Spectral Domain Visible Optical Coherence Tomography using Balanced Detection

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1. Introduction

Harnessing the potential of optical imaging systems for medical diagnosis is something that Optical Coherence Tomography (OCT) has successfully secured it's place in. In particular, retinal imaging using such systems is widely used in both hospitals and optician clinics proving the viability of such systems to be clinically accepted and regularly utilised. However, the journey for these systems continues within the realm of research labs, advancing the systems with proof of concept designs such as what will be presented by this abstract. Conventional OCT instruments to image the retina are driven by optical sources operating in the infrared (IR) spectral range (typically at around 800 nm). Over the years, interest has shifted to lower wavelengths [5], seeing a rise in visible OCT (VIS-OCT) systems being investigated. This work presents a VIS-OCT system operating at a central wavelength of 580 nm, able to provide an axial resolution in-air of around 3 μm. The instrument incorporates two state of the art line-scan cameras within a novel spectrometer configuration for detection. The spectrometers have been configured using hardware and software modalities to operate in a balanced detection mode. To generate images, the complex master slave method is employed [6].

2. Methods and results

As depicted in figure 1, light from a supercontinuum source (SC) is firstly filtered to remove the excess IR and visible light leaving only the required spectral range. It is then coupled into a fibre coupler with a 90:10 splitting ratio, directed to a reference and sample arm of an interferometer, respectively. Light from the imaged object and from the reference arm interferes in a 50:50 directional coupler, whose outputs direct light towards the two spectrometers. Data acquired by the two cameras (Teledyne e2v OctoPlus) is then conveyed via camera link cables towards the two inputs of a frame grabber (Teledyne Dalsa Xtium-CL MX4). A LabVIEW in-house developed software is finally used for calibration purposes as well as for the real-time display of the B-Scan images.

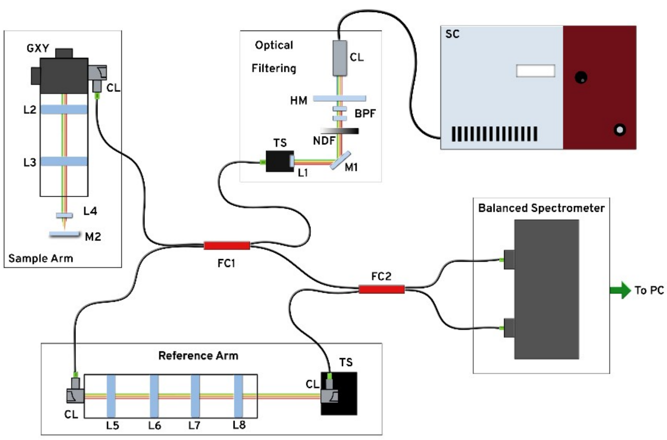

Fig. 1. Optical set-up of the VIS-OCT system. L1-8: Achromatic Lens. GXY: Galvanometer Scanners. CL: Collimator. M1-2: Mirror. FC1-2: Fibre Coupler. TS: Translation Stage. HM: Hot Mirror. BPF: Bandpass Filter. NDF: Neutral Density Filter. SC: Supercontinuum Source.

Thus far, the system (first iterations described in [4] and [3], with over 80 dB of sensitivity in balanced detection mode (250 μW on the sample), was used to generate B-Scans and volumes of static samples such as the infra-red card and fruits, as well as in-vivo images from human tissue (thumb). The 9 dB improvement (measured close to OPD = 0 mm) given by the balanced configuration is visible when comparing the unbalanced images from individual cameras with the balanced image (as can be seen in figure 2.) These images serve as proof of concept for the system prior to retinal imaging.

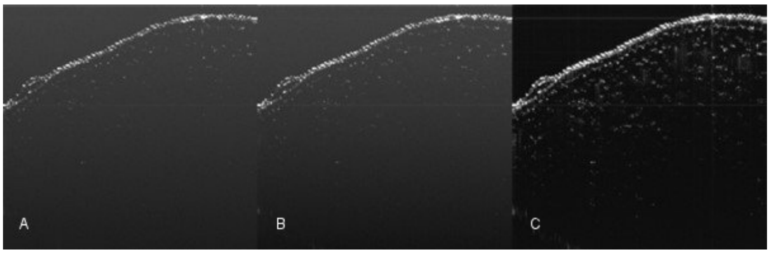

Fig. 2. OCT B-Scan obtained of an onion, showing the effect of balanced detection where images (a) and (b) are acquired via the individual cameras whereas image (c) utilises both cameras in balanced detection mode. OPD = 0mm at the top of the image and increasing in sample depth vertically downwards. The size of the image is 2.4mm laterally and 1mm in depth.

When imaging the retina, laser safety protocols restrict the power of light sent to the sample to 250 μW. This small amount of optical power, combined with the limiting reflectivity of the retina to return the light will inherently produce an image with poor contrast. Additionally, the optical noise of the supercontinuum sources is significant and degrades the image quality further [1]. These factors are motivators toward the balanced detection scheme which enhances the image quality and sensitivity to be more comparable to those obtained from higher wavelengths. To efficiently use the balanced detection scheme, a pixel to pixel calibration between the two detectors is required to successfully reduce the noise and enhance the sensitivity of the instrument. To achieve this, a computational method similar to that described in references [7] [2] has been utilised, harnessing the temporal noise properties of the supercontinuum to do so.

High axial resolution, spectroscopic potential from the use of visible light and in-house designed spectrometers are combined with novel software to produce a functional OCT imaging system operating at 80kHz which sees the potential of in-vivo imaging for detection and monitoring of retinal disease. Proof of concept images of tissue and other samples have been obtained and will be presented to demonstrate the capabilities.

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4. References

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