Detection of skin cancers: Lowering the cost, size and complexity of Optical Coherence Tomography systems using novel diode lasers

Dr David Bajek

University of Dundee, Ninewells Hospital & Medical School ▪ Scottish Photobiology Service ▪ The Scottish Photodynamic Therapy Centre ▪ NHS Tayside

Skin Cancer & The Power of Light

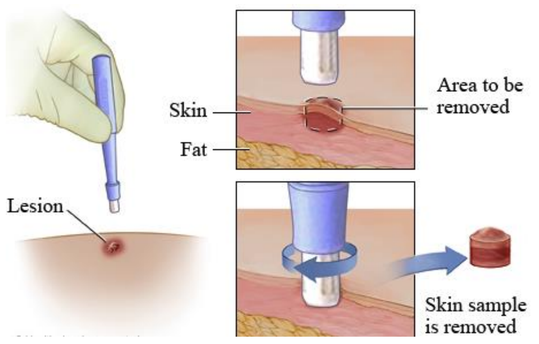
In the UK alone, there are approximately 400 new non-melanoma skin cancer cases every day

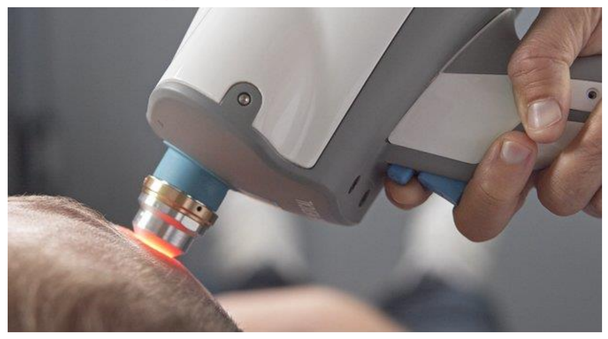
The Photobiology Unit was established in 1973 to meet the clinical needs of patients with photosensitivity. Working alongside dermatology, our team of doctors, nurses, clinicians and researchers work closely together on the treatment of a wide range of dermatoses and photo-dermatoses, including skin cancer. We present our innovative research on using light for the diagnosis and treatment of skin cancers, where my objective is to deliver on rapidly practicable and green solutions which benefit our NHS patients.

Benefits of Optical Coherence Tomography (OCT)

Using light for *diagnosis*: OCT is an imaging technique which, in dermatology, allows layers of tissue beneath the surface of the skin to be analysed for diagnosis of harmful growth such as non-melanoma skin cancers, including and basal-cell carcinomas. Infrared light is directed through layers of a patient's tissue, rapidly tuned in wavelength, and reflected onto a detector, the data from which is compiled to form a full image. This allows the depth and spread of a tumour, as well as its response to treatment, to be monitored non-invasively without the need for biopsy.

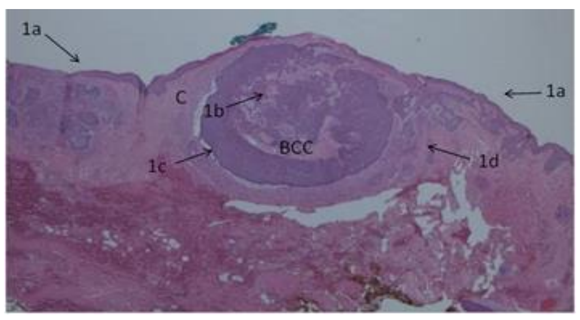
✗ **Punch Biopsies:** → ✓ **OCT:**

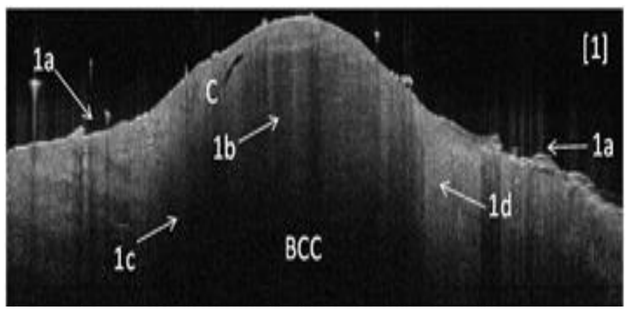




✗
- Invasive
- Pain
- Risk of infection
- Human analysis

→ ✓
- Non-invasive
- Painless
- Contactless Imaging
- Computational analysis



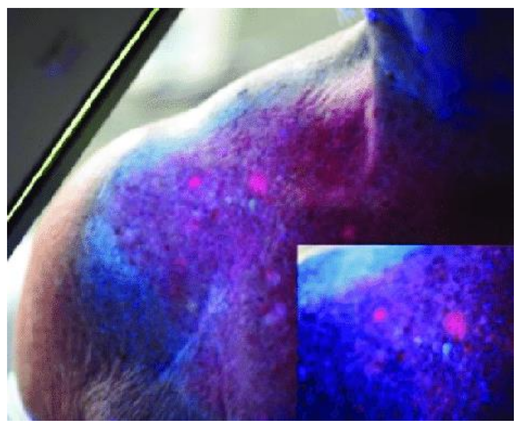


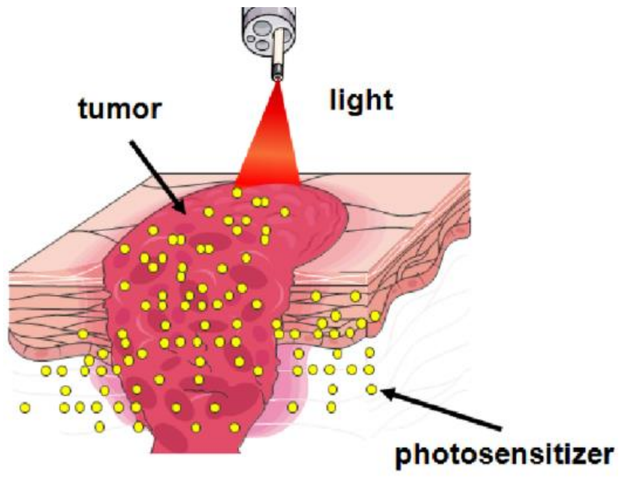
(Top) Punch biopsy procedure compared to contactless OCT procedure

(Bottom) Biopsy of Basal Cell Carcinoma compared to corresponding OCT image

Photo-Dynamic Therapy (PDT)

Using light for *treatment*: Photodynamic Therapy (PDT) is a treatment which involves the destruction of abnormal cells (including cancer) using light. The patient is given medicine called a photosensitiser, which is preferentially taken up by the cancer cells. The cancer cells are then exposed to light, which causes a reaction in the photosensitiser which destroys them.



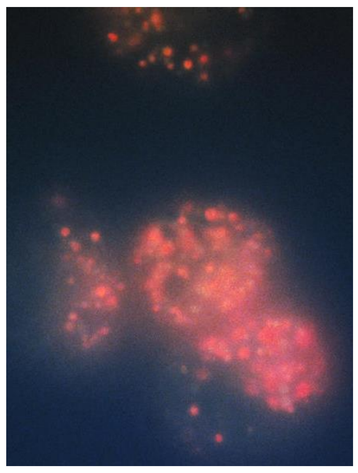


(Left) Patient with photosensitising drug applied. Abnormal tissue fluoresces under ultraviolet lamp, giving excellent visual guide of where to concentrate PDT treatment.

(Right) Diagram of photosensitiser being taken up by a tumour prior to exposure to PDT

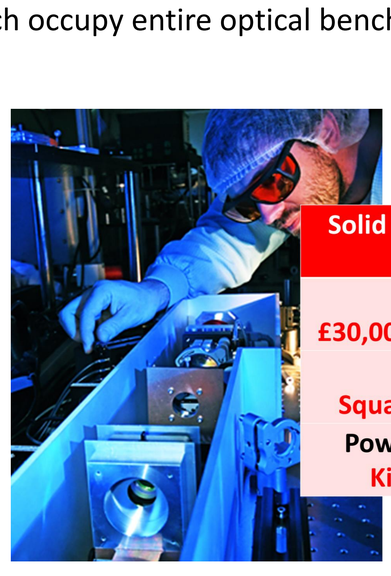
How can OCT help PDT?

OCT-guided PDT: Our research will use OCT as a simple imaging technique which will be complementary to both diagnosis AND treatment of skin cancers. Whilst OCT is an excellent alternative imaging tool for diagnosis, the same technology can be used to inform the efficacy of our PDT by imaging the cancer at various stages throughout treatment. Not only would this help avoid subjective visual judgement of a concluded treatment course but could reliably detect any untreated cancer which lies deeper within the tissue.



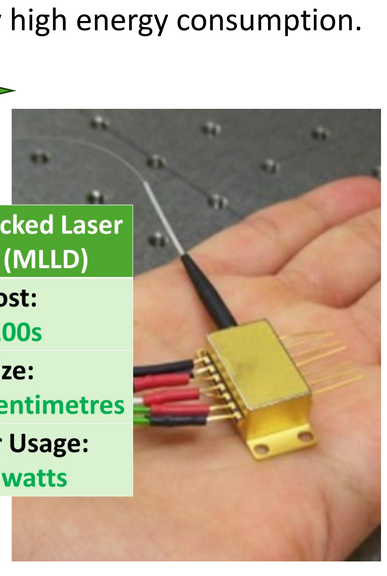
Benefits of Mode-Locked Laser Diodes (MLLDs)

Light *sources:* The problem with existing OCT technology comes down to cost, size, and complexity. The laser alone can range well over £30k and occupy spaces of metres or more. Our innovative research wishes to solve this problem using mode-locked laser diodes (MLLDS). MLLDs are low-cost, compact, and versatile devices which can fit in the palm of a hand, compared to their bulky and expensive solid-state counterparts which occupy entire optical benches, and require very high energy consumption.



✗ ✓

Solid State Laser	Mode-Locked Laser Diode (MLLD)
Cost: £30,000 – 250,000	Cost: £100s
Size: Square Metres	Size: Square Centimetres
Power Usage: Kilowatts	Power Usage: Milliwatts



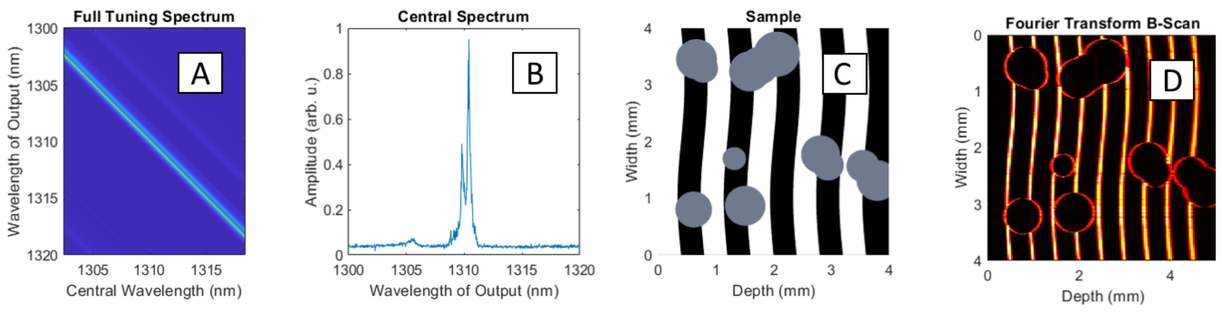
MLLDs energy consumption is substantially lower, and therefore a greener technology which is far less expensive to run. MLLDs can be fabricated to a wide variety of output powers and wavelengths, and are easily combined into an array of several types if required for multiple studies. Most alternative lasers require a second hidden laser (the optical pumping laser) to function, adding to their footprint. MLLDs, however, can function using the operating electrical signal only (electrical pumping), cutting down on manufacturing and complexity. Moreover, varying this electrical signal can tune the output (wavelength, power) – a highly attractive feature in many imaging applications. We have already demonstrated and published record-breaking fast scan rates and the sharp tunable optical spectra required of a laser in an OCT system using MLLDs*:*

Bajek D, Nature Scientific Reports, 2021 doi: 10.1038/s41598-021-02502-w

Our Research Summary and Future Outlook

- **OCT provides a painless, non-invasive alternative cancer-detecting method**
- **MLLDs offer a low-cost, compact and greener laser source for OCT imaging**
- **OCT can significantly improve the efficacy & duration of PDT treatment**

In addition, we have recently branched our research into computational modelling of imaging techniques and the analysis of OCT images for quality and accuracy. Our latest models also allow us to assess the potential quality and performance of any laser intended for use in OCT imaging, by analyzing a sample of its output spectrum and tunability. This can greatly inform our choice of MLLD fabrication properties (growth, architecture, chemical components) and eliminate costly experiments which would otherwise be required.



Computational modelling: Real optical spectra taken from the output of a candidate laser (MLLD) and run through our models, which are also capable of random sample image generation. Depending on the quality of the laser's output, the quality and accuracy of the image may be quantitatively compared to an ideal imaging scenario.

The future sees us replacing invasive and subjective diagnostic techniques with green, low-cost, hand-held devices which can computationally analyse the presence of skin cancer, as well as the efficacy of the patient's treatment.

For further information, please contact
David Bajek: dbajek001@dundee.ac.uk