THE HOW AND WHY OF A $10 OPTICAL COHERENCE TOMOGRAPHY SYSTEM

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Optical Coherence Tomography (OCT) is the fastest growing medical imaging modality with more than $1Bln worth of scans ordered and over $400M worth of equipment shipped in 2010, just nine years after its commercialization. It is at various stages of acceptance and approval for eye care, coronary care and skin cancer care and is spreading rapidly to other medical specialties. Indeed, it is the leading success of translation of biophotonics science into clinical practice. Significant effort is being made to provide sufficient evidence for efficacy across a broad range of applications, but more needs to be done to radically reduce the cost of OCT so that it can spread to underserved markets and address new, fast growing opportunities in mobile health monitoring. Currently, a clinical OCT system ranges in price from ~$50k to ~$150k, typically is housed on a bedside trolley, runs off AC power, and requires skilled, extensively trained technicians to operate. The cost, size, and skill level required keep this wonderful technology beyond the reach of mainstream primary care, much less individual consumers seeking to monitor their health on a routine basis outside of typical clinical settings and major urban medical centers. Beyond the first world market, there are 6.5 billion people with similar eye and skin cancer care needs which cannot be met by the current generation of large, expensive, complex, and delicate OCT systems.

This paper will describe a means to manufacture a low cost, compact, simple, and robust OCT system, using parts and a configuration similar to a CD-ROM or DVD pickup unit (see figure 1). Essentially, this system—multiple reference OCT (MR-OCT)—is based on the use of a partial mirror in the reference arm of a time domain OCT system to provide multiple references, and hence A-scans, at several depths simultaneously (see figure 2) [1,2]. We have already shown that a system based on this configuration can achieve an SNR of greater than 90 dB, which is sufficient for many medical imaging and biometry applications.
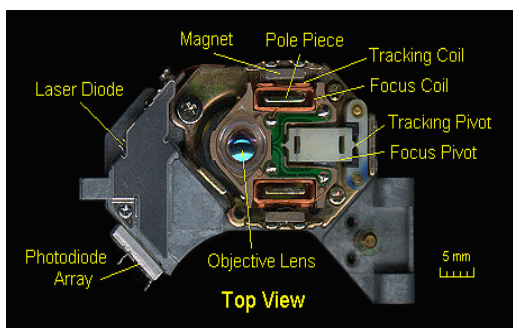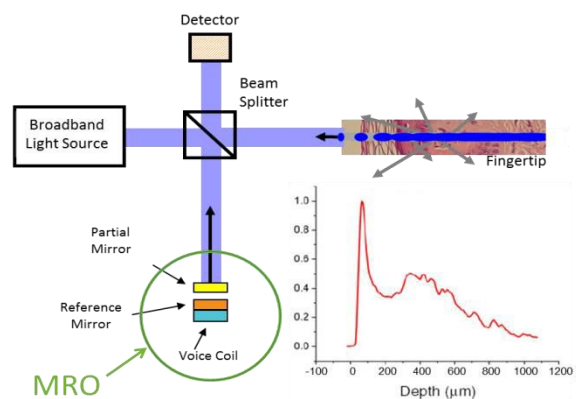

Fig. 1. A typical CD-ROM pickup unit.

Fig. 2. Multiple reference time domain OCT (MR-OCT) system using a partial mirror.

Using this approach, a full depth scan of 1 to 2 mm can be achieved with a reference mirror movement of tens of microns. This can be accomplished using a voice coil similar to a DVD focus coil and a setup that is similar to a CD-ROM pickup unit. In volume, these can be purchased today for approximately $5. Because an MR-OCT system has a similar architecture, level of complexity and componentry, we believe it, too, can be built for a cost of the order of $10. Schematics showing the similarities between a CD-ROM unit and a time-domain OCT system are shown in figures 3 and 4. Each has a beam-splitter, light source, detector, and sample arm. The addition of a reference arm and some modifications, including replacing the laser with a super-luminescent diode, converts it to an OCT system. Of course, such costs are only possible when the annual market is of the order of at least hundreds of thousands of units. One application with the market size sufficient to facilitate OEM costs similar to CD-ROM or DVD pickup drives is biometrics, so we investigated the ability of this technology to provide enhanced fingerprint security for mobile devices.
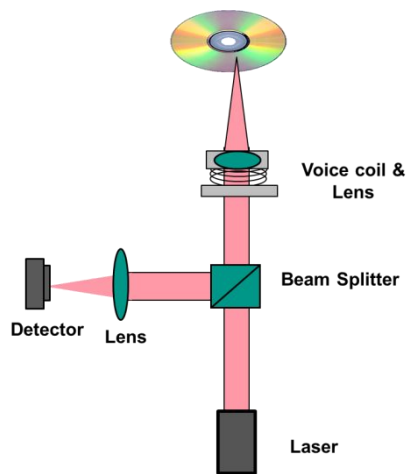

Fig. 3. Simplified schematic of a typical CD-ROM pickup unit.
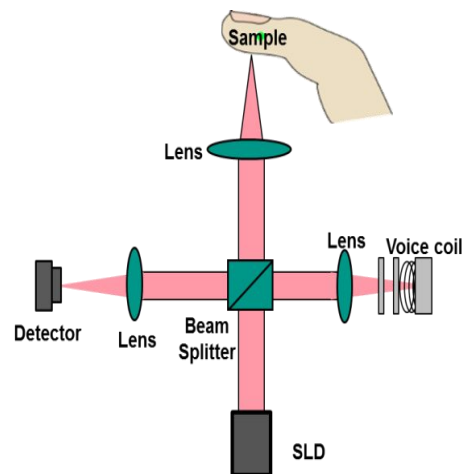
Fig. 4. Simplified schematic of an MR-OCT system showing similarity to CD-ROM pickup unit.

A further advantage of the small travel required by the voice coil scanner in this configuration is that scan rates can be an order of magnitude greater than those achievable with traditional time-domain OCT. Frame rates of greater than 16 Hz are generally considered to be sufficient to avoid typical human motion induced artifact. In order to demonstrate fit for purpose scanning we have built a 3,000 A-scans per second MR-OCT system using a voice coil actuator for the reference mirror and applying it to biometric scanning. This is sufficient to deliver B-scans of more than 180 A-scans at 16 Hz.

A 3D MR-OCT fingerprint scan is shown in figure 5. We show that the primary (sub-dermal) and secondary (surface) fingerprints correlate well with each other. We also show that ridges and sweat ducts can be sufficiently well rendered for biometric purposes. Furthermore, we have demonstrated that using Doppler or correlation mapping (cmOCT), the blood flow can be detected to establish liveness. The combination of (a) correlation of the sub-dermal fingerprint with the surface fingerprint, (b) analyzing additional features, such as sweat glands (an indicator of stress), and (c) detecting liveness has the potential of yielding a much higher level of biometric security. [3] The fact that the primary (sub-dermal) fingerprint correlates well with the secondary (surface) fingerprint ensures that the MR-OCT depth fingerprint is compatible with existing enrolled surface fingerprint databases.

An MR-OCT system was built on a miniature optical bench to demonstrate its feasibility (see figure 6).
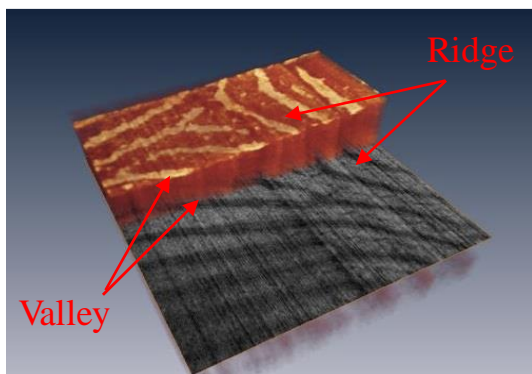

Fig. 5. 3D image revealing primary, secondary ridges and sweat ducts of the fingerprint obtained using MR-OCT.
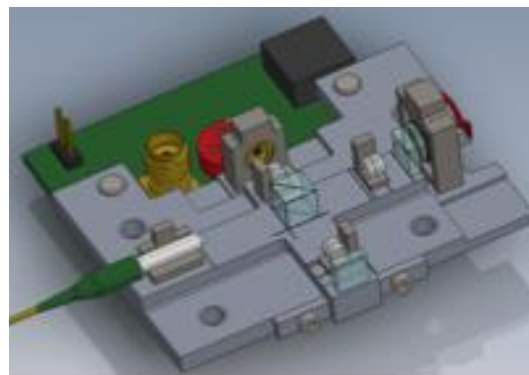
Fig. 6. Miniature MR-OCT device measuring approximately 40 x 50 x 10 mm.

The papers associated with this presentation present biometric and non-destructive testing results from MR-OCT systems and discuss the viability of this approach to bring the advantages of OCT to the masses. The results show that an OCT system, of sufficient quality for biometric security, biological imaging, and non-destructive testing applications [4,5], can be built from components with the potential to be integrated into a low cost mobile consumer device. Future work will focus on integration and demonstration of the device in key application areas.

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