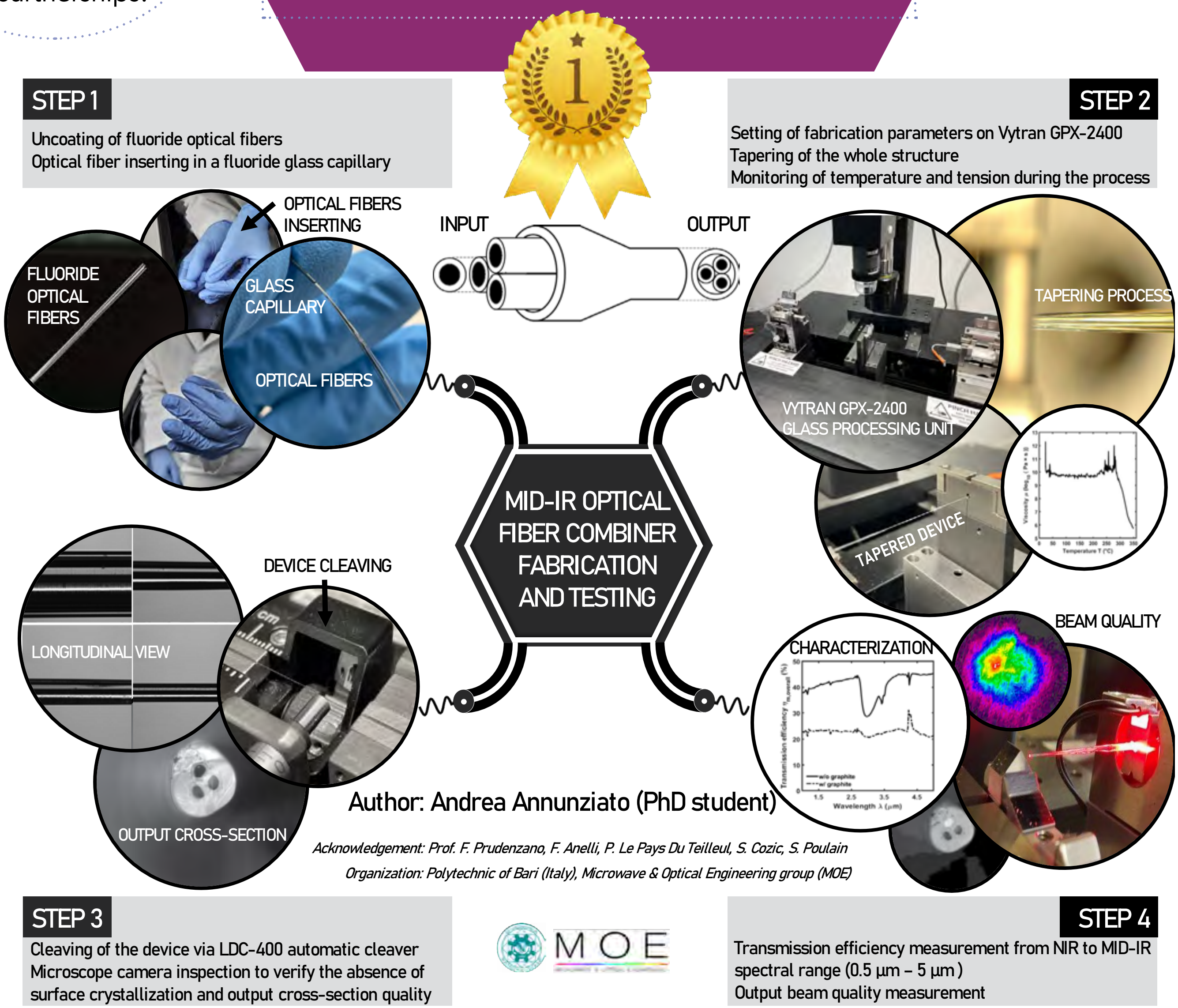
[7]https://jwst-docs.stsci.edu/jwst-near-infrared-camera/nircam-operations/nircam-target-acquisition/nircam-coronagraphic-target-acquisition
[8]https://blogs.nasa.gov/webb/2022/09/01/nasas-webb-takes-its-first-ever-direct-image-of-distant-world/

We are delighted to share details about the successful completion of the Infoptica Challenge, an initiative by Optica that attempts to merge the realms of art and science to further the global education in optics and photonics. This event was designed to make complex scientific concepts, centred on optics and photonics, accessible and engaging through visually appealing, easy to follow infographics. The challenge showcased the creativity of the participants and contributed to the creation of a pertinent infographic database for educational and outreach purposes. This event underscores Optica's commitment to advancing the field through innovative and inclusive educational initiatives.

We are proud to spotlight the winners and their exceptional work in this edition, celebrating both their achievements and their active involvement within the Optica Fabrication & Testing group. This year, in addition to honoring traditional winners meticulously selected by our judges, we embraced the voice of the public by introducing the People's Choice Award. This new accolade allowed us to gauge and honor the entries that resonated most with the broader community, enriching the competition with diverse perspectives and engagement.

Interested in collaborating on student-centric projects? Reach out to Demi at debasmita.banerjee@ucf.edu to discuss potential partnerships.

Infoptica



Reference: A. Annunziato et al., "Fused optical fiber combiner based on indium fluoride glass: perspectives for mid-IR applications," Opt. Express 30, 44160-44174 (2022)

Patterned Metasurfaces for All Optical Communication

Ajinkya Bharat Palwe*, Gaurav Pratap Singh, Sweta Rani, Arun Jaiswal, Shobha Shukla, Sumit Saxena

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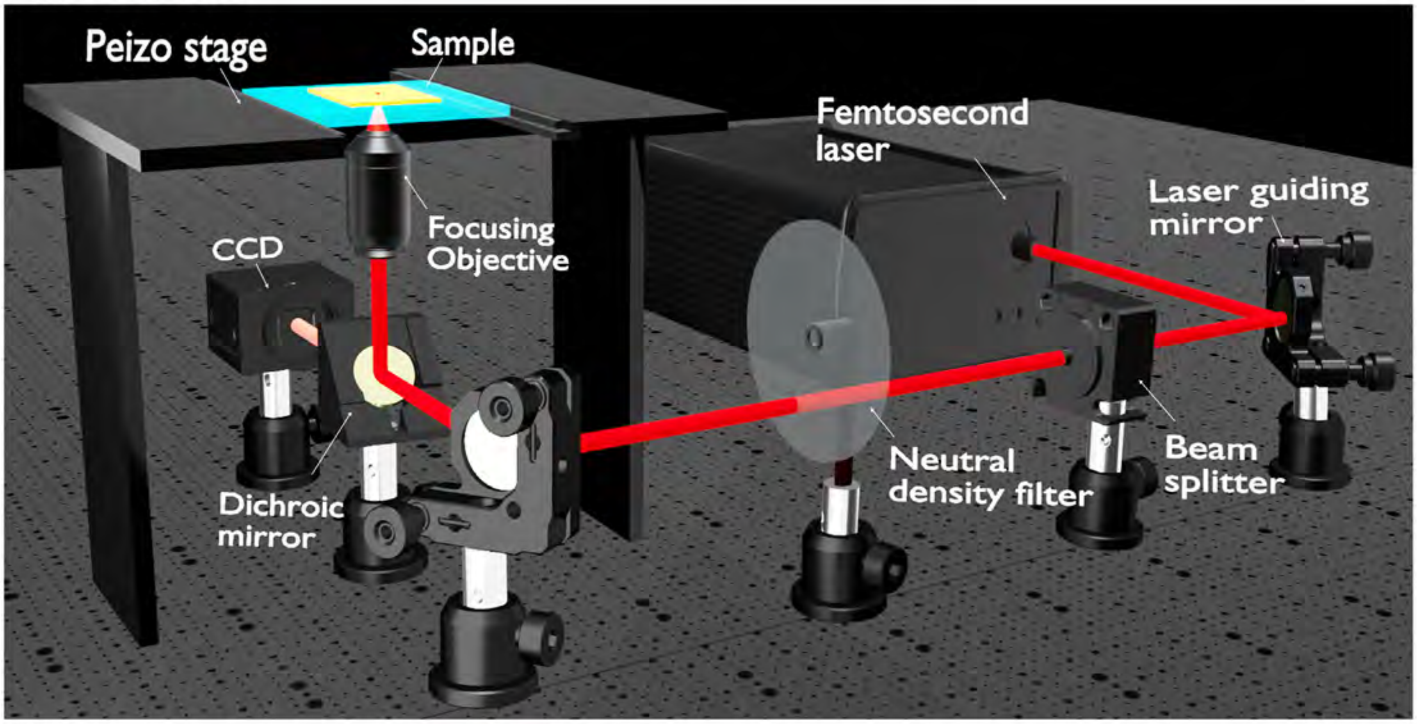
Nanostructure Engineering and Modelling Laboratory, Department of Metallurgical Engineering and Materials Science,

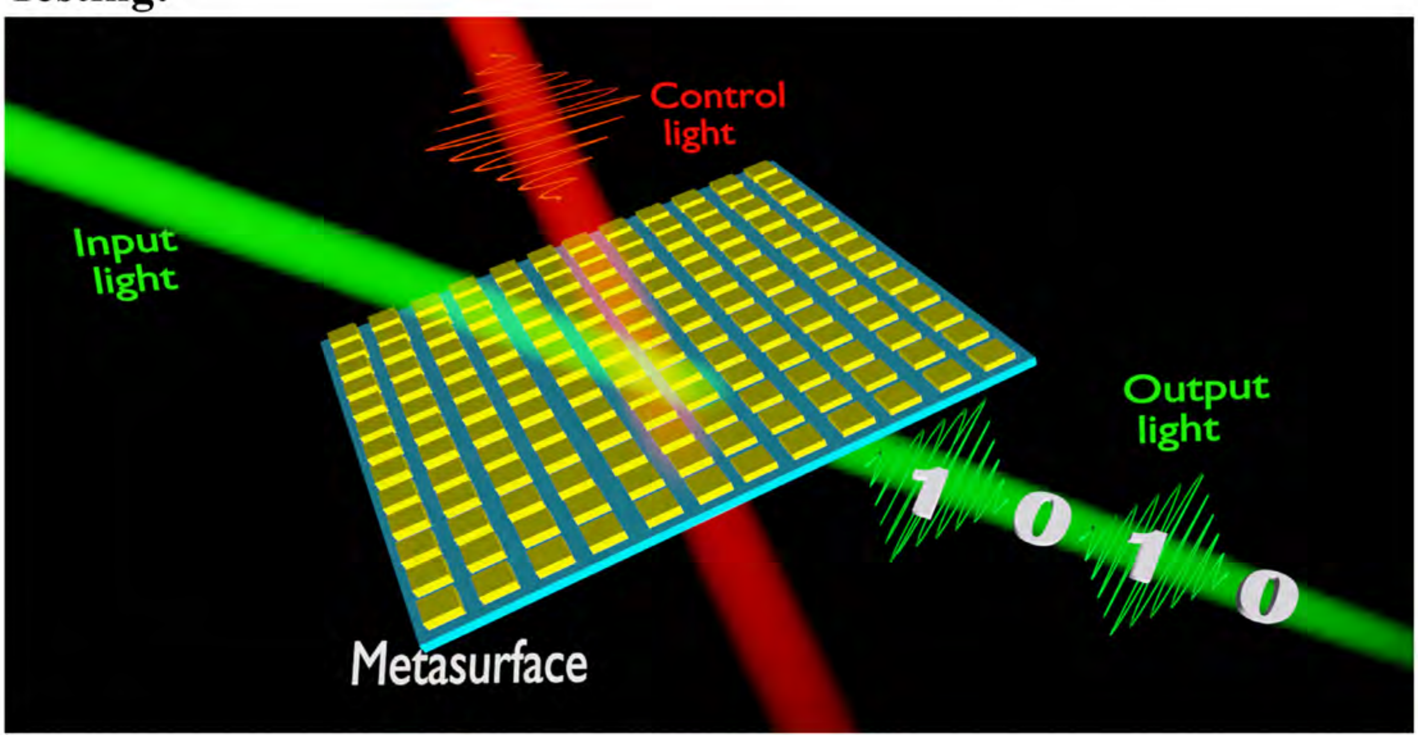
Indian Institute of Technology Bombay, Mumbai-400076

People's Choice Award

Fabrication:



Testing:



Proposal of a Convenient Method for Testing Optical Alignment Status

The Application of Deflectometry and Sine Condition Test in One Setup

Author: Hyemin Yoo
Organization: Wyant College of Optical Sciences, University of Arizona

What do we measure for an Optical Alignment Test?

-We must know how ***wavefronts vary over multiple field points*** of the system-under-test.
-Power, spherical, constant coma, linearly field-dependent astigmatism, and linearly field-dependent focus should be minimized to get a ***good image quality over the field of view***.

Why is it HARD to do Optical Alignment?

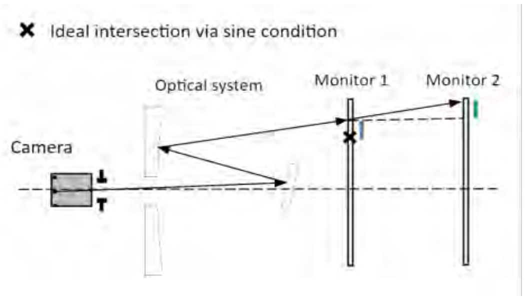
-The test instrument should be moved to multiple field points to distinguish on-axis and off-axis wavefronts.
-The ***interferometer method*** requires reference optics such as a perfect sphere or flat which can be expensive.
-***Deflectometry*** can be used, but it requires high-precision geometrical calibration.

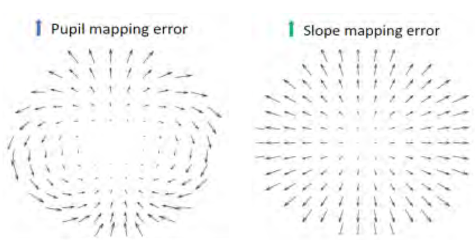
"The *Sine Condition Test Adopted Deflectometry* can SOLVE these Problems"

NO Reference Optics | **NO Geometrical Calibration** | **NO Need to Move Over the Field**

Merging two different metrology systems remove the degeneracy between off-axis and on-axis aberrations

How Does it Work?





<Monitor 1> <Monitor 2>

-We need a deflectometry setup, a camera, and a monitor. Place the optical system in the middle.

-Note that ***deflectometry measures ray intersections*** at two monitor positions.

-***The Sine Condition defines the reference*** in the system. Therefore, no need for geometrical calibration.

-Calculate ***ideal intersections at the first monitor plane via the Sine Condition***.

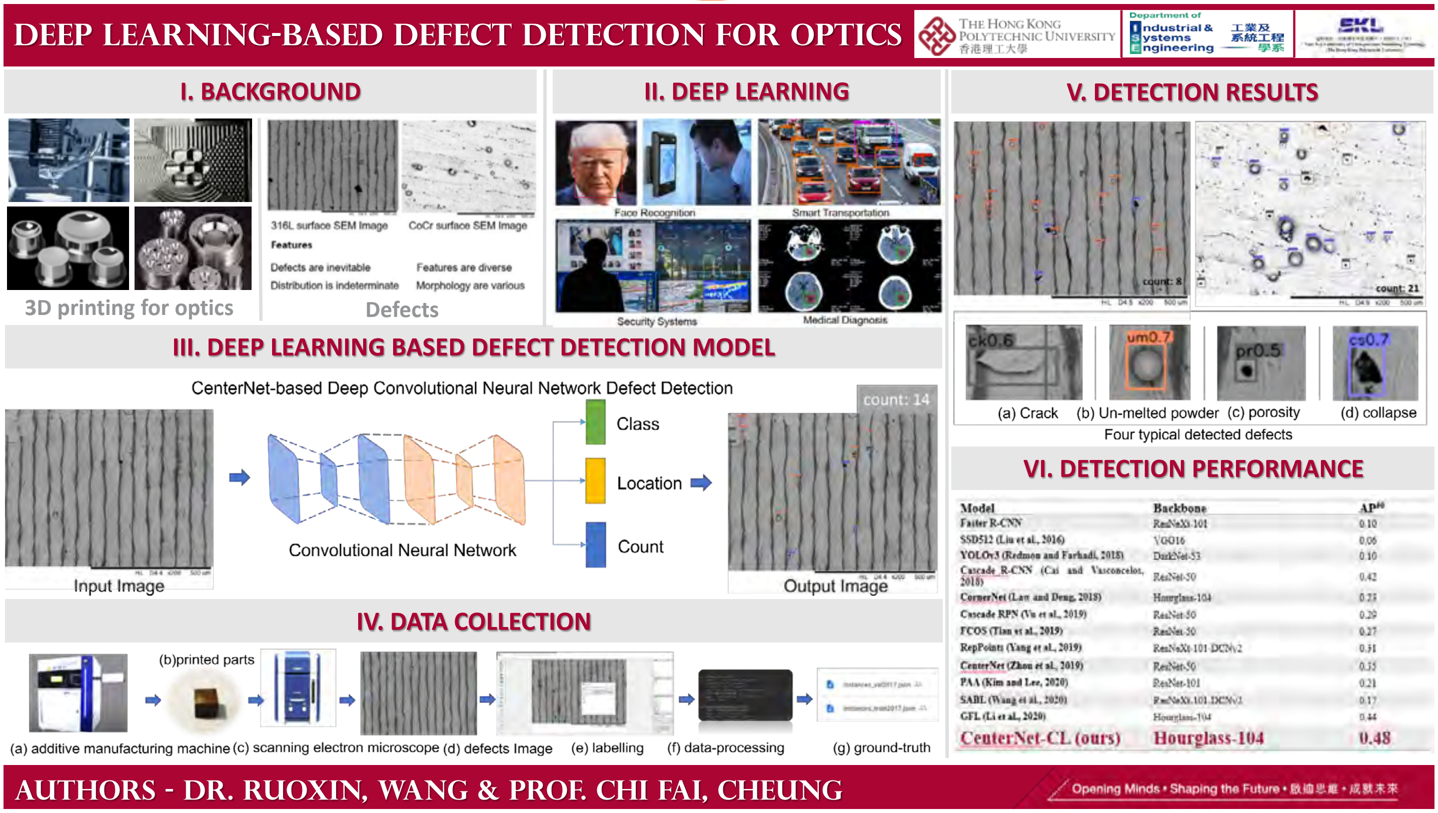
-The vector fields of differences in ray intersections contain information about aberrations related to alignment status.

-***The pupil mapping error*** indicates aberrations at off-axis field points, while ***the slope mapping error*** indicates on-axis aberrations.

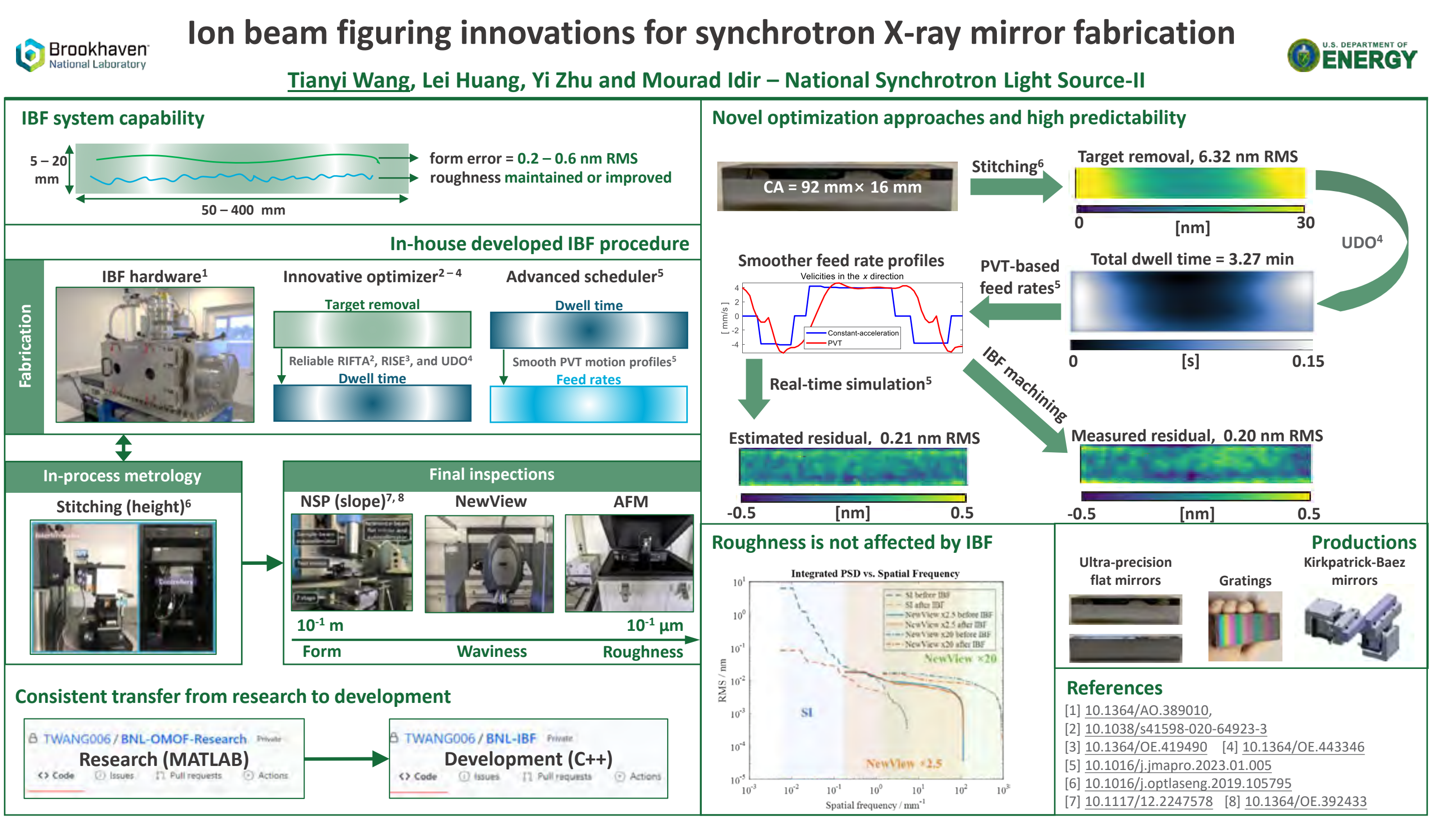
-For more information, visit the following link https://doi.org/10.1364/AO.475915.

"We can test the Optical Alignment Status in a CONVENIENT and CHEAPER way with the Implementation of the NEW Alignment Method!!"

Infooptica



Special Mention



Infoptical

As we close this edition of our newsletter, we want to extend a heartfelt invitation for you to engage and collaborate with us. Our team at the Optical Fabrication and Testing Group is constantly exploring new avenues for contribution, driven by a shared commitment to excellence and innovation in the field of optics. We are incredibly proud of our team's achievements and the impactful events we've shared with you, which not only demonstrate our passion but also our dedication to advancing the global understanding and application of optics.

To further amplify our efforts and extend our reach, we are actively seeking extramural funding and sponsorship. Many of our initiatives, as described in this newsletter, have the potential to contribute significantly to a broader audience and make a positive impact on the world. We believe that with additional support, we can continue to organize and participate in events that not only spread knowledge about optics but also inspire and engage the community at large.

Your contribution can be a part of this meaningful journey, helping us to illuminate minds and drive innovation in optics. We invite individuals and organizations interested in supporting our mission to join our community. Together, we can make a lasting difference, fostering a brighter future through the power of optics and photonics.

Stay tuned for more information on our upcoming events. We are committed to engaging and enlightening you with the latest developments and innovations in optics. Your suggestions, comments, or ideas are invaluable to us, and we encourage you to share them.

Please contact OF&T Chair, Dr. Christopher Holmes, University of Southampton, at Christopher.holmes@southampton.ac.uk with any feedback or proposals. For inquiries about advertisement space, please reach out to us.

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