Defining the Information Limit for a Laser Beacon

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Abstract

To date, laser guide star (LGS) system performance has primarily been measured on the efficiency of exciting mesospheric sodium atoms and total return flux. While this focus has led to numerous advances, the ultimate utility of an LGS system is determined not by the efficiency and raw return flux, but the quality of the wavefront measurement attained from the laser beacon. Thus, a simple efficiency metric for LGS operation is inadequate for evaluating important system-level design decisions. A laser system that is less efficient at exciting sodium atoms may out-perform a more efficient laser format if the less efficient format leads to greater wavefront measurement sensitivity. This effect is most readily seen in LGS systems incorporating pre-compensation of the laser beacon to achieve a smaller beacon width in the mesosphere. A smaller dimmer beacon may yield less total measurement error than a larger brighter beacon, even if the efficiency of the laser excitation is reduced. This work examines the interaction between the spatial coherence of the beacon and the noise gain of a theoretical wavefront measurement to explore the fundamental information limit for a given beacon format. The analysis first examines the optimal beacon size with a Pyramid and modified Zernike wavefront sensors (WFS), and then extends the analysis to a theoretical wavefront sensor model to numerically approximate the fundamental limit for a general linear WFS for any beacon size or shape. Using this formulation, the suitability of various proposed LGS system designs (pre-compensation, beam shaping, pulse tracking, etc.) can be evaluated to determine the optimal design from the perspective of minimizing wavefront measurement error.

Keywords: laser guide star, pre, compensation, wave front sensing, sensitivity, simulation

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