New Aperture Partitioning Element

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ABSTRACT

Partitioning the pupil reduces the degree of baseline redundancy, and therefore improves the quality of images that can be obtained from the system. A practical realization of this approach uses an aperture partitioning element at an aft optics pupil of the optical system. This paper describes the design, implementation and testing of a new aperture partitioning element that is completely reflective and reconfigurable. The device uses four independent, annular segments that can be positioned with a high degree of accuracy without impacting optical wavefront of each segment. This mirror has been produced and is currently deployed and working on the 3.6 m telescope.

1.0 INTRODUCTION

Postprocessing in an optical system can be aided by adding an optical element to partition the pupil into a number of segments. When imaging through the atmosphere, the recorded data are blurred by temperature-induced variations in the index of refraction along the line of sight. Using speckle imaging techniques developed in the astronomy community, this blurring can be corrected to some degree. The effectiveness of these techniques is diminished by redundant baselines in the pupil. Partitioning the pupil reduces the degree of baseline redundancy, and therefore improves the quality of images that can be obtained from the system. It is possible to implement the described approach on an optical system with a segmented primary mirror, but not very practical. This is because most optical systems do not have segmented primary mirrors, and those that do have relatively low bandwidth positioning of segments due to their large mass and inertia. It is much more practical to position an adjustable aperture partitioning element at an aft optics pupil of the optical system. This paper describes the design, implementation and testing of a new aperture partitioning element that is completely reflective and reconfigurable. The device uses four independent, annular segments that can be positioned with a high degree of accuracy without impacting optical wavefront of each segment. This mirror has been produced and is currently deployed and working on the 3.6 m telescope.

ANALYSIS

Figure 1 illustrates the benefit conferred by aperture partitioning in conditions of strong turbulence (D/r_0>50). The left side shows data formed by convolving a satellite CAD image with a simulated full-pupil atmospheric point-spread function. The right side shows four blurry images produced by the four annular subapertures with the *same* atmospheric wavefront. The total amount of signal is the same in each data set. The image that can be obtained from the partitioned configuration is clearly better than the conventional full-aperture configuration.

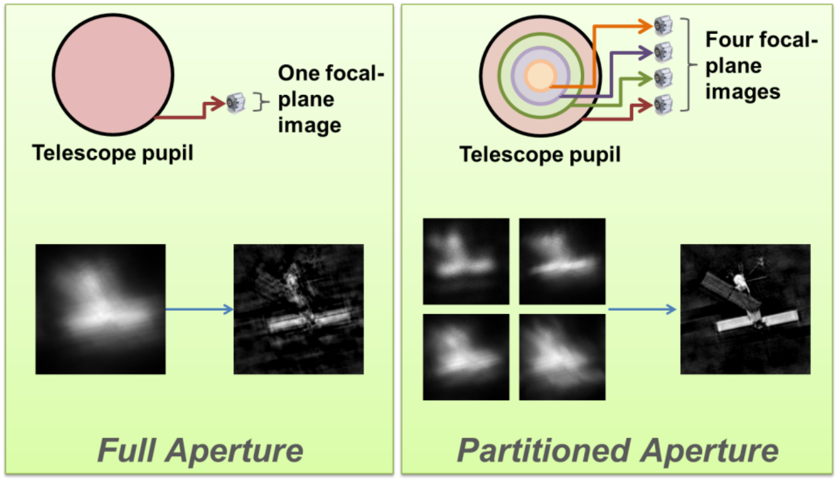

Figure 1 – Full aperture versus partitioned aperture imaging results

The physical realization of the aperture partitioning element used is shown in Figure 2. It is all reflective, avoiding dispersion effects, and is adjustable to support different arrangements of images on the focal plane. This design has a patent pending which also includes an active realization. It has three adjustors on each of the three annular mirror segments which move in and out normal to the mirror surface. The annular mirror segments are diamond turned aluminum.

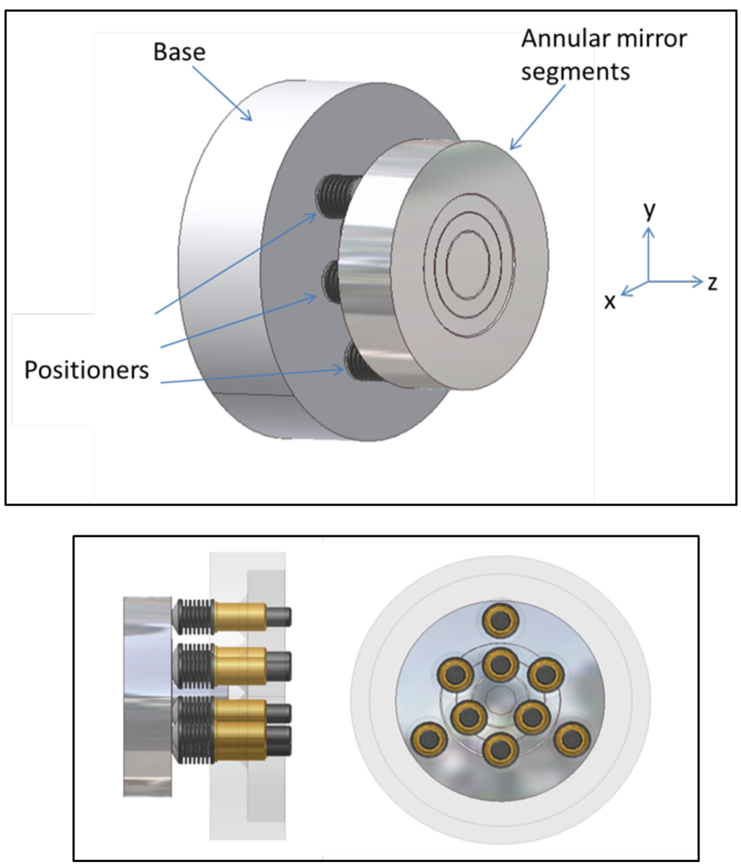

Figure 2 – Physical realization of aperture partitioning element

The driving requirement on the nine adjustors shown in Figure 2 was the ability to make very small position adjustments that result in stable mirror angles of each of the three annular mirror segments. The angle of the middle segment is adjusted by adjusting the angle of the angle of the base of the device using conventional positioners. These angles determined the position of the images on the image plane. The two image configurations considered were two up/two down as shown in Figure 1 and four in a row. For the image plane selected, the small adjustment requirement translated into a resolution requirement of .004" on the positioners. Two types of positioners were considered, threaded adjustors and squiggle motors[1]. If an operator is assumed to have control of quarter turn increments, the 254 threads-per-inch adjustor has a resolution of around .001" where a squiggle motor has a much smaller resolution of .00002". The lack of a need for electronics and ease of integration of the threaded adjustor made it the preferred choice.

Since the threaded adjustors were required to hold as well as position segments, a bellows flexure was designed to hold a matched bearing cup to the ball end of the flexure under a slight preload as shown in Figure 3. The matched bearing cup was threaded into the back of the aluminum mirror segments also shown in Figure 3.

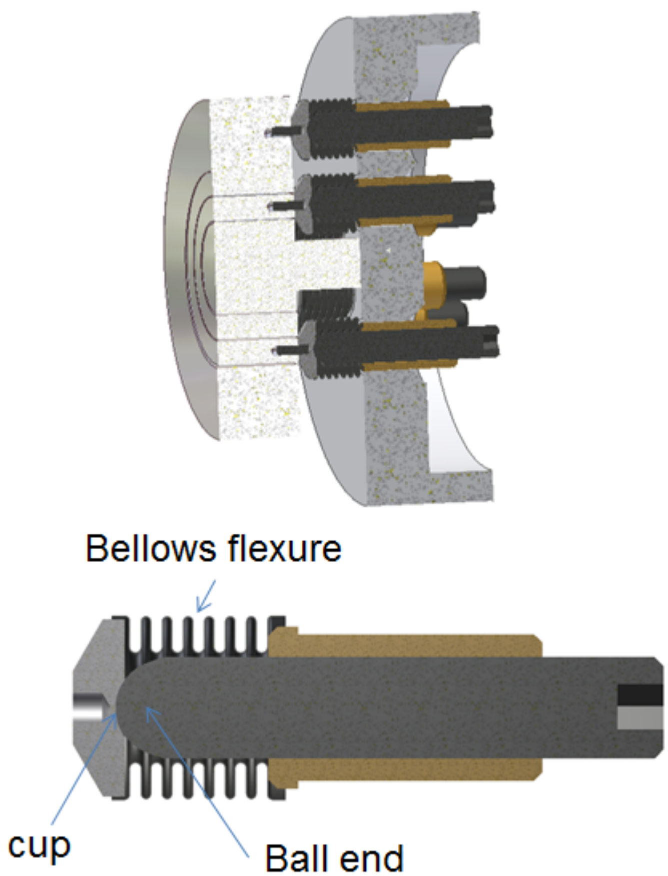

Figure 3 – Threaded adjustors

A finite element analysis determined both gravity and the enforced displacement of the adjustors would cause negligible stress in the aluminum mirrors. An interferometric measurement of the assembled device showed acceptable static wavefront aberration with no negligible change when segment angle was changed.

The aperture partitioning element has been installed in the 3.6 m telescope and is currently in operation. Figure 4 shows a preliminary result of a binary star with the four resulting images and the resulting postprocessed image.

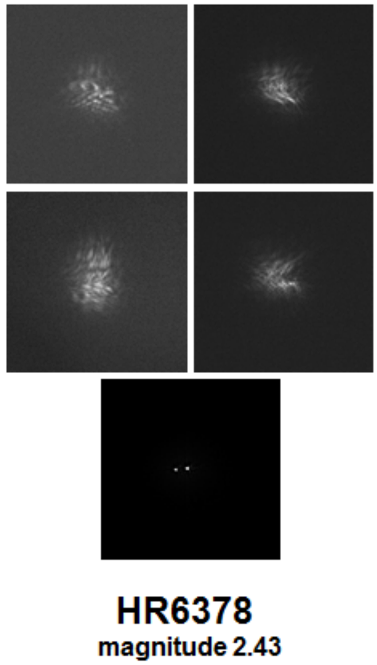

Figure 4 – Four partitioned images of binary star with postprocessed image

2.0 CONCLUSION

A new approach to postprocessing has been enabled by the successful implementation of an aperture partitioning element. Demonstrated results have shown that the device meets all positioning and wavefront requirements and displays stable behavior over time. Future efforts will explore active implementations that change the number of image partitions as a function of image parameters such as the signal-to-noise ratio. This flexibility will be useful to handle changes in observing geometry over the course of a satellite pass and as a means of injecting diversity to improve the condition number of the image reconstruction problem.

3.0 REFERENCES

1. http://www.newscaletech.com/technology/squiggle-motors.php