# Fusing focal and pupil plane wavefront sensors: Combining the Zernike and Shack-Harmann wavefront sensors for high dynamic, high sensitivity wavefront sensing

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**Abstract**

Each wavefront sensor has advantages and disadvantages. The Shack-Hartmann wavefront (SH) sensor has a high dynamic range but low sensitivity, especially for low-order modes. On the contrary, the Zernike wavefront sensor (ZWFS) has a low dynamic range but high sensitivity. In this work we combine both of these wavefront sensors to exploit the strengths of each to obtain a high dynamic range, high sensitivity wavefront sensor. To do this, we place a Zernike phase mask in a focal plane just before the SH, such that the signal of the ZWFS is encoded in the amount of light each subaperture of the SH receives. As the Zernike mask has little influence on the wavefront, the SH can measure the wavefront as if the ZWFS was not there. This compact system would use the same detector (and the same photons) to output the signal of the ZWFS and the SH by processing the signal from the detector accordingly. Several fusion techniques to combine the data are discussed to achieve the best and most robust performance. Another benefit of including the Zernike mask is the possibility of measuring discontinuity modes that the SH is blind to, not only being able to measure them but also helping avoid confusing these discontinuity modes from continuous ones (such as differential piston and tip/tilt).

**Keywords:** Zernike wavefront sensor, Shack, Hartmann wavefront sensor, Hybrid wavefront sensor

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