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Effects of non-paraxial off-axis focussing in high-energy laser systems on the reliability of phase retrieval algorithms

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Modern high-intensity laser systems use off-axis-parabolic mirrors with short focal lengths to achieve highest on-target intensities. These mirrors offer the advantage of achromatic focusing while achieving small focal spots due to very small f-numbers. Adaptive optics (AO) is also commonly used to mitigate wavefront aberrations and therefore reduce deformations of the focal spot.
A typical AO setup is built from a deformable mirror and a successive wavefront sensor to run in a closed loop. When used right before the final focusing optic, leakage light from a turning mirror is transported through an imaging system that both images the surface of the deformable mirror onto the wavefront sensor and reduces the beam diameter to a suitable size. This imaging-system, however, itself introduces aberrations to the beam, which therefore influence the quality of the achieved focal spot.
A widely used approach to compensate for this effect is to measure the intensity distribution in several planes of the focal region and run a phase retrieval (PR) algorithm to estimate the wavefront accountable for the deformations present in the focal spot. The commonly used algorithm for this application is the Gerchberg-Saxton algorithm which is most often implemented using complex Fourier transformations to switch between near and far field. However, this invokes that paraxial assumptions can be made, which is not the case for focusing with a high numerical aperture (NA).
In this talk, we present a numeric study of the effects of non-paraxial focusing on the intensity distribution of the focal spot compared with regular paraxial focusing. Also, the effect of off-axis focusing is discussed. The results are used to re-consider the reliability of PR results of the Gerchberg-Saxton algorithm when working with high-NA systems. A NA threshold where the regular algorithms still can be used is determined and a modification of the PR algorithm for higher NA is proposed.

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