Fourier filter LGS wavefront sensing for ELT sized telescopes: comparison of Pyramid and Ingot

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Abstract

All the upcoming Extremely Large Telescopes (ELTs) include artificial Laser Guide Stars (LGS) to increase the sky coverage of their Adaptive Optics (AO) systems. Given the thickness of the sodium layer, where the LGS are created, these artificial stars end-up to be extended 3D objects. On a large pupil, like the ELTs, the sub-apertures of a Shack-Hartmann wavefront sensor see the LGS as an elongated object depending on their position with respect to the laser lunch telescope. As a result, a detector with a large number of pixels per sub-aperture is required to fully sample the elongated spots and minimize centroiding errors. As an alternative, we propose to explore the use of Fourier Filter Wavefront Sensors (FFWFS), such as the pyramid WFS but not only, as they could potentially offer an interesting alternative, significantly less pixel-intensive.
As a first step, we developed a new method of simulating extended sources for FFWFS, which allows accelerating the simulation by a factor of over sixty times when compared to the traditional methods. Taking advantage of this, we then compare the performance of two sensors: the well-known Pyramid, and the Ingot (as proposed by Ragazzoni).
When comparing the sensitivity to photon noise of a diffraction limited source with a 2D 1" source for a 3- and 4-sized Pyramid WFS, a 20 factor decrease was observed. This lost sensitivity is equivalent to a decrease in limiting magnitude of 6.5. Then, comparing the sensitivity of the Pyramid WFS and the Ingot WFS, both had a similar behavior in the horizontal direction (across the elongation of the LGS), but the Pyramid had almost twice the sensitivity along the elongation, meaning that overall the Pyramid is more sensitive than the Ingot.

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