Lithium Niobate near IR waveguides for astrophotonic and spectrometry applications

(Student paper)

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In order to develop new photonic chips for astronomy and spectroscopy, optimized near infrared waveguides and functions in lithium niobate have been conceived and fabricated. The characterization results on these electro-optic samples, in particular a multiplexed integrated spectrometer and a high contrast beam combiner, will be presented.

Keywords: *Electro-optics, lithium-niobate, IR waveguides, spectrometry, astrophotonics*

INTRODUCTION

Integrated optics devices are increasingly being used for astronomical applications, due to the robustness of the systems, which is of special interest in the field of interferometry, where a high number of beam are to be collected, guided and combined, while keeping the relative phase stable, or temporally controlled by means of active scan. In parallel, aside recovering the flux from the source, an interesting application is to obtain directly on-chip the spectrum of the source, without having to disperse light through bulk optics. In this case, the advantage of compact systems, in particular through guided optics, is to avoid difficult alignment of the beam, and in particular, in applications where stability is compulsory, such as drone, nanosat or other air-borne applications.

A diversity of astronomical instruments have been using the performances of passive waveguides (PIONEER, GRAVITY in SiO2/Si [1], FIRST using fibers [2], DRAGONFLY with photonics lanterns [3]). In future instruments, active control of the phase inside the waveguide allows for implementing interesting functions on-chip: Photometry balancing, to increase fringe contrast; fringe locking or fringe scanning [4]; wavelength multiplexing…Therefore, developing dedicated functions for improving the performances of future instruments is a very interesting field of research.

In this presentation, we will show some updated results on novel applications developed using near IR electro-optic Ti:diff waveguides in Lithium Niobate. Mainly, the results that will be presented concern a spatial and temporal multiplexed Fourier transform integrated spectrometer [5], and a high contrast active beam combiner, with corresponding photometries, in order to develop new generation nullers in the field of exoplanet research (LIFE, [6], Asgard/Hi5 [7]).

RESULTS

Near IR multiplexed spectrometers using lithium niobate:

The first device we will present is an integrated optics Fourier transform spectrometer (SWIFTS) that has been fabricated in lithium niobate. It can be shown that the spectral resolution is related to $R = 2nL / \lambda$, where n is the effective refractive index of the guided mode and L is the length of the sampling region. Besides, the spectral etendue (before aliasing) is related to $\lambda^2/4n\Delta z$. Therefore, for typical pixel pitchs of $\Delta z = 10\ \mu m$, the spectral etendue at $\lambda = 1.5\ \mu m$ is limited to 37nm. In order to increase the effective spectral etendue, electro-optic modulation of the fringes, by using a Mach-Zehnder modulator at the input of the waveguide (see Fig. 1), allows to temporally scan the fringes under the pixel and reduce the effective sampling distance between two consecutive data. However, as the EO scan is not strong enough to scan a large number of fringes, spatial multiplexing is proposed. In this case, as a proof of concept, 4 parallel waveguides are fabricated, with periodically placed antenna, but slightly shifted between consecutive waveguides. Therefore, we multiply by 4 the number of data (spatial multiplexing) in a first stage, and in a second stage temporal scan allows to fill the gap between consecutive antenna. By stitching the temporal and spatial data, we are able to increase the spectral etendue. Of course, the drawback of this approach is that flux is divided between the number of parallel waveguides, and temporal scanning limits the exposure time, so this method is reduced to relatively powerful optical sources, in particular, it is very well adapted to laser and SLED spectral characterization.

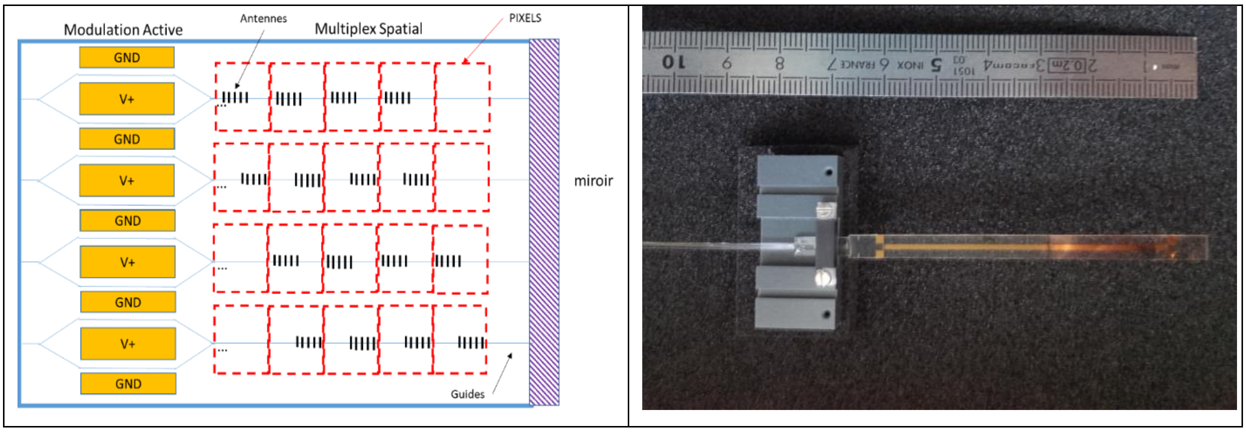

Fig. 1. Left: Schematics of the multiplexed SWIFTS interferometer, with the Mach-Zehnder modulators allowing for temporal fringe scanning. Right: Picture of the assembled device, showing the 5cm long electrodes and the input fibers.

Near IR beam combiners for high contrast interferometry :

A second typical building block is a high contrast interferometer, with parallel control of photometry (see Fig. 2). This is a basic photonic function for nulling interferometry applications. In the system presented here, a first stage of directional couplers allows for photometric control (V2 and V3). Then, the central beam combiner allows for high contrast interferometry, as the fringes are scan through the last EO modulator (V1).

We will present the results on characterization in terms of contrast performances, monochromatic and wideband in the near IR, and polarization behavior.

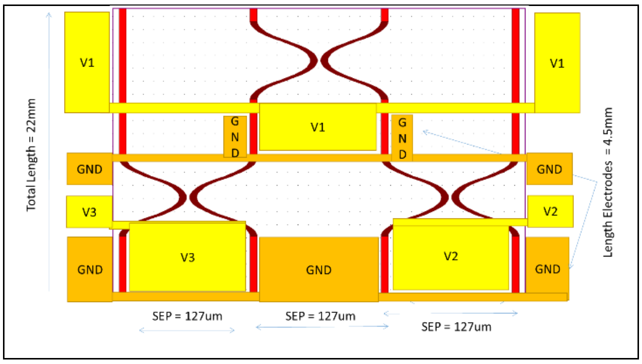

Fig. 2. Schematics of the dual stage nulling interferometer, with a first stage of photometry control and a second stage for fringe scanning. The two central outputs allow for interferometry studies, whereas the external channels allow for photometry control.

DISCUSSION

Preliminary results show that spatial multiplexing (stitching the signal obtained from shifted antenna as shown in figure 1), allows for spectral recovery of an unknown wavelength by comparison to a calibrated dataset, with a resolution of 20pm. This shows that the SWIFTS interferometer works well as a lambdameter, and has now to be validated using wideband sources.

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