Student Showcase

2019 Programme

Student Showcase programme

11th October 2019

09:00	Registration	
09:30	Opening statement	
Healthcare		
09:40	Keynote talk	Justin Phillips (Google)
10:10	Short talks	Sina Schack
		Kevin Baumann
		Sanggil Han
10:40	Coffee break and poster session	
11:00	Keynote talk	Jonathan Cooper (University of Glasgow)
11:30	Short talks	Tommaso Busolo (ALMA, on wearable biosensors)
		Oliver Vanderpoorten
		Adam Zaczek
12:00	Lunch and poster session	
13:00	Flash talk competition	
Sustainability		
14:00	Keynote talk	Lan Hoang (IBM)
14:30	Coffee break and poster session	
15:00	Keynote talk	Peter Pedersen (OpenSeneca)
15:30	Short talks	Toby Jackson
		Virgil Andrei
		Prem Gill
16:10	Panel discussion on responsible innovation	
16:55	Closing statement, group photo	

Keynote Speakers

Justin Phillips
Senior Research Scientist, Google

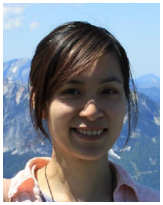
The challenge of accurate heart rate monitoring from the wrist

The wrist is a convenient site for placement of optical heart rate monitors. However recording accurate heart rate from smartwatches and fitness bands can present a significant engineering challenge. This talk explores the effects of environmental, physical and physiological factors on the accuracy of the heart rate. Limb motion is a particularly severe cause of error and the talk covers research at Google and elsewhere in optical design and novel algorithms to remove motion-related artefacts from the pulse signal.

Jonathan Cooper
Wolfson Chair of Bioengineering, University of Glasgow

Professor Jon Cooper major research interests are in medical diagnostics, and he has a track record of spin-out and translation of devices into industry and practice. In one strand of work, rapid, zero-cost "origami paper" diagnostics are being trialled in rural Uganda as species-specific DNA sensors to identify the cause of infectious disease and inform treatment "in the field". Further examples include bathroom diagnostics, sold as products on the high street (e.g. Boots the Chemist).

Lan Hoang
Researcher, IBM



Waste water management is a challenge which is increasing, in particular due to global urbanisation. Automatisation and deep learning algorithms can help face this challenge. Lan is working on reinforcement learning applications on water networks and wastewater treatment plants. She is also focusing on the creation of applied research outputs that can address the industry's needs.

Peter Pedersen
PhD student, Cambridge

Air quality reference stations provide data with low spatial and temporal resolution. They are also expensive, inhibiting their implementation in low-income countries. The design of mobile air quality sensors with a cost below £100 per unit is presented here together with the implementation of a citizen science monitoring scheme of PM2.5 in Buenos Aires, Argentina.

HEALTHCARE SHORT TALKS

A Novel System Enabling the Structural Determination of Bacterial Spore Coat Proteins

Sina Schack
Department of Chemical Engineering and Biotechnology, University of Cambridge
Sina Schack, ss2427@cam.ac.uk

Bacterial spores survive extreme hostile environments for thousands of years. This resilience is due to the outermost layer, the spore coat, which comprises up to 100 different types of proteins; however, their molecular mechanisms are poorly understood [1, 2]. This is due to a lack of structural knowledge since spore coat proteins, in the past, have been impervious to crystallisation attempts. Hence, we wish to propose a novel route for the structural determination of spore coat proteins: the cry system. In this system, (1) the protein of interest is fused to the crystallisation domains of cry proteins. The recombinant crystal is (2) expressed in *Bacillus thuringiensis* which, during spore formation, naturally releases the recombinant crystal into solution. The mixture of spores and crystals is (3) purified on a sucrose gradient, and (4) diffraction data is collected by cryo-EM, MicroED or free-electron X-ray laser methods. In this work, we used the cry system to produce three-dimensional, bipyramidal crystals of four spore coat proteins (ExsFA, SafA, CotE, CotY) in addition to the more distinctly related lytic enzyme SleC. Features of these recombinant proteins were studies by SEM and TEM. Future work will attempt to deliver the very first, high-resolution structure of these coat proteins.

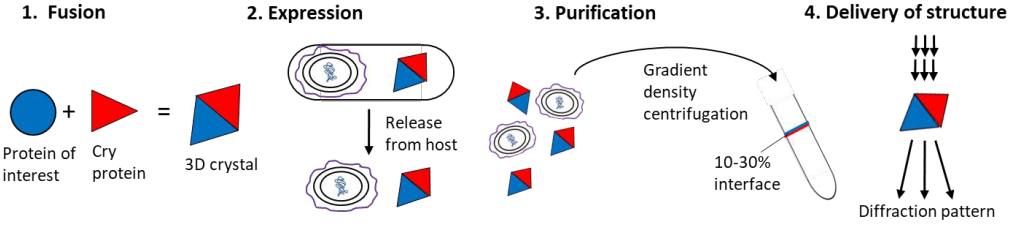


Figure: Four steps to structure determination using *Bacillus thuringiensis* cry proteins.

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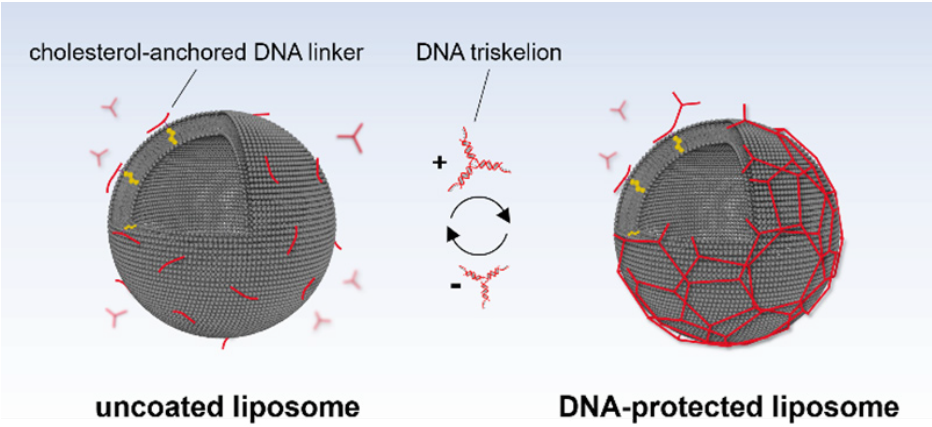
Responsive coating and stabilisation of liposomes by clathrin-inspired DNA self-assembly

Kevin Baumann[1,*], Tuomas Knowles[1], Ulrich Keyser[2]
[1]Departement of Chemistry, University of Cambridge
[2]Departement of Physics, University of Cambridge
*knb32@cam.ac.uk

Antibody drug conjugates are promising drugs for cancer treatment, which combine the specificity of an antibody with the potency of a cytotoxic payload. Site specific conjugation of payload can be achieved by reacting a payload and linker to cysteine residues. We investigated the physical stability of an antibody mutant containing an inserted unpaired cysteine in the upper CH2 domain with fluorescence techniques (chemical denaturation curves, stopped-flow), differential scanning calorimetry and hydrogen-deuterium mass spectrometry and X-ray crystallography.

Antibodies containing unpaired cysteines have been observed in one of three states; the cysteine is either capped with a cysteine, fully-reduced, or participating in an additional disulfide bond. We find that the variants show different thermodynamic and kinetic stability properties than the wild-type. Despite these differences in stability, conjugation with these states yields ADCs with similar drug to antibody ratio.



Implantable Biosensors for Monitoring Brain Function

Sanggil Han and George Malliaras

Bioelectronics Laboratory, Electrical Engineering Division, Cambridge University,
9 J J Thomson Avenue, Cambridge, CB3 0FA, UK

Understanding brain function holds the key for treating various pathologies such as epilepsy, Alzheimer's and Parkinson's disease. Investigations into the brain function have been centred around either electrophysiology studies, which only provide a partial view of brain function, or researches based on energy metabolism via indirect techniques such as MRI imaging. If we can simultaneously record both electrophysiology together with metabolite concentrations directly inside the brain, this would be really useful for understanding brain function and dysfunction. Therefore, the aim of this work is to develop implantable biosensors that combine both metabolite sensors and electrophysiology recording sites in order to allow simultaneous measurements of metabolite (e.g. glucose) concentrations and the action potential of individual neurons.

In this work, organic electrochemical transistors (OECTs) are used as glucose sensors, and the gate electrodes of OECTs are also employed as electrophysiology recording sites. For making OECT glucose sensors, the enzymes (i.e. glucose oxidase) were attached on the gate electrodes. To be specific, the effective surface area of the gate electrodes increased by forming Pt-nanoparticles for the purpose of accommodating as many enzymes as possible. In order to immobilize enzymes on the gate electrodes, chitosan was used for providing electrostatic binding with enzymes, since the surfaces of enzymes and chitosan are negatively and positively charged at a physiological condition, respectively. Furthermore, in order to increase the adhesion between them, glutaraldehyde was also employed for activating covalent bonding. The glucose sensors exhibited a good sensing performance with a fast response time within 10 sec. *In vitro* validation of the implantable probe equipped with these glucose sensors will be performed prior to animal experiments.

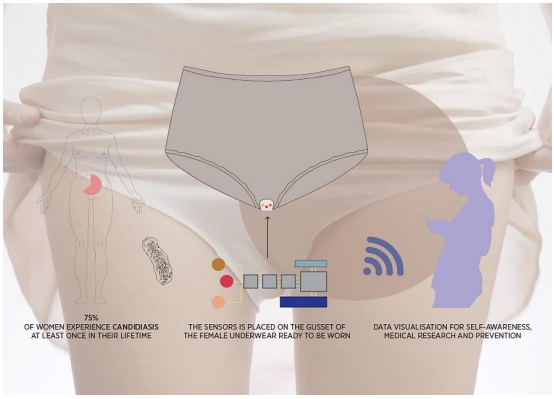
Alma - Wearable Biosensor for Monitoring Vaginal Discharge

Giulia Tomasello[1*] Tommaso Busolo[2] James Che[3] Michele Calabrese[4]
1 Self-Employ, 2,3,4 University of Cambridge

*tomasello.gi@gmail.com

Alma is a non-invasive wearable biosensor designed for the detection of vaginal infections. Studies have shown that the most important biomarkers in vaginal fluids are pH and lactate [1,2]. The project aims to develop a less conspicuous, wearable system that is low cost and reusable, capable of detecting pH and lactic acid from vaginal secretions and gather data that can be used to reconstruct an individual's physiological profile, see Figure 1. These data will be interfaced with a mobile app designed to monitor the vaginal chemistry and generate educational awareness. The sensors array is largely based on existing wearable sensors[3,4]. These sensors have been validated for sweat, saliva and tears analysis[3,5,6]. The pH sensor was fabricated first due to its simpler design. The key tasks were: reference electrode fabrication, pH electrode fabrication and sensor testing. All the fabrication were done in the Kar-Narayan Lab in the Department of Materials Science, University of Cambridge. Alma is designed to empower women to become familiar with their own bodies and active patients, more willing to seek healthcare professional advice when necessary and break some of the taboos that are still attached to gynaecological health.

Giulia Tomasello is a Designer innovating in women's healthcare combining biotechnology and interactive wearables. Tommaso Busolo is a PhD student in Smart Textile and James Che is a PhD student in Biochemist at the University of Cambridge. Michele Calabrese is a Physicist and currently student doctor at the University of Cambridge.



Alma is the winner of the Re-Fream Project 2019 awarded from EU Horizon 2020 and winner of Biomaker Spirit Award in 2018.

Figure 1. Envisaged user interface of wearable sensor

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Scalable integration of nano-, and microfluidics with hybrid two-photon lithography

Oliver Vanderpoorten[1,2,3], Quentin Peter[2], Pavan K. Challa[2], Ulrich Keyser[3], Jeremy Baumberg[3], Clemens F. Kaminski[1], and Tuomas P. J. Knowles[2,3,*]

[1]Department of Chemical Engineering and Biotechnology, University of Cambridge, Philippa Fawcett Drive, Cambridge, CB3 0AS, UK

[2]Department of Chemistry, University of Cambridge, Lensfield Road, Cambridge, CB2 1EW, UK

[3]Cavendish Laboratory, Department of Physics, University of Cambridge, J. J. Thomson Avenue, Cambridge, CB3 0HE, UK

*tpjk2@cam.ac.uk

Nanofluidic devices have great potential for applications in areas ranging from renewable energy to human health. A crucial requirement for the successful operation of nanofluidic devices is the ability to interface them in a scalable manner with the outside world. Here, we demonstrate a hybrid two photon nanolithography approach interfaced with conventional mask whole-wafer UV-photolithography to generate master wafers for the fabrication of integrated micro and nanofluidic devices. Using this approach we demonstrate the fabrication of molds from SU-8 photoresist with nanofluidic features down to 230 nm lateral width and channel heights from micron to sub-100 nm. Scanning electron microscopy and atomic force microscopy were used to characterize the printing capabilities of the system and show the integration of nanofluidic channels into an existing microfluidic chip design. The functionality of the devices was demonstrated through super-resolution microscopy, allowing the observation of features below the diffraction limit of light produced using our approach. Single molecule localization of diffusing dye molecules verified the successful imprint of nanochannels and the spatial confinement of molecules to 200 nm across the nanochannel molded from the master wafer. This approach integrates readily with current microfluidic fabrication methods and allows the combination of microfluidic devices with locally two-photon-written nano-sized functionalities, enabling rapid nanofluidic device fabrication and enhancement of existing microfluidic device architectures with nanofluidic features.

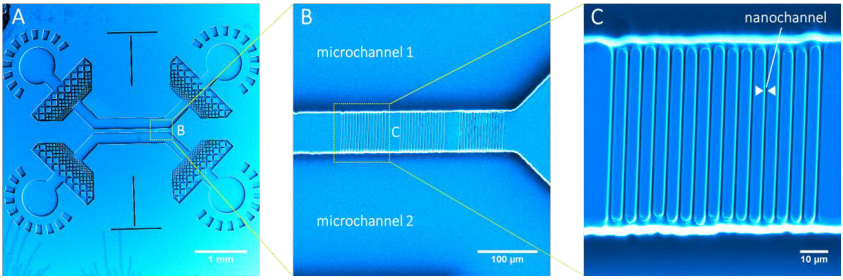

Figure 1. SEM micrograph of a nanofluidic chip imprinted in PDMS. Magnifying the region between two microfluidic resevoirs shows their connection by nano channels written by 2P-DLW.

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Investigating the glass transitions and stabilities of amorphous drugs and polymers with terahertz time-domain spectroscopy

A. J. Zaczek*, J. A. Zeitler
[1]Department of Chemical Engineering and Biotechnology, University of Cambridge, Philippa Fawcett Drive, Cambridge CB3 0AS, UK
*Corresponding author, az404@cam.ac.uk

Amorphous drugs are of interest in the pharmaceutical industry due to their enhanced bioavailability. However, these drugs are often unstable at room temperatures, leading to a short shelf-life. Mixing the active drug with a polymer can enhance the shelf-life of and potentially make these pharmaceuticals feasible for modern use. Glass transitions occur within an amorphous sample. While the alpha-transition has been well documented [1], the beta-transition which occurs at lower temperatures is ultimately responsible for amorphous stability [2] and must be investigated for optimal drug storage. Both of these transitions can be detected with terahertz time-domain spectroscopy, leading to a more complete analysis into the stability of amorphous drugs and amorphous solid dispersions.

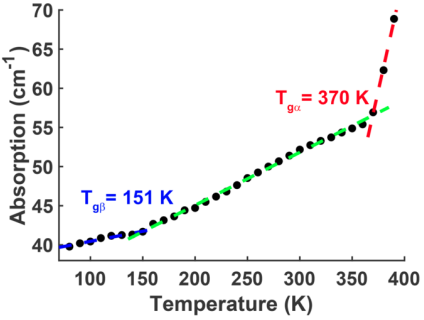

Figure 1. The alpha and beta glass transitions of PVP/VA, a common co-polymer used in pharmaceutical mixtures, determined via terahertz time-domain spectroscopy.

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FLASH TALK COMPETITION

Is there a water content threshold for cluster formation in glycerol?

J. Kölbel*, J. A. Zeitler
[1]Department of Chemical Engineering and Biotechnology, University of Cambridge, Philippa Fawcett Drive, Cambridge CB3 0AS, UK
*Corresponding author, js2303@cam.ac.uk

The stability of freeze-dried formulations due to residual water is a topic of significant interest. Glycerol, a cryoprotectant that is widely used in freeze drying, is mixed with water in different concentrations and measured with terahertz time-domain spectroscopy over a wide range of temperatures. Here, the question of whether there is a threshold for water clustering or a gradual change in the relative amount of unclustered water upon increased water content is addressed [1]. When plotting the absorption coefficient versus temperature, four distinct temperature regions are identified that are characteristic with the three relaxation regimes of disordered organic molecular materials with temperature. The onset temperature of molecular mobility can be extracted from the terahertz experimental data [2]. Rather than a gradual change we find evidence from this data for a distinct threshold at a water concentration of 3 to 5 wt.%.

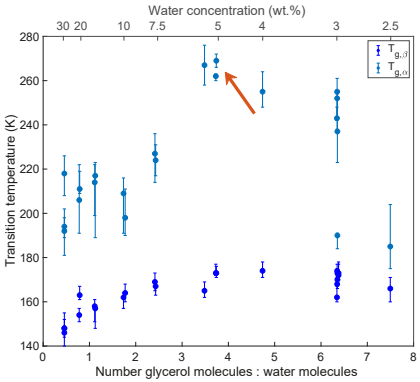

Figure 1. Glass transition temperatures $T_{g,\alpha}$ and $T_{g,\beta}$ for different water concentrations and corresponding molar ratios. Error bars are obtained by varying the transition points and calculating alternative transition temperatures. The maximum $T_{g,\alpha}$ is highlighted.

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Spinal cord thin film stimulator

Ben Woodington

Bioelectronics Laboratory, University of Cambridge, UK
bw422@cam.ac.uk

I have developed a minimally invasive spinal cord stimulator using thin film electronics and micro-fabrication techniques. The device will offer advantages over current technologies and is soon to be validated within a cadaveric model. The device is up to 200x thinner than commercial alternatives which opens the door to sensing spinal signals, currently unreachable with today's technology.

Fluorescent amyloid fibre patterns for application in optoelectronics

L. Hecker*[1], W. Wang[2], C. Poudel[1], I. Mela[1], G. Soavi[3], I. Paradeisanos[3], Y. Y. S. Huang[2], C.F. Kaminski[1]

[1]Department of Chemical Engineering and Biotechnology, University of Cambridge

[2]Department of Engineering, University of Cambridge

[3]Cambridge Graphene Centre, University of Cambridge

*Lisa Hecker, lh551@cam.ac.uk

Amyloid aggregates are formed by a variety of different proteins and share a characteristic, beta-sheet rich structure. This gives rise to a range of properties that are interesting for application in technological devices. The self-assembly into fibrillar structures, high mechanical and chemical stability and an intrinsic fluorescence in the visible range make amyloids an ideal, biological building material [1]. However, patterning and controlled deposition of the aggregates remains a problem. We present an amyloid-hybrid material which can be structured into aligned, µm sized fibres while resembling the characteristic properties of natively grown structures. A low-voltage electrospinning approach with functional protein core and stabilising polymer shell permits the efficient fabrication of mm long protein-polymer fibres in arbitrary patterns [2]. The electrospun core-shell structures can be deposited onto substrates or produced as free standing fibres. This new, optically active and strong biomaterial has potential for applications in interconnected photonic and bioelectronic devices.

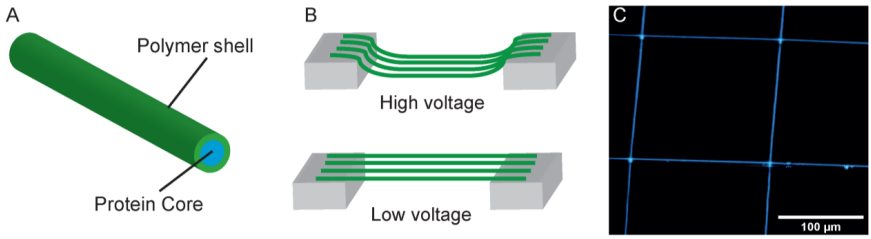

Figure 1. A: Schematic of the new hybrid material with amyloid core and supporting polymer shell. B: 2D and 3D patterns can be created with free standing or substrate deposited fibres. C: Fluorescence microscopy image of the novel amyloid material.

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Holographic control of light propagation in optofluidic waveguides

Ralf Mouthaan

Department of physics, University of Cambridge, UK
rpm40@cam.ac.uk

This project aims to exploit holographic techniques to control light propagation in optofluidic waveguides. Previous work has allowed light at the distal tip of the waveguide to be controlled, enabling the development of hair-thin holographic fibre endoscopes for the detection of pre-cancerous tissue. Current work aims to control light propagation along the entire length of the optofluidic waveguide, opening up possibilities in refractive index sensing, localised spectroscopy and optical tomography.

Terahertz look for understanding protein aggregation

Talia Shmool
Department of Chemical Engineering and Biotechnology, University of Cambridge, UK
tas61@cam.ac.uk

Freeze-dried formulations are typically used in the pharmaceutical sector to produce stable products which have a shelf-life of years. However, the lyophilisation process can expose protein molecules to various stresses, resulting in protein aggregation. In this work terahertz time-domain spectroscopy was used at variable temperatures (100 - 400 K) to track the structural dynamics of a range of freeze-dried formulations. By understanding which formulations aggregate and developing insight into aggregation mechanisms, formulation stability can be optimised.

Towards a New Flexible Sensor System with High Spatial Resolution Based on Microparticles Inside Hollow-Core Photonic Crystal Fibers

M. Koeppel[1,2]*, A. Sharma[3], E. Renner[1], S. Xie[3], B. Schmauss[1,2,3], P. St.J. Russell[3,4]
[1]Institute of Microwaves and Photonics (LHFT), University Erlangen-Nürnberg, Erlangen, Germany
[2]Graduate School in Advanced Optical Technologies (SAOT), University Erlangen-Nürnberg, Erlangen, Germany
[3]Max Planck Institute for the Science of Light, Erlangen, Germany
[4]Department of Physics, University Erlangen-Nürnberg, Erlangen, Germanytas61@cam.ac.uk
*max.koeppel@fau.de

A novel concept for future fiber-optic sensor systems is based on optically trapped particles inside a hollow-core photonic crystal fiber (HC-PCF) [1]. In such a system, the particle itself is the sensing element and propelling it along the fiber while monitoring its response to external perturbations allows quasi-distributed sensing. The measurement of various quantities such as temperature or electric field has already been demonstrated [1, 2]. This concept is highly flexible, reconfigurable and achieves an unprecedented resolution in the µm-range by incorporating an optical frequency domain reflectometry ranging system (COFDR) [3]. Using the COFDR technique which is similar to a FMCW radar, an optically trapped polystyrene particle could be located with a standard deviation of 10.6 µm inside a HC-PCF.

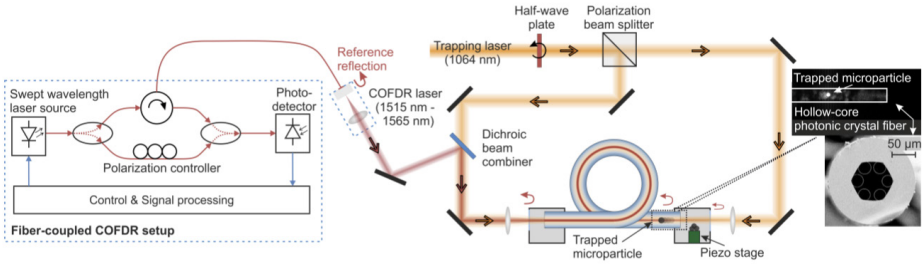

Figure 1. Trapping setup and COFDR localization system for the trapped microparticle.

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Compressed Sensing at Massive Scale

Bilal Chughtai* and Andrew Thompson
National Physical Laboratory
*bc464@cam.ac.uk

The *unsourced random access* problem concerns how huge networks of devices (such as might occur in Internet of Things applications) communicate. The CHIRRUP algorithm was proposed in [1] as a practical solution to this problem. In short, each device sends a unique message consisting of B bits, which is encoded using a codeword of length m drawn from a codebook of discrete binary chirps. The receiver is tasked with identifying as many of the K messages as possible from their noisy superposition. Note that the total number of possible messages is n=2^B. The CHIRRUP algorithm achieves this goal by exploiting the mathematical properties of the binary chirp codewords.

Compressed sensing is a recently emerged paradigm in signal processing which centres on finding sparse solutions to underdetermined linear systems**.** More precisely the task is to find a sparse vector x from y=Ax+e, where A is an m x n matrix, and e some noise vector. It turns out that CHIRRUP can also be viewed as an algorithm for solving the compressed sensing problem. Compressed sensing algorithms usually have complexity at least linear in the signal dimension n. Unusually in this context, CHIRRUP has sublinear complexity, which means it is able to be applied to problems at massive scale.

The algorithm proposed in [1] is limited in this context, in that it assumes all coefficients are either 1 or 0. In this work, we extend the CHIRRUP algorithm to be able to handle more general coefficients, say with expected range [1 2]. We explore a modification to a certain "acceptance" criterion incorporated in the algorithm, attempting to optimize it to maximize the proportion of nonzero coefficients correctly identified.

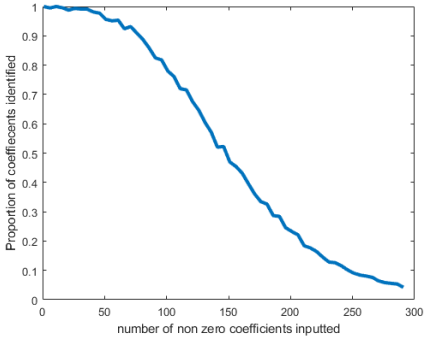

Figure 1. A plot showing the performance of the modified algorithm in a regime with m=2^13, n=2^28

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Random number generator using noise of MEMS sensor

James Meech
Department of Engineering, University of Cambridge, UK
jtm45@cam.ac.uk

This project attempts to harness the physical processes that produce MEMS sensor noise as a new novel way to generate non-uniform random variates in hardware with improvements in speed and efficiency over the current state-of-the-art methods. The results show that MEMS sensors sampled with ADCs are a viable source of non-uniform random variates and have the potential to be both faster and more efficient than all state-of-the-art methods of non-uniform random variate generation. Hardware innovations such as these are essential to allow machine learning programs to churn through the large amount of computations required to produce their spectacular results.

Deep learning applied to hyperspectral endoscopy for online spectral classification

Alexandru Grigoroiu[1,2*], Jonghee Yoon[1,2] and Sarah E. Bohndiek[1,2]
[1] Department of Physics, University of Cambridge, UK
[2] Cancer Research UK Cambridge Institute, University of Cambridge, UK
[*]Corresponding author, ag745@cam.ac.uk

Hyperspectral imaging (HSI) is being explored in endoscopy as a tool to extract biochemical information from tissue optical properties that may improve contrast for early cancer detection in the gastrointestinal tract. Motion artefacts during medical endoscopy have traditionally limited HSI application, however, recent developments [1] in the field have led to real-time HSI deployments. However, the sheer volume of data acquired using HSI in endoscopy makes real-time processing a significant challenge. Here, we present a CNN that is able to provide high accuracy classification of HSI data acquired during endoscopy. Performance was assessed using a Macbeth ColorChecker Chart, methylene blue stained pig oesophagus videos and in vivo images of different stages of human oesophageal cancer.

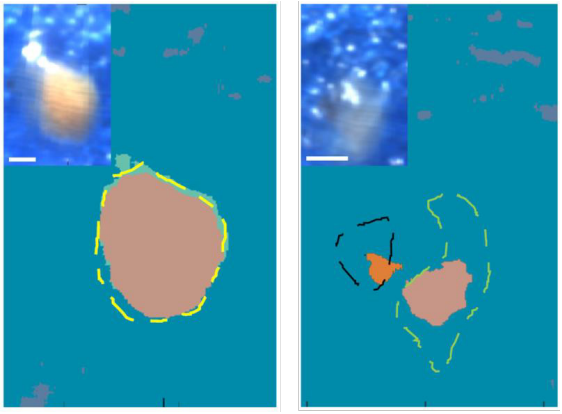

Figure 1. Classification maps for a gastric tissue sample (left) and an adenocarcinoma sample (right). The yellow prediction boundary encompasses the gastric epithelium, the black boundary encompasses the adenocarcinoma

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Understanding dissipative behaviour in superconducting microresonators over a wide range of readout power

T.K. Skyrme, C.N. Thomas, S.Withington, D.J. Goldie, A.L. Hornsby, S. Doyle, P. Barry
Cambridge University, Cardiff University, University of Chicago

Ultra-low-noise high-quality-factor superconducting transmission lines and microresonators have applications in many areas of quantum technology: qubits, spin resonance experiments, parametric amplifiers, quantum detectors and multiplexers. Understanding the mechanisms responsible for loss and decoherence, their physical origins, and their relationship with applied readout power is essential. We describe a method for modelling and understanding loss when several non-linear dissipative mechanisms are present simultaneously. We explore behaviour over a wide range of readout powers, spanning 6 orders of magnitude, in the case where two-level systems and sub-gap quasiparticle heating are present and interact dynamically. Our method attributes quality factors to different loss mechanisms, and considers the steady state values of dielectric energy and quasiparticle population. Many phenomena are seen, which are predicted and verified experimentally: for example, the distortion of resonance curves in the I-Q plane, bistability, and under certain circumstances, the rapid switching on of resonance curves at low readout powers. The measurement of quality factor as a function of readout power, even when the resonance curve is highly distorted, turns out to be a particularly valuable way of uncovering information about the dissipative processes present. We show that the relationship between quality factor and readout power ultimately determines the best operating point of many devices, and warn against the consequences of ignoring non-linear dissipative loss in superconducting resonators used for low-noise and high-quality-factor applications.

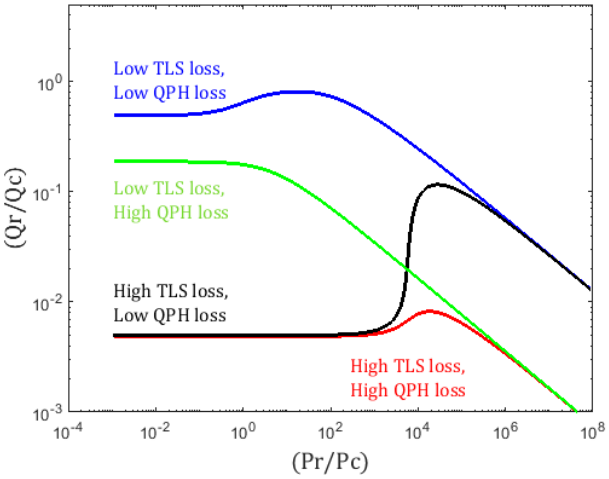


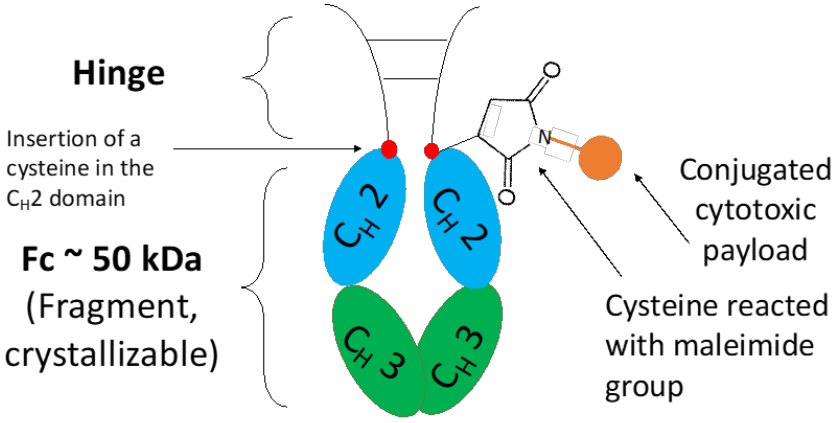
Figure.1. Modelling the behaviour of superconducting microresonators over a wide readout power range. Qr/Qc and Pr/Pc are the normalised quality factor and applied readout power. The consequences on behaviour when different dissipation mechanisms dominate is compared. The severity of two level systems (TLS) and quasiparticle heating (QPH) effects are compared by changing the values of quality factors attributed to each mechanism.

Exploring the structure and stability of antibody variants engineered for site-specific conjugation

Carolina T Orozco, Matthew J Edgeworth, Paul Devine, Alistair R Hines, Jonathan J Phillips, Nicholas Bond, Sophie E Jackson

Antibody drug conjugates are promising drugs for cancer treatment, which combine the specificity of an antibody with the potency of a cytotoxic payload. Site specific conjugation of payload can be achieved by reacting a payload and linker to cysteine residues. We investigated the physical stability of an antibody mutant containing an inserted unpaired cysteine in the upper CH2 domain with fluorescence techniques (chemical denaturation curves, stopped-flow), differential scanning calorimetry and hydrogen-deuterium mass spectrometry and X-ray crystallography.

Antibodies containing unpaired cysteines have been observed in one of three states; the cysteine is either capped with a cysteine, fully-reduced, or participating in an additional disulfide bond. We find that the variants show different thermodynamic and kinetic stability properties than the wild-type. Despite these differences in stability, conjugation with these states yields ADCs with similar drug to antibody ratio.



open-seneca: development of a low cost air quality sensor network and its implementation to measure PM2.5 in the city of Buenos Aires, powered by citizen science

Peter Pihlmann Pedersen [1,2] , Lorena Gordillo Dagallier [1,2] , Sebastian Horstmann [1,2] , Charles Christensen [1,2] , Christoph Franck [1,2] , Raphaël Jacquat [1,2] , Norberto Pablo Vidal [3] , Saif Syed Ahmad [4] , Nicole E. Weckman [5] , Matias Acosta [6]

[1] open-seneca

[2] Department of Chemical Engineering and Biotechnology, University of Cambridge, UK

[3] Secretary of Government of Environment and Sustainable Development of Argentina, San Martín 451, Buenos Aires, Argentina

[4] Department of Oncology, University of Cambridge, Cambridge, UK

[5] Cavendish Laboratory, University of Cambridge, Cambridge, UK

[6] Center for Science & Policy, University of Cambridge, Cambridge, UK

info@open-seneca.org

Air quality reference stations provide data with low spatial and temporal resolution. They are also expensive, inhibiting their implementation in low-income countries. The design of mobile air quality sensors with a cost below £100 per unit is presented here together with the implementation of a citizen science monitoring scheme of PM2.5 in Buenos Aires, Argentina. During 7 weeks, 20 mobile sensors were used to gather over 400,000 data points across 3,500 km. Hourly mean PM2.5 values between 0 and 70 μg/m³ were measured and compared to a reference station. By doing a data baseline correction using different measures of centre in the data set from 15-minute periods, the method identified 20 pollution hotspots. Quadrants between 200 and 400 m 2 with PM2.5>30 μg/m³ above the baseline can be visualized using a new methodology of interactive
online maps. The data from this mobile sensor network is complementary to and enriches that of a stationary station. Insights on the added value of citizen engagement are also outlined. The expansion of these schemes offers strong potential for monitoring air quality in urban areas, particularly those that do not currently have reference stations and have limited financial resources.

SUSTAINABILITY SHORT TALKS

The future for sensors in forest ecology

Toby Jackson
Department of Plant Sciences, University of Cambridge, UK
tj312@cam.ac.uk

Forest ecology fieldwork relies on a number of sensors, ranging from simple thermometers to sonic anemometers and gas analysers. Progress in this field is often hampered by the cost of these sensors (and the necessary data loggers) as well as a lack of relevant technical skills. I will give an overview of the commonly used sensors and outline some opportunities for improvement. I will also discuss my own project (in development) using strain gauges to measure the likelihood of wind damage in the worlds tallest tropical trees.

Novel approaches to synthesize up-scaled photoelectrochemical devices

Virgil Andrei
Department of Chemistry, University of Cambridge, UK
va291@cam.ac.uk

The light-driven conversion of small molecules such as water and CO2 into so-called solar fuels (e.g. H2, CO) represents an attractive alternative for simultaneous energy harvesting and storage. While great progress has been made in the development of light absorbers, their integration with catalysts into photoelectrochemical (PEC) devices for fuel production still poses challenges. Beside the performance and stability of common PEC prototypes, their scalability and choice of catalyst are also major factors which must be considered for commercial applications. In the Reisner group, I aim to address those issues by developing approaches to synthesize and characterize up-scaled PEC devices, which are able to produce fuels autonomously in the absence of external bias. To overcome the overpotential losses of electroreduction, we introduce state-of-the-art photocathodes obtained by protecting triple cation mixed halide perovskite solar cells with a Field's metal encapsulant. By combining the perovskite photocathodes with robust BiVO4 photoanodes, tandem PEC devices of sizes up to 10 cm2 can be obtained which sustain unassisted water splitting in aqueous media, revealing key general insights for the encapsulation of perovskite optoelectronic devices. Looking beyond water splitting, I am also working on PEC devices that can couple the more challenging CO2 reduction to water oxidation. By interfacing the perovskite photocathodes with an earth abundant molecular cobalt catalyst, selective aqueous CO2 reduction can be maintained at light intensities as low as 0.1 Sun, providing potential pathways for maximizing daylight utilization. The resulting perovskite-BiVO4 PEC tandems sustain a bias-free syngas production for several days, operating as standalone artificial leaves in neutral pH solution. The overall findings are applicable to a wide range of photoelectrochemical systems, with the ultimate goal of contributing towards a circular carbon economy via photoelectrocatalysis.

Seals from Space: Identifying change in Antarctic ecosystems via the monitoring of ice-seals and sea ice habitats by very high-resolution satellite imagery

Prem Gill
Departement of Geography, University of Cambridge, UK
psg32@cam.ac.uk

Antarctic pack-ice seals (APIS) are long-lived, upper trophic-level predators and amongst the largest consumers of Antarctic krill. Therefore, the monitoring of APIS populations can indicate changes in the Antarctic ecosystem. However, APIS inhabit the inaccessible sea ice zone, making traditional ground surveys logistically difficult. As a result, reliable population estimates and habitat information for APIS are lacking. To overcome these challenges, very high-resolution (VHR) satellite imagery will be used to detect seals for counts at local scales and identify habitat hotspots at regional scales. Given that sea ice volume is predicted to decline significantly by the end of the century, the monitoring of APIS and their habitat is pivotal to polar marine conservation.

Here, we discuss satellite / aerial surveys conducted on breeding ice-seals to test automated seal-detection and provide the first VHR sea ice classification techniques. Resulting insights into habitat preference will enable us to: predict responses to climate change; map penguin-seal-fisheries competition; inform the first robust pan-Antarctic ice-seal population estimates. Population trends and shifts in habitat extent determined from this data will inform IUCN red list assessments. We will also discuss the capacity for dynamic conservation management provided by an automated system for near real-time habitat mapping.

POSTER SECTION

A Gas Sensor to Selectively Measure VOCs

Andrew Stretton[1,2*], Lisa Hall[1]
[1]Department of Chemical Engineering and Biotechnology , University of Cambridge, UK
[2] EPSRC CDT Sensor Technologies and Applications
*ajs309@cam.ac.uk

VOCs (Volatile Organic Compounds) are bad for human health. Breathing them is generally a bad idea. Despite this, telling the difference between a harmful and a harmless VOC is a challenge. It normally requires the use of large, complicated and expensive equipment. Commercial gas sensors are small, simple and inexpensive, but lack selectivity for VOCs. This poster shows an automated device that achieves VOC selectivity for benzene in the single parts-per-billlion concentration, within 10 minutes and with equipment that costs <<£500.

Single figure ppb selectivity

Analysis time of <10 mins

Low cost device (<< £ 500)

Automated data collection

Live Attenuated Influenza Virus: Understanding flu vaccines via super-resolution microscopy

Luca Mascheroni[1]*, Sameer Ayaz[3], Oliver Dibben[3], Helen Bright[3], Colin Crump[2], Clemens Kaminski[1]
[1]University of Cambridge, Department of Chemical Engineering and Biotechnology, Cambridge
[2]University of Cambridge, Department of Pathology, Cambridge
[3]AstraZeneca, Speke, Liverpool
*lm775@cam.ac.uk

Live Attenuated Influenza Virus (LAIV) is the main component of seasonal flu vaccines produced by the industrial partner AstraZeneca. The seasonal vaccines produced over the years have proved to have fluctuating effectiveness; the reason underlying such variability in performance is, hoverer, not yet clear. A poor clinical efficacy has been linked to low infectivity in in vitro assays, which suggests that the poor vaccines' performance might be due to the intrinsic infection mechanism of the LAIV viruses. Here, we aim at finding out the molecular reasons for the deficient life cycles of some LAIV particles by means of super-resolution optical imaging.

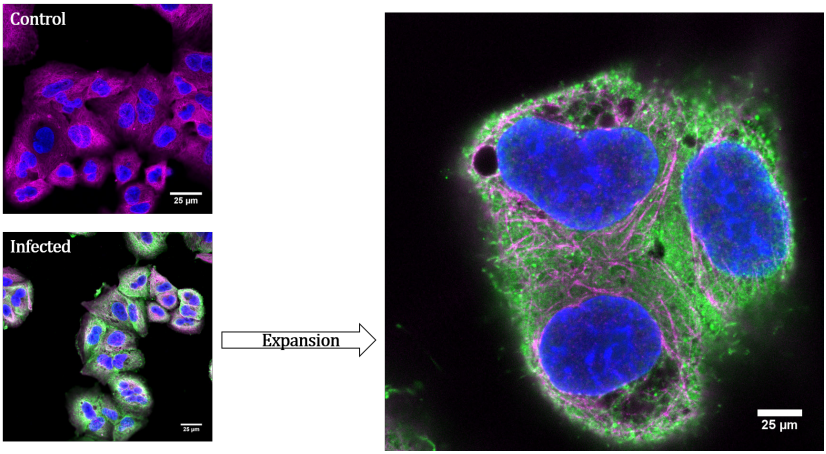


Figure 1. A549 cells infected with Live Influenza Attenuated Viruses (LAIV) imaged via confocal microscopy (left) and via expansion microscopy (right), which gives the same image in super-resolution. Blue: nuclei; magenta: microtubules, green: LAIV.

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High throughput micro/nano-fluidics for protein detection

R.J.P. Jacquat[†§*], S. Ghosh[†‡§], O. Vanderporten[†], J.C. Stewar[‡], P.K.Challa[†§], K. Liis Saar[†§], Q.A.E. Peter[†], H.L. Stern[§], T. Müller[#], S. Hofmann[‡], T.P.J. Knowles[†§]
[#]Fluidic Analytics AG, Cherry Hinton Road, CB1 8DH,Cambridge, UK
[†]Department of Chemistry, University of Cambridge, , Cambridge, UK
[‡]Department of Engineering, University of Cambridge, Cambridge, UK
[§]Cavendish Laboratory, University of Cambridge, Cambridge, UK
*rj380@cam.ac.uk

Neurodegenerative diseases are a public health challenge with the ageing of the population. In the Centre for Misfolding diseases, we focus on disorders caused by protein aggregations, like Alzheimer's, Parkinson's and Creutzfeldt-Jacob diseases. The correct function of protein in the cells is given by its shape, but the functional state is not necessarily the shape which minimises the free energy. Furthermore, in the case of the above diseases, a misfolded protein can "corrupt" the well-folded one and start to form aggregates. In addition to the lack of function from the absence of well-folded protein, the aggregates are toxic to the cells. A better understanding of this aggregation could lead to novel therapeutic approaches. My current project uses a combination of two existing methods to determine the charge and the size of proteins present in heterogeneous solution (capillary electrophoresis [1] and diffusional sizing [2]). The former method separates the proteins in function of their mobilities, the last methods sizes the separated proteins. We expect from this device to be able to determine the different concentration of species present in the aggregation process at different time. The time to separate is quicker than the standard size exclusion chromatography and combine within the chips allow in theory a better separation with smaller peak broadening. In addition, I am interested in working with confocal microscope. It allows to reach a lower concentration, and to have access to new information of the species looking at the number of photons that each molecule emits.

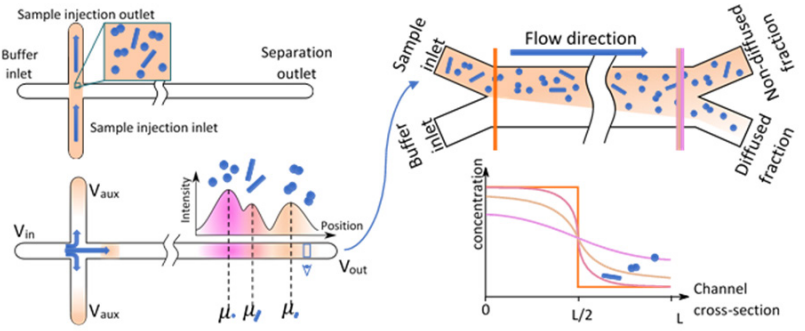

Figure 1. On the left hand side, the separation of proteins mixture using a voltage difference. Separation in function of the mobility. On the right hand side, the size measurement of the protein using the diffusion device. The ratio of the fraction diffuse and non-diffuse depend of the protein size.

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Design and optimisation of point of care diagnostics to quantify Hepatitis B viral load

Akashaditya Das[1]*, Dr. James W Ajioka[1]
[1]Department of Pathology, University of Cambridge
*Email address: ad906@cam.ac.uk

Hepatitis B virus is transmitted in cells as a partially double stranded circular DNA genome. It infects liver cells known as hepatocytes where it replicates rapidly and damages the host cell. Symptoms of the acute infection include loss of appetite, nausea, vomiting, body aches, mild fever, dark urine and progresses onto jaundice, cirrhosis and potential liver failure. Consistently high levels of HBV virus in the blood are associated with a 15-fold higher risk of developing Hepatocellular carcinoma [1]. It is estimated that in 2015 viral hepatitis was responsible for 1.34 million deaths with HBV accountable for 900,000 of these deaths [2].

A universal vaccine for HBV has existed since 1982 but the distribution channels required to vaccinate worldwide are lacking, especially in low income and middle-income countries. HBV infection can be spread from mother to child via the placenta or via exposure to infected bodily fluids. It is more common for those infected before the age of five to become chronically infected with HBV than those infected after the age of 5. For those who were not vaccinated and now live with chronic or acute HBV, only 9% of sufferers know their status worldwide and only 8% of this 9% are being treated [2]. The development of a nucleic acid point of care test that doesn't rely on the expensive equipment would allow for more information regarding infection statistics to be available to decision makers allowing them to make informed decisions.

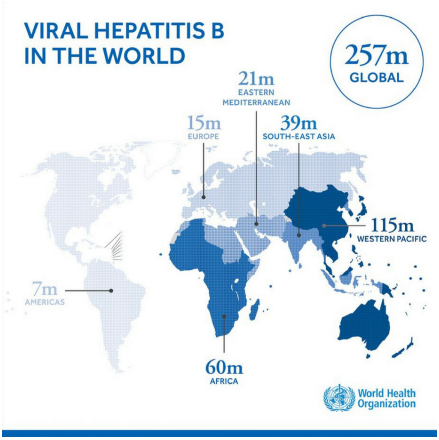

Figure 1. Global infection distribution of recorded HBV infections in the world in 2015 [2].

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Comparison of different camera technologies for photoluminescence of silicon solar cells with inhomogeneous white light emitting diode excitation source

Bernd Doll[1,2,3*], Johannes Hepp[1,2,3], Larry Luer[1], Oleksandr Stroyuk[3], Claudia Buerhop[3], Jens Hauch[1,3], Christoph Brabec[1,3,4]

[1]Institute Materials for Electronics and Energy Technology, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, 91058 Erlangen, Germany

[2]Graduate School in Advanced Optical Technologies, Paul-Gordan-Straße 6, 91052 Erlangen, Germany

[3] Helmholtz-Institut Erlangen-Nürnberg, Erlangen, 91058 Erlangen, Germany.

[4] Bavarian Centre for Applied Energy Research. Immerwahrstr. 2, 91058 Erlangen, Germany.

*Corresponding author, E-Mail: bernd.doll@fau.de

Fast and non-destructive quality control tools are important to assess the reliability of photovoltaic plants. The most detailed tool is luminescence imaging. To overcome the time consuming electrical wiring of silicon solar panels for electroluminescence [1], we developed a high throughput photoluminescence (PL) method with white conventional 100 W light emitting diodes and inhomogeneous illumination [2].

In Figure 1 PL images acquired with an InGaAs and a Si detector camera technologies are shown. With both cameras cracks are visible for different Si solar cell technologies.

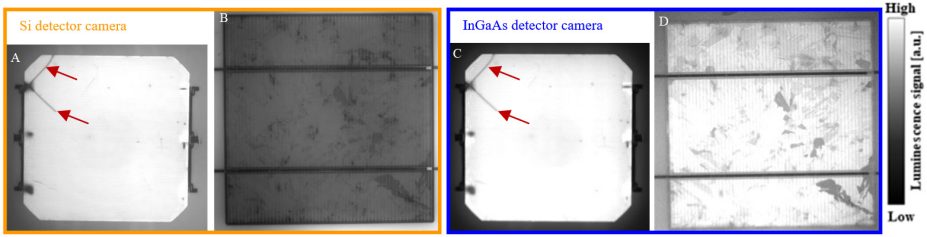

Figure 1: PL images, A and B acquired with Si detector, C and D acquired with InGaAs detector. A and C are PL images of an internal back contact Si solar cell with cracks indicated by arrows. B and D are PL images of a multi crystalline Si solar cell.

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Bio-Nano-Hybrid Materials for Vaccine Formulation

Christoph O. Franck,[1*] Dr Ljiljana Fruk,[1] Dr Chris van der Walle[2]

[1] Department of Chemical Engineering and Biotechnology, University of Cambridge, Cambridge, UK

[2] AstraZeneca plc, Cambridge, Granta Park, CB21 6GH, United Kingdom

* Corresponding author: cof20@cam.ac.uk

During the last two decades, DNA vaccines have emerged as promising therapeutic agents to tackle cancers, autoimmune and allergic diseases.[1] However, state-of-the-art drug delivery systems for DNA vaccines lack efficacy and precision, leading to dangerous side-effects during therapy.[2] This project aims at formulating a DNA vaccine delivery platform, based on well-defined, functionalized poly dopamine nanoparticles (PDA NPs), to overcome the drawbacks associated with DNA vaccine administration. While highly bio-compatible PDA NPs have already been shown to enhance the efficiency and the in vivo half-life of single-stranded DNA vaccines, the adequate delivery of plasmid DNA (pDNA) medicines has not been achieved.[3] In order to immobilize negatively charged pDNA vaccines on the nanocarrier surface, PDA NPs will be modified with positively charged arginine moieties in a co-polymerization process. The main milestones of the project involve the synthesis and detailed characterization of the NPs and functional linker molecules, the construction and amplification of pDNA in a bacterial host, loading experiments of the drug onto the NPs as well as stability, release profile studies of the final vaccine as well as in vitro and in vivo tests.

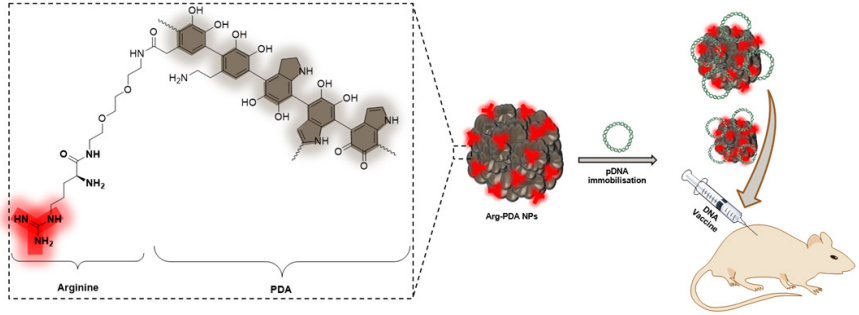

Figure 1: Arginine-modified PDA NPs will be used to immobilize pDNA vaccines through electrostatic interactions on the carrier particle surface. The formulated pDNA@Arg-PDA NPs will then be screened in in vitro and in vivo tests.

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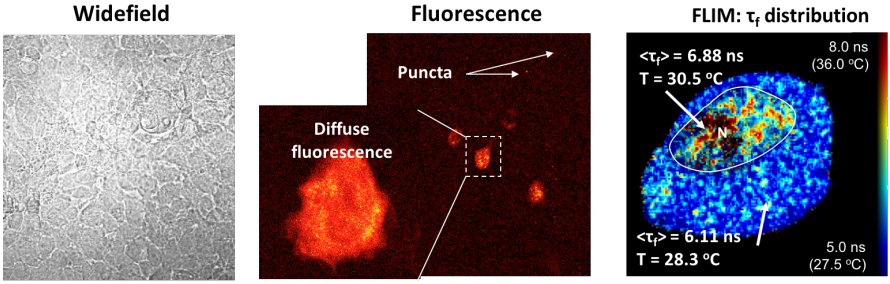
[2] T. Medjitna et al., Dev. Biol. 2006, 126, 261-270.

[3] W. Tao et al., Theranostics 2016, 6, 470-484.

In vitro intracellular thermometry to investigate amyloid aggregation

C. W. Chung[1,2*], T. Euser[2,3], G. S. Kaminski Schierle[1,2]
[1]Department of Chemical Engineering and Biotechnology, [2]Sensor CDT, [3]Cavendish Laboratory
[*]cwc53@cam.ac.uk

A characteristic of Alzheimer's disease is the aggregation of amyloid-β 1-42 (Aβ42) peptides, which has an associated enthalpic barrier[1], in neuronal cells. Hence, intracellular thermometry using cationic linear fluorescent polymeric thermometers (FPTs, synthesised by the Inada Group, Tokyo University[2]) was proposed to quantify the energy flow and cost associated with Aβ42 aggregation *via* temperature. This was achieved through fluorescence lifetime imaging microscopy (FLIM), which detected the temperature-dependent fluorescence decay lifetime (τ_f) of the FPTs (fig.1a&b). Experiments were conducted in human embryonic kidney (HEK-293T) cells and its amyloidal Arctic mutant (Aβ42-E22G). An average temperature difference of 1.2 °C was visualised between the nucleus and cytoplasm in HEK-293T cells (fig.1c). A better understanding of biological interactions (i.e. changes to membrane permeability due to Aβ42 aggregates) is needed to reliably map temperature profiles in Aβ42-E22G cells.



(a) (b) (c)

Figure 1. Intracellular thermometry in HEK-293T cells – Permeation of the FPTs into HEK-293T cells observed under (a) widefield and (b) fluorescence mode, where either diffuse (used for analysis) or punctate fluorescence (rejected for analysis) was observed. (c) A temperature gradient within the cell was observed, with the nucleus (denoted by N) at a higher temperature than remaining parts of the cell.

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SERS sensing with AuNP:CB[5] aggregates: The role of citrate

David-Benjamin Grys[1*], Bart de Nijs[1], Wei-Hsin Chen[1], Wenting Wang[1], Junyang Huang[1], Oren Scherman[2], Jeremy Baumberg[1]

[1]NanoPhotonics Centre, Cavendish Laboratory, University of Cambridge
[2]Melville Laboratory for Polymer Synthesis, Department of Chemistry, University of Cambridge
*dbg27@cam.ac.uk

Gold nanoparticle clusters are inexpensive surface-enhanced Raman substrates requiring a minimum of sample preparation [1]. Strong electric fields between adjacent nanoparticles significantly enhance Raman scattering of molecules trapped inside the nanogaps. For quantitative sensing, it is crucial to control the size of the nanogaps. This is achieved by employing Cucurbit[n]urils, rigid pumpkin-shaped molecules which act as molecular spacers to yield highly repeatable SERS signals. With optimised parameters, it is possible to reach detection limits in the nanomolar range for a variety of analytes.

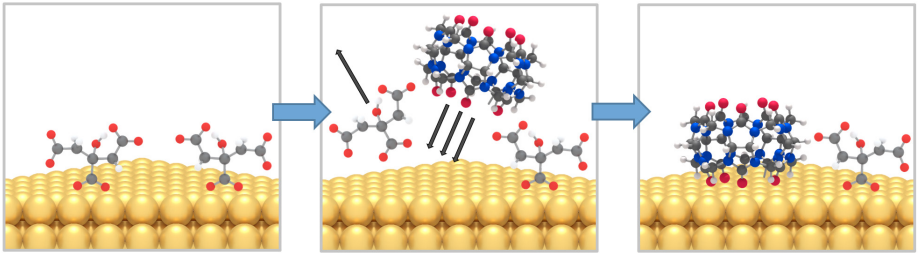

Figure 1. Gold nanoparticle surface (AuNP): Proposed displacement of surface-bound citrate anions by Cucurbit[5]uril.

This contribution presents the mechanisms and implications of the surface chemistry in citrate-capped gold nanoparticles on the long-term repeatability (ageing) of SERS measurements (Figure 1).

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Comparative Assessment of High-Performance Analogue Front-End Architectures for Closed-Loop Neural Stimulating/Recording Systems

Farnaz Fahimi Hanzaee[1*] and Emmanuel M. Drakakis[1]
[1]CDT in Neurotechnology, Department of Bioengineering, Imperial College London
*Department of Electronic and Electrical Engineering, University College London
farnaz.fahimi.19@ucl.ac.uk; e.drakakis@imperial.ac.uk

The electrical activity of neurons is highly affected by the clinical state of an individual. This has led to the utilisation of multiple methods to study the nervous system at different temporal and spatial resolutions. Designing a miniature, portable neural recording system would make the continuous monitoring of patients' clinical conditions possible. Importantly, however, having low frequency and amplitude makes biopotential signals highly susceptible to noise. This could make designing a low-power implantable recording system more challenging, as achieving a high signal-to-noise ratio (SNR) plays an important role in the reliability of such sensing devices. This was the primary motivation for the current project, where we attempted to find an optimal solution for designing a low-noise, low-power and high-precision instrumentation amplifier (IA) unit of recording analogue front-end modules for potential use in closed-loop systems.

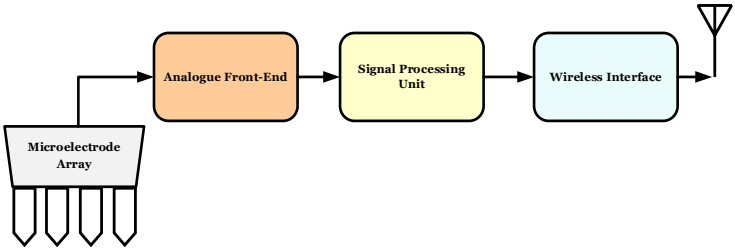

Figure 1. The analogue front-end receives the recorded signal from implanted electrodes and provides amplified signals with high SNR for downstream processing units.

We compared the performance of two prevalent circuit design techniques, namely, chopper stabilisation (CHS) and correlated double sampling (CDS), to determine a suitable means to remove non-ideal facets of IAs such as low-frequency noise, DC offset and finite gain. Furthermore, to analyse the effect of technology scaling on the noise performance of the sensing system, we simulated IAs based on the CHS/CDS techniques in two distinct CMOS technologies (0.35µm and 0.18µm). Finally, we investigated the performance of the CHS-based IA in a closed-loop system where a stimulus, in the range of a few volts, is applied to the same tissue area that the weak local field potential signal is recorded from (in the range of microvolts). Our measurements revealed that CHS is a more powerful technique in supressing the input-referred noise (IRN) of the amplifier. Moreover, the comparison of CHS- and CDS-based IAs in 0.35µm and 0.18µm technologies demonstrated that the smaller technology suffers from a higher level of IRN for an amplifier with the same architecture and a similar gain and bandwidth. Our results showed that by incorporating an amplifier with sufficiently high common-mode rejection ratio and using proper filtering, the recording signal can be suitably recovered from the stimulation artefact in a closed-loop system.

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Beyond Sequencing: Single-Molecule G-quadruplex Nanopore Assay

Filip Boskovic*, Jinbo Zhu, Kaikai Chen, Ulrich F. Keyser
[1]Cavendish Laboratory, University of Cambridge
*fnb24@cam.ac.uk

DNA is the information carrier in the cell and usually forms a right-handed double helix. Beyond the helix, unusual noncanonical structures can naturally occur in a guanine-rich strand of DNA.[1] These structures are **G-quadruplexes (Gq)** and are formed in **guanine-rich single-stranded DNA**. They are of paramount significance to gene expression regulation, but also drug targets for cancer and human viruses.[2] Current ensemble and single-molecule methods require fluorescent labels, which can affect Gq folding kinetics. Here we introduce, a **single-molecule Gq nanopore assay (smGNA)** to **detect Gqs inside of genomic fragments** and **kinetics of Gq formation**. We use ~5 nm solid-state nanopore sensors to detect various Gq structural variants attached to designed DNA nanostructures. Gqs can be identified by localizing their positions along designed DNA carriers establishing smGNA as a tool for potential whole-genome Gq mapping.[3] In addition, smGNA allows for discrimination of (un-) folded Gq structures, provides insights into single-molecule kinetics of Gq folding, and probes quadruplex-to-duplex structural transition. smGNA can elucidate the formation of Gq at the single-molecule level without labelling and has potential implications on the study of these structures both in single-stranded DNA and in the genome. Furthermore, smGNA is adapted for detection of Gq and Gq-related substructures. It can discriminate Gqs and G-loops and it can detect local mispairing of DNA i.e. unhybridized DNA. smGNA sensor has a potential for **whole-genome mapping of secondary DNA structures at the single-molecule and the single-cell level**.

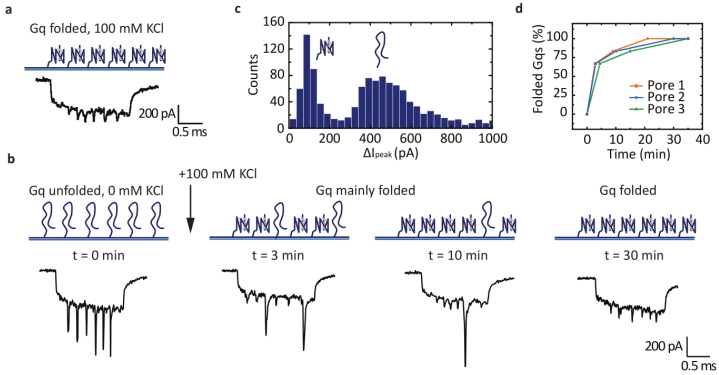

Figure 3. smGNA discriminates unfolded and folded G-quadruplexes (Gqs) and is able to monitor the single-molecule kinetics of their folding. a) Gqs folded control. b) Single-molecule kinetics of Gq folding. c) Discrimination of folded and unfolded Gqs based on the signal drop. d) Kinetics of Gq folding.

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[3] Bošković F, Murat P, Guilbaud G, Sale JE, Keyser UF. Whole-genome G-quadruplex and related substructures mapping at the single-molecule level. *In preparation*.

The influence of FUS on mRNA localisation and local protein synthesis

Francesca W. van Tartwijk[1], Julie Qiaojin Lin[2,3], Christine E. Holt[4], Clemens F. Kaminski[1,3*]
[1] Department of Chemical Engineering and Biotechnology, University of Cambridge, UK
[2] Department of Clinical Neurosciences, University of Cambridge, UK
[3] UK Dementia Research Institute, University of Cambridge, UK
[4] Department of Physiology, Development, and Neuroscience, University of Cambridge, UK
[*]Corresponding author, cfk23@cam.ac.uk

FUS is an RNA-binding protein that can phase-separate, which enables it to form RNA(-containing) granules. This capability is important in gene expression; in neuronal processes, it may allow regulation of local protein synthesis (LPS). Some FUS mutants adopt a poorly soluble and fibrillar hydrogel-like state, which is associated with certain forms of motoneurone disease. Entrapment of mRNAs in such aggregates may contribute to axonal degeneration by compromising LPS, which is reduced in the presence of mutant FUS [1]. However, it remains unclear which axonally localised mRNAs might be affected, though bioinformatic analyses have yielded lists of candidates.

Here, several methods have been developed to validate the axonal interaction between FUS and candidate mRNAs (Figure 1), using the established LPS model system of *Xenopus laevis* retinal ganglion cells (RGCs). These methods have been tested for the mRNA encoding nicotinamide mononucleotide adenylyltransferase 2, an essential neuronal survival factor with a very short half-life. Though it was found that *nmnat2* mRNA does not localise to axons in the RGC model system, the established methods will be used to test other classes of candidate mRNAs, such as those encoding proteins involved in maintenance of the (axonal) cytoskeleton or synaptic transmission.

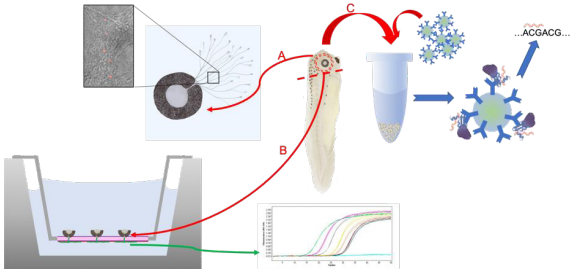

Figure 1. Methods for testing candidate mRNAs. The localisation of mRNAs can be investigated by (A) fluorescence *in situ* hybridization and (B) by qPCR on axonal samples. The interaction between FUS and mRNA molecules can be verified through immunoprecipitation from followed by qPCR (C).

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Impact of Coseismic Landslides on Himalayan Chemical Weathering

G.E. Hughes[1]*, E.T. Tipper[1], M.J. Bickle[1], C. Anderman[2]
[1]Dept. of Earth Sciences, University of Cambridge, Cambridge, CB2 3EQ, UK
[2]GeoForschungsZentrum, Telegrafenberg, Potsdam, 14473, Germany
*gh436@cam.ac.uk

Chemical weathering of silicate rocks is a key regulatory process of atmospheric CO_2, over geological time, with atmospheric derived carbonic acid being neutralised by the hydrolysis of silicate rocks and eventually being converted to carbonate. The rate of silicate chemical weathering is dependent on temperature, rainfall and erosion rates, that is supply of reactants. The 2015, Nepal earthquakes, magnitude 7.3 and 7.5, triggered thousands of coseismic landslides, affecting delivery of rock material to rivers.

Our research is examining whether this increase in landslides perturbed sediment and chemical weathering fluxes, a connection which is difficult to establish owing to the infrequent nature of such events. We seek to identify the provenance of the sediment, changes in sediment fluxes, and to determine the chemical evolution of the sediment as it is transported down river.

Depth profiles of suspended load samples and ADCP data were collected from the Sun Kosi and Sapta Kosi Rivers, immediately after the 2015 earthquakes and annually for each of the 4 following years. The chemistry, grainsize and flux of the sediments Kosi Basin will be presented. The sediment chemistry was partitioned into carbonate, silicate and Fe-oxide fractions by sequential extraction.

Mineralogical control, source effects and degree of sediment weathering were investigated by plotting silicate mobile/immobile (molar) elemental ratios for K, Na, Ca_{Sil}, Ca_{Carb}, building on pioneering work from [1]. The complexity of the mineralogical controls on elemental concentrations and how this impacts estimates of chemical weathering will be discussed.

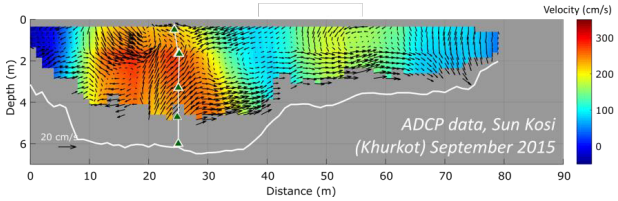

Figure 1. Example of Acoustic Doppler Current Profiler Data, showing sample locations (triangles), channel architecture and water velocity distribution.

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A wireless RFID/NFC wearable sensor platform: Bridging the divide from (bio)chemical sensing to the digital world

Ivana Murković Steinberg[1*], Matthew D. Steinberg[2], Petar Kassal[1]

[1]University of Zagreb, Faculty of Chemical Engineering and Technology, Marulićev trg 19, 10000 Zagreb, Croatia

[2] GoSense Wireless Ltd, Allia Future Business Centre, Kings Hedge's Road, Cambridge, CB4 2HY, UK

[*]Corresponding author, ivana.murkovic@fkit.hr

This poster introduces our research and current progress on the development of a low-cost wireless platform for wearable (bio)chemical sensing. The challenge has been to bridge the *connectivity gap* that exists between (bio)chemical sensors and the digital world [1]. Specifically, our research aim has been to develop both hardware and (bio)chemical interfaces compatible with different types of transduction principles - electrochemical, optical, and chemiresistive - that allow seamless connection to mobile devices, and ultimately to the Sensor Internet of Things (SIoT). For this purpose we work exclusively with near-field communication (NFC) technology. The poster illustrates the NFC platform, presents some of the integrated solutions with novel sensing chemistries for both passive and battery-assisted applications - including *smart bandages* [2, 3] and *T-shirts* as wearables for wound and sweat monitoring (Fig. 1). To conclude, an overview of our current research on low-cost printed chemistries for immobilisation on paper and textiles for optical sensing are shown.

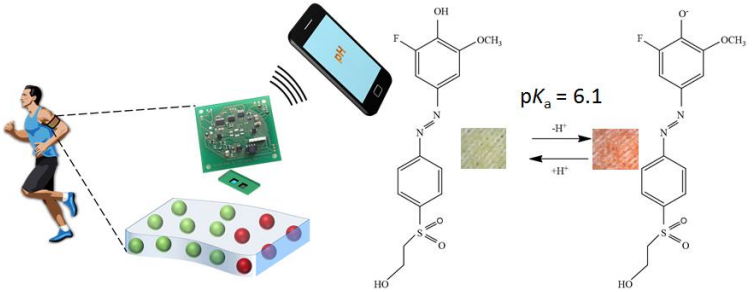

Figure 1. Concept of a textile based wearable sensor with NFC wireless connectivity for optical monitoring of sweat pH

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Differentiation of dental soft- and hard tissues using remote speckle-analysis during Er:YAG laser ablation

Benjamin Lengenfelder[a,b], Karen Schwarzkopf*[a,b], Nicolai Oetter[b,c], Fanuel Mehari[a,b], Eric Eschner[a,b], Florian Klämpfl[a,b], Florian Stelzle[b,c], Marco Kesting[b,c], Zeev Zalevsky[b,d], and Michael Schmidt[a,b]

[a] Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Institute of Photonic Technologies (LPT), Konrad-Zuse-Straße 3/5, 91052 Erlangen, Germany
[b] Erlangen Graduate School in Advanced Optical Technologies, Paul-Gordan-Straße 6, 91052 Erlangen, Germany
[c] Department of Oral and Maxillofacial Surgery, University Hospital Erlangen, Glückstraße 11, 91054 Erlangen, Germany
[d] Faculty of Engineering, Bar-Ilan University, Ramat-Gan, 52900, Israel

*Karen Schwarzkopf, karen.schwarzkopf@lpt.uni-erlangen.de

The application of Er:YAG (λ = 2940 nm) lasers in dental surgery is on the rise due to a contact-free and precise ablation of dental soft and hard substances causing minimal thermal damage in the adjacent tissue and only little perceived pain for the patient [1][2]. One obstacle is the lack of a feedback-system to differentiate tissue types in real time. With the laser-speckle-sensing (LSS) method a remote, non-destructive and automatable feedback modality is available. By recording and subsequently analyzing the movement of a secondary speckle pattern, it is possible to capture the response of the biological matter in form of microvibrations which typically occur during the ablation process in the laser ablation zone [3].

To prove the concept, three hard tissues (dentin, enamel, bone) and four soft tissues (pulp, mucosa, muscle, fat) of porcine specimens are evaluated. The experimental set-up consist of three main components: (i) a pulsed Er:YAG laser (Glissando, Wavelight, τ = 360 µs, E_p = 200 mJ) for tissue ablation, (ii) a cw laser (λ = 532 nm, P = 32 mW) for speckle pattern generation, and (iii) a high-speed camera (Phantom v1210, Vision Research, frame rate: 300 kHz, resolution: 128 x 16 pixel) for recording the speckle pattern. By manually starting (i) and (iii), a video of the speckle pattern movement during ablation is generated. Next, correlation analysis of this video is performed and the absolute speckle shift between the individual images can be computed in subpixel resolution. Since the speckle shift is linear related to the temporal tilt of the tissue surface [4], it also stands in relation to the temporal oscillation profile of the ablation area. Therefore, the maximal amplitude of the speckle shift (a_{max}) and the oscillation duration (t_{vibr}) are defined as tissue differentiation parameters. It is assumed that a_{max} is smaller for hard tissues since they are characterized by a higher Young's modulus leading to a higher resistance against deformation. Consequently, a lower surface vibration amplitude, a smaller surface tilting angle, and thus a lower measured speckle shift on the sensor plane is expected. In contrast, t_{vibr} is assumed to be smaller for hard tissues since the acoustic attenuation is normally higher in hard biological matter and thus strongly dampens the microvibrations. The preliminary results indicate that is possible to distinguish between two groups: hard tissue (dentin, enamel, bone) and soft tissue (pulp, mucosa, muscle). However, the technique is not sensitive enough to differentiate within the groups. In conclusion, the remote laser-speckle-sensing method could currently be used to identify the transition from soft to hard tissue or vice-verse which would improve the application of lasers in surgery, especially dentistry.

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Paper diagnostics:
Engineering paper proteins for printed biosensors

Lorena Gordillo Dagallier,[1,2*] Dr Ronan Daly,[2] Prof Lisa Hall[1]

* Corresponding author: lmg53@cam.ac.uk

[1] Department of Chemical Engineering and Biotechnology. University of Cambridge, UK.
[2] Institute for Manufacturing, Department of Engineering. University of Cambridge, UK.

Printed paper biosensors have arisen as diagnostic devices that could potentially enable early diagnosis in resource-limited settings, in terms of achieving affordable, user-friendly, equipment-free, and easy to manufacture devices [1]. Paper biosensors can incorporate microfluidics to perform complex bioassays and have been completelely fabricated via printing processes [2]. However, the use of paper for detecting infectious and chronic diseases has not been as successful as anticipated. One of the main challenges is their limited sensitivity and specificity, related to the immobilisation of proteins on paper and degradation of protein's activity during manufacturing [3].

This PhD aims to create paper-binding proteins to tackle paper compatibility and protein stability in printed paper biosensors, with a focus on reducing the cost and number of production steps to enable local manufacturing in resource limited areas. The specificity of the binding of cellulose-binding peptides could help preserving the protein's activity once attached to paper fibres. The protein could be formulated into a cellulose-based ink for digital printing, forming bioactive paper films. A printed biosensor tagerted to an analyte of interest will be designed to demonstrate the proposed diagnostics platform.

The first year has been focused on choosing and a suitable cellulose-binding module and characterising the binding of recombinant cellulose-binding fluorescent proteins to different cellulose morphologies.

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Warm near-infrared instrumentation for ground-based exoplanet surveys

Peter Pihlmann Pedersen[1*], Didier Queloz[1], Catriona Murray[1], Laetitia Delrez[1], Samantha J. Thompson[1], Martin Crook[2], SPECULOOS consortium[3]

[1]University of Cambridge, Exoplanet Research Centre, UK
[2]STFC, Cryogenics and Magnetics Group, RAL, UK
[3]www.speculoos.uliege.be
[*]Corresponding author, ppp25@cam.ac.uk

Observing in the IR can provide clear SNR gains for observing objects with effective temperatures below 3000 K, such as late M-dwarfs. Moving into the IR, however, has notoriously been a difficult and expensive region to progress to, especially for robotic facilities. Recent advances, with new detector materials, have presented the potential to meet and exceed the performances of the current state-of-the-art, based on HgTeCd. Instrumentation based on HgTeCd, unfortunately, are expensive and tend to require liquid nitrogen for cooling. Their operating temperatures can therefore demand frequent maintenance for ground-based operations, a logistical and financial burden for robotic telescope facilities. In this study, we present the feasibility, as modelled computationally, of using an alternative detector type, based on InGaAs, for the robotic ground-based exoplanet transit survey facility SPECULOOS. Through this study, we also present a novel method of mitigating the negative effects of atmospheric variability due to water vapour on time-series photometric data, as demonstrated in Figure. (1).

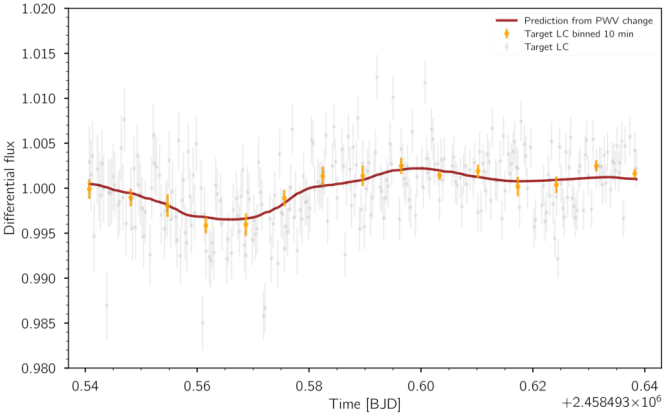

Figure 1. A false transit feature (grey and orange) observed by SPECULOOS, with the predicted change in flux due to a change of Precipitable Water Vapour (PWV) during the night (red) superimposed.

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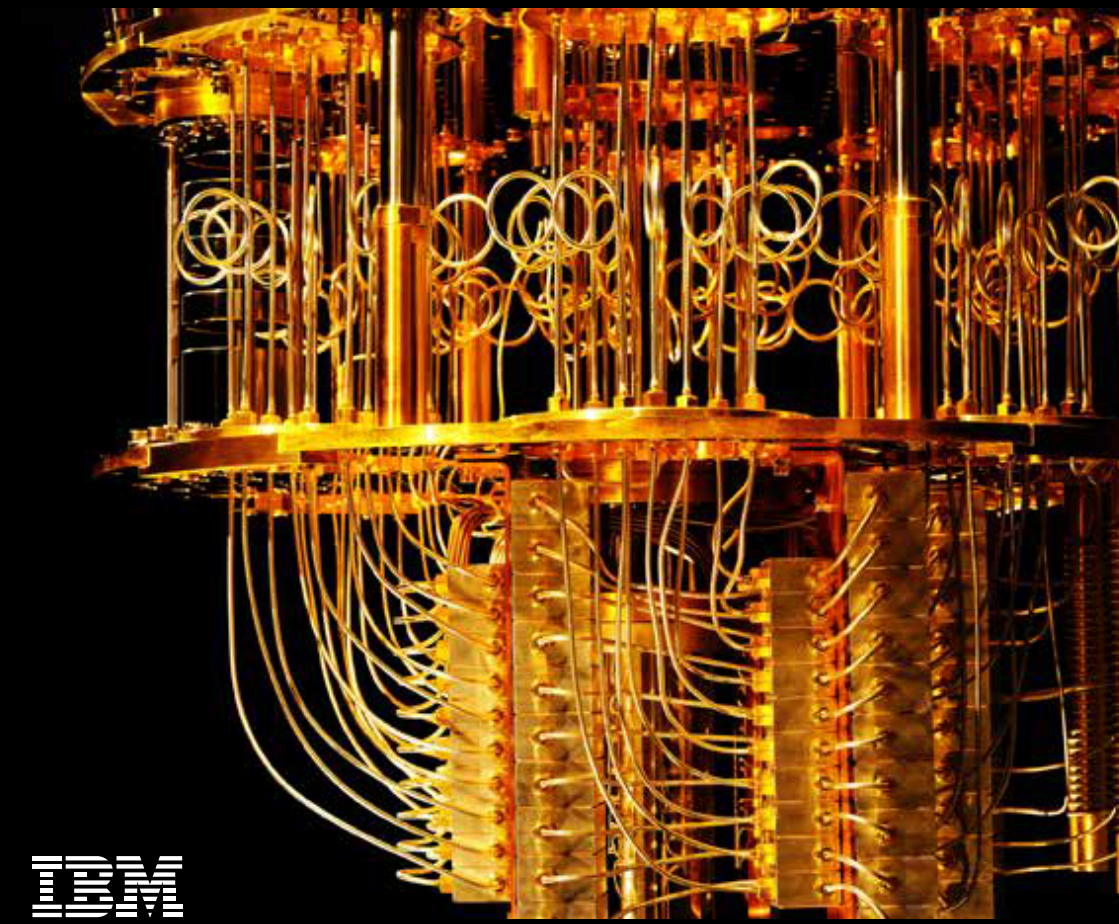

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