Thermally Tuned Swept Laser Source for Optical Coherence Tomography

Degree programme: BSc in Mechatronics and Systems Engineering (Medical technology | Robotics)
Thesis advisors: Dominik Inniger, Prof. Christoph Meier
Expert: Dr. Daniel Boss

Existing swept laser sources tend to be the main cost driver in Swept Source Optical Coherence Tomography systems and are limiting the use of these devices. The aim of this project is to develop a low-cost alternative using a thermally tuned Vertical Cavity Surface Emitting Laser and to characterise its performance. If this alternative proves to be technically feasible, it could be used in many ophthalmic devices.

Context

When using highly coherent laser source, Swept Source Optical Coherence Tomography (SS-OCT) allows for a larger imaging depth. The main barrier to their widespread use is their price. The goal of this project is to develop a low-cost alternative to these sources which could make SS-OCT a viable technique for many existing applications. Research in Vertical Cavity Surface Emitting Laser (VCSEL) technology has shown that the wavelength is dependent on the temperature of the VCSEL. We exploit this relationship by heating the VCSEL with an optimized current waveform.

Methods

After a literature review and familiarization with VCSEL physics, the experimental setup was started. The first task was to couple the light from the VCSEL into an optical fibre to measure it. Once the tunability by the driving current was confirmed, we went on to build an SS-OCT system to further characterize the light emitted by the laser. This allowed the temporal behaviour of the wavelength sweep to be measured and its linearity, bandwidth, repetition rate, coherence length and sensitivity to be optimized. Once satisfactory B-scans were obtainable, a test was performed on an ex-vivo porcine eye.

Results

The VCSEL could be tuned to sweep through a bandwidth of 9nm with a central wavelength of 860nm at a repetition rate of 2kHz. This results in an axial OCT resolution of 43 microns. Higher frequencies are possible, but at the cost of a bandwidth loss of about 2.5nm per decade. By using a square root waveform as the driving current, a reasonably linear wavenumber sweep could be achieved. More optimisation of this waveform could lead to a perfectly linear sweep, which would allow some post-processing steps to be omitted, further reducing the cost. The acquired B-scan of a porcine eye shown in the figure 1 demonstrates the effectiveness of a VCSEL as a swept source.

Outlook

The results show that a thermally tuned VCSEL can potentially be used as a low-cost alternative to established swept sources. This is promising for applications where a large measurement range is required. For example, measuring the length of the eye to monitor the progression of myopia, which is an increasing problem in children. Work on this project will continue and the next steps will be to improve upon the current system to see if it can be turned into a product.

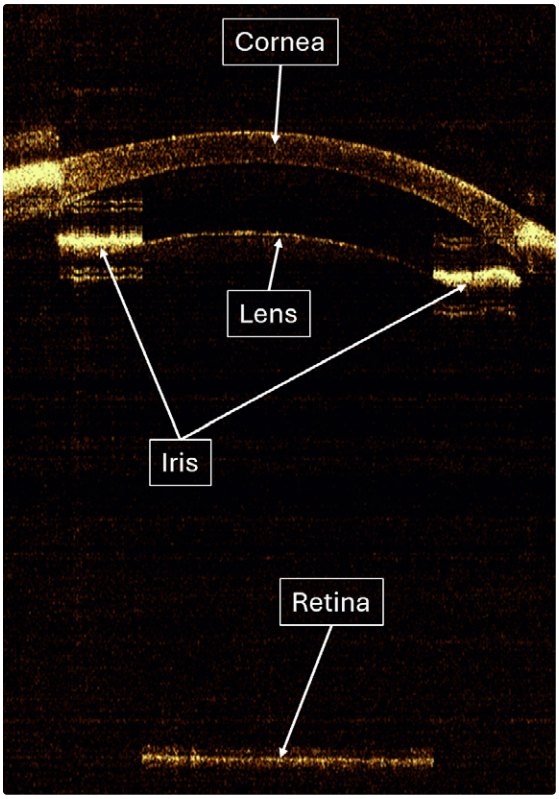

Figure 1 : B-scan of ex-vivo porcine eye at an A-scan rate of 5kHz, 1000 A-scan per B-scans and a resolution of 43

Loris Christen
Optics and Photonics
079 132 88 75
loris.christen@gmail.com