

# 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 order 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 prevents from using them at their full potential (modulation required for the Pyramid wavefront sensor, only second stage adaptive optics with the Zernike wavefront sensor) and arises 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 benefit in 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 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 play as of now important roles for different wavefront sensing and control applications. Finally, some ideas to improve converge speed of this technique are presented with the ultimate hope that it could one day be used for real-time purposes.

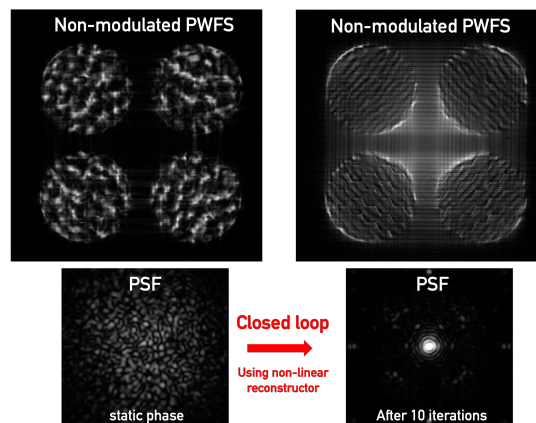


Figure 1: Using Gerchberg-Saxton algorithm to invert non-modulated PWFS signal: demonstration on SEAL bench at UCSC.