Your Research Partner for Photonics Solutions

Pharmaceuticals | Food Technology | Medical Devices | Sensors & Systems

Innovation Through Light

CENTRE FOR ADVANCED PHOTONICS & PROCESS ANALYSIS

CAPPA

Who We Are

CAPPA – Centre for Advanced Photonics & Process Analysis

*CAPPA is a research centre of **Munster Technological University** (MTU), conducting both applied and fundamental research on photonics for applications in areas as diverse as telecommunications, medical devices, food and pharmaceutical manufacturing. The group is co-located both in MTU's Bishopstown campus and in the **Tyndall National Institute** through the MTU@Tyndall partnership.*

Innovation for Industry – CAPPA provides photonics solutions to companies in sectors such as photonics, medical devices, food and pharma, on scales from short-term consultancy to multi-year collaborative projects.

Advanced Research – CAPPA conducts internationally-recognised academic research on topics such as the non-linear dynamics of lasers and ultrafast laser physics, and the understanding of the dynamics of novel semiconductor materials and devices.

49 PEOPLE
21 RESEARCHERS
28 POSTGRADUATE STUDENTS

€16 MILLION
FUNDING AWARDED
IN LAST 5 YEARS

23 PROJECTS
BIGGER THAN €100K
CURRENTLY ACTIVE

COLLABORATING WITH
11 OF THE TOP 100
UNIVERSITIES INTERNATIONALLY

90 PAPERS
PUBLISHED IN PEER-REVIEWED
JOURNALS IN LAST 5 YEARS

ENGAGED WITH
OVER 220 COMPANIES
IRISH, EUROPEAN AND INTERNATIONAL
IN THE LAST 5 YEARS

MTU
Ollscoil Teicneolaíochta na Mumhan
Munster Technological University

- ***CREATE Building***
- ***4 Labs, ~200 m²***

Tyndall
National Institute
Institiúid Náisiúnta

- ***Photonics Centre***
- ***3 Labs, ~150 m²***

The CAPPA Technology Gateway is co-financed by the Government of Ireland and the European Union through the ERDF Southern, Eastern & Midland Regional Programme 2021-27

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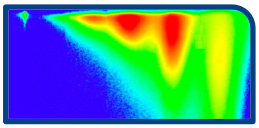
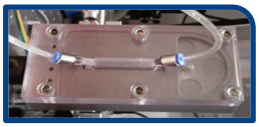
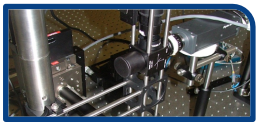
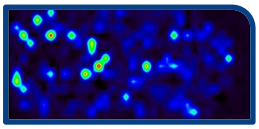
Overview of Capabilities

CAPPA Provides Photonic Solutions for:

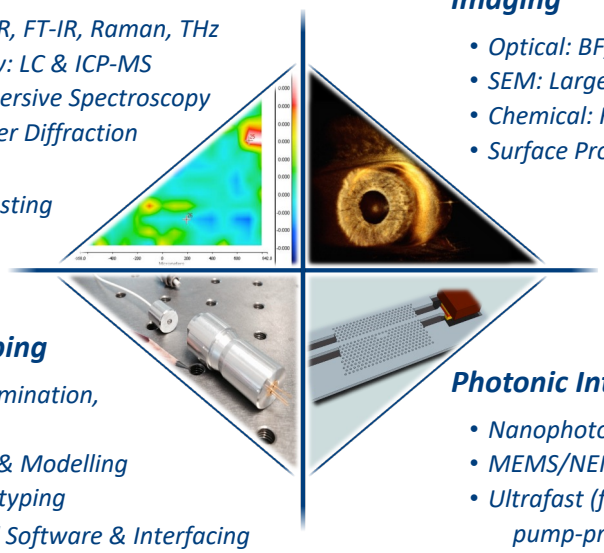
Research	• *Semiconductor Light Sources* • *Dynamics of Complex Systems* • *Interaction between Light & Materials*	
Product Development	• *New Semiconductor Materials & Devices* • *Optical Test Equipment* • *Illumination for Industrial Applications*	
Process Improvement	• *Applied Spectroscopy for Process Control* • *Advanced Inspection Technologies* • *Analysis of Products & Processes*	
Consultancy	• *Wide Array of Contract Services* • *Imaging: Optical, SEM, Surface Profiling* • *Identification: UV to IR, Mass Spec.*	

Material Properties

- *Optical: UV-Vis, NIR, FT-IR, Raman, THz*
- *Mass Spectrometry: LC & ICP-MS*
- *X-Ray: Energy Dispersive Spectroscopy*
- *Particle Sizing: Laser Diffraction & Imaging*
- *Physical: Tensile testing*

Imaging

- *Optical: BF, DF, DIC & Fluorescence*
- *SEM: Large chamber environmental*
- *Chemical: Raman & FT-IR Imaging*
- *Surface Profiling: Contact Profilometry*



Design & Prototyping

- *Optical design: Illumination, Fibre Coupling*
- *Device Simulation & Modelling*
- *3D Print fast prototyping*
- *Equipment Control Software & Interfacing*

Photonic Integration

- *Nanophotonic device fabrication*
- *MEMS/NEMS structures*
- *Ultrafast (fs) processes characterisation: pump-probe, TRPL*

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What is Photonics?

Photonics: the science of generating, controlling and manipulation light

*The global market for photonics products is €654 billion, of which €103 billion is produced in Europe. The European photonics industry employs 390,000 people directly, and involves over 5,000 SMEs. Photonics is a **Key Enabling Technology** for a wide range of application areas:*

Industrial Manufacturing
- *In-line process monitoring*
- *Machine vision*
- *Laser cutting/welding*

Information & Communications
- *Optical fibre comms*
- *Internet, BIM networks*
- *In-car entertainment*

Sensing & Detection
- *Environmental monitoring*
- *Water & Soil analysis*
- *Autonomous cars*

Imaging & Microscopy
- *Contaminant identification*
- *Medical imaging*
- *Chemometrics*

Lighting, Displays & Solar Cells
- *TVs, cameras, phones*
- *Energy-efficient LEDs*
- *PV solar panels*

Medical Devices & Technology
- *Point-of-care diagnostics*
- *Cancer screening*
- *Health monitoring*

The field of photonics is at the cross-roads of several disciplines including physics, electronics, mathematics and chemistry. It has revolutionised telecommunications and the internet through the development of fibre-optic networks, but is also hugely important in a diverse range of other fields. Almost all materials have a spectral response, and optical technologies have the advantages that they can be **cheap** and **compact**, usually have a small footprint so can be **integrated at-/in-line**, and are typically **non-invasive** and **non-destructive**. This makes photonics an ideal solution in industries such as **food**, **pharmaceutical**, **bio-medical** and **agriculture**.

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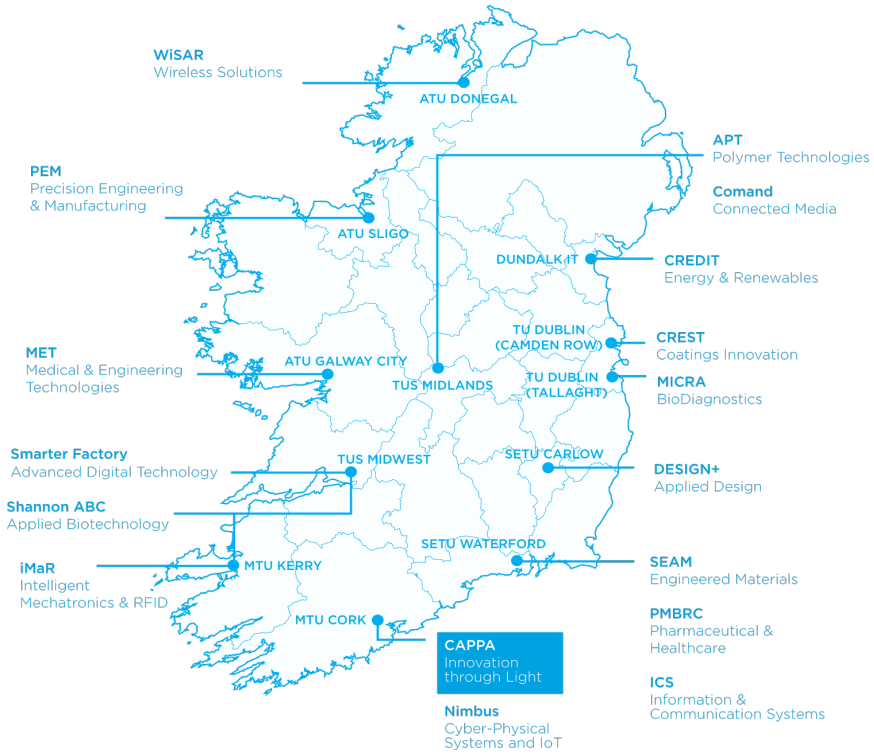
Technology Gateways Network

Delivering Solutions to Industry – an Enterprise Ireland funded network

*The **Technology Gateway** at CAPPA is one of 17 gateways funded by Enterprise Ireland around the country, and the only one focused on photonics applications. The gateways have a remit to deliver technology solutions to Irish industry, and the CAPPA gateway is successfully providing photonic solutions for industries in the **Pharmaceutical**, **Food & Beverage** and **Medical Device** sectors.*



- An open access point for industry to industry-relevant technology expertise
- Technology solutions for the close-to-market needs of Irish industry
- Regionally-based Gateways acting as a portal to the nationwide expertise in the Technology Gateway Network and the wider Irish research infrastructure
- Ongoing development of technology offers guided by an industry-led steering committee

www.technologygateway.ie

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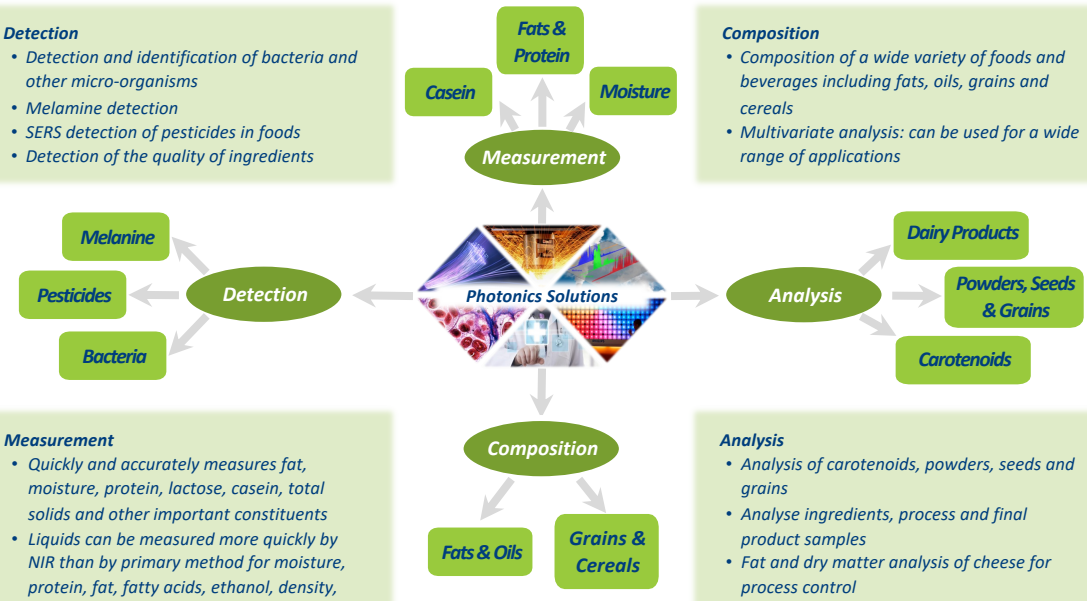
Photonics for the Food and Beverage Industry

Application Case Study

The manufacture of food and beverage products is Ireland's most important indigenous industry with a turnover of €27.5 billion. The beverage industry in Ireland is estimated to be worth approximately €1.5 billion. The sector employs over 250,000 people and supplies the majority of produce to Ireland's €15 billion domestic food sector. Ireland is the largest net exporter of dairy ingredients, beef and lamb in Europe and the largest exporter in Europe of powdered infant formula. Photonics makes significant contributions to the research and development of a variety of different food applications.

Detection
- *Detection and identification of bacteria and other micro-organisms*
- *Melamine detection*
- *SERS detection of pesticides in foods*
- *Detection of the quality of ingredients*

Composition
- *Composition of a wide variety of foods and beverages including fats, oils, grains and cereals*
- *Multivariate analysis: can be used for a wide range of applications*



Measurement
- *Quickly and accurately measures fat, moisture, protein, lactose, casein, total solids and other important constituents*
- *Liquids can be measured more quickly by NIR than by primary method for moisture, protein, fat, fatty acids, ethanol, density, solids, organic acids, carbohydrate profile and other important constituents*

Analysis
- *Analysis of carotenoids, powders, seeds and grains*
- *Analyse ingredients, process and final product samples*
- *Fat and dry matter analysis of cheese for process control*
- *Rapid, multi-component analysis simultaneously*

Innovation Voucher Case Study: *Beverage Bottle Sterilisation*

An Irish start-up company approached CAPPA to explore the feasibility of the product which was carried out through **Enterprise Ireland Innovation Vouchers** and direct funded engagements. The company wanted to explore how clean beer bottles are and develop a system to reduce contamination in the industry. Subsequently a simple demonstrator was designed and developed and the operation of the device was explored. CAPPA were involved with the design and manufacture of a prototype for the company to showcase to potential clients.

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Photonics for Dairy

Application Case Study

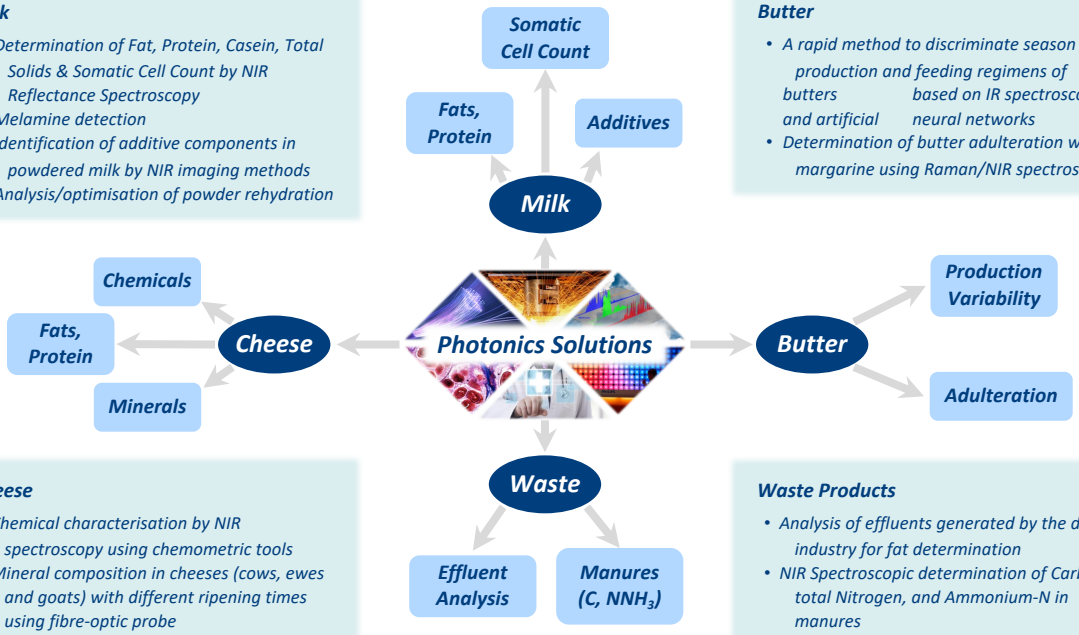
Global milk production is expected to exceed 1000 million tonnes by 2025 and is an important part of Ireland's Agri-Food sector; the Irish dairy industry exports 90% of its production to over 140 countries, valued at €3.1 billion. Photonics can, and does, provide a range of invaluable solutions to the dairy industry:

Milk

- *Determination of Fat, Protein, Casein, Total Solids & Somatic Cell Count by NIR Reflectance Spectroscopy*
- *Melamine detection*
- *Identification of additive components in powdered milk by NIR imaging methods*
- *Analysis/optimisation of powder rehydration*

Butter

- *A rapid method to discriminate season of production and feeding regimens of butters based on IR spectroscopy and artificial neural networks*
- *Determination of butter adulteration with margarine using Raman/NIR spectroscopy*



Cheese

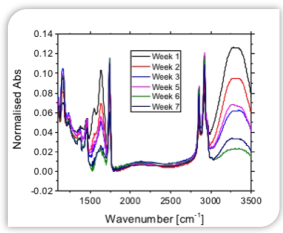
- *Chemical characterisation by NIR spectroscopy using chemometric tools*
- *Mineral composition in cheeses (cows, ewes and goats) with different ripening times using fibre-optic probe*

Waste Products

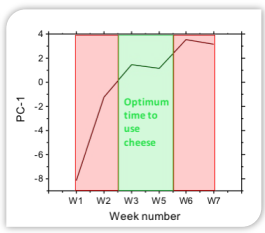
- *Analysis of effluents generated by the dairy industry for fat determination*
- *NIR Spectroscopic determination of Carbon, total Nitrogen, and Ammonium-N in manures*

Innovation Voucher Case Study: *Maturity Cycle of Processed Mozzarella Cheese*

A pizza company approached CAPPA to develop a quality control test for mozzarella cheese, availing of a €5,000 Enterprise Ireland Innovation Voucher. The problem was an issue with the cheese burning during pizza preparation depending on the maturity of the cheese. CAPPA gathered 8000 NIR spectra over 7 weeks, and used ***Chemometrics*** (Principle Component Analysis) to develop a model to identify the current maturity of the cheese, and hence determine the optimum cheese maturity point.



NIR spectra of mozzarella cheese



PCA model of maturity cycle

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Photonics for Pharmaceuticals

Application Case Study

*The importance of the pharmaceuticals sector to Ireland is well established, with **9 of the top 10 global companies** based in Ireland. The largest cluster of pharmaceutical operations is in Cork, employing over 8,000 people in the region alone. Photonics makes significant contributions to the development and deployment of Process Analytical Technologies (PAT), a major priority within the industry currently, and has applications inline, at-line and offline.*

- *Drug identification, raw material classification*
- *Blend uniformity, API distribution*
- *Chemometrics, multi-variate analysis*

Product Analysis

- *Process Analytical Technologies (PAT)*
- *Inline/online sensors (gases, pH, …)*
- *Monitoring phase changes*

Process Monitoring

Quality Control

- *Cleaning verification*
- *Particle size analysis for powders*
- *Root cause analysis of contaminants*

Packaging

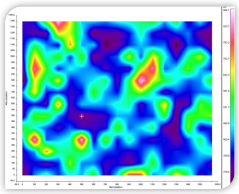
- *Laser-inscribed tablet labelling*
- *Anti-counterfeit measures*

Case Study: *Blend Uniformity via Raman Spectroscopy*

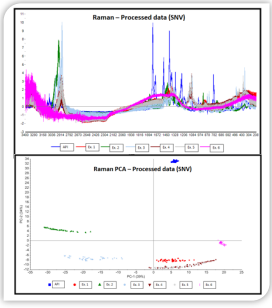
Concentration: Sample blends with between 10% and 90% API were prepared; standard HPLC (calibration set) was compared with Raman spectroscopy measurements (validation set); R^2 values were 0.9974 for the calibration set, 0.9602 for the validation set.

Distribution: The distribution of API over a 2.08 mm^2 area was measured with Raman mapping, using the main Raman peak at 1620 cm^{-1}. Results indicate a slight separating of the API from other excipients. For a sample with nominal 25% API concentration, the average measured via Raman was 25.4% (st. dev. 8.8%), with a min. of 6.9% and max. of 45.6%.

Identification: Spectra from 7 ingredients (1 API & 6 Excipients) were collected. Data pre-processing with SNV (Standard Normal Variant) and analysis with PCA (Principle Component Analysis) indicated clear clustering of results, allowing rapid raw material classification.



Above: Raman map of API distribution.



Right: PCA analysis of spectra for raw material classification.

Pharmaceutical Manufacturing Technology Centre (PMTC)

CIT/CAPPA are members of the industry-led, EI/IDA-funded Pharmaceutical Manufacturing Technology Centre:

www.pmtc.ie

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Photonics for Medical Devices

Application Case Study

Ireland is one of the leading manufacturing hubs for medical devices: 17 of the top 25 global companies have a base here. The sector employs over 25,000 people nationally, and exports €8 billion worth of medical products annually to over 100 countries. Biophotonics technologies are a key enabler for the current drive towards preventative medicine and personalised ("home health") care.

Biomedical Imaging

- *Optical Coherence Tomography; real-time, 3D sub-surface imaging, e.g. for eye care*
- *Multi-modal IR-vis cameras for skin cancer diagnosis*

Point-of-Care Diagnostics

- *Lab-on-chip blood analysers*
- *Non-contact optical pulse velocimetry for screening of arterial stiffness*
- *Breath gas analysis (incl. for neo-natal care)*

Advanced Surgical Tools

- *Functionalised guidewires in keyhole surgery – blood velocimetry*
- *Multi-modal tomography/spectroscopy in endoscopes, for tumour detection/sizing*

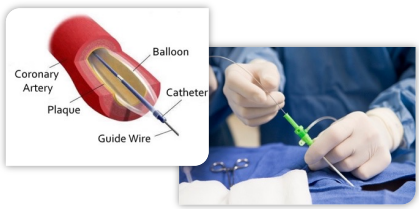
Device Manufacturing

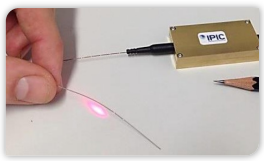
- *Automated quality inspection tools, e.g. radiuscope for intraocular lenses*
- *Precision metrology of components/tools*
- *Contaminant identification/analysis*

Industry Case Study: *In-Vivo Blood Flow Measurement*

A multi-national manufacturer of surgical guidewires, ***Lake Region Medical***, joined the ***IPIC Research Centre*** on a project to functionalise their guidewires. These are thin, flexible wires used in minimally invasive surgery, introduced initially to define the path to target. Larger items such as catheters are then inserted over the guidewire and guided to the target area.

CAPPA and the Photonics Packaging Group at Tyndall National Institute incorporated an ultra-fine optical fibre within the guidewire, and successfully used it to measure blood flow at the tip via Doppler velocimetry. The company demonstrated the module at TCT 2014, the world's largest interventional cardiovascular conference.





The IPIC side-fire module

IPIC sfi Lake Region MEDICAL

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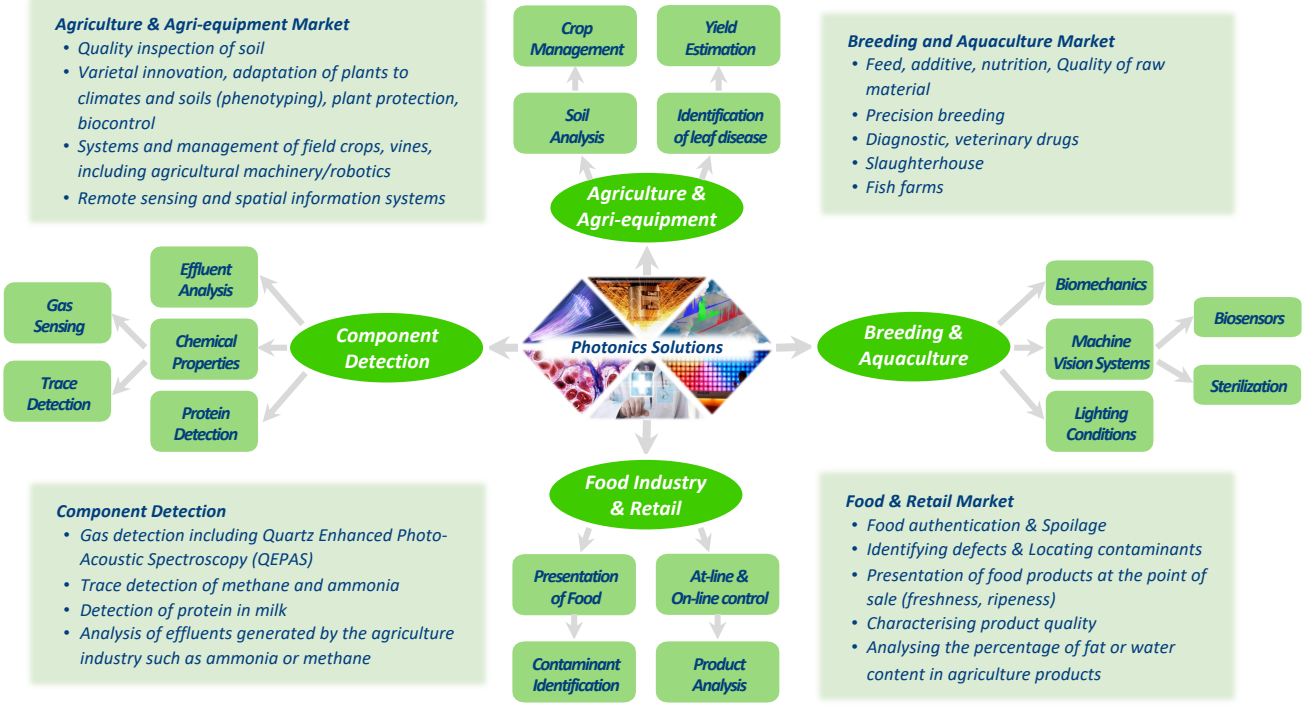
Photonics for Precision Agriculture

Application Case Study

Precision agriculture brings together information from field, animal and machinery based sensors, together with localised weather forecast data, localised soil information and grass growth data gleaned from satellite imagery to assist farmers in making precise decisions in relation to inputs, technologies and management practices. Thus Precision Agriculture, by enabling better targeting of inputs and resources, can increase both a farmer's bottom line and improve the environment.



Innovation Voucher Case Study: *Development of In-Depth Processing and Analysis of Herd*

StrongBó, a real-time livestock data company approached CAPPA to assist them in the development of their new system. The products developed by the company measure a number of significant parameters on individual animals in the herd. The animals' weight is measured each time it attends a trough for water. The work undertaken included an automated data-cleaning algorithm. This was able to deal with scenarios such as where more than one animal was on the instrument. In addition to this interpolation was applied to deal with missing data. All data went through a time series-smoothing model to evaluate the overall trend of each animal over time. This was then used to calculate the water consumed by each animal per day, predict the animals' weight and to evaluate the growth rate of the animal at the resolution of a single day. The research allowed StrongBó to manage a massive amount of data and keep the system live.

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Photonics for Design

Capability Case Study

Optical design is the art of modelling and engineering an optical setup to meet a required performance, footprint, cost and other constraints. CAPPA has the expertise and a suite of advanced software modelling tools to address a range of design tasks, from simple illumination to complex optical components and complete optical engine design.

Case Study: *Inferneco*

- **Customer Problem:** Inferneco is a start-up company delivering products primarily to the fire lighting (ignition) area. Recently through contacts in the drinks industry the company started exploring the idea of developing a simple disinfection unit that would work in a variety of public establishments.
- **CAPPA Contribution:** CAPPA were involved in the design and manufacture of a prototype for the company to use as a showcase to potential customers.
- **Project Outcome;** CAPPA was able to help Inferneco with initial feasibility of their product, assistance with navigating the funding sources available to them and the introduction and engagement available to develop a ready to market product.

Case Study: *EnteraSense*

- **Customer Problem:** EnteraSense is a start-up company developing an ingestible biosensor that detects bleeding in the gastrointestinal tract in real time without requiring a complicated intervention. The company approached CAPPA with a view to developing the optical elements of a swallowable pill. The unit had to be small enough to fit inside a pill shaped container which the patient would ingest.
- **CAPPA Contribution:** CAPPA investigated a variety of ways in which the signal detection could be improved, implementing bespoke LEDs, filters and detection systems. CAPPA investigated appropriate layouts of the optical components in order to produce the most efficient design.
- **Project Outcome;** CAPPA helped develop a demonstrator prototype to exhibit at high profile medical device conferences.

Optical Design Process

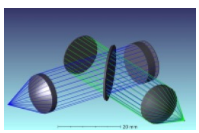
Design Specification
Requirements & Specifications
Limitations & Restrictions

Design Concept & Development
Ray tracing, mapping, colorimetry, etc.
Parts selection/specification, integration

Design Verification
Test and measurement
Prototype build

Solution Delivery/Transfer
Reporting & documentation
Training

Applications	Sectors
Laser optics	*Retail/advert/industrial/interior lighting*
Off-the-shelf component selection	*Exterior/building/public space lighting*
Design enhancement & integration	*Machine vision*
Illumination systems modelling	*Specialist e.g. medical device/sensing*
Customised optical component	*Food and beverage*
Lens design	*Pharmaceuticals*
Imaging and detection systems design	*Medical device*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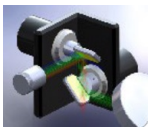
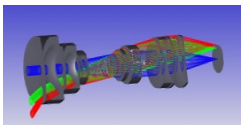

Dialux


Autodesk Inventor Professional

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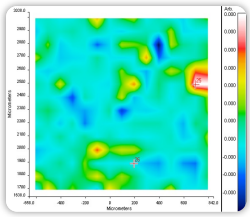
Optical Spectroscopy

Capability Case Study

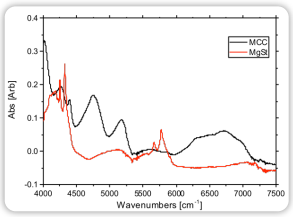
Light is an excellent way to gather information in a non-invasive, non-destructive manner; the unique, 'fingerprint' spectral response of different molecules can be used to determine composition, monitor processes, and inspect quality. CAPPA operates a suite of powerful spectroscopy techniques.

Infrared Spectroscopy

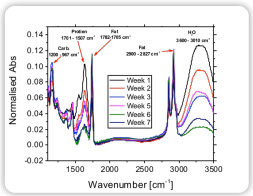
Medicine: Here, we are using Infrared (IR) spectroscopy to gather information on the distribution of different ingredients in a blend. This type of spectroscopy is capable of measuring a material in solid, liquid or gas state and can be applied to a host of applications such as quality control, contaminant identification, moisture content, density, hardness, changes due to heating and cooling, and many more. The IR mapping spectra were collected on a Perkin Elmer Spotlight 400 FT-IR Imaging System with a Spectrum 400 FT-IR Spectrometer.



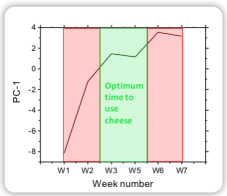
Distribution of ingredients in a powder



Reference spectra of blend ingredients



IR spectra of mozzarella cheese

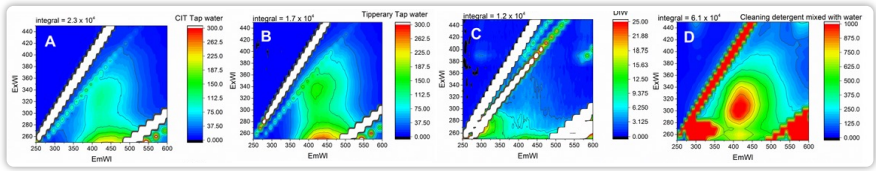


Modelled maturity cycle

Food: The example on the left shows the use of IR spectroscopy to measure the maturity cycle for mozzarella cheese. In this case, we performed analysis over a seven week period collecting a spectra each week. We then used software (multivariate analysis) to process the information and create a model, which can be used to predict the maturity of an unknown sample.

Fluorescence Spectroscopy

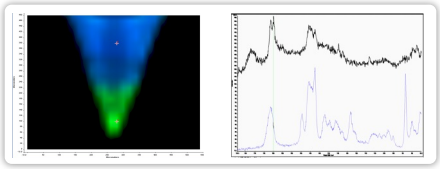
CAPPA develops sensors and detection equipment using light, the goal of these projects can be cost reduction, miniaturisation or other specific applications. The example here is an on-going project to develop a miniature fluorescence spectrometer with the aim of monitoring dissolved organic matter (DOM: humic-like, tyrosine-like, tryptophan-like and protein-like) found in water, without any sample handling. Depending on the level of detail required, it is possible to determine what type of organic matter is present in the water based on the fluorescence excitation and emission wavelengths.



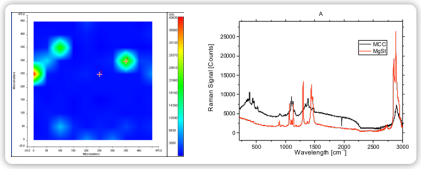
A: CIT tap water; B: Tipperary tap water; C: Deionised water; D: Water sample collected from floor.

Raman Spectroscopy

Two examples are shown; the first is of a microneedle showing API (tip of needle, green) and excipient (base, blue) with reference spectra on right. The second example shows Raman mapping to measure a blend. This type of measurement can be used for quality control and also for counterfeit detection. Raman mapping spectra were collected on a Perkin Elmer RS400 with a laser excitation source of 785nm with an output of 250mW.



Raman image of a microneedle showing API and excipient. Right: Reference spectra; API (top), Excipient (bottom).



Map showing blending of a compound. Right: Reference spectra of the blend.

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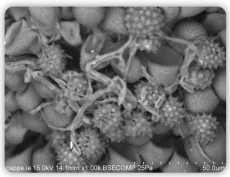
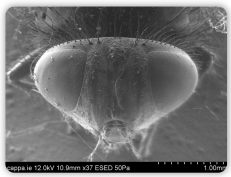
Scanning Electron Microscopy

Capability Case Study

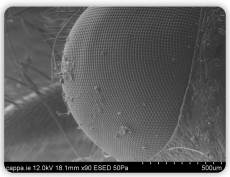
*CAPPA operates a variable pressure **scanning electron microscope** (SEM) [Hitachi S-37000N VP-SEM] equipped with **energy-dispersive X-ray spectroscopy** (EDS) [Oxford Instruments X-MaxN 80 T]. The microscope allows magnification up to x300,000 with a resolution of 20nm. The large chamber can accommodate samples up to 300mm in diameter and 110mm in height, and the variable pressure mode allows viewing samples in their natural or wet state, without the need for metal coating.*



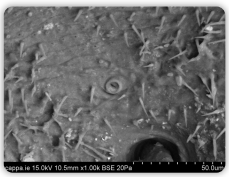
SEM image of daisy pollen (x1000 magnification)



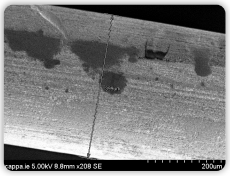
SEM image of a fly



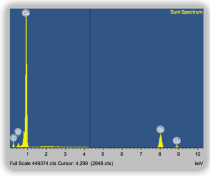
Higher magnification image of fly's eye



SEM image of a crab shell



SEM image of communications cable showing degradation



Element identification from same communication cable

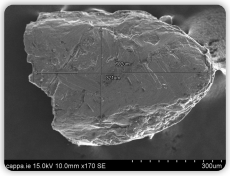
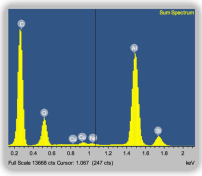
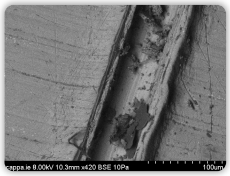


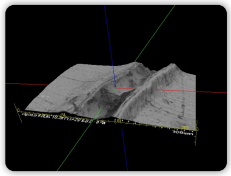
Image of contaminant particle



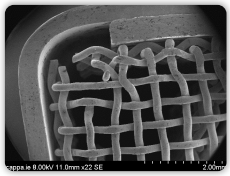
Element identification from same contaminant particle



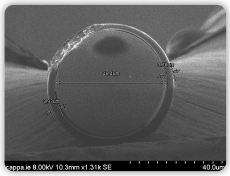
2D SEM image of groove in a metal plate



3D SEM image of same groove in a metal plate



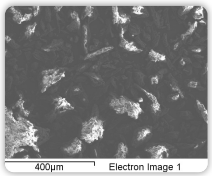
SEM image of damage in a wire mesh



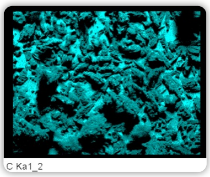
SEM image of fibre optic cable

Energy Dispersive X-Ray Spectroscopy (EDS)

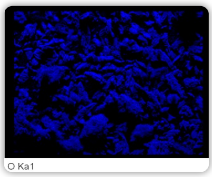
The EDS system works in tandem with the SEM to provide further characterisation of the elemental composition of samples. The analysis below was performed on a 1% (w/w) MgSt in MCC blend.



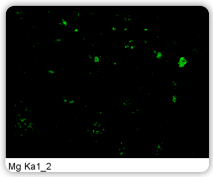
SEM of MgSt and MCC blend



Carbon distribution



Oxygen distribution



Magnesium distribution

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Portable/Remote Sensing

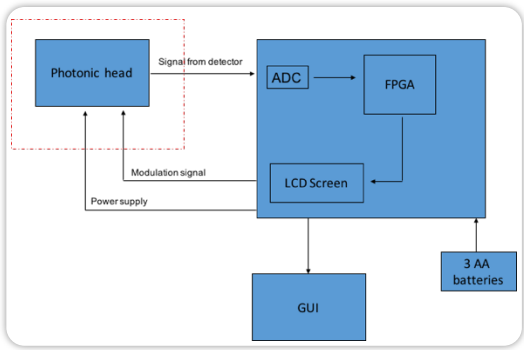
Developing a Sensing Platform Technology

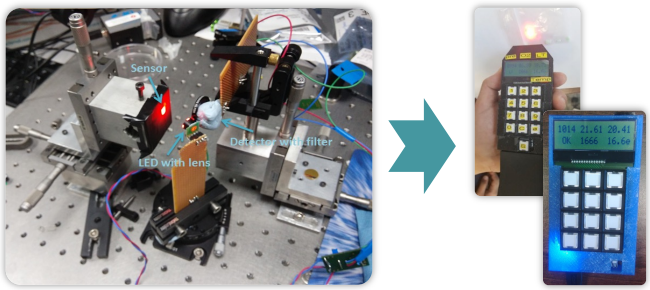
A distinct advantage of optical sensors is their flexibility. A typical optical sensor will generally include components such as a light source, detector, control electronics, on-board data processing and user interface. While a particular application may require careful tailoring of these (e.g. choice of wavelength, modulation scheme, etc.), CAPPA has developed the underlying platform technology which can be rapidly adapted to provide fast prototyping and testing of bespoke sensing applications.

The platform developed by CAPPA offers two formats:

- A ***fully stand-alone module***, where all data processing is perform on-board using the FPGA, including fluorescence signal/lifetime calculation, conversion to actual analyte concentration, ambient pressure/temperature compensation, data storage (e.g. SD card) and readout;
- *A **miniature 'node' module***, which performs optical excitation and raw data collection only, with post-processing carried out on PC or in the cloud, via a USB or wireless connection.

Both formats include control/modulation of the light source, drive components for photodetector, analog-to-digital converter, etc., and can drive multiple sensors for ambient parameters (temp/pressure) monitoring. The photonic head can be tailored for a range of measurements, e.g. direct absorption or monitoring of a fluorescent biomarker. The entire unit is compact, portable and cost-effective.





- ***Compact solution, can be adapted for handheld, remote or in-line use***
- ***Photonic head can be tailored to measurement of choice***
- ***can be fully stand-alone, or remote sensor 'node'***

Case Study – Miniaturised remote oxygen sensor

Partner company Luxcel Biosciences produce a set of low-cost materials whose fluorescent lifetimes respond to the gas concentration in their environment. CAPPA have developed a hand-held sensor module which can illuminate their oxygen-sensitive material and collect the time-resolved fluorescent signal, complete with a user interface for calibration and data management. This enables the fluorescent material to be placed inside transparent packaging of e.g. food, medical device or pharmaceutical products, and to interrogate the oxygen concentration within the package from outside.

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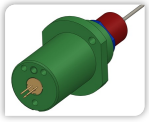
Example CAPPA Projects

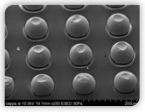
An overview of some of CAPPA's previous and current industry projects

Below is a non-exhaustive list giving examples of the types of projects CAPPA has worked on previously with industry partners. These vary from small consultancy projects to large multi-annual, multi-partner projects, and demonstrate how photonics provides solutions for many applications.

AgriFood and Dairy

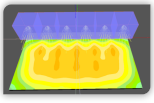
- Spectroscopic development of a maturity model for cheese (ZZ Ltd)
- Milk quality analysis (Agri industry)
- Sol-gels for optical pH monitoring in fish farms (Faaltech)
- Analysis of milk powder rehydration (Teagasc)





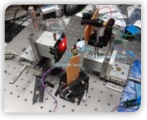
Medical Devices and Healthcare

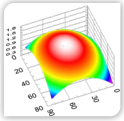
- Swallowable capsule for detection of internal bleeding (Enterasense)
- Process development and improvement (Alcon)
- Contamination identification and lens fabrication quality analysis (Alcon)
- UV disinfection of drinks bottles (Inferneco)
- UV sterilisation configuration for portable baby bottle steriliser (Shasta)
- Medical tools integrated to photonic devices (Lake Region)
- Development of on-site infection detection system (Veterinary)
- Swept-source lasers for Optical Coherence Tomography (Superlum)



Pharmaceuticals

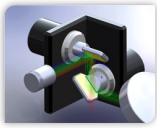
- Product formulation and contamination analysis (Astellas)
- Glass transition temperature analysis of polymer material (DePuy)
- Solid dose drug identification in dried micro-needles (LeoPharma)
- Spectroscopic cleaning verification (PMTC)

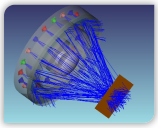




General Photonics

- Emergency Lighting Signage (Alba Lighting)
- Sealant Quality for Electrical Casing (Dexgreen Ltd)
- Optical design and simulation for a laser range finder (SensL)
- Development of anti-reflection optical coatings (Superlum)
- H2020 proposal preparation helped win the company €4.2M EU funding (PMD)
- Database development for warehouse tracking (Aldi Irl.)
- Large-scale optical displays (Epi-Light)
- Optical simulation and design of telescope lens train (Blackrock Castle Observatory)
- Cross-section analysis of encapsulated product (Boston Scientific)
- Hardware/software interface development (Gas Analysis Services)
- Golf aid for shot alignment (Egan Golf)





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Funding Opportunities

A summary of available research funding programmes and mechanisms

Many national and EU funding agencies provide funding support for industry research at a range of scales, both with and without research partners. CAPPA have extensive experience with funding applications (well over 100 in the last 8 years) and can assist companies in identifying the most appropriate funding mechanism, and in navigating the paperwork, proposal writing and grant admin.

Direct Funding

- The most straightforward funding mechanism – company covers full cost of research. Can be any scale of project. Advantages: ***Confidentiality; Full IP ownership; Fast project start-up***.
- However, potentially missing out on leveraging significant additional money from funding agencies.
- CAPPA operates a ***Stepping Stone*** programme which includes a ***free*** half-day analysis of your research question/innovation idea.

Key to Funding Agencies

- ***EI*** *– Enterprise Ireland, www.enterprise-ireland.com*
- ***SFI*** *– Science Foundation Ireland, www.sfi.ie*
- ***IRC*** *– Irish Research Council, www.research.ie*
- ***DAFM*** *– Dept. of Agriculture, Food & Marine, www.agriculture.gov.ie/research*
- ***EU*** *– European Union [Horizon Europe Programme], https://research-and-innovation.ec.europa.eu/*

S Small-Scale Projects (~€0 – €50k)

- ***Innovation Vouchers (EI)***
  - EI will provide €5k for short research investigations. Company either just pays the VAT, or can co-fund up to additional €5k
  - Can be 'redeemed' at any registered knowledge provider

M Medium-Scale Projects (~€50k – €200k)

- ***Innovation Partnerships (EI)***
  - Typically, €100-200k project, over 1-2 years
  - Company funds 20-60% in cash
- ***Enterprise Partnership Scholarships/Fellowships (IRC)***
  - Company part-funds an MSc/PhD student or Postdoc
  - 1 call per year, Fellow could be based in company
- ***IPIC Centre Targeted Projects (SFI)***
  - Typically 30-50% company contribution
  - Fast start-up, wider benefits of IPIC membership
- ***National Challenge Funds (SFI)***
  - Academic/industry collab., addressing specific topics
  - Initial €250k funding, with possibility for further €1-2M

L Large-Scale Projects (>€200k)

- ***Horizon Europe Projects (EU)***
  - EU Consortium of min. 3 partners
  - Cutting-edge research, projects can be several €M
  - 75%/100% funding of industry partners' activities
- ***EIC Accelerator (EU)***
  - Up to €2.5M funding for SMEs (TRL 5-8)
  - Open and Challenge (targeted) calls
- ***FIRM Projects (DAFM)***
  - Food-related research [industry support for research institute projects]
  - Consortium of Irish research institutes, up to 5 years
- ***Investigator/Partnership Programmes (SFI)***
  - Support multi-year research project of academic PI
  - Steer academic research, early access to new results

N.B. This is by no means a comprehensive list of available funding opportunities. CAPPA can help find the best option for you – come talk to us!

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Testimonials

Here's what some of our industry clients have to say about CAPPA

Ken Reynolds *Business & Technology Manager*
ProPhotonix

ProPhotonix gained access to key research and development expertise that would otherwise not have allowed them to develop this product. The company now has a market disruptive product available to them with key customers targeted.

Jerry Larkin *Plant Reliability Manager*
GE Healthcare

CAPPA have become our go-to on materials investigation issues. CAPPA lab, people and systems are technically first-class, but also flexible and business-friendly.

Barry Walsh *MS&T Tech Transfer Lead/ Chief Scientific Officer*
Alcon

Alcon have a long standing relationship with CAPPA going back over 5 years. We use the expertise of CAPPA on an ongoing basis for carrying out tests on products. Having CAPPA on our doorstep is hugely beneficial to Alcon as it provides us with the cutting edge analytical technology we need to make informed decisions on our process and projects.

Ruairi Monaghan *R&D Engineer*
NuWave Ventures

We found our experience working with CAPPA to be very rewarding. Their expertise augmented our team's skills, allowing us to expedite development of our air sampling systems in a much shorter timescale than possible otherwise. Dealing with the people involved was also simple and professional from start to finish.

Frank Riedewald *CEO*
Composite Recycling

With the help of the knowledge and expertise provided by the CAPPA centre, Composite Recycling was successful in achieving €50k funding under the SME Instrument Phase 1 call. We are now firmly driven towards developing our technology and ideas further and will be working closely with the CAPPA centre to submit a proposal for a larger phase 2 call later in the year.

Chiara Di Carlo *R&D Engineer*
Enterasense/Vysera Biomedical

CAPPA helped us to better understand the challenges of the technology and identify the most effective way to develop and test a functional prototype. The team in CAPPA is extremely skilled and they delivered a high-performance prototype. In particular, we really appreciated the fact that the team listened to our direction and worked with us to deliver exactly what was needed. The team responded quickly to changes and offered innovative solutions to overcome problems and challenges met during the project.

Seamus Lane *Managing Director*
ZZ Ltd

The CAPPA group engaged with us from the onset where they explored the viability of the project prior to the Enterprise Ireland application. The group maintained contact with us during the entire process where they demonstrated commitment to understanding the issues and the impact to our business. The group were successful in building a quality control model to allow us asses the maturity of mozzarella helping to ensure customer satisfaction. We would highly recommend the CAPPA group and would have no hesitation in working with the group in the future.

Les Egan *CEO*
Egan Concepts Ltd

Egan Concepts gained access to knowledge and facilities outside of their core competencies of product and industrial design. The project allowed them to evaluate a wide variety of lasers with different output powers and beam quality at various wavelengths and price points. Guidance on the electrical, optical and thermal management of the sources was provided which was integrated into a working prototype and will be incorporated into the final product design.

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Pharmaceutical Cleaning Verification using Deep UV Resonance Raman Spectroscopy (DUVRSS)

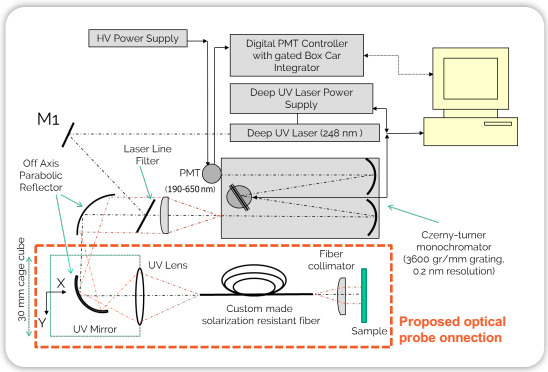
*Cleaning verification is a quality control process for determining the effectiveness of a cleaning event, and forms an important component of **Process Analytical Technology (PAT)**. It is used to establish that product cross contamination is controlled, ensuring patient safety and product quality. Current verification is made using visual inspection and/or analytical verification (e.g. Total Organic Carbon (TOC), HPLC/UPLC, UV or conductivity). This project aims to develop a preferred direct surface measurement using **Deep UV Resonance Raman Spectroscopy**.*

Proposed Solution - DUVRSS

Deep UV Resonance Raman Spectroscopy provides a combined Raman and fluorescence spectra measurement with improved detection limits vs Surface-enhanced Raman spectroscopy (SERS) and a considerable level of chemical specificity. Rapid analysis & feedback on contaminant levels and identity can be achieved with minimal sample preparation. Specific improvements on existing technologies like HPLC are contained within an easy-to-use analysis protocol. This project will:

Build a bench top prototype to determine the detection/sensitivity of DUVRRS for use with pharmaceutical excipients, APIs and cleaning agents.

Investigate the applicability of using an optical fibre to develop a contact probe for hard to reach areas

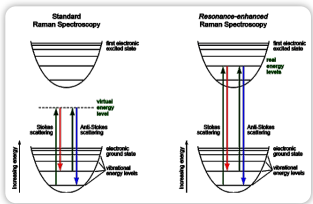


Industry Impact

- ***Help identify difficult to clean areas***
- ***Simultaneous multi-component detection***
- ***Reduced production downtime from days to hours***
- ***Improved sample response times prevent a measurement backlog***
- ***Identification of molecular functional groups allows end users to apply targeted cleaning procedures***

Raman Spectroscopy

Raman spectroscopy is a non-contact, non-destructive, method of elucidating the composition and structure of unknown materials without sample handling, processing, or use of reagents. Visible and near-IR lasers have photon energies below the first electronic transitions of most molecules, but when the photon energy of the laser lies within the electronic spectrum of a molecule, as is the case for UV lasers and most molecules, the intensity of Raman-active vibrations can increase by many orders of magnitude. This effect is called "resonance-enhanced" Raman scattering.



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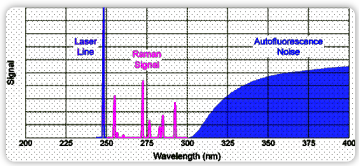

Advantages of DUV Resonance Raman

- ***Rayleigh Advantage:** Scattering of photons is ~$1/\lambda^4$, so higher in the UV.*
- ***Resonance Enhancement:** Factors of ~10^5 compared to normal Raman scattering.*
- ***Fluorescence Avoidance:** Excitation in the UV allows easy filtering out of fluorescence, since Raman fingerprints are far away.*
- ***Ambient Background Elimination:** Essentially no background irradiation from solar or artificial lighting.*
- ***Chemical Specificity:** Only those Raman bands associated with electronic transitions are enhanced, enabling easier interpretation.*

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Upper Gastrointestinal Bleeding (UGIB) Sensor

Irish MedTech Awards 2017 Category Finalist

*CAPPA and EnteraSense Ltd have been shortlisted as one of three finalists in the category **Academic Contribution to MedTech** for the Irish MedTech Awards 2017. The nominated project is developing a swallowable capsule which is capable of monitoring gastrointestinal bleeding for up to three days, communicating externally via a wireless Bluetooth connection. The technology will eliminate unnecessary endoscopies and speed up diagnosis.*

The Problem: Identifying Gastrointestinal Bleeding

Acute gastrointestinal bleeding is a potentially life-threatening abdominal emergency that remains a common cause of hospitalization. Upper gastrointestinal bleeding (UGIB) is defined as bleeding arising from the oesophagus, stomach and duodenum; peptic ulcers are a common cause.

Today, diagnosis is achieved through a combination of clinical factors including patient history, physical examination and lab tests, but a full endoscopic examination is required as a conclusive means of diagnosis. This means that ***every patient with a suspected bleed needs to undergo endoscopy***. Endoscopy is not always promptly available, is expensive and invasive.

The EnteraSense Solution

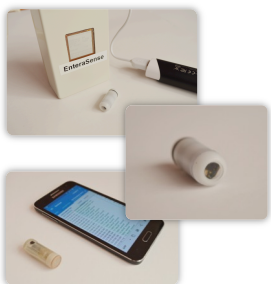
EnteraSense is developing an ingestible capsule and external receiver to identify and monitor UGIB without the need for endoscopy. The capsule contains an optical-based sensor which gathers data from the environment and uses an algorithm to determine if blood is present. This is then transmitted wirelessly to a receiver (e.g. PC, smartphone) for real-time diagnosis. The product addresses UGIB both as in-patient and in triage setting.

ENTERA SENSE www.enterasense.com

EnteraSense Limited is a medical device diagnostic company founded in 2015 by Donal Devery, Dr. Chris Thompson and Dr. Marvin Ryou from Brigham and Women's Hospital in the United States. The company is based in Galway, Ireland and has a licensed technology agreement from Brigham and Women's Hospital/Harvard Medical School which enables the company to develop devices for diagnosing and monitoring Upper Gastric Bleeds.

CAPPA has assisted EnterSense with:

- ***Improving signal detection of the sensor***
- ***Developing a simplified system for prototype design => working demonstrator***
- ***Optimising component layout for efficiency and minimum footprint***
- ***Teaming with the TEC Gateway (also at MTU) to develop the wireless comms and GUI***



Benefit for Patients	Benefit for Healthcare System
• *By providing a prompt diagnosis, enables the patients to receive immediate treatment. This reduces risk of death, complications and potentially the length of stay.*	• *By identifying false re-bleeders, it allows immediate saving of unnecessary endoscopy, estimated at over €700M.*
• *Patients are better screened and receive endoscopy only when necessary.*	• *Further savings due to the potential reduction of length of stay.*
	• *Better use of endoscopy resources and hospital beds.*

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Wide Field Fluorescence Imaging System

Irish MedTech Awards 2018 Category Finalist

*CAPPA and Hooke Bio have been shortlisted as one of three finalists in the category **Academic Contribution to MedTech** for the Irish MedTech Awards 2018. Hooke Bio is an emerging biotech company focused on the development of high throughput and high content testing platforms for faster and more effective drug screening. The nominated project is developing a wide field fluorescence imaging system.*

The Problem: Need for Microfluidic Screening

There is an important unmet need for new medicines that can be mediated by the use of ultra-high-throughput microfluidic screening. In drug discovery, pharmaceutical companies screen thousands of possible drug candidates against disease models. However some 95% of new drugs fail during development, with many failures attributed to efficacy and safety issues as the industry currently does not have the capacity to screen every possible drug candidate, concentration or vary the drug efficacy safety tests due to sheer numbers. **High-throughput screening is required to screen vast numbers of drugs** and drug combinations, as their effects on cells are difficult to predict. As a result, the testing of such drugs becomes an engineering issue.

The Hooke Bio Solution

Hooke Bio has developed a platform that runs screening tests 20 times faster and at a quarter of the cost of current commercial systems. The Enigma Platform integrates dispensing, incubation and measurement on one platform without the need for robotics. In addition to being faster and cheaper, it can also undertake 3D cell culture. This means pharmaceutical companies can test new drugs against more physiologically relevant cell disease models.

HookeBio

www.hookebio.com

Hooke Bio is a microfluidics company operating in the preclinical drug discovery and personalised medicine. It draws its strength from the close co-operation it has between its biologists and engineers. Hooke Bio has patented microfluidics technologies that allow their screening platform to work with volumes of liquid 10 to 100 times less than current liquid handling systems. This approach requires very high throughput automated testing at small volumes with relevant, translatable disease models. Their primary focus is on drug combinations.

CAPPA has assisted Hooke Bio with:

- ***Developing the photonics***
- ***Imaging and image analysis elements***
- ***Improving the system from a single line test unit to an 8\16 line unit***
- ***Designing and prototyping a bespoke imaging system***
- ***Integration with a tailor made software solution***

"I would happily recommend CAPPA because of their high levels of expertise. CAPPA are very flexible and willing to engage with industry. I wouldn't even know where to look for the service in the country and probably in Europe"

– Mark Lyons, CEO

Benefit for Patients	Benefit for Healthcare System
• *Personalised combination screening could become a reality and would remove the element of uncertainty that surrounds chemotherapy*	• *Integration of dispensing, incubation and measurement on one platform without the need for robotics*
• *Employing combination screening and drug repurposing could be used to treat a wide range of diseases such as cancer and heart disease*	• *Ability to test new drugs against more physiologically relevant cell disease models*
	• *Unlimited drug screening at the early crucial drug discovery phases*

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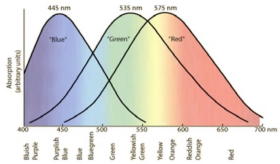
Multi-Spectral Imaging for Skin Cancer Detection

Project Background

- The concept behind this project was to research, develop designs and inevitably build a multi-spectral imaging device which will have up to 16 different colour LED chains.
- Together with the device, a means of acquiring and storing the data was constructed for the advantages of data integrity, confidentiality and analysing the images at a later time.
- Spectral Imaging shows great promise for medical applications due to its non- invasive nature.

Multi-Spectral Imaging

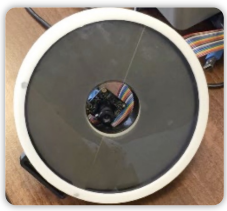
- The information gathered from this procedure can broaden the understanding of an object, its composition and structure by viewing the object through a range of spectral wavelengths.
- A multi-spectral camera will capture multiple different wavelengths and have a separate value for each wavelength, which means each pixel will have a different spectral signature.



Equipment Needed

- Imaging Camera

- Multispectral Source

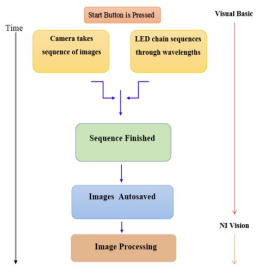


Testing Method

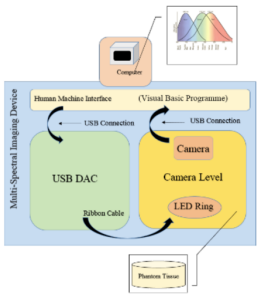
- The object under test should have the same, or close to the same optical properties of human skin.
- A phantom was constructed by using a rubber like material called Polyurethane.
- Uniform absorbing and scattering substances were added before and after hardening. i.e. Titanium dioxide and ink.

Project Plan

Flow Diagram



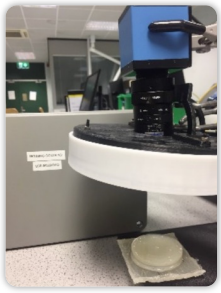
Device Diagram



User Interface

- Simple user interface design
- "Plug and Play"

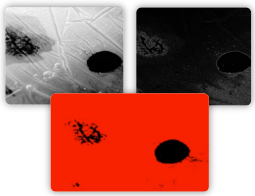
Finished Device



Results

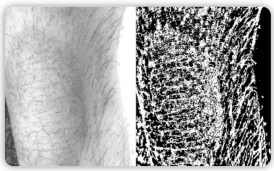
Margin Detection

- Through image processing, margin detection shows great detail of the area under examination.



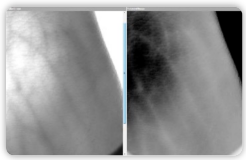
Dermatitis

- Haemoglobin absorbs lower wavelengths such as Blue and Green.
- This is useful for highlighting margins of rashes and dermatitis.



Vascular Mapping

- The structure and position of veins can be emphasized by the device.
- This has many medical benefits and has the potential of offering an uncomplicated alternative to current methods.



Conclusion

- A functioning non-invasive multi-spectral imaging device was successfully constructed.
- Images were collected and processed, leading to a clearer understanding of the objects under observation.
- A useful recipe for Phantom Tissue was established.
- With more time/resources, the design has potential to be simplified to a handheld unit.
- This could lead to cheaper medical expenses and quicker results.

Reference: Nave, R., 2005. hyperphysics. [Online] Available at: http://hyperphysics.phy-astr.gsu.edu/hbase/vision/colcon.html

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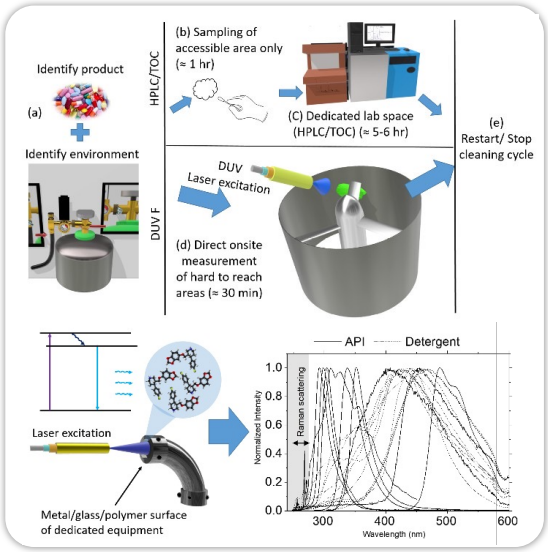
Pharmaceutical Cleaning Verification using Deep UV Laser Induced Fluorescence Spectroscopy (DUV-LIFS)

Cleaning verification and validation is a requirement in the pharmaceutical industry. Due to the limited number of mobile devices that do effective and accurate onsite cleaning verification, it is mostly done via lab-based quality control techniques. These techniques, such as high-performance liquid chromatography (HPLC) or total organic carbon, often lead to extending the validation of the cleaning by days. The void of more sensitive, accurate, and portable instruments to verify cleaning onsite has to be filled. The use of deep ultra violet (DUV) laser – induced fluorescence for detecting carryover of active pharmaceutical ingredients (APIs) and detergents onsite is a novel technique introduced by CAPPA. The specificity of the technique allows API traces having concentrations as low as ≈0.20 µg/cm^2 to be identified within a very short amount of time, even if the API to be detected has a low fluorescence efficiency.

DUV – LIF for Cleaning Validation in Hard to Reach Areas

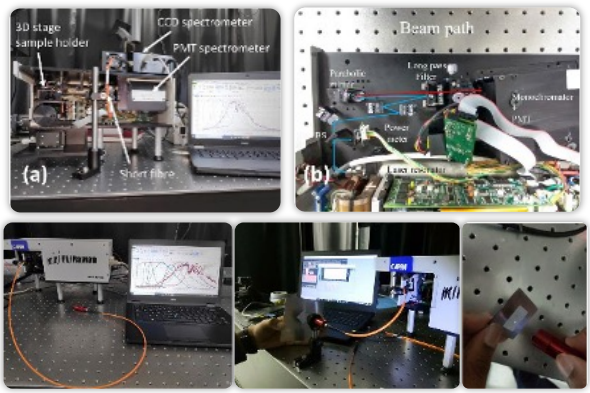
Deep UV LIF set up in CAPPA provides a combined Raman and fluorescence spectra measurement with improved detection limits. DUV laser-induced fluorescence of trace API over any polymer/glass substrate has better signal to background ratio (SBR) compared to FTIR absorption techniques. Processing times of DUV laser-induced fluorescence trace detection are shown to be much less than swab based methods.



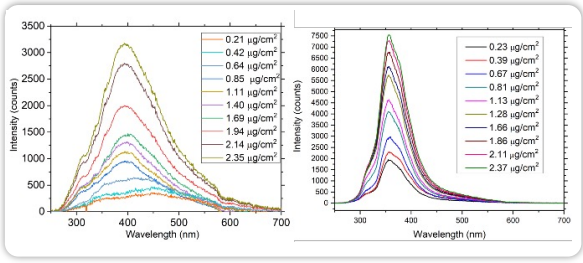
Industry Impact

- ***Help identify difficult to clean areas***
- ***Simultaneous multi-component detection***
- ***Reduced production downtime from days to hours***
- ***Improved sample response times prevent a measurement backlog***

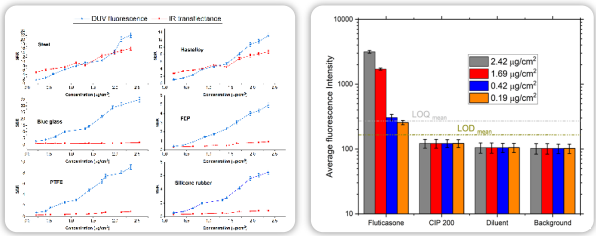
Initial Instrument Design



Lower Limits of Detection than other Spectroscopic Methods



Higher Chemical Specificity



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