CAPE

Technology from Science

Centre for Advanced Photonics and Electronics (CAPE)

UNIVERSITY OF CAMBRIDGE

UNIVERSITY OF CAMBRIDGE

CAPE Partners and former Partners

HALEON

BIACD

中国中车 CRRC

HUAWEI

JAGUAR LAND ROVER

ADVANCE NANOTECH

Perfecting the Art of Electronics ALPS

Disney Research

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ERICSSON

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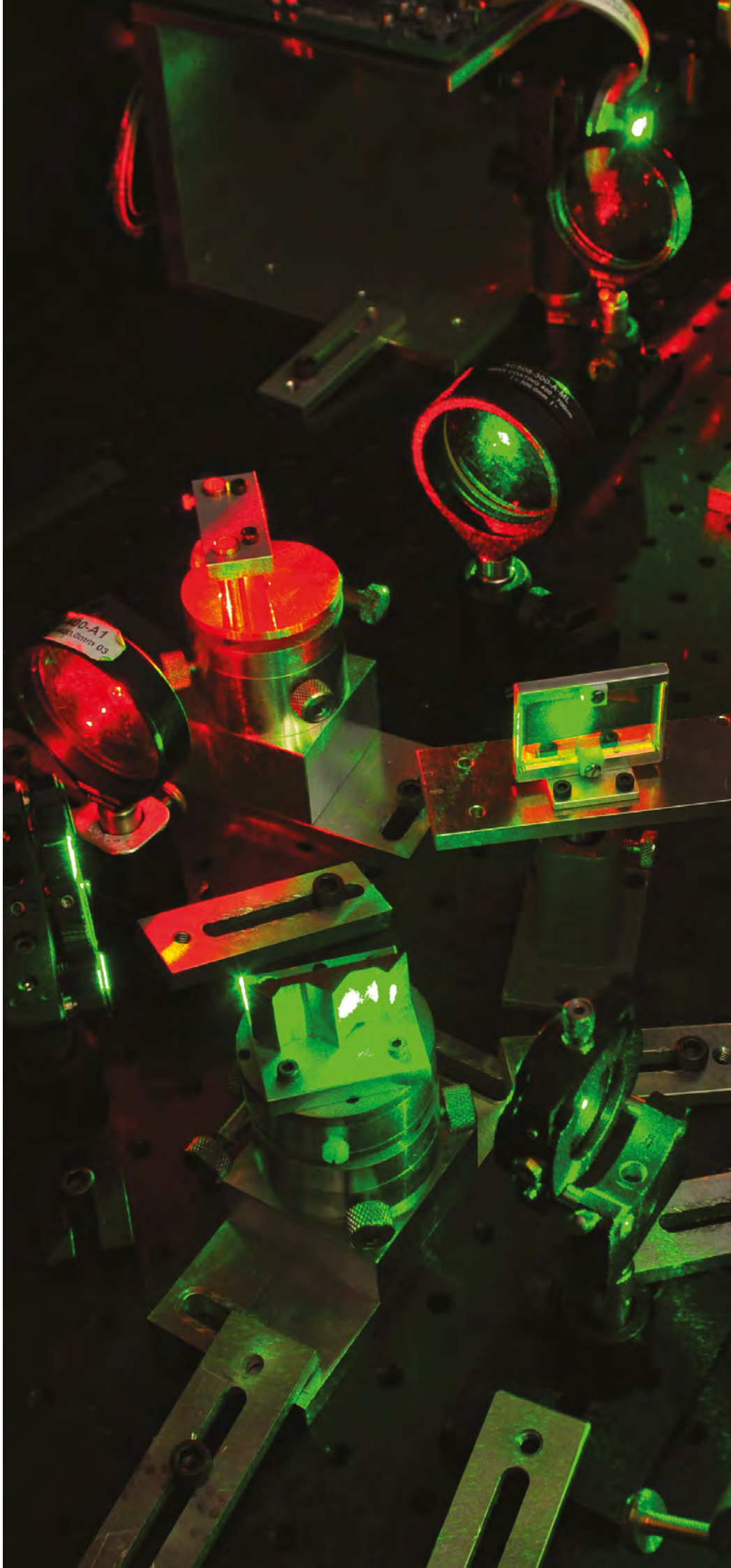

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Introduction

The Centre for Advanced Photonics and Electronics (CAPE) is a unique partnership between the University of Cambridge and a small group of international photonics and electronics companies whose market orientation places them in a non-competitive supply-chain or value- chain relationship with respect to each other.

CAPE was established on 1 October 2004, to enable the University of Cambridge to address global issues in partnership with companies of international importance. Founded upon the University's world-leading facilities and expertise in electronics and photonics, CAPE is housed within the University's Electrical Engineering Division although its activities involve many academic researchers beyond Cambridge University Engineering Department.

CAPE operates under the CAPE Partnership Agreement (CPA), forming a model of joint university-industry research that is vertically integrated and commercially relevant. Through joint governance and joint sponsored research, the CAPE Partnership has developed a research portfolio at the cutting edge of contemporary technology.

CAPE delivers "Technology from Science." We do this by accessing world-leading expertise in every branch of engineering and science at the University of Cambridge and by collaborative work with the support of cutting-edge R&D facilities within the Electrical Engineering Division.

CAPE's objective is threefold

Technology advancements

through landscaping and project work

Business opportunities

between CAPE Partners

Outreach activities

to a wider community

CAPE's approach is to invent and develop through multidisciplinary research in strategic areas of interest to both the UK (as specified by EPSRC) and beyond. We cover all levels from materials, processes, components, and systems to customer expectation.

CAPE creates business opportunities and future vision. CAPE Partners' engagement provides a unique opportunity to interact and to broaden each other's views. This enables all of us to make a greater impact on society and further enhance the business value of our enterprises.

There are opportunities to expand CAPE projects by leveraging the industrial funds invested through CAPE via external bodies such as the UK government. Membership of CAPE can also provide networking benefits from existing links between the University of Cambridge and other academic centres, in both the UK and elsewhere.

The CAPE research portfolio during the first phase of CAPE (2004-2010) amounted to £7.5 million, with a further £15.1 million invested during the second phase (2011-2023). CAPE was also instrumental in the University attracting further funding of over £14 million from other sponsors and industry partners, which together with the initial £12 million support from the University for building infrastructure gives an overall investment of £48.6 million. The research outcome is mostly important early-stage IP. CAPE Partners have taken some projects forward to the stage of mass production and framework technology transfer, such as holographic head-up displays and Smectic-A liquid-crystal technology.

CAPE and our CPA are constantly evolving to adapt to internal and external environmental needs, with the aim of enhancing academic research and creating benefit for business. The mix of partner interests has shifted over the years, but CAPE Partners continue to represent business interests on a global scale.

Professor Daping Chu

Director of CAPE

Highlights

62
CAPE projects

22.6
CAPE research funding (£M)

26
additional leveraged funding (£M)

48.6
Total investment (£M)!!!!!!!!!!!!!!!!!!!!!!!!!!!!

83
CAPE Acorn Fund winners

63
across 63 Acorn projects

13 Postdoctoral Blue Sky Award

36 CAPE Postgraduate Award (CAPA)

14 CAPE Undergraduate IIB Award (CAUPA)

11
current and past partners

20
Principal Investigators (PIs) involved

72
Researchers

42
CAPE lectures

67
patents

167
publications

CAPE Model of Academic-Industrial Partnership

The CAPE model for industrial/academic collaboration is specialised and unique, differing in many ways from existing arrangements between industry and other universities, e.g., programmes available in the USA at MIT, Stanford and UC Berkley. CAPE resembles a joint development agreement more closely than any university research club does.

Máire Geoghegan-Quinn, European Commissioner for Research, Innovation and Science visits CAPE

The key features of CAPE are:

1

CAPE is a partnership between the University and a small group of international photonics and electronics companies whose market orientation places them in a non-competitive supply-chain or value-chain relationship with respect to each other.

CAPE relies on the CAPE Partners being able to accommodate each other's business interests to allow this collaboration.

2

The executive body in CAPE is the Steering Committee, which commissions all CAPE research. Members are from both academic and industrial partners, with equal voting rights between the academic and industrial interests, i.e., sharing the governance of all CAPE research within the University with the industrial partners.

3

All financial contributions to CAPE are spent on jointly commissioned research that is directly for the benefit of the CAPE Partners, apart from a small percentage that is set aside for CAPE operations.

Each CAPE Partner will invest a minimum contribution per year in CAPE (some of which may be in-kind). Apart from the small percentage set aside for CAPE operations, all this resource will be available for jointly-commissioned research over which CAPE Partner has direct control through their representation on the CAPE Steering Committee.

4

CAPE offers wide access to engineers, scientists and postgraduate students within the Electrical Engineering Division, the Engineering Department and other areas of the University and in the other CAPE Partners.

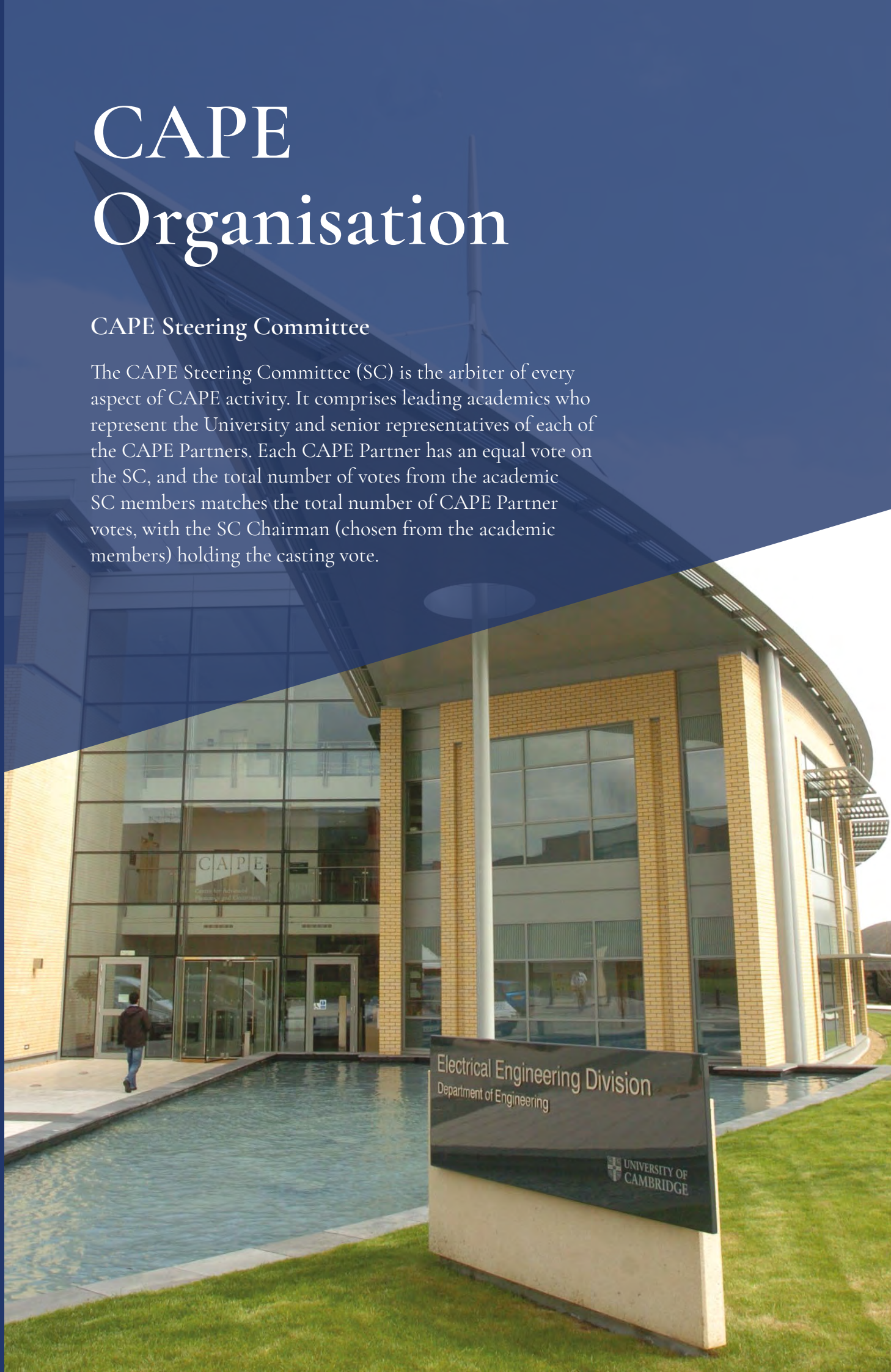
5

CAPE seeks to engage with business development processes in CAPE Partners. Exchange of scientists and engineers between the industrial and academic partners, including the possibility of the placement of an embedded researcher within the Electrical Engineering Division, is a rule rather than an exception.

CAPE Organisation

CAPE Steering Committee

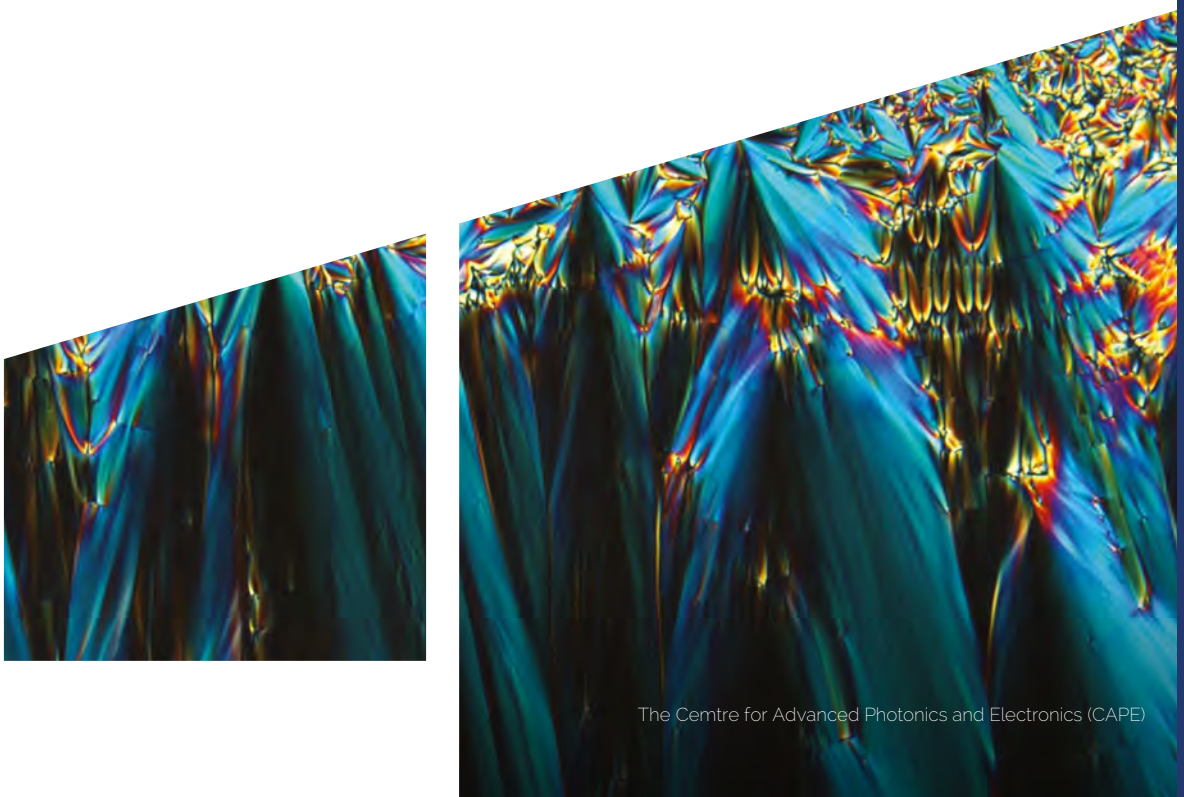
The CAPE Steering Committee (SC) is the arbiter of every aspect of CAPE activity. It comprises leading academics who represent the University and senior representatives of each of the CAPE Partners. Each CAPE Partner has an equal vote on the SC, and the total number of votes from the academic SC members matches the total number of CAPE Partner votes, with the SC Chairman (chosen from the academic members) holding the casting vote.



CAPE Technology Focus Groups

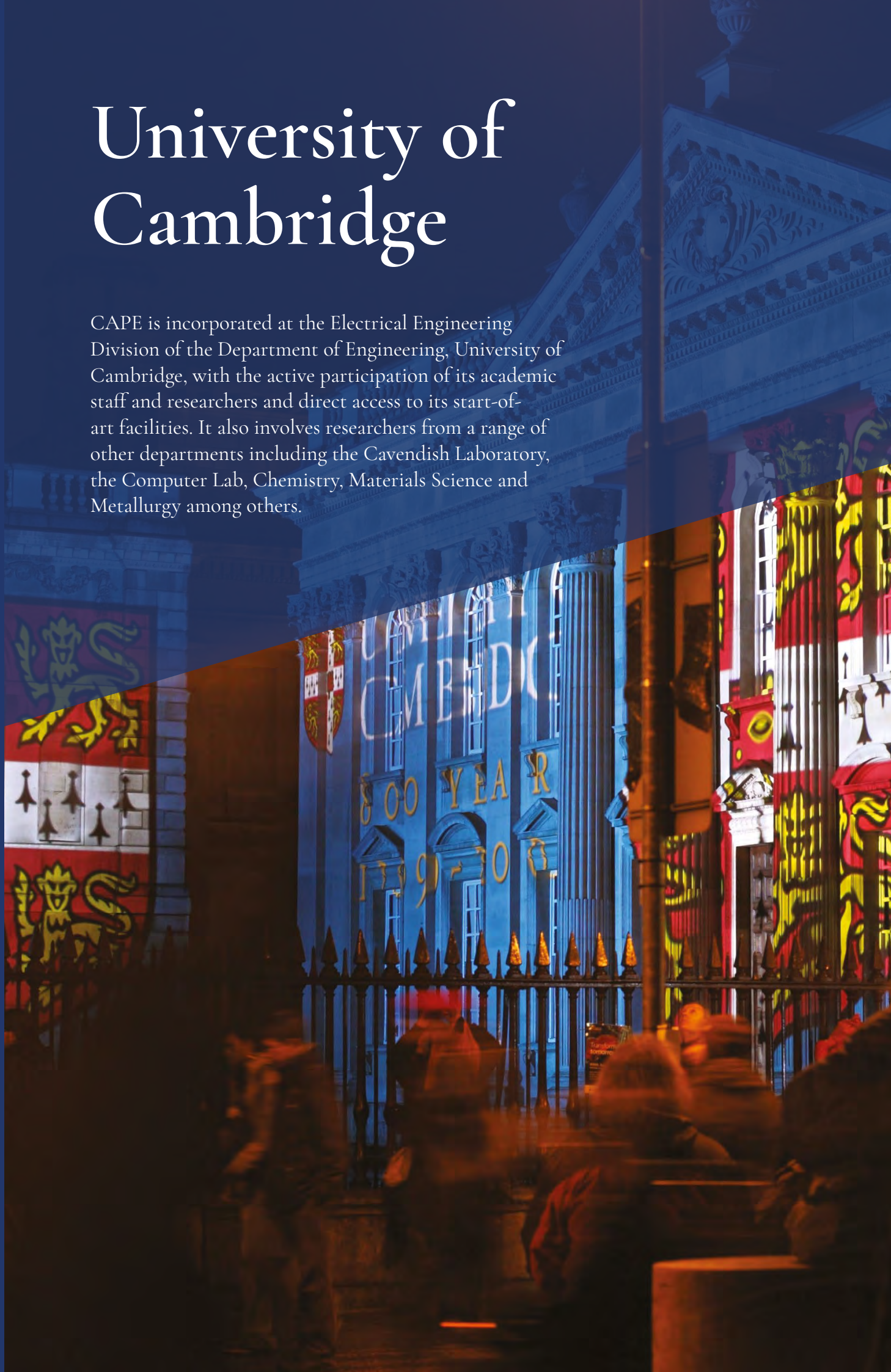
On behalf of CAPE SC, the CAPE Technology Focus Groups (TFGs) oversee CAPE technology. Appropriate representatives from the University and all the CAPE Partners sit on each TFG with the option for an academic or an industrial member to chair either. Each TFG covers a specific technological area and oversees CAPE project progress, either at detailed or executive level as appropriate. The current TFGs are:

1. **Materials and Manufacturing Processes TFG**
2. **Devices and User Interfaces TFG**
3. **Communication Network and System Design TFG**
4. **Energy and the Environment TFG**
5. **Systems and Devices for Healthcare TFG**



University of Cambridge

CAPE is incorporated at the Electrical Engineering Division of the Department of Engineering, University of Cambridge, with the active participation of its academic staff and researchers and direct access to its start-of-art facilities. It also involves researchers from a range of other departments including the Cavendish Laboratory, the Computer Lab, Chemistry, Materials Science and Metallurgy among others.



The Department of Engineering is the largest in the University of Cambridge. Its breadth and scale bringing unique advantage. The Department creates world-leading engineering knowledge that fosters sustainability, prosperity and resilience and shares this knowledge and transfers it to industry through publication, teaching, collaboration, licensing and entrepreneurship.

UNIVERSITY OF CAMBRIDGE
Department of Engineering

The Electrical Engineering Division is one of the six academic divisions within the Department. The Division pursues fundamental electrical, electronic and photonic research at the material, device and system levels with a focus on creating integrated solutions in the fields of nanotechnology, sensing, energy generation, energy conversion, displays and communications, bioelectronics and internet of things. With 26 academic staff and over 250 researchers, technicians and administrators, the division offers end-to-end research provision from basic research for early-stage invention, process development and proof-of-concept demonstrator through to application deployment. The Nanoscience Centre and Cambridge Graphene Centre are part of the Electrical Engineering Division. In 2019, the division had a portfolio of active research grants of £53.3M.

Electrical Engineering
CAMBRIDGE

'The world we live in today has been enabled by electrical engineering — processing, displays, power, communications.'

Research Themes

Our research covers all aspects of electrical engineering from the nano-scale to heavy-duty power applications, organised across six cross-cutting themes:

1 Communications, Pervasive and Intelligent Systems

- Systems-level perspective to consider the emergent properties of complex interconnected systems
- Understanding of the underpinning physics combined with appropriate mathematical abstraction

2 Functional Nano and Layered Materials

- Application driven exploration of new device materials
- Fundamental discovery and characterisation of properties to functional device integration and manufacturing pathways

3 Multiscale Power and Energy Systems

- Future energy systems from grid scale power to small scale energy harvesting
- Power semiconductor devices, power conversion systems and superconducting electrical machines

4 Photonic and Quantum Technologies

- Future photonic devices based on silicon and III-V materials
- Quantum technologies for communications and computing

5 Smart Electronics and Surfaces

- Fundamental surface science to applied industrial systems
- Applied to wearables, stretchables and large-area electronics

6 Systems and Devices for Health

- Deliver technological breakthroughs which address the healthcare challenges of an ageing population and the wider economic and functional pressure on global healthcare systems

People

150	POSTGRADUATE STUDENTS
90	RESEARCH STAFF INC. RESEARCH FELLOW
26	ACADEMIC STAFF
14	TECHNICIANS
11	ADMINISTRATORS
5	ACADEMIC RELATED STAFF

Facilities

The Electrical Engineering Division offers state-of-the-art photonics and electronics research and prototype development facilities with 5,000m² of research, cleanroom and laboratory space at its purpose-built site in West Cambridge, including 440m² of Class 10,000, Class 1,000 and Class 100 cleanroom areas.

Some of the equipment available to support CAPE research projects includes:

- 7 thin film deposition systems
- >5 nanomaterial growth systems
- 2 reactive ion etch systems
- Deep reactive ion etcher
- Rapid thermal annealer
- Bioruptor
- Ink-jet printing system
- Wire bonding facility
- 0.5µm double-sided mask aligner
- E-beam lithography system
- Wet chemical processing facility
- Optical and stylus profilometers

Views from the University

Professor Andy Neely

Pro-Vice-Chancellor: Enterprise and Business Relations, University of Cambridge

'The mission of Cambridge University is to contribute to society. To make this contribution – especially at scale – the University needs to collaborate with world-class organisations. Organisations that want to take ideas and insights being developed in the University and use them to improve the products and services they offer. CAPE is a great model to enable such collaboration. Bringing together world leading firms with researchers in the University, CAPE supports collaboration and research that makes a real difference.'

Professor Ian White

Formerly Deputy Vice-Chancellor of the University of Cambridge and currently Vice-Chancellor of the University of Bath

'CAPE has had an immense and lasting impact on my research, stimulating new ideas, making possible innovative research, and providing the lasting support and industrial expertise to allow ideas to be turned into real engineering solutions that have impact. In my view, CAPE has been an outstanding success and I pay great tribute to its leaders and industrial partners for their excellence.'

'The CAPE initiative has been a pioneer in fostering the University–industry relationship in a successful way. CAPE has been an example for other academics in the University to liaise with industrial partners and form a long-term relation.'

Lisa Wears

Assistant Director of Technology, Research Operations Office, University of Cambridge

'CAPE is an excellent model for collaboration between the University and industrial partners, Cambridge Enterprise values in particular the long term partnerships which allow exploration of routes to market for leading edge, early stage technology originating in the University.'

Dr Malcolm Grimshaw

Head of Physical Sciences, Cambridge Enterprise

Professor Richard Prager

Head of Cambridge University Engineering Department

'The strength of Cambridge University Engineering Department is built on a combination of pure research excellence and external relationships that enable us to focus our work and apply it effectively. CAPE has pioneered the development of industry-university research collaborations and has inspired many other consortia in Cambridge and beyond. It remains an exemplar as it continues to nurture young innovators, drive fundamental research and deliver commercial impact.'

Professor Andrew Flewitt

Head of Electrical Engineering Division, Cambridge University Engineering Department

'CAPE has been at the heart of the Electrical Engineering Division in Cambridge for over a decade. Its unique structure allows industry partners not only to tackle major research challenges with academics in the University but with each other as well. This collaborative environment has delivered real economic benefits to the industrial partners, enabled outstanding research in the University and helped to inspire new generations of professional engineers. I have no doubt that the collaborative CAPE ethos will continue to flourish in the years ahead.'

CAPE Activities

Acorn Fund

Supporting innovative research from young researchers

CAPE has created a special funding scheme, the CAPE Acorn Fund, to support innovative research initiatives from young researchers, in parallel or complementary with their current research.

The circulation of a new call occurs three times a year for three categories of researchers:

1 Postdoctoral Blue Sky Award

For Research Associates from the Cambridge University Engineering Department. The award is £20,000 for a 12-month Blue Sky research project. The deadline is at the end of August with up to two of the most innovative projects awarded.

2 CAPE Postgraduate Award (CAPA)

For PhD students from all University of Cambridge Departments. The deadline is in March and multiple winners – individuals or small teams can receive awards up to £2,000 for 6-month projects.

3 CAPE Undergraduate IIB Award (CAUPA)

For Engineering 3rd year undergraduate students who are aiming for IIB project in their upcoming year. The prize is £500 (£250 is a cash prize and £250 towards research). Applicants may enter with any topics they would like to pursue for their 4th year Type-B engineering project in the next academic year as part of their studies towards their degree. The duration of the project is 9 months and the deadline to apply for this call is in January in the applicants' 3rd year.

Thus far, the Acorn Awards have received positive feedback from students and research associates. The CAPE Office, in collaboration with departments and the Teaching Office, is raising awareness of the awards.

Blue Sky Research Award Winner

'The experience of winning the CAPE Acorn Blue Sky Research Award has been very rewarding, it's a huge encouragement for me personally and I feel confident to pursue the proposed work when the CAPE committee affirms our proposed concept. The award provides financial support that was required to develop the concept for a "Full 360° 3D Light Field Capture and Display System". More importantly, the award provides me with experience, the experience of working on research of my interest and the experience of managing my time and resources.

Within an everyday work schedule, I need to think harder on how to work more efficiently and when I can spare a few hours to work on the research of my interest. The key is to do it consistently and once we did, the results were rewarding. This year, we managed to carry out simulation and experimental works, file patent applications and publish an invited journal article in Journal of the Optical Society of America A.'

Dr Kun Li, Research Associate, Electrical Engineering

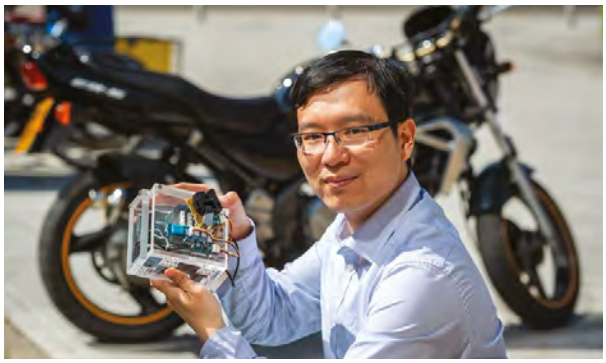
CAPA (CAPE Postgraduate Research Award) Winners

Isabella Miele and Oliver Burton – Postgraduate students

Speech-to-braille communicator for deafblind people

Deafblindness is a combined sight and hearing loss, causing difficulties with communication, access to information and mobility. This unique disability affects an estimated 394,000 people in the UK and varies in degrees of severity. Either or both of the disabilities that form deafblindness can be congenital or acquired in later life. The combined hearing and vision loss significantly affects the life of an individual even if, when taken separately, each single sensory impairment can be relatively mild.

Thanks to CAPE Acorn Postgraduate Research Award 2017, we have developed a proof-of-principle speech-to-braille communicator to give deafblind people the ability to understand spoken words. We have created a novel, cheap and open-source prototype for a refreshable braille cell that is scalable to a full braille keyboard. By combining the new haptic interface with open-source speech-to-text recognition software we created a new assistive technology system. We thank the CAPE Acorn committee for the generous financial support, which has enabled us to work on an extremely interesting project with the potential to improve the very challenging lives of people with deafblindness.



Tien-Chun Wu — PhD student in Electrical Engineering

Development of multi-sensor platform for real-time air-quality monitoring

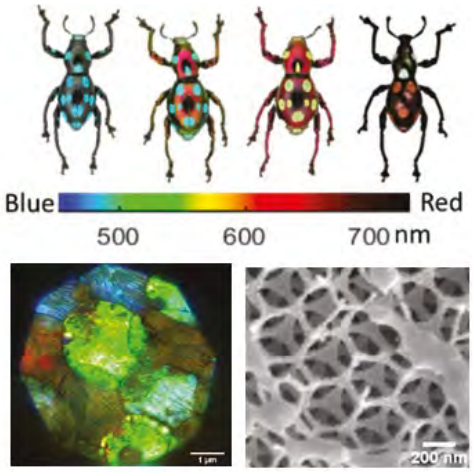
The project involves the establishment of distributed wireless networks consisting of multiple miniaturised MEMS-based sensors to enable remote monitoring of local air quality in real-time. I developed cloud-based analytics algorithm and interface for recognition of pollutants and particle matters components using low-cost sensors that have not only allowed for visualisation of ubiquitous spatial mappings of both metropolitan and indoor air quality index (AQI), but also enabled transmission of timely alerts of detection of toxic and combustible analytes. Furthermore, the multi-sensor array approach I employed has also promoted development of algorithms to compensate for interfering effects for improvement of detection accuracy.

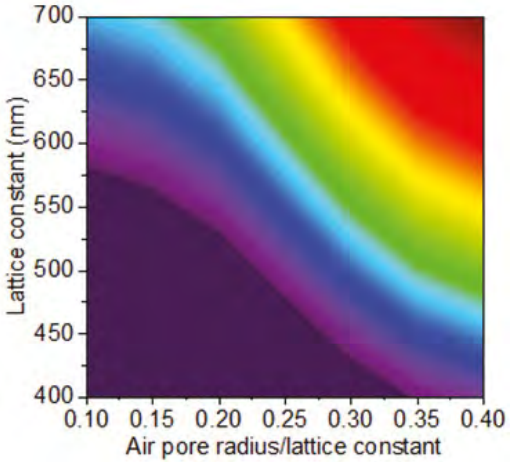
Throughout the course of the Acorn project, the development of expertise involving communications protocol, cloud-based interface, and recognition algorithms has made important contributions towards my PhD research on the topic: mobile-embeddable breath analysis for personal healthcare monitoring, representing a significant step towards internet of things (IoT) realisation of miniaturised ultralow-power inkjet-printed graphene-based CMOS-integrated sensor arrays.

Yin Chang — Postgraduate student, Dept of Chemistry

Biomimetic diamond structured photonic crystals and the inspirations for industry

Pachyrhynchus weevils have photonic crystal structures that are able to display colours from blue to red. Our research found these jewel-like weevils have a single diamond structure lattice with lattice constant of 400-500 nm. The single diamond lattice is an attractive structure for engineering because it has the widest open bandgap for whole crystal orientations. With the CAPA award fund, we characterised the optic spectrum with optic fibres and the nanostructures with SEM and TEM. Different oriented crystal models were constructed and simulated with FDTD. Band diagram of different diamond lattice constants and chitin-air filling fraction were then constructed which provides important information for future optic device designs. Moreover, this study is inspiring for self-assembly mechanisms of large-scale (400-500 nm) single diamond structure, which cannot be achieved by engineering techniques so far.





Acknowledgements:

Pachyrhynchus weevils are captive and bred in Taiwan. The researchers thank Dr Hui-Yun Tseng for providing the species and for biology and genetics discussions.

CAPE Lectures

CAPE regularly organises CAPE Advanced Technology Lectures in the Electrical Engineering Building which are also streamed online. Recordings of the lectures are available on our YouTube channel (youtube.com/CAPECambridge). Lectures that have taken place since 2020 include:

Damjan Stamcar, Sony Technology Partnerships Europe.
'Introduction to Sony and its Academic Engagement Models'
12 July 2023

Prof. Ming Wen, Tongji University.
'Hetero-atomization of Bi-metals Ultrathin Nanostructure and Their Electro-catalytic Performance'
6 July 2023

Prof. Hannah Joyce, University of Cambridge.
'Semiconductor nanowires: harder, better, faster, stronger'
20 June 2023

Prof. Cheng-Wei Qiu, National University of Singapore.
'Low-dimensional and van der Waals Meta-photonics'
9 June 2023

Dr Jingze Yuan, Chinese Academy of Science.
'Light: Science and Applications - towards a top tier journal in optics and photonics'
17 May 2023

Philip James, Haleon.
'Research to Industrialization'
5 April 2023

Prof. Amor Abdelkader, University of Bournemouth.
'Nanostructures for Energy and Sustainability'
8 March 2023

Dr Wei Zhang, Huawei London Research Center.
'DetClip: Scalable Open-Vocabulary Object Detection via Fine-grained Visual-language Alignment'
18 January 2023

Dr Richard Langford, University of Cambridge.
'X-ray and insitu transmission electron microscopy to study calcium phosphate nucleation from bioactive glass dissolution'
14 December 2022

Dr Deepak Venkateshvaran, University of Cambridge.
'Nanomechanics of materials used in flexible electronics'
30 November 2022

Dr Michael Crisp, University of Cambridge.
'Backscatter communication for the next billion devices'
17 August 2022

Prof Stefan Hofmann, University of Cambridge.
'Material Futures'
13 July 2022

Prof. Hong-Seok Lee, Seoul National University.
'Holographic Flat Panel Display'
15 June 2022

Tom Watt, Claudia Maw, Philip James, GSK Consumer Healthcare.
'Consumer Healthcare - Finding Research that Changes the World'
4 May 2022

Dr Jennifer Schooling, Cambridge Centre for Smart Infrastructure and Construction.
'Developments in Smart Infrastructure and Construction'
30 March 2022

Dr Yan Yan Shery Huang, University of Cambridge.
'3D Printing and Biofabrication for Healthcare and Sustainability'
23 February 2022

Paul Heremans, IMEC and KULeuven.
'Semiconductor sensor and actuator technologies for augmented reality and human-machine interfaces'
2 December 2021

Professor Judith L MacManus-Driscoll, University of Cambridge.
'Achieving High Performance Resistive Switching Through Careful Materials Selection and Engineering'
10 November 2021

Dr Tero Ojanperb, Aalto University.
'Platform strategy – how to win with platforms'
20 October 2021

Prof. Peter Robinson, University of Cambridge.
'Of Machines and Men'
22 September 2021

Valerian Meijering, Jaguar Land Rover.
'Designing augmented reality head up display from a human factor perspective'
25 August 2021

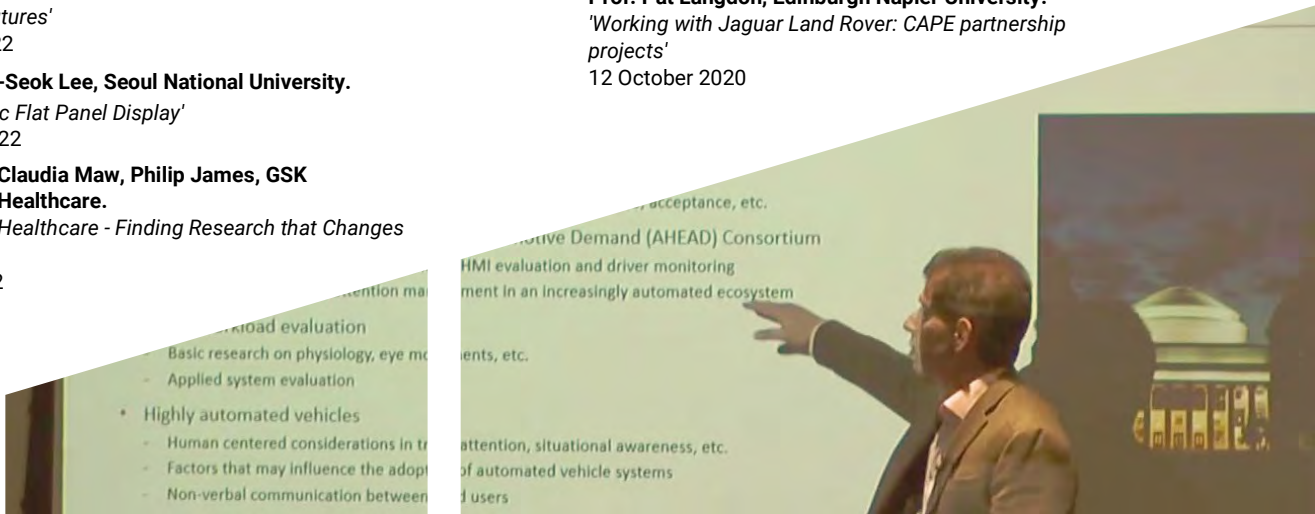
Dr Teng Long, University of Cambridge.
'Power Electronics in Energy Conversion - Latest Advances'
15 July 2021

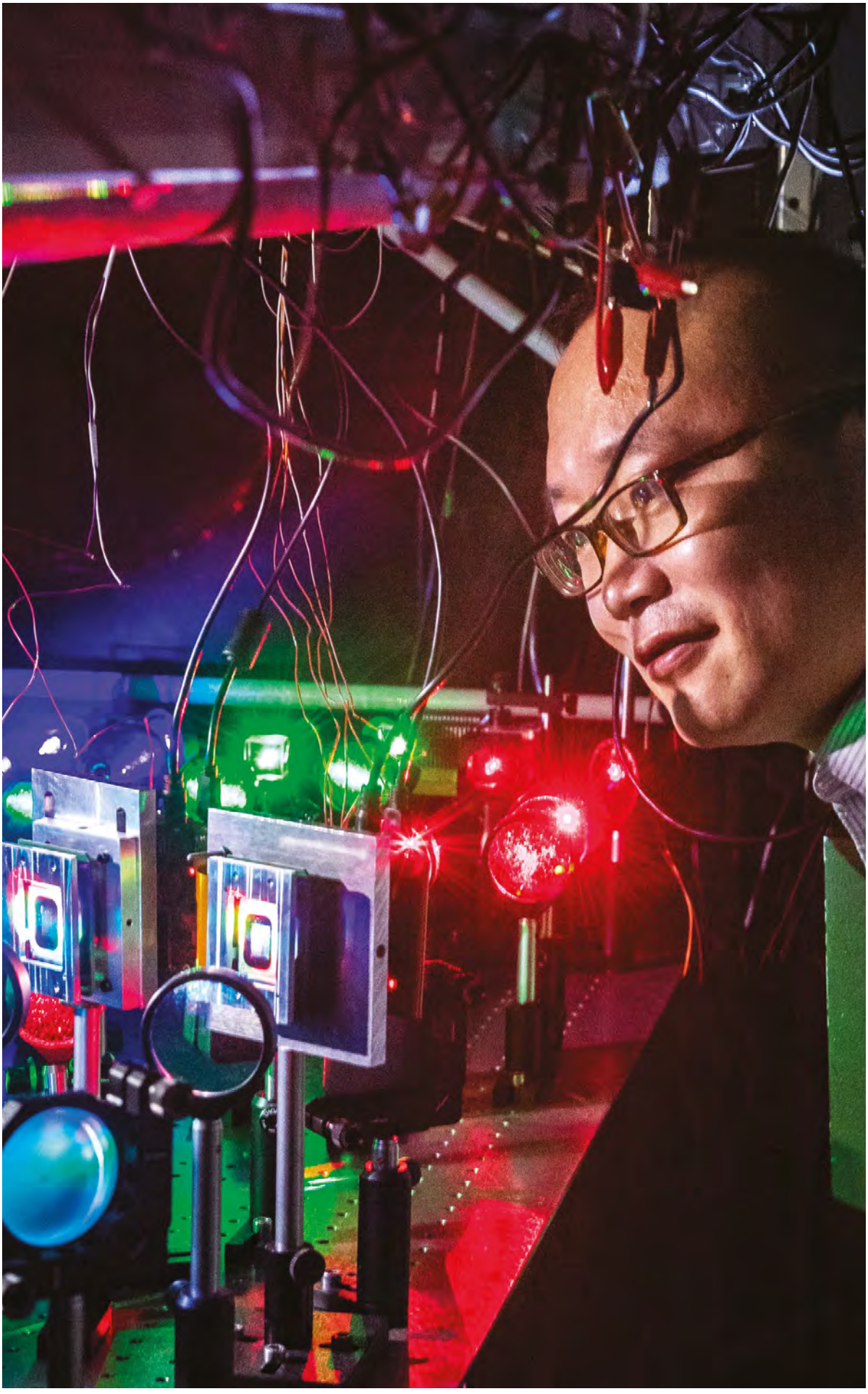
Koichi Amari and Klaus Zimmermann, Sony Europe.
'Sony R&D research interest: Advanced Display and Photonics Technology'
26 May 2021

Ashutosh Tomar, Jaguar Land Rover.
'Light weight electronics with simplified architecture in automobile'
28 April 2021

Tom Watt, Angelos Echiadis- GSK Consumer Healthcare.
'GSK Consumer Healthcare: Present and Future areas of interest'
31 March 2021

Prof. Pat Langdon, Edinburgh Napier University.
'Working with Jaguar Land Rover: CAPE partnership projects'
12 October 2020



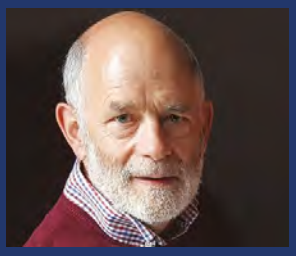


Views from PIs and Researchers

Dr Tim Flack

University Lecturer in Electrical Power and Energy Conversion

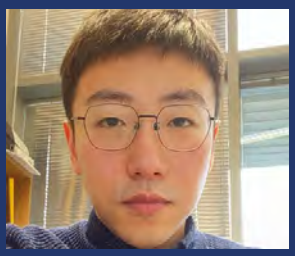
'My research has greatly benefitted through collaboration with Jaguar Land Rover (JLR), facilitated by CAPE as one of its partners. We have developed new technologies such as active rectifiers for vehicle alternators, which improve the efficiency and power density of these devices; a new energy storage method to mitigate against the spikes in power demand in active anti-roll bar control systems; a new type of integrated starter-alternator for mild hybrid vehicles. Regular contact with JLR engineers has kept the research fresh and exciting, knowing that it is solving real difficulties in vehicle electrical power systems design. The collaboration has meant that a number of postdocs and PhD students have benefitted from industrial visits and input, which has been a great opportunity for them and their future careers. The research has led to a number of conference and journal papers, all of which have been partially credited to our main link person at JLR due to his detailed knowledge of the sector, and hence research priorities. It is this expertise, as well as the ongoing input, which has made the collaboration so valuable.'



Professor Peter Robinson

Department of Computer Science and Technology, University of Cambridge

'The Department of Computer Science and Technology worked with Jaguar Land Rover on research into Enhancing Driver Experiences through Vision Research (Endeavour) from 2015 to 2018. CAPE helped establish contact with the right people and made it easier to set up a contract. The project resulted in nine publications and a couple of invited keynote addresses. Several promising lines for further work have emerged, for which funding is still being sought.'



Dr Tongyun Li

Collaboration of CAPE with BIACD

'The smart in-building wireless system using flexible transmission technology (SWIFT) project is a CAPE project in collaboration with Beijing Institute of Aerospace Control Devices (BIACD). The project aims to deliver a world leading in-building wireless solution based upon Cambridge's digital distributed antenna system (DDAS) architecture and its embedded processing algorithm.

Over the past three years, the research teams in Cambridge and Beijing have worked together to develop an industrial level DDAS prototype. This has been transformed into a series of real-life products, including a wireless distribution system that can combine 14 mobile services/ bands onto a single network infrastructure for indoor coverage. Such a system can achieve over three times higher data transmission efficiency than the current industrial standards in an optical network, and thus has lower cost and power consumption than existing solutions.

The system has the potential to carry digitised RF carriers over standard IP network infrastructure together with conventional digital data, allowing a cloud and converged network architecture to be built for multi-service and multi-operator wireless coverage in a highly efficient way. The project has also enabled business activities in both organisations collaboratively to allow DDAS products to be commercialised in both China and the UK. These include a successful patent application and a licensing agreement signed between the University and BIACD. Currently, a follow-on project is under negotiation, aiming to bring the research outcome to a new level in order to meet the new challenges of the next-generation wireless communication networks.'

Professor Patrick Langdon

Formerly PRA at the Engineering Design Centre, Cambridge University Engineering Department, currently Professor of Engineering Design, Transportation, and Inclusion, Edinburgh Napier University

'The Engineering Design Centre and the Signal Processing Group have been working together with Jaguar Land Rover (JLR) under the CAPE Partnership since 2011. During this time, it has been a facilitating channel for two PhDs, and more than five years' worth of collaborative projects looking at key issues and technology opportunities in the automotive Human Machine Interface area. The CAPE Partnership has acted as an enabler to conceive jointly applied research projects that service the needs of JLR with a short lead-time to realisation of results.

The work has covered a wide range of research topics. One of the first and most successful has been the Motion Adaptive Touchscreen System for Automotive (MATSA), started in response to a JLR visit to the Cambridge University Engineering Department. Based on work done previously by Dr Patrick Langdon on compensation filtering for input devices for people with Cerebral Palsy, this aimed to develop a vibrating-acceleration compensation and intent recognition algorithm to be implemented as a system to improve interactive display usability in the vehicle environment. MATSA led to the development of the predictive display technology that enhances and automates the execution of the demanding task of interacting with in-vehicle systems under various road and driving conditions. It significantly improves human-machine interaction in automotive applications and enables safe, dependable control of in-vehicle systems by employing novel statistical inference techniques and suitable sensing technologies within a principled Bayesian inference framework. Experimental data from several pilot on-track studies testify to the efficacy of the developed HCI technology. It will enable JLR not only to substantially improve usability of their current in-vehicle displays, e.g. touchscreens, but also offers an effective means to easily interact with emerging display technologies, such as head-up and 3-D displays, in automotive applications via its mid-air, contactless, selection capability.

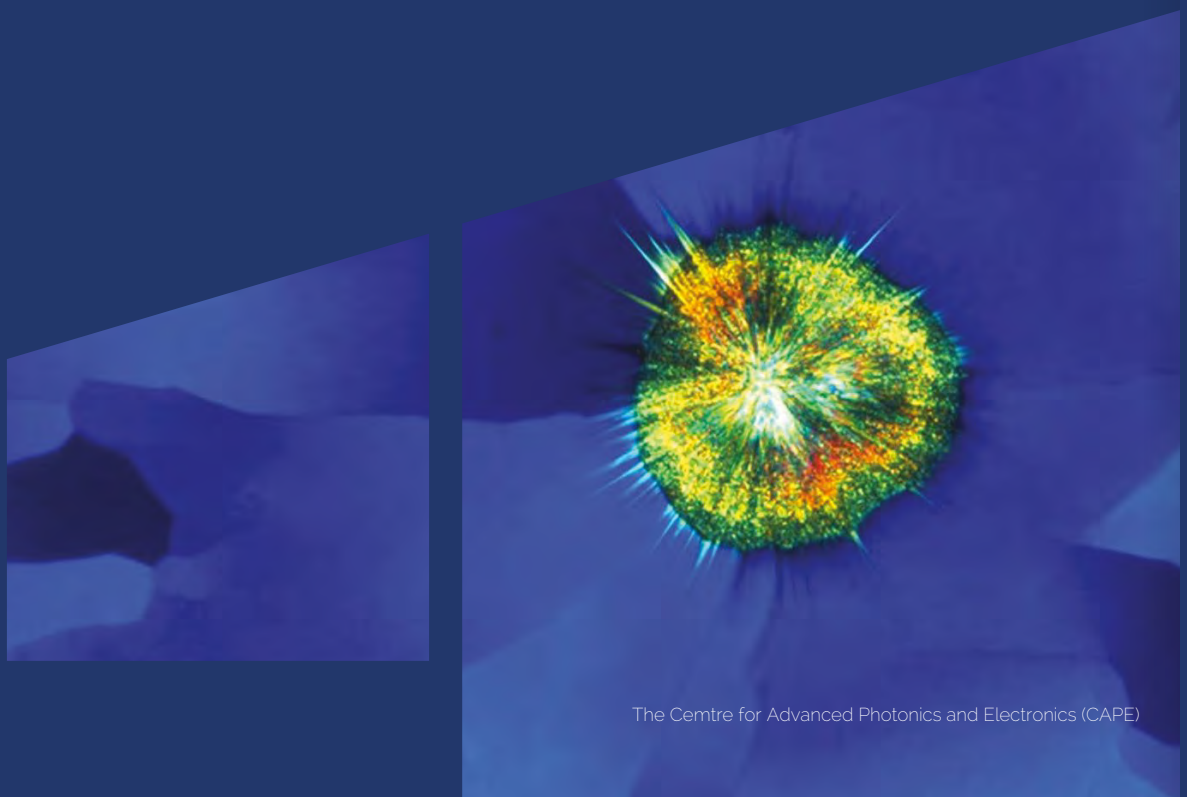
Following the initial success of MATSA, two very different projects show the scope of the potential for collaboration:

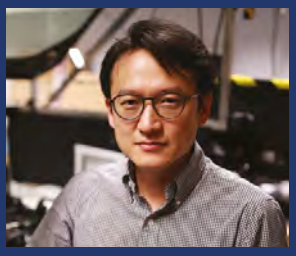
The Inclusive Human Machine Interfaces (iHMI) project researched, developed and delivered a new method for developing technologies that offer opportunities to inclusively customise and personalise the in-vehicle experience. The approach was based on obtaining market research to generate a persona; carrying out ethnographic interviews with real people matching the persona. The project identified and enumerated future HMI technology likely to be usable by 2025, identifying existing inclusive design usage cases with cars in 2015. The booklets were then used as a high-quality visualisation platform for each persona usage case, presenting the same usage cases with future designs using cars with extrapolated future HMI interfaces. The main project deliverable was a boxed set of eight Doculets. A series of two internal JLR workshops on the use of the approach accompanied this, and a Techfair Display. This project was widely distributed in JLR and the method perceived as very useful. The boxed sets became a permanent resource found on most desks in R & D in Coventry.

In Driver Intent and Preferences Prediction and Profiling using Bayesian Learning from Asynchronous-heterogeneous Data (DIPBLAD), several technologies that are key to intelligent vehicles were developed and trialled using prototype implementations and subsequently patented. These developed technologies substantially benefit and aid JLR efforts to deliver a more personalised, safer and pleasant driving experience. It also enables additional JLR smart vehicle functionalities in the future especially for autonomous driving where knowing the driver-to-vehicle position (inside and outside the vehicle) and his/her profile as well as preferences can be crucial.

Through working with CAPE, a number of important generic benefits have been established.

1. *The CAPE Partnership allows the customisation of the working relationship for experimental and logistic facilities*
2. *Once new technology innovations have been identified, working with JLR through CAPE greatly facilitates the patent procedure*
3. *CAPE provides an "Industrialised" collaboration framework that encourages a close collaborative working environment with regular reviews and deliverables*
4. *CAPE provides contact and cross-fertilisation of ideas and results between multiple projects ongoing within JLR*
5. *Formulating novel solutions amenable to practical applications'*





Dr Kun Li

CAPE research with Jaguar Land Rover and Huawei

'I have been working with CAPE industrial partners for six years, two years (2013-2014) with Huawei and four years (2015-2018) with Jaguar Land Rover (JLR). Projects I have been involved in are:

Huawei: Auto-stereoscopic mobile 3D display, developing novel methods in achieving full resolution auto-stereoscopic (glass-free) mobile display.

JLR: Automotive Immersive Head-Up Display (iHUD), developing next-generation head-up displays for automobiles with a large projected image plus high resolution, high brightness and depth perceptions.

Compared to fundamental research for non-industrial sponsors, research for industry is more application driven; the industrial project needs to demonstrate developed concepts. The project deliverables may also change according to the industrial partner's needs and new mini-projects could evolve.

I did not think that I could file this many patent applications (14 PCTs, 2 granted). Paper publications, however, often need to wait until the patent applications have been filed. Still, if I find research highlights during the project I am often able to publish them.

I have seen direct impacts of my research; the developed demonstrator has been installed in a prototype car and was used for various tests both for our research and other research such as production teams within the industrial partner.

I have established personal contacts with the industry and we work closely with our contacts in the company. We meet as often as every two weeks and the partner company has been supportive, providing parts we need to carry out the project more efficiently.

I would highly recommend this type of experience to others within the University as it enables me to get a different perspective from industry and an appreciation for my effort. We work with company contacts as a team and it is very important for the applied work that is likely to be adopted by the industry.

I am currently developing a new concept for Light Detection and Ranging (LiDAR) through the CAPE Acorn Blue Sky Research Award 2018. I plan to demonstrate my concept at the end of this year and wish to extend it into a CAPE project.'

Dr Matthew Pryn and Dr Pawan Shrestha

CAPE collaboration with Jaguar Land Rover

'CAPE has provided us with an ideal opportunity and platform to work on industrial projects. As a researcher, this collaboration gives us a unique insight into the strategy, mindset, and tools used by world-leading technological companies. As an engineer, it is extremely exciting to be able to turn research into functional and patentable prototypes. We also get to help develop long-term research goals, steering future industry development. CAPE allows us to work with a range of brilliant professionals from a wide variety of industries and academic backgrounds, and helps us create new and innovative ideas, allowing us to get involved in high impact academic projects.'

Dr Jin Li

CAPE collaboration with Disney Research

'I have been working with Disney Research for three years on the project 'Coarse Integral Hologram for 3D Images'. Through working with industrial partners, we source academic research challenges from the current non-academic projects. We can also research the non-academic project from fundamental start point. I am very happy with this type of research experience and would recommend it to other academics. In the future, I would like to continue working with Disney Research on other projects.'

CAPE in the News

CAPEable Collaboration, University/industry collaboration is enabling leading edge research in Cambridge

24 November 2009

CAPE has bought together the Cambridge University Engineering Department's Electrical Engineering Division with several industrial partners.

'CAPE provides a new form of joint university-industry research that is leading edge and commercially relevant'

Professor Daping Chu

The CAPE formed as a way in which the university could address global issues involving open innovation, in partnership with companies of international importance in the supply chain in the photonics and electronics industry.

Full Article: *https://www.newelectronics.co.uk/electronics-technology/cover-story-capeable-collaboration/20856/*

An electronic partnership

We are on the brink of a manufacturing revolution for photonic and electronic devices, and it is vital that the UK is able to capitalise on the cutting-edge research taking place at universities such as Cambridge to attract global industries. Not content with just being a world leader for research in this field, the Centre for Applied Photonics and Electronics (CAPE) has also established a unique model for working, which takes collaboration between academia and industry to a new level.

'When CAPE was set up, we realised we needed to have a more equal and open approach when interfacing with industry'

Professor Daping Chu

Full Article: *https://issuu.com/uni_cambridge/docs/annual-report-2011-report*

PHOTO CREDIT: JAGUAR LAND ROVER

Heads up: Cambridge holographic technology adopted by Jaguar Land Rover

26 November 2015

Cambridge researchers have developed a new type of head-up display for vehicles that is the first to use laser holographic techniques to project information such as speed, direction and navigation onto the windscreen so the driver does not have to take their eyes off the road. The technology – which was conceptualised in the University's Department of Engineering more than a decade ago – is now available on all Jaguar Land Rover vehicles. Researchers behind this technology suggest it to be another step towards cars that provide a fully immersive experience. It could even improve safety by monitoring driver behaviour.

'We're moving towards a fully immersive driver experience in cars, and we think holographic technology could be a big part of that.'

Professor Daping Chu

Full Article: *https://www.cam.ac.uk/research/features/heads-up-cambridge-holographic-technology-adopted-by-jaguar-land-rover*

Smart glass goes from clear to opaque and back again 27 million times

8 June 2016

Researchers at the University of Cambridge have developed a type of 'smart' glass that switches back and forth between transparent and opaque, while using very low amounts of energy. The material, known as Smectic A composites has potential for installation in buildings or automobiles, reducing energy bills by avoiding the need for costly air conditioning.

'You could have smart windows in an office building that automatically became more or less opaque, depending on the amount of sunlight coming through.'

Professor Daping Chu

Working with industrial partners, the Cambridge researchers have been developing 'Smectic A' composites over the past two decades. The team, based at the CAPE, has made samples of Smectic A based glass, and is also able to produce it on a roll-to-roll process so that it can be printed onto plastic. It can switch back and forth from transparent to opaque millions of times, and stay in either state for as long as the user wants.

Full Article: *https://www.cam.ac.uk/research/features/smart-glass-goes-from-clear-to-opaque-and-back-again-27-million-times*

Through a glass, darkly, as Cambridge scientists break new ground

13 June 2016

Researchers at Cambridge University have developed a glass that can change from see-through to opaque at the touch of a button.

The invention uses an advanced form of liquid crystal — but they say it needs much less power than previous forms of 'privacy glass'.

Full Article: *https://www.itv.com/news/anglia/update/2016-06-13/through-a-glass-darkly-as-cambridge-scientists-break-new-ground/*

The patented work is being commercialised by Cambridge Enterprise, the University's commercialisation arm, to a major industrial partner through a technology framework transfer agreement.

Full Article: *https://www.businessweekly.co.uk/news/academia-research/smart-glass-technology-hands-you-power-turn-sun*

> *'We started making it in plastic, which meant we could attach it to things like windows in order to reduce the effects of solar radiation, since the energy is being scattered rather than absorbed'*
>
> Professor Daping Chu

Smart glass technology hands you the power to turn off the sun

17 June 2016

Smart glass that alternates between transparent and opaque – allowing people to switch the sunlight on and off – could revolutionise the energy efficiency of buildings, vehicles and advertising displays across the globe, the Cambridge inventors believe.

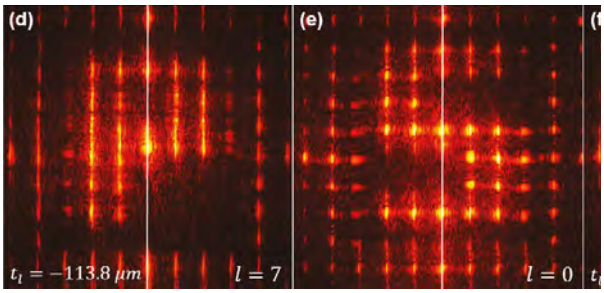
University of Cambridge researchers say the solar control could dramatically reduce energy bills by eliminating the need for costly air conditioning or other artificial methods of temperature control.

Daping Chu: The car of the future — with head-up technology

19 June 2017

Professor Daping Chu outlines his work on the car of the future and the use of Head-Up Display technology together with his Jaguar Land Rover collaborators.

Full Article: *https://soundcloud.com/university-of-cambridge/the-car-of-the-future-with-head-up-technology*

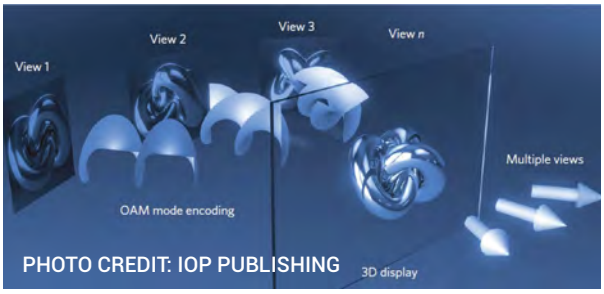


Optical physics research update — 3D display exploits twisted light

20 July 2016

Scientists at the University of Cambridge and the Walt Disney Company have proposed a 3D display that exploits the orbital angular momentum (OAM) of "twisted" light. The team says that its nine-by-nine pixel display demonstrates a new and powerful technique for organising and transmitting the massive amounts of data required for displaying 3D images – and eventually video.

Full Article: *https://physicsworld.com/a/3d-display-exploits-twisted-light/*



Momentum multiplexing

31 August 2016

Disney, the famous US film studios, may be the last organisation that you would expect to be interested in the orbital angular momentum (OAM) of light. However, Disney Research in California has teamed up with the Photonics and Sensors Group at the Cambridge University to investigate the prospect of constructing future 3D displays based on OAM multiplexing (J. Opt. 18, 085608; 2016).

Daping Chu and co-workers are exploring the opportunities for using OAM modes to carry different views of an object, which can then be demultiplexed to create a multi-view 3D display. To date, the researchers have demonstrated a three-view display based on the approach, whereby three different image patterns can be encoded into arrays of OAM beams and then spatially separated for the viewer.

Full Article: *https://www.nature.com/articles/nphoton.2016.171*

> *'There is no problem to scale it up to a much larger number, a few tens of views, at least, in terms of coding the information into a large number of modes. However, it is technically challenging to multiplex many images as well as separate them in space.'*
>
> Professor Daping Chu

3D displays momentum multiplexing

12 February 2019

Encoding and Multiplexing of 2D Images with Orbital Angular Momentum Beams and the Use for Multiview Colour Displays

Full Article: *https://spj.sciencemag.org/research/2019/9564593/*

Cambridge researchers and Jaguar Land Rover develop immersive 3D head-up display for in-car use

20 August 2019

Researchers from the University of Cambridge are working with Jaguar Land Rover to develop next-generation head-up display technology that could beam real-time safety information in front of the driver, and

allow passengers to stream 3D movies directly from their seats as part of a shared, autonomous future.

Engineers are working on a powerful new 3D head-up display to project safety alerts, such as lane departure, hazard detection, sat nav directions, and to reduce the effect of poor visibility in poor weather or light conditions. Augmented reality would add the perception of depth to the image by mapping the messages directly onto the road ahead.

Full Article: *https://www.cam.ac.uk/research/news/cambridge-researchers-and-jaguar-land-rover-develop-immersive-3d-head-up-display-for-in-car-use*

'Development in virtual and augmented reality is moving really quickly. This consortium takes some of the best technology available and helps us to develop applications suited to the automotive sector.'

Valerian Meijering, Human Machine Interface & Head-Up Display Researcher for Jaguar Land Rover

PHOTO CREDIT: JAGUAR LAND ROVER

World-first structural electronics research for in-car electronics

19 November 2019

Pioneering structural electronics research led by Cambridge PhD student Ashutosh Tomar on behalf of Jaguar Land Rover has been unveiled as a world-first for next-generation in-car personalisation.

Mr Tomar, who is also the Electrical Research Technical Manager at Jaguar Land Rover, has been working on the Lightweight Electronics in Simplified Architecture (LESA) research technology – used in flexible wearables and curved OLED TVs – for car interiors. It has formed part of his PhD research, under the supervision of Professor Daping Chu, Director of both the Centre for Advanced Photonics and Electronics (CAPE) and the Centre for Photonic Devices and Sensors.

Full Article: *http://www.eng.cam.ac.uk/news/world-first-structural-electronics-research-car-electronics*

Predictive touch technology developed by Cambridge engineers in collaboration with Jaguar Land Rover has won an innovation prize

7 April 2020

The project led to the development of predictive touch technology that interacts intelligently with in-vehicle systems by simplifying pointing and selection processes. The technology uses a gesture tracker and other sensory data such as an eye-gaze tracker, along with a prediction algorithm.

The technology was developed between 2012 and 2018 by the CAPE as part of the CAPE Motion Adaptive Touchscreen System for Automotive — MATSA (1 and 2) project. The research team included Professor Simon Godsill, Dr Bashar Ahmad, Dr Lee Skrypchuk and Professor Pat Langdon.

Full Article: *http://www.eng.cam.ac.uk/news/cambridge-engineers-scoop-innovation-accolade-jaguar-land-rover-awards*

AI-based 'no-touch touchscreen' could reduce risk of pathogen spread from surfaces

23 July 2020

A 'no-touch touchscreen' developed for use in cars could also have widespread applications in a post-COVID-19 world, by reducing the risk of transmission of pathogens on surfaces. The patented technology, known as 'predictive touch', was developed as part of a CAPE collaboration with Jaguar Land Rover led by Professor Simon Godsill.

Full Article: *http://www.eng.cam.ac.uk/news/ai-based-notouch-touchscreen-could-reduce-risk-pathogen-spreadsurfaces*

Views from Partners

Ashutosh Tomar

Technical Manager at Jaguar Land Rover

'Removing weight from the car is one of the key requirements of future cars, as this leads to better range and reduction in carbon emissions. While industry is looking into materials and mechanical reductions, project LESA looks into how to reduce the weight of electronics and the electrical architecture of the car. As the area of research is large, hence Cambridge CAPE and Jaguar Land Rover research came together to focus on this challenge head on. We looked into key parts and components that make up the electrical architecture of the car, like networks, computers, sensors and cables. Now we are working towards some key areas where we can significantly reduce the weight of underlying electronics. This is an ongoing research where two institutions are working collaboratively.'

Dr Quinn Smithwick

Senior Research Scientist at Disney Research

'In order to preserve Disney's long history of fostering innovation, and continue this legacy, Disney Research, the company's technological research arm, joined CAPE to guide and develop fundamental future display technologies. In addition to driving the increase in quality and capabilities of ubiquitous commercial displays through content and standards, Disney Research leveraged the CAPE collaboration to incorporate these new mechanics into unique displays to enrich the experiences Disney creates.'

Dr Quinn Smithwick, Senior Research Scientist at Disney Research, has been collaborating with CAPE for several years. Disney Research's partnership in the CAPE program ended in April 2019, but the final project will continue until August 2020.

Dr Lee Skrypchuk

Human Machine Interface
Technical Specialist at
Jaguar Land Rover

'Jaguar Land Rover (JLR) joined CAPE in 2011. CAPE has given JLR the opportunity to work with some of the world's leading scientists on innovative technologies for the automotive industry. The access CAPE gives to all areas of the University of Cambridge means that we can take advantage of a multidisciplinary research team. We have successfully worked with many academics across the university: Professor. Daping Chu (Engineering), John Clarkson (Engineering), Patrick Langdon (Engineering), Peter Robinson (Computer Science), and Simon Godsill (Engineering). Each has contributed significantly, from patents to prototype technologies; all generated through projects in which we worked closely with the academics to deliver technical solutions that can be used in an automotive context.
The best examples of this include the MATSA (Motion Adaptive Touchscreen for Automotive) project and the iHUD project, which through a thorough programme of research have produced high-quality technology demonstrators that JLR have used to define future technology strategy and deployment. Both have been rigorously integrated and tested in-vehicle to ensure that the theoretical principles they are trying to achieve can be realised within the automotive environment.

JLR has been involved in a number of different types of projects that either focus on a single key technological area as well as those that look at a variety of technical solutions and ways to apply existing methods differently. There are theoretical projects that focus on understanding human behaviour in the context of the automobile. PhD studies are also investigating a key research topic in detail as well as generating new concepts and building prototype systems.

CAPE differs greatly from other academic collaborators in terms of expertise and IP rights. It relies on partners being non-competitive which generates interesting projects discussions and raises the potential for collaborations between partners who have mutual interest in a specific technology but for very different reasons. The CAPE terms are favourable for a company like JLR. For any company that wishes to work with the University of Cambridge, JLR believes the partnership with CAPE is an excellent way of leveraging the world-class research staff and facilities at the University of Cambridge.

JLR will continue to work on strategically relevant projects with CAPE, in accordance with our technical synergies, international legal requirements and business priorities, where we need some of the best minds in the business that help us solve problems related to the delivery of premium vehicles globally.'

Get Involved

Work with CAPE

CAPE always welcomes the participation of new industry partners who look to leverage our expertise and at the same time provide a synergistic fit with our existing partners. Established for over 15 years, CAPE has a record of successful technology development within a robust model for university-industry collaboration. Contact us to explore ways to work with us.

Advantages of working with CAPE

Technology from science

- Work with world-leading scientists and engineers to develop innovative science into practical solutions that can be applied by your company
- Jointly commission research for the benefit of the CAPE Partners with direct control through representation on the CAPE Steering Committee
- Projects are supported by access to the cutting-edge R&D facilities within the Electrical Engineering division

Established governance structure

- Management of CAPE is by the Steering Committee with equal voting rights for the CAPE Partners and the University
- The CAPE Partnership Agreement (CPA) provides fair IP terms agreed between the University and CAPE partner
- Our pre-determined terms and conditions allow for fast project approval
- The CAPE Office provides dedicated support to partner projects and interests

Gateway to Cambridge

- CAPE is a gateway to all areas of the University of Cambridge, including researchers in the Department of Engineering, Cavendish Laboratory, The Computer Lab, Chemistry Department, Materials Science and others
- Research themes covered by CAPE researchers include AI, Batteries, Big Data, Energy, Healthcare, Graphene, Sensors, etc.
- CAPE's track record has established its reputation among academics and the wider University, facilitating good collaborations with CAPE Partners

Partnerships

- The CAPE Partners have non-competitive market positions by design, so there are potential business opportunities between partners with a mutual interest in exploiting a technology

Other benefits

- Exchange scientists and engineers between industrial and academic partners, through our embedded researcher scheme
- Expand CAPE projects by leveraging the industrial funds invested through CAPE via external sponsors such as the UK government
- Membership of CAPE provides networking benefits from existing links between the University of Cambridge and other academic centres, in both the UK and elsewhere

'For any company that wishes to work with University of Cambridge, the partnership with CAPE is an excellent way of leveraging the world-class research staff and facilities at the University of Cambridge.'

Ashutosh Tomar, Jaguar Land Rover

Ratan Tata, Chairman of Tata Group, visits CAPE

CAPE Office

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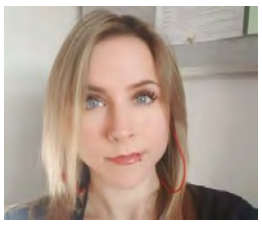

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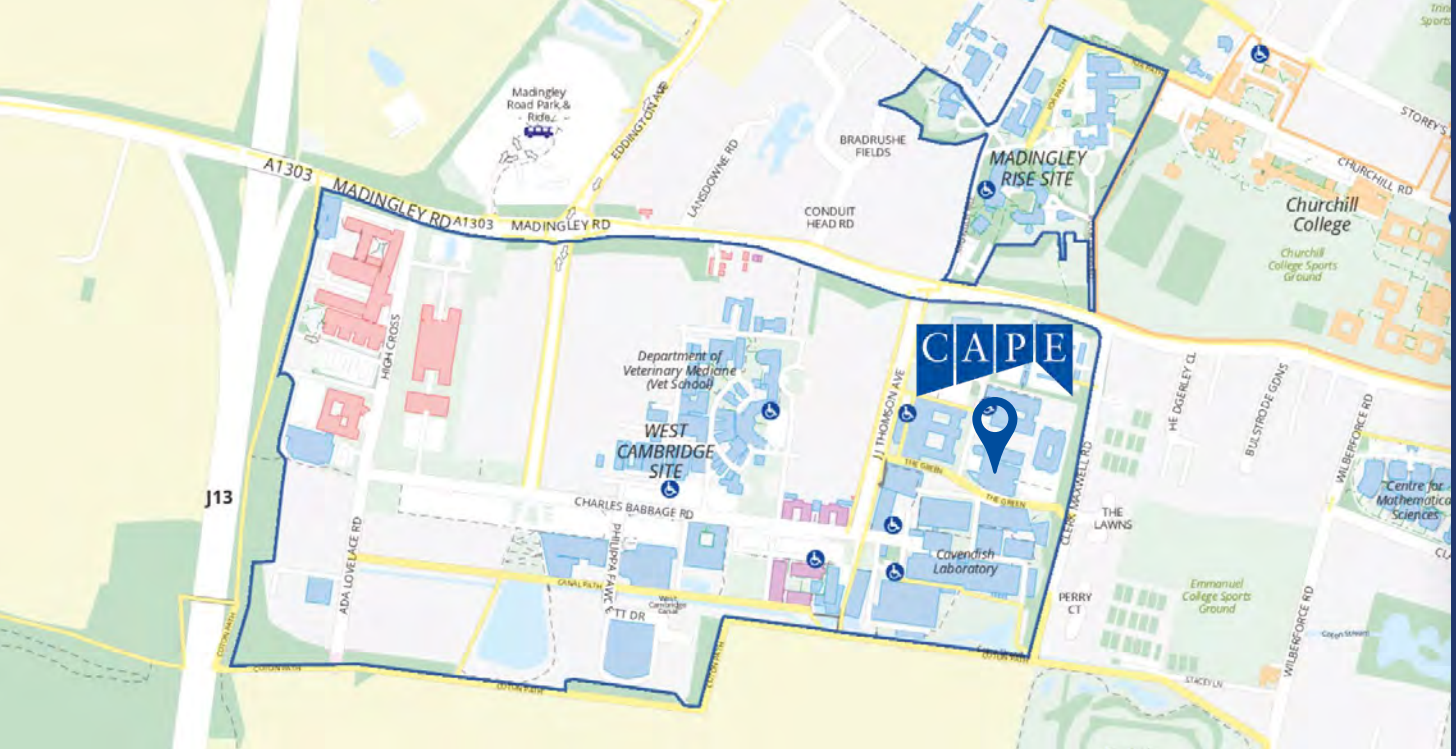

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This brochure was produced by the CAPE Office, August 2023. Except where stated otherwise, it does not necessarily represent the official views of the CAPE Partners or the University of Cambridge.

CAPE

Technology from Science

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