HIGH SPEED OCT SYSTEM USING EXTERNAL CAVITY LASER

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We describe a new concept for the implementation of a scanning laser for OCT applications with a capability of more than one spatial point in 1µs thanks to high speed E/O materials in a tuneable etalon

Keywords: External cavity laser, Optical coherent tomography

Optical Coherent Tomography (OCT) using swept sources (SS-OCT) is the most diffused and promising solution for evolving towards high speed. High speed OCT will allow the possibility of real time 3D imaging that can be massively used in healthcare, mainly in ophthalmological diseases diagnosis; but, most important thing, it will enable real-time non-invasive imaging for surgery and, in next future for industrial process control and autonomous driving.
A 200x200 points image with 25 frames repetition rate requires one million scans per second (1µs scanning time). In order to reach this speed a short cavity laser (short photons lifetime) with no moving parts is required.
In our design we adopt an External Cavity Laser (ECL) approach using a semiconductor based gain chip and a tuneable narrow-band, large Free Spectral Range (FSR) etalon filter inserted into a short cavity (few centimetres), as shown in figure 1.

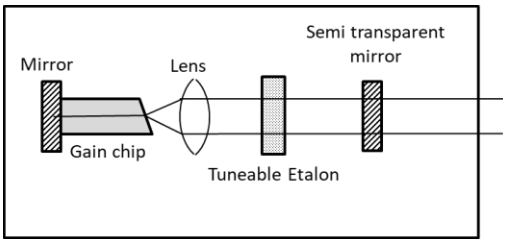

Figure 1 – Schematic of the ECL.

The tuneable etalon is the element allowing the laser scan over the needed wavelength range and is composed by a fast electro-optic material sandwiched between two transparent electrodes and two high reflective mirrors providing large finesse.
It is know from literature [1] that the resolution along the beam propagation direction for an OCT system is related to the scanning frequency by the formula

$$\Delta Z = \frac{c}{2n(\Delta f)}$$

Where c is the light speed, n is the refractive index of the medium and Δf is the total scanned frequency interval. For a good axial resolution (< 10 µm) the required scan is around 12.5 THz (100 nm). Also important is to have enough coherence length for reasonable field depth (generally some cm), thus asking for a limited spectral width of the laser spectrum. The variation of the refractive index in order to cover a FSR follows the relation $\Delta\lambda_{FSR}=\lambda_0*\delta n$. A large FSR asks for a significant variation of the refractive index. The known fast E/O materials as $LiNbO_3$ or RTP show a very small electro-optical coefficient and therefore they would require a very high driving voltage at high speed.
Our patented solution is to “synthesize” large scans with multiple shorter range scans (i.e. 100 nm with 4 scans of 25 nm each) as depicted in figure 2.

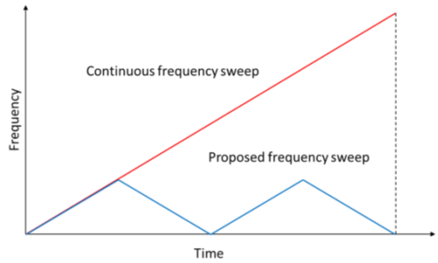

Figure 2 – synthesised laser scan

The signal measured after the OCT interferometer is shown in figure 3 and compared with the signal obtained using a continuous sweep (dashed). The two results are very similar and both allow for a correct evaluation of the beating frequency.

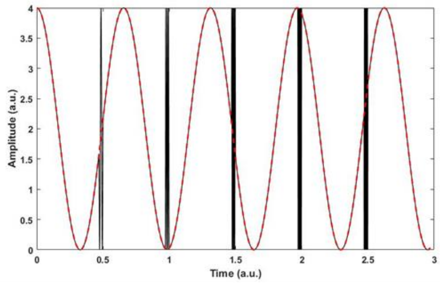

Figure 3 – comparison of the beating signals

References

1. **John Grasel - Exploring Frequency Domain OCT Systems** published 2011.