A fully static OCT sensor using glass integrated optics system based on the LLIFTS technology

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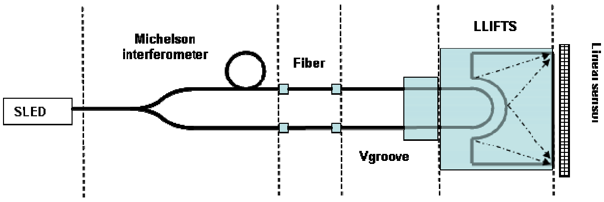
Abstract: Optical Coherence Tomography (OCT) sensors traditionally use optical delay line with moving parts. In other way, OCT systems with linear detector array are more simples and do not need moving elements. They can be based on the measurement of a Fourier interferogram made along the linear pixel array. Nevertheless, optical bulk parts are often used. In this paper, an entire integrated system is proposed from the two input signals to compare (reference and probe) to the linear optical detector. Leaky Loop Integrated Fourier Transform (LLIFTS) technology is used to have a fourier interferogram along an edge of the glass chip which is glued on a CCD linear detector array without protective glass window. After describing the system principles, first measurements are presented.

Introduction: Nowadays a lot of kind of OCT sensors using different technologies as optical delay line (displacement of a reference mirror), optical grating or tunable source (SWEPT)[1] are available. The integration of theses systems can be complex to realize and not enough robust for easy use. The solution proposed in this paper is to use a linear optical coherence technology[2] for making a Fourier interferogram on a linear photodetector array. For example, this solution has been used with the analysis of the Young interference pattern issued from the superposition of two diffraction beams coming from two fibers, reference and probe signals. Using initially a SLED source, a fringe packet is observed. Its maximum position gives the optical phase difference between the two signals and the packet amplitude can give the amplitude probe signal. The FWHM of the SLED is directly related to the phase shift resolution and the size of the interferogram gives the accessible phase range or the imaging depth of a real sample to analyze. Due to the numerical aperture of single mode fiber, the size of the interferogram is limited in this configuration. In this paper, we propose to use glass integrated optic function to obtain the Fourier interferogram on the edge of the glass chip. For this purpose, a LLIFTS function is used[3]. In order to have a compact system, the CCD linear photodetector array is glued on this edge without optical lenses in order to have a stable module with an unique calibration table. The LLIFTS permits to increase the interferogram size and ideally the interferogram size would be limited only by the length of the linear sensor. In this paper, a 4096 pixels linear photodetector array is used with a square pixel pitch of 10x10µm^2.

Description and realization of the system: The integrated optics glass chip is composed of two input single mode waveguides working in the wavelength range of 700-1000nm made by ion exchanged technology (Ag^+/Na^+). Each input waveguide is followed by a bend waveguide forming a loop. A planar waveguide is realized near the loop waveguide characterized by a gap between the two structures. Following the gap, a part of the light leaks in the planar waveguide tangentially of the bend waveguide. The planar waveguide allows this light part to reach the edge of the glass chip thanks to the vertical confinement. The modulation of the gap controls the amplitude and the size of the optical beam at the end of the component. The superposition of the two beams coming from the loop gives access to the fourier interferogram. The spatial fringes period at the end of the waveguide is enlarged due to the symmetry of the device. It must also be sampled by a linear detector array. This period is $\Lambda = (\lambda L)/(2nR)$ with L the length of the plane waveguide, R the radius of the loop and n the refraction index of the glass. Three to four pixels are used to obtain a correct sampled interferogram. Using this method, a spectrometer has been already proposed with a spectral resolution close to 4nm at λ=850nm[4]. The linear detector array without the protective glass window has been approached mechanically to have a distance close to 60µm in order to reduce the diffracted effect at the output of the glass chip. For this purpose, the device is initially set on a large support which is then glued on the optoelectronic module as shown in Fig. 1.



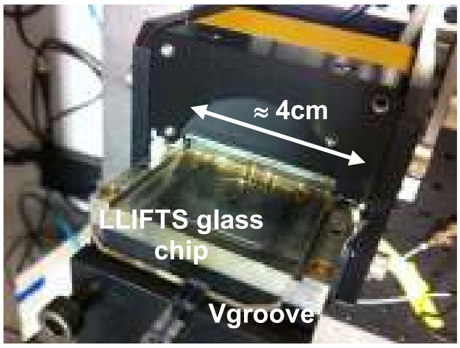
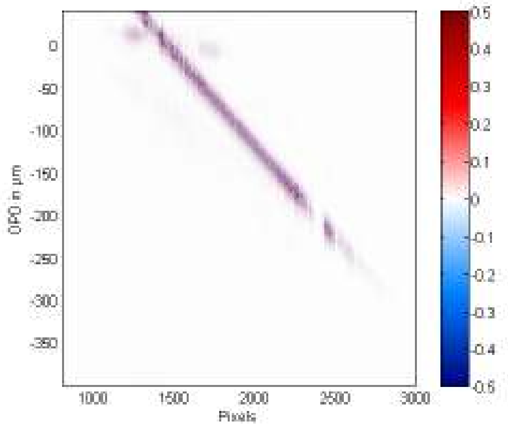


Fig. 1: Left: optical set up used to analyse the displacement of the fringe packet along the linear sensor. Right: picture of the sensor composed of two input fibers, the glass chip and the linear photodetector array.

First measurements: To analyze this system, an optical set-up is used to have two optical signals coming from a single SLED. For that, we use a Michelson interferometer permitting to have two different signals injected in two respective fibers. A displacement of one of the two mirrors allows the control of the Optical Phase Difference (OPD) between the two input signals. On Fig. 2, the position of the fringe packet can be observed following the OPD. A linear evolution of the maximum is observed over the mirror distance of around 300µm which is related to a pixel range of 1200 of the linear camera. With this linear detector array and a larger interferogram, OPD close to 1mm can be expected using this kind of static device. OCT analysis over a depth of this distance can be then investigated.



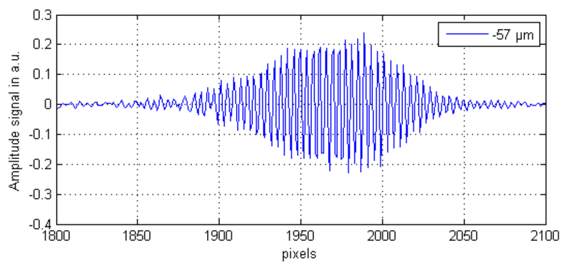


Fig. 2: Left: Evolution of the Fourier interferogram versus the OPD. Only the envelope has been eliminated to observe the useful interferogram. Right: zoom on the fringe packet at the OPD=-57µm of the SLED characterized by a wavelength center 870nm and a FWHM of 100 pixels (around 25 optical fringes).

It will be show that after a calibration step or basic signal treatment, the results can be improved. The perspective is to increase the integration, adding the y-junction after the SLED. Only two fibers will be used to reach a reference mirror and the sample under test.

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