Calibration of pixel's grid location of a CMOS silicon matricial detector based on Young's fringes for space-based high accuracy astrometry

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The field of astronomical science is highly challenging for instrumentation, requiring a comprehensive knowledge of the acquisition chain systematics from the optics to the focal plane. In the context of exoplanet detection, a proposal was made for the Theia space-borne mission at ESA's M8 call for missions (Malbet, 2024), as well as an hosted payload on the future NASA's HWO. The purpose of this proposal is to detect Earth-like planets at distances of up to 10 parsecs using the star's astrometric signal.

In order to detect this signal, the centroid of the star must be measured at sub-microarcsecond precision. The preliminary error budget, in conjunction with other calibrations (typically optical distortion), necessitates a pixel position knowledge requirement on the focal plane geometry of down to 5e-5pix for the HWO telescope and 5e-6pix for the Theia mission.

Since 2012, researchers in the US and France have been working on a calibration method based on the projection of scrolling Young's fringes on a matricial detector (Crouzier, 2016; Shao, 2023). This method is used to measure the geometrical shift of the pixel's peak response with regard to a perfect grid at pixel pitch period. This is achieved by measuring the dephasing of the signal between the pixels and subsequently fitting physical parameters to the measurements.

The present study involves the simulation of the aforementioned calibration method and sensitivities to instrumentation instabilities, with the objective of deducing the calibration unit requirements (i.e. laser power, mechanical stability, electronic and photon noise). Subsequently, the positional coordinates of the initial pixel were determined through the utilisation of a dedicated testbed that was derived from the work of (Crouzier, 2016). The detector utilised in this study is a Grenoble French CMOS silicon matrix manufactured by the compagny Pyxalis.