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A modal approach to optical gain compensation for the PWFS

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Summary

A major PWFS issue is the so-called Optical Gain (OG) effect: PWFSs experience a nonlinearity-induced sensitivity reduction –of 50% or worse at the fitting error on median atmospheric conditions, and this sensitivity loss worsens as the turbulence residual increases. OG affects system performance, jeopardizes loop stability and prevents efficient non-common path aberration compensation.

We present a theoretical definition of our own modal approach to OG impact mitigation, and investigate its impact on nonlinearity error depending on the AO control basis, demonstrating a Karhunen-Loëve inspired basis is the better choice for PWFS operation.
We also evidence that scalar gain compensation of the OG is insufficient on high order systems, as the high spatial frequency range spanned covers high OG discrepancies over the controlled basis. We quantify the performance improvements obtained with OG modal compensation through end-to-end numerical simulations, evidencing a considerable AO performance improvement over a non-modal method, in particular for faint guide stars and in tough seeing conditions.

Finally, we present a sky-ready method for tracking the modal OG across the control basis: analyzing the propagation of a short-lived sinusoidal excitation of preselected DM modes, we are able to recover the instataneous optical gain and extrapolate this information to all the modes of the system.

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