

Figure 1 | Sketch of reflection without lateral and angular deviation (black arrows), and with lateral shift D and angular deviation $\theta_{\text{out}} - \theta_{\text{in}}$ (red arrows).

angle of incidence for an interface between air and glass (which have refractive indices n of 1 and 1.5 respectively).

This dependence of the reflectivity can be extreme near the Brewster angle, because light polarized parallel to the plane of incidence experiences a zero in reflection (Fig. 2). For instance, varying the angle of incidence from $\theta_{\text{in}} = 80^\circ$ to $\theta_{\text{in}} = 90^\circ$ results in an increase in the reflection (intensity) of about 63%. In this example, which is in the high-reflection regime, the intensity variation gives preference to a shift of the beam direction towards 90° . It is the other regime of low reflection and high transmission, which occurs for smaller angles, that is probed by Merano *et al.* for the first time.

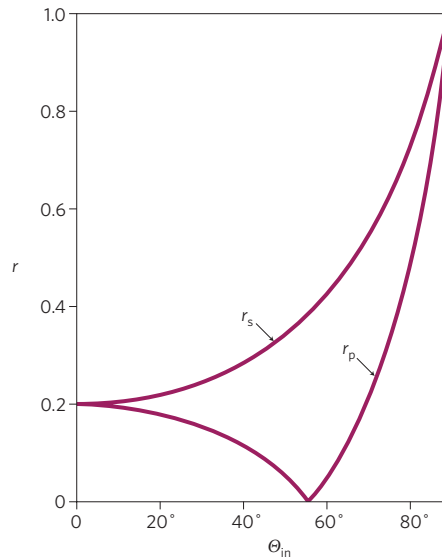


Figure 2 | Functions of amplitude reflectivity versus angle of incidence θ_{in} of incidence for light polarized parallel, r_s , and perpendicular, r_p , to the plane of incidence. The values are for reflection at a boundary between air with refractive index $n_1 = 1$ and glass with refractive index $n_2 = 1.5$. The reflected intensity is given by $R = r_s^2 + r_p^2$.

A previous experimental study⁷ investigated the angular deviations at microwave frequencies, but in this issue the effect has been investigated with extremely high precision at near-infrared wavelength. In the experiment by Merano *et al.*, the beams were reflected by an air–glass interface and measured using a calibrated split detector at a wavelength of 820 nm

and a beam width of less than 10 mm at the collimating objective in front of the light-emitting diode. Beam waists of between 34 and 95 μm were studied. To measure the effect (of the order of 10^{-2} to 10^{-5} radians) accurately, a lateral resolution of just nanometres and an angular resolution of less than a milliradian were required and achieved. Such precise quantitative results were possible only after suppressing various parasitic effects.

The experimental procedure has shown that large far-field beam displacements can occur. The experimental results are supported by a straightforward theory that considers the intensity of plane-wave components of the beam, rather than treating the beam as a single ray. By quantitatively taking the effect into account in any reflection process, it should be possible to improve the level of uncertainty in experimental measurements of angles in the future. \square

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RESEARCH AND EDUCATION

Committed to optics

The creation of institutes dedicated to combining photonics research and education under one roof is helping the field to thrive. The latest country to embrace the idea is Australia, with the opening of a new institute in Sydney.

Rachel Won

Recent years have witnessed the emergence of institutes devoted entirely to pursuing photonics education and research, in clear recognition of the growing importance of the field. The latest to appear on the scene, the Institute of Photonics and Optical Science (IPOS), has just been launched at the University of Sydney and is the first and only one of its kind in Australia.

The institute was approved by the university in 2007, formally established in

2008 with Benjamin Eggleton as the Director and officially launched on 23 April 2009. It links research and postgraduate teaching programmes across the faculties of Science and Engineering at the University of Sydney to create a world-class centre with more than 30 academic and research staff and 40 postgraduate students. It consolidates a number of strong existing photonics research groups at the University of Sydney, such as the Centre for Ultrahigh-bandwidth

Devices for Optical Systems (CUDOS), the former Optical Fibre Technology Centre (OFTC), the Fibre Optics Laboratory, the Astrophotonics group and other groups covering quantum photonics, biophotonics and lasers.

So what are the driving forces for creating such dedicated institutes? The rapid growth in optics research is one of the most prominent, spanning from the development of lasers and waveguiding of light through to

the manipulation of light by subwavelength structures, and the phenomena of slow and superluminal light. At a more commercial level, photonics is also the underlying technology of the Internet with applications in telecommunications, sensing, biomedical uses, astronomy and robotics. Not only that, it is also an important technology for 'green' products, such as solar cells and light-emitting diodes, that help to save or generate energy and improve our quality of life. In light of the impact of optical sciences on the way we live and communicate, many people consider it essential to draw together research and teaching in photonics and optics.

In fact, this point has already been acted on. Back in 1929, the Institute of Optics was launched at the University of Rochester, representing the very first institute to offer an education programme in optics in the United States. Thereafter, other schools, such as the College of Optical Sciences at the University of Arizona and CREOL, the College of Optics and Photonics at the University of Central Florida, were also established. Recent examples in Europe include the Karlsruhe School of Optics and Photonics at the Universität Karlsruhe, which was established in 2006, and the Abbe School of Photonics in Friedrich-Schiller-Universität Jena, established in 2008. The new addition of IPOS reflects yet again the significance of optical sciences in society.

"IPOS is to Australia what the Institute of Optics of the University of Rochester, the College of Optical Sciences of the University of Arizona, and CREOL, the College of Optics and Photonics, are to the USA, as a real point of focus for photonics," said Alan Willner from the



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IPOS is temporarily headquartered in the School of Physics, University of Sydney, while waiting for its new home.

University of Southern California, who was the keynote speaker at the launch symposium of IPOS. "Having photonics schools or institutes is imperative as they bring together focus and excellence in photonics under one roof," Willner emphasized.

Building on a substantial track record of research excellence at the University of Sydney, IPOS has the mission of providing Australia with the innovation, the scientists and the engineers to create

and maintain a position of world leadership in the photonics community and industry. According to Eggleton, the director of IPOS as well as the research director of CUDOS, the short-term goals are to consolidate and unify the photonics and optics groups in the University of Sydney into a single organization, launch a new Masters degree in photonics in 2010, establish new photonics laboratories associated with the relocation of staff from the Optical Fibre Technology Centre on the main campus, and build a new home for IPOS (which currently has its headquarters in the School of Physics) over the next 2–3 years.

"The budget based on the research income across the different research groups is approximately four million Australian dollars per annum," revealed Eggleton. He envisages that the budget will increase as the programme grows through the Masters degree, and so will the staff numbers and funding after the opening of the new building.

"In the long run, we aim to create a visible and high-profile flagship research and education institute for Sydney, Australia and the Asia-Pacific region," said Eggleton. The combination of research and teaching of IPOS in breadth and depth of photonics is unique in the Southern Hemisphere, and the institute will be a centre of excellence in the Asia-Pacific region, he added. "Our aim is to grow IPOS into a world-leading research and education institute."



IPOS/UNIVERSITY OF SYDNEY

The official opening of IPOS.

The institute offers three types of education programme, namely a Graduate Diploma and a Masters degree in Photonics and Optical Science, and a PhD programme. The Graduate Diploma programme provides two semesters of coursework, and the Masters degree is a three-semester full-time programme. The latter combines coursework with the opportunity to conduct original research, providing students with a strong mix of high-level conceptual understanding and practical training. The PhD programme is a research-only programme. Diverse research activities can be found in the institute, in areas such as microfluidics, slow-light generation, plasmonics, supercontinuum generation, microstructured optical fibre, nonlinear optical materials, fibre lasers and astrophotonics.

When asked about the impact of IPOS on CUDOS, Eggleton explained that CUDOS is a multi-university research Centre of Excellence (COE) funded by the Australian Research Council from 2003 to 2010, whereas IPOS will be a research and education institute of the University of Sydney. Both will run in parallel and feed off each other. The COE establishes a critical research mass, a research focus and collaborations within Australia. “The Institute is a more permanent vehicle for research, teaching and infrastructure,” Eggleton told *Nature Photonics*. “Many of the real challenges are ahead of us as we grow and aim to become a world-leading institute.”

“What they are doing in IPOS is a model for the rest of the world, with the government and research leading

individuals getting together,” said Willner, adding that he hoped to see more examples following a similar path. He also pointed out that more direct involvement from the federal government in the setting up of photonics schools and institutes in the United States is appreciated.

All in all, it is encouraging to see the emergence of new schools and institutes of photonics. It signifies the importance of photonics and optics in the community. The approach should not only be a model for the photonics community, but could also be a generic model for new and emerging sciences and could be used to set ‘best practice’ for other disciplines. □

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