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Simulation Environment for Segment and Petal Phasing of Large Telescopes

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Pupil fragmentation, also known as the island effect, poses a serious problem for adaptive optics in large telescope. If the petals of a segmented mirror are aligned so that they overlap with the spider vanes, as is e.g. the case with the six petals of the adaptive M4 in the ELT, phase discontinuities between neighboring petals can become difficult to detect reliably. Moreover, radiative subcooling of the spider vanes against the night sky can give rise to wakes of cold air on the downwind side of the spider trusses, causing asymmetric spider seeing that induces additional phase steps between the pupil sectors (sometimes called "low-wind effect"). Currently, several approaches are under investigation to measure the phase steps using wavefront sensors (WFS) in K-band (2200nm) where Fried's length r0 can exceed the spider width d (in the ELT, d = 530 mm).

In this work, we present a numerical simulation environment for segment and petal phasing of large telescopes. In order to highlight its capabilities, we study a lateral shearing WFS to sense pupil fragmentation in K-band. To accurately measure the phase step across all spider vanes on a single detector of minimal size, we consider a shearing mask in which the pie slice shaped pupil region around each spider vane is sheared perpendicular to the vane by the distance 1.5—2 d. The total shearing pattern is thus reminiscent of a windmill. We find that the petal phase step can be measured by averaging the irradiance along the central corridor of width 0.5–1 d where the petals left and right of the spider overlap after shearing. The response function and achievable sensitivity are compared to that of a pyramid WFS and a phase contrast WFS. The shear mask could e.g. consist of a glass plate with six sets of gratings, each aligned with one of the spider vanes. The gratings are optimized to suppress all diffraction orders except +1 and -1 and the lateral shearing distance can be tuned by pistoning the grating plate vs. the detector.

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