Hierarchical Fringe Tracking to Increase Sensitivity of Optical Long Baseline Interferometers

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1. The concept of hierarchical fringe tracking

2. The telescope Spatial Filter

3. Hierarchical cophasing with 2 telescopes spatial filter

4. A very broad band dispersed fringes 2T spatial filter and piston sensor

5. Discussion

6. Conclusion

Abstract

We discuss the basis of a new concept of fringe tracking (FT) called the HFT for Hierarchical Fringe Tracking, which would significantly increase the limiting magnitude of cophasing and coherence of Optical Long Baseline Interferometers (OLBI). For the VLTI, the gain is expected to be of the order of 5 magnitudes, boosting the sensitivity of the 2nd generation VLTI instruments GRAVITY and MATISSE and their scientific potential, particularly for Active Galactic Nuclei and Planet and Star formation. It also solves the standard contradiction between imaging performances (that imply more apertures) and sensitivity, which in classical OLBI fringe trackers decreases with the number of apertures. This would be a decisive advantage for future large interferometers like the PFI “Planet Formation Imager”. In HFT, we cophase pairs of telescopes, then pairs of pairs, then cophased group of telescopes. The HFT is based on a system called a T2SF (two telescopes spatial filter) that merges two beams, transmits most of the light when the beams are cophased as if produced by a single cophased aperture, and deflects the light for non-cophased beams toward pixels measuring the corrective piston. We describe a very broad band T2SF based on dispersed fringes onto an intensity or phase mask, called the Marrakesh T2SF. This MT2SF can measure the OPD between two beams, in a range larger than the largest wavelength, with only 3 to 5 measures. The combined gain in spectral bandwidth and reduced read out noise results in the magnitude gain. We discuss the design, optimization and performances of the MT2SF as well as its integration into the global control loop of a Hierarchical Fringe Tracker.

Fig. 1: Hierarchical cophasing

Fig. 2: two telescopes Spatial Filter

Fig. 3: Hierarchical fringe with T2SF

Fig. 4: broadband dispersed fringes schematic 2 telescopes spatial filter and piston sensor

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There are several ways to realize a 2T spatial filter that transmits a single mode (i.e, single OPO) beam when the two incoming beams are in phase.

The "cophasing mask" is computed from the dispersed fringes at zero OPD.

When the piston between the two input beams is zero, this grid transmits 82% of the total flux. After the mask, the flux is collimated again and an inverse dispersion is applied. The resulting piston is achromatic and single mode.

When the piston reflected from the cophasing grid is used to find the piston, using a second grid, which discriminates between positive and negative piston shifts. The optimum secondary grid is deduced from the reflected fringes at piston +1µm (left half) and -1µm (right half). This grid is used to select a single mode very broadband dispersed fringe scheme that allow deducing the piston from 3 single pixel measures. The advantage of such a system is that it can work in a very broad spectral band without increasing the number of measures.

From the coupling efficiency of the filters, the flux used for each FT pair and the number of measures, we show that we can gain 2 magnitudes on the best possible integrated optical pair wise FT, and maybe up to 1.5 magnitudes on the GRAVITY internal FT.

We still have to fully simulate the control loop of such a system and to investigate the range of unambiguous piston measurement with more sophisticated algorithms than the straightforward measure described here.

For the VLTI with 4 UTs, the gain is estimated to be at least:

• 2 magnitudes with regard to the best possible pairwise Integrated optics Fringe Tracker (using phase diversity and 3 integrated optics in 3 bands In a phase diversity approach).

• 3.5 magnitudes with regard to the GRAVITY fringe Tracker.

Reference:
