

Focal Spot Improvement of a Chirped Pulse Amplification Laser by Using a Single Actuator Mechanical Deformable Mirror

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An innovative mechanical deformable mirror capable of correcting simultaneously astigmatism and defocus is used to optimize the focal spot of a 10 TW chirped pulse amplification laser. The focused intensity has increased by more than an order of magnitude, with a focal spot of 1.14 times the diffraction limit. This deformable mirror can be used advantageously to correct static aberration in similar laser systems.

The evaluation and correction of wavefront aberrations is a problem of paramount importance in high intensity laser systems, particularly those based on the chirped pulse amplification technique. In fact, optical aberrations are a major problem in any large laser chain, degrading the focal spot quality and dramatically decreasing the Strehl ratio of the peak focused intensity. In multiterawatt to petawatt-level Nd:glass-based laser systems, the main aberrations present can be of a static nature, resulting from the propagation inside optical elements such as grating compressors, or dynamical, arising from thermal effects in the rod and disk amplifiers, in particular thermal lensing and thermal birefringence astigmatism. These effects, apart from inducing serious wavefront distortions, limit the repetition rate to a few shots per hour at best.

Several approaches are currently used to compensate for these aberrations, such as bimorph or membrane deformable mirrors (DM), which can compensate virtually any wavefront shape to a very high precision, with the possibility of shot-to-shot feedback. Mechanical DM provide a compact, scalable and cost-effective alternative, in particular for laser systems with large beam apertures or well-defined static aberrations [1,2], the most common being defocus and astigmatism. We have designed and characterized a compact ($\varnothing 75$ mm) and elegant single actuator DM with four contact points that is suitable for the simultaneous correction of both these aberrations [3]. The mirror is scalable to large sizes, can correct astigmatism with arbitrary orientation and up to considerable magnitudes, and is simply based on the mechanical deformations applied at specific points, which were shown to replicate the relevant Zernike polynomials.

In this work we describe the integration and practical application of this DM to a chirped pulse amplification, hybrid Ti:sapphire-Nd:glass laser chain, producing 10 TW peak powers. The mirror was installed at the back-reflecting position of the final double-passed $\varnothing 45$ mm Nd:glass rod amplifier, and it was adjusted while monitoring the wavefront and far-field profile at the target plane. The initial aberrations (4.5λ P-V) were minimized, resulting in a focal spot 1.14 times the diffraction limit. This has represented an increase in excess of one order of magnitude to the peak intensity.

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