Faraday Partnerships

smartmoves
The Newsletter for the Smart Optics Faraday Partnership

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Smart Optics Continues!

The Smart Optics Faraday Partnership was launched in June 2001 with support from the **Department of Trade and Industry** to fund the day-to-day running of an active network promoting contact between users of and developers of advanced optical technologies. The partnership was invited by the **DTI** to submit a case for continuing support, and this opportunity was used to review our progress and look forward for the next 3 years and beyond—emphasising a broadening of scope and increasing exploitation.

The formal review took place in May 2004, and was strongly supported by our co-sponsors **PPARC** and **EPSRC**. Our case was approved and the partnership has been funded for a further three years at the maximum possible rate available under the Faraday scheme.

Highlights:
£12.1M leveraged research funding (including £3M from industry)
101 Faraday Partners of which 34% are involved in 18 projects
67% of Partners are pursuing new opportunities with other partners
58% have signed non-disclosure agreements with other partners
10 Faraday Associates receiving industry-relevant training

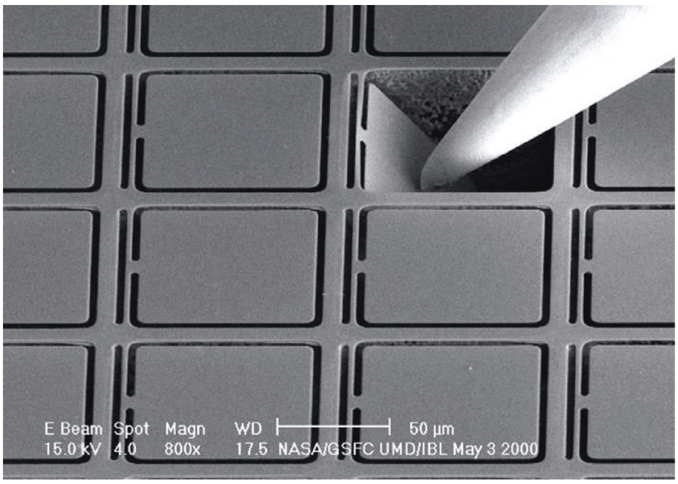
Networking at a Smart Optics Forum

By the spring of 2004, Smart Optics has generated a thriving network of people in optics-related businesses and academic groups, with a shared enthusiasm for commercialising innovation in optics. Many of these groups are now jointly developing new products and processes with very large commercial potential, some of which are close to reaching market. Of those closest to market, 5 have filed patents and/or built working prototypes, and are in the process of drafting business plans and generating internal proposals for funding the development of market-ready products. We expect that these and others in our growing portfolio will generate £12M commercial turnover by 2007 and £45M by 2010.

Smart Optics has often been in the vanguard of best practice and we were commended at our review for our open and inclusive methods, and the measurable impact that we have had in giving a form and focus for the development of advanced optics in the UK. A report summarising our activities for the first three years and plans for the next three is being prepared and will be available on the Smart Optics web site, **www.smartoptics.org**

Smart Focal Planes for Europe

Smart Optics is pleased to announce the successful funding and commencement of the Framework 6 Joint Research Activity on Smart Focal Planes, part of the OPTICON *Integrated Infrastructure Initiative*. The total budget for this activity over three years is €3.4M with €1.6M being contributed by the partners and the remainder from the European Commission. The programme is seen as an important part of underpinning the UK's technology development strategy for future involvement in Extremely Large Telescope design and manufacture. The UK ATC's programme coordinator for Smart Focal Planes is Dr Callum Norrie: "This project will evaluate, develop and prototype European technologies for Smart Focal Planes and will build up and strengthen a network of expertise in Europe. We are particularly keen to engage industry—particularly SMEs—in the development of technologies which can be batch produced to enable future complex instruments to be built economically".



NASA/Goddard Space Flight Center, USA

Reconfigurable MOEMS shutter array

Technologies to be developed include: Novel manufacturing techniques for Image Slicers; Cryogenic Beam Manipulators for multi-object spectroscopy; Reconfigurable Slit Mechanisms; Fibre coupled Integral Field spectrographs in the IR; MOEMS for programmable cryogenic slit masks. Further information can be found from issue 3 of the Smart Optics newsletter or by contacting Callum. **c.norrie@roe.ac.uk**

CONTENTS:

Adaptive Optics for All

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Adaptive Optics (AO) is most well known for its success in the field of astronomy where near diffraction limited performance has been achieved from terrestrial telescopes—but AO is also solving problems in retinal imaging, vision, free-space communications, laser systems and more. So far, each user group is originating their own system from scratch, with obvious expertise requirements and impact on cost and time. Our consortium is working on a low-cost, high performance plug-and-play toolkit for AO which will provide capability for all of the areas mentioned and more—moving adaptive optics out of the laboratory and into industrial and medical applications.

The growth of adaptive optics

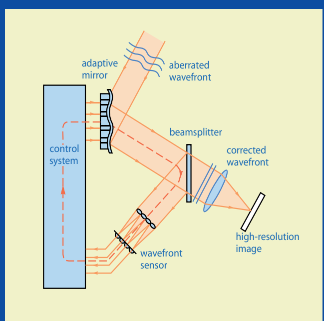
There are situations where conventional optical systems are limited by the dynamic nature of the problem that they are trying to solve. An optical system that can adjust itself dynamically to cope with, for example, changing optical aberrations is needed – in other words an adaptive optics system. A good example is in ground-based astronomy where the dynamic aberrations due to turbulence in the Earth's atmosphere are compensated for in real time with adaptive optics. The results are impressive, with enormous improvements in resolution – recovering close to diffraction limited performance.[1]

Though initially developed for compensating the effects of atmospheric turbulence in vertical paths for telescopes, adaptive optics is now employed in a range of fields: from retinal imaging to high power lasers.

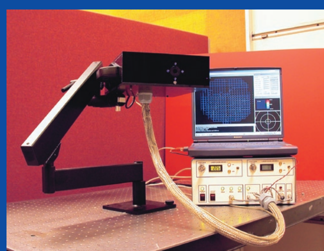
Adaptive optics technology with the use of wavefront sensors has recently been applied to the eye, for laser refractive surgery and for high resolution retinal imaging. A narrow optical beam is directed into the eye to form a spot on the retina and the reflected light is used to measure the aberrations that degrade the optical quality of the eye. There are a number of ways this information can be used: improving the resolution of retinal images using deconvolution techniques or guiding corneal laser ablation for refractive surgery or spectacle prescription. Alternatively, the measurements can be used in real time to correct the aberrations with an adaptive mirror. In this case, the performance of retinal imaging instruments such as fundus cameras and laser scanning ophthalmoscopes (LSO) can be pushed to resolve individual photoreceptors.[2]

Adaptive optics

An adaptive optics system consists of three elements: a wavefront sensor, a wavefront corrector and a control system. The wavefront sensor—for example an interferometer— provides a measure of the time-varying aberrations that need to be corrected. The wavefront corrector, which is typically a deformable mirror or maybe a LC device, is adjusted to compensate the measured aberration. Finally a control system is required to link the sensor and corrector.



The example above is a closed-loop configuration since the wavefront sensor measures the residual wavefront error after correction by the mirror.



An experimental compact ophthalmic wavefront sensor developed by the Photonics Group at Imperial College London for the study of the optical quality of the eye of premature babies.

The method is now also being applied to new techniques such as optical coherence tomography, were it offers improvements in signal and resolution.

Adaptive optics may also be useful for remote sensing and free-space line of sight communications channels. Here, an optical beam propagated through the atmosphere to measure environmental parameters or transmit information, for example, is disrupted by atmospheric turbulence. This results in intensity fade or signal loss. The effects are especially bad near the ground where turbulence effects are strongest. In these situations the adaptive optics system has to operate at high speed – with correction bandwidths in the kHz range.

The requirements for each of these applications are very diverse – e.g., for the eye, low-light levels and eye-safety are of paramount importance, whereas for atmospheric laser propagation, high-speed wavefront correction, and the ability to operate with intensity scintillation are important. The types and strengths of the aberrations to be corrected vary considerably between applications. So far, each research laboratory or company has had to develop their own AO system, often using some commercially available components, such as deformable mirrors or spatial light modulators. Considerable effort is often spent re-developing and understanding the intricacies and subtleties of the adaptive optics before the real work of applying it to the particular application starts.

To address this problem, we are developing a public interface specification for a complete modular adaptive optics system, and a set of exemplar low-cost components, with modules for wavefront sensing, correction and control. Users can construct a system with this set of modules or use a subset: either way it is our aim to massively simplify the process in designing and implementing AO systems.

Plug-and-play adaptive optics

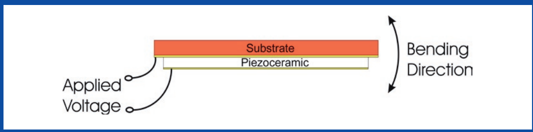
There are a number of different types of wavefront sensor, namely, Shack-Hartmann, curvature, pyramid, and lateral and radial shearing interferometers, the choice and design of which can be optimised for the particular application. The most widely used and well understood is the Shack-Hartmann, consisting of a lenslet array in front of an image detector. It is also one of the most versatile and as such will be the primary wavefront sensor module for the toolkit (with different detector options for different sensitivity/speed requirements).

There are also several different wavefront corrector technologies available covering a broad range in terms of specification and cost. In particular, spatial light modulators, membrane mirrors, MEMS mirrors and bimorph mirrors have all been widely utilised. Bimorph mirrors offer high performance with large deformation strokes—particularly important in applications such as retinal imaging. Bimorph mirrors and drivers will form part of the toolkit. The flexibility of the bimorph technology will allow a range of mirror configurations to be offered for different types of applications.

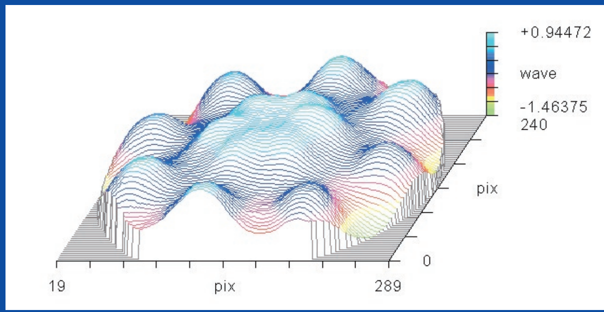
The core of the AO toolkit is the control unit, which will be a stand-alone

Bimorph Mirrors

The bimorph mirror in its simplest and most widely used form consists of a piezoceramic disc bonded to a rigid substrate. The figure below shows a schematic cross section of such a device.

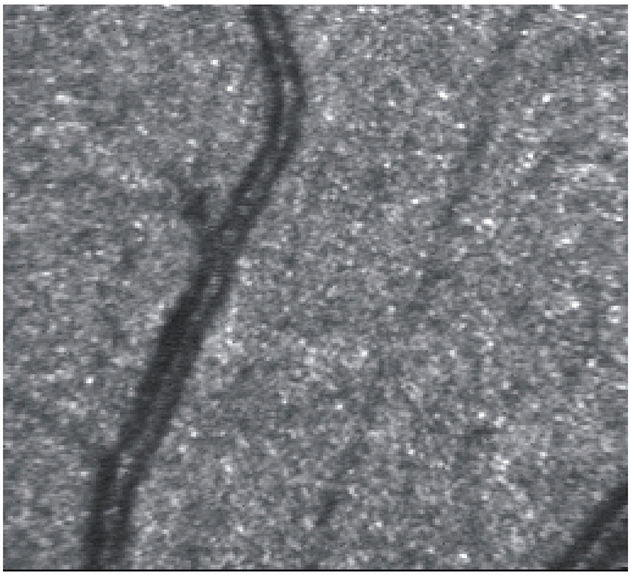


Application of a voltage across the piezoceramic layer produces an in-plane expansion/contraction of this layer causing the mirror to bend or flex in the same way as a bimetallic strip when heat is applied. Compared to other deformable mirror technologies such as membrane mirrors, bimorph mirror fabrication uses lower cost components and involves fewer and much simpler processes. The finished product is physically far more robust and the specification can be tailored to meet particular requirements by making simple changes to the fabrication process. Thus the bimorph mirror design can be optimised for a particular application with minimal impact on cost, yield or reliability. The design parameters such as pupil size and electrode layout are determined by consideration of the wavefront correction required for the specific application together with the boundary conditions imposed by the mounting scheme.



Surface plot from a 45-channel bimorph mirror, manufactured at Imperial College, with the electrodes biased alternately +ve or –ve in the 1st and 3rd rings.

system containing the electronics to read and process data from the wavefront sensor and calculate the signals to send to the deformable mirror (although the same output signals can be used to drive other technologies such as spatial light modulators). By avoiding the limitations of general purpose PC platforms, this approach will offer significant performance advantages – vital for high-speed atmospheric correction.



High resolution retinal image acquired with a confocal scanning laser ophthalmoscope showing photoreceptors.

At the heart of the toolkit approach is an open, freely available specification. So although the toolkit will be complete, it will also allow each user to pick and choose from the modules, and facilitate the integration of outside components if required. To achieve the maximum value for this work we are making the information about the toolkit and its specifications available in the open-source style, and information about the work can be found here: **www.imperial.ac.uk/research/photonics/research/topics/aotoolkit.htm** We welcome all suggestions for this project and are very interested to capture requirements that we may not be aware of.

The AO Toolkit Partners

This project is supported by Smart Optics, and brings together expertise from different fields with a common interest in AO: the Photonics Group at Imperial College London, BAE Systems, Davin Optronics, OptiSense and Smart Optics.

Acknowledgements

Gordon Kennedy, Jonathan Brooks for images

Links

[1] **http://caao.as.arizona.edu/**
[2] **http://www.opt.uh.edu/research/aroorda/**
[3] **http://research.opt.indiana.edu/Labs/AdaptiveOptics/default.html**

Diary

Details of these events are available on our website

21st - 25th June 2004 - SPIE Astronomical Telescopes & Instrumentation 2004

2nd July 2004 - Materials for Displays, Institute of Physics, London

8th July 2004 - Business - University Research Collaborations, Cranfield University

15th July 2004 - Smart Optics Project Review Forum, UCL

19th - 25th July 2004 - Farnborough Air Show

13th - 17th September 2004 - SPIE Remote Sensing Conference, Spain

16th - 17th September, 2004 - Murcia Summer School, Spain

18th - 21st October 2004 - Topical Meeting on Optoinformatics, Russia

New Smart Optics Faraday Partners

Edinburgh University, Adaptive Optics; **Gray Cancer Institute**, Radiation Physics; **King's College, London**, Laser-Generated Plasmas; **Kingston University**, Development of Optical Sensors & Fibre Optic Sensors; **Psi-Tran Ltd**, Nanotechnology & Space Systems.

Jobs Portal

The Smart Optics website has a 'jobs portal' where we can place job vacancies for positions related to smart optics R&D, and also place CVs of Faraday Associates looking for work. This portal is available for use by all members of the Smart Optics network. **www.smartoptics.org/recruitment.asp**

Smart Optics Student Profile—Christopher King

I spent 4 years as an undergraduate at the University of Bristol studying physics. My final year research was concerned with the amplification of low voltage signals using a cryo-cooled transformer, research concerned with improving a condensed matter experiment in the labs.

Vacation employment in the electrical engineering industry whilst at Bristol provided me with real-world experience and a full-time job for three years after graduation. I was employed to produce electrical designs for factories, hospitals, schools and other industrial installations for many clients, including Lancaster NHS trust, Manchester Science Park and Technopark. Whilst in this employment, aside from learning many things about industry, I came to realise that it was not really the road I wanted to follow. I hankered after getting back onto physics after my spell as an electrical engineer. A swift decision followed and I enrolled on a taught M.Sc. course at UCL in *Spacecraft Technology and Satellite Communications*. My research project involved investigating thin diamond films for possible application in the space environment. The M.Sc. was something of a risk as I was self funded for the year living in the most expensive city in the country.

Christopher King

During the M.Sc., Dr Steve Welch advised me to apply for the Faraday CASE Ph.D. studentship on offer at the Optical Science Laboratory at University College London, for work on the Optical Manipulation and Metrology project. I am now halfway through my first year of this and enjoying it immensely. We are aiming introduce a new paradigm of metrology for the next generation of telescope optics and for free-form surfaces.

What is most pleasing about this work is the industrial and academic collaboration that is taking place to produce a tangible asset at the end. Smart Optics has been excellent in providing business oriented courses for the associates and I expect the Faraday Associateship to add extra weight to the Ph.D. I have learned much about how to take university research and turn it into business assets and I feel that this will be extremely valuable, whether I remain in academia or move to industry. Christopher W. King.

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Technology Translation

The Smart Optics Faraday Partnership has a number of 'technology translators'—business literate scientists/engineers whose tasks include supporting projects from before inception (uncovering needs) to after completion (exploitation). They do this by spending time finding out who's got what and who needs what, and then finding ways of matching the two together. Most Smart Optics supported projects comprise teams matching up a science or technology to a commercial/industrial requirement, and can include help from Smart Optics in identifying suitable funding support, be it from research council, private sector or DTI. If you have a technology of interest to the Smart Optics sector, or an industrial or commercial need that you think might be solved by Smart Optics or a supporting technology, or already have a project in mind that the Partnership might be able to help with, then please contact one of these technology translators in the first instance:

Jon Holmes—based at Sira Electro-Optics, Kent
Email: jon.holmes@siraeo.co.uk, Telephone: 020 8468 1770

Steve Welch—based at the Mullard Space Science Laboratory, London & Surrey
Email: sjw@mssl.ucl.ac.uk, Telephone: 01483 204195

Mark Bonnar—based at the UK Astronomy Technology Centre, Edinburgh
Email: mpb@roe.ac.uk, Telephone: 0131 668 8434

Current Projects & Threads

If you have an interest in any of these currently active projects and opportunities, then please contact the supporting technology translator in the first instance:

Jon: *Ophthalmoscope*—a hand held device for ophthalmology; ***Smart Marking***—use of high power lasers and SLM generated kinoforms to perform single-flash marking; ***ALFONSO***—devices for free-space optical communications.

Steve: *Toolkit for AO*—building a set of low-cost universal AO building blocks; ***CF Mirrors***—exploring a new method for making static and deformable mirrors out of carbon-fibre; ***Adaptable Imaging Camera***—building compound lens systems using modally addressed liquid crystal devices; ***Smart X-ray Optics***—AO for X-ray applications; ***Thermochromic Surfaces***—passively variable emisivity; ***Modulated Light Cameras***.

Mark: *POPS*—developing cryogenic optical pick-off arms and supporting robotics; ***Optical Metrology and Manipulation***—using wavefront sensors as a tool for extreme metrology; ***Large Optics Manufacturing Study***—preparing the UK to compete for the production of large optics; ***EZ-headset***—exploiting new displays in helmet mounted systems; ***Tunable fibre optic sensors***—environmental & structural monitoring; ***OPTICON***—smart focal planes; ***ATRIUM***—laser scanning opthalmology.

WANTED!

Potential consortium partners and industrial contractors working in MOEMS… please contact Colin Cunningham at UK ATC if you are interested to discuss how you can get involved in prototyping novel devices. **crc@roe.ac.uk**