Results of diffraction effects in segmented mirrors: co-phasing with integrated curvature signal

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ABSTRACT

In this paper, we study the ability of a curvature sensor (CS) to measure co-phasing errors in a segmented primary mirror. We study a new fast and low memory-consuming algorithm based on the definition of an integrated curvature signal. This signal results from the integration of the CS response in enclosures matching the shapes of the segments in the mirror. This gives a low number of measurements, equal to the number of segments. The determination of the position of the segments is speeded with an analytical response model, which we formulate in matrix form. In this way, we can make an analysis of the error propagation that is valid for measurement errors or imprecision of the response model. The procedure is well suited to mirrors with a large number of segments, as in the case of ELTs.

Keywords: Curvature sensor, active optics, segmented mirror co-phasing, ELTs

1. INTRODUCTION

One of the most critical aspects of the operation of segmented-mirror telescopes is the alignment and co-phasing of the segments. The tolerance to misalignments depends on the type of observation and reaches a minimum in high resolution imaging, as in adaptive optics. A routine to detect and control the position of the segments is thus imperative, and should be precise, reliable and fast, especially if it is executed during nighttime.

Optical techniques can be classified in two groups, depending on the type of illumination that they employ: internal light sources (commonly a laser), or bright stars. The first choice has some advantages. One of them is the possibility of making the alignment during day-time without taking up usable time. Also, with a light source close to the center of curvature of the primary mirror, it is possible to make the light reflect only in the primary mirror, thereby avoiding aberrations at the other optical surfaces. These techniques usually involve interferometry and are severely affected by vibrations. We shall not go into further detail on this subject.

With starlight illumination, the telescope works in the usual configuration with light passing through all the optics, but all or some part of the light is directed to an specific instrument. This is the case in Keck telescope, with the broad- and narrow-band techniques using a Shack-Hartmann sensor.[1,2] The basis of this method is the analysis of the far-field diffraction patterns of subapertures between two segments. Bello-Figueroa,[3] and Schumacher, Devaney & Montoya[4] have later improved this technique.

In this paper, we explore another possibility with external illumination. The device used is a CS, as was first proposed by Rodríguez-Ramos & Fuensalida.[5–7] Similar approaches have been studied by Chanan, Troy & Sirko,[8] who propose the *phase discontinuity sensing* technique on the basis of simulations and tested on-sky with the Keck telescope. Cuevas et al.[9] suggest increasing the defocus in the CS detectors to simplify the analysis of the signal. They demonstrate the validity of their approach through laboratory experimentation.

While the combination of the broad- and narrow-band techniques allows sufficient precision and a wide capture range, there is a problem with the alignment of the lenslet mask and the image of the primary mirror. The diffracted field changes if the subapertures are not centered with the separation between segments. The problem increases with ELTs, with apertures in the range of 30 to 100 meter and a large number of subapertures (in the order of six times the number of segments).

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