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# Using numerical models and iterative algorithms to perform non-linear reconstruction of Fourier-filtering wavefront sensor signals.

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## Abstract

Because of their intrinsic high sensitivity, Fourier-filtering wavefront sensors (FFWFS) are becoming key elements for high-performance adaptive optics systems. These sensors exhibit orders of magnitude higher sensitivities than the widely-used Shack-Hartmann wavefront sensor, but this extremely appealing behavior comes with a drawback: such sensors have a limited linear range, which prevent from using them to their full potential (modulation required for the Pyramid wavefront sensor, only second stage adaptive optics with the Zernike wavefront sensor) and introduces significant wavefront control issues.

We study a set of methods to invert FFWFS signal in a non-linear fashion, based on a numerical model of the sensor and iterative algorithms (as the Gerchberg-Saxton algorithm for instance). We discuss the improved dynamic range of these methods while comparing noise propagation with respect to linear reconstruction schemes. Polychromatic performance of these reconstructors are also assessed. These inversion techniques are performed in end-to-end simulations but also demonstrated on the adaptive optics SEAL testbed at UCSC and on KPIC instrument at Keck.

Focusing on the Pyramid wavefront sensor and the Zernike wavefront sensor, we show that using these kinds of approaches can improve phase estimation from FFWFS signals. Such a class of reconstructors are (for now) not suited for real-time as they require multiple Fast-Fourier-Transform to perform reconstruction. However, we show how such non-linear reconstructors may already play important roles for different wavefront sensing and control applications. Finally, some ideas to improve convergence speed of this technique are presented with the ultimate goal that it could one day be used for real-time purposes.

**Keywords:** wavefront reconstruction, Fourier, filtering wavefront sensors

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