Spatio-Temporal Distortions in Chirped Pulse Amplification Grating Compressors

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The spatio-temporal distortions resulting from the propagation of beams with common wavefront distortions through grating compressors are analyzed using the formalism of Kostenbauder matrices. Given that grating compressors introduce aberrations themselves, the implications of using wavefront correction devices at specific points of the laser chain are considered in terms of an overall optimization of the focused beam intensity.

For more than two decades, grating compressors [1] have been a fundamental component at the end of high power laser chains based on the chirped pulse amplification concept [2], and remain so. Conjugated with aberration-free grating stretchers [3], they have been used to provide compression of pulses with energies from hundreds of millijoules to hundreds of Joules, resulting in pulsewidths from tens to hundreds of femtoseconds, and allowing the routine generation of petawatt peak powers [4].

Due to their fundamental role and position, misalignments in grating compressors affect the temporal pulse shape [5], enlarging the pulsewidth or introducing temporal distortions such as a pedestal or additional pulses. Therefore, there is great concern in performing a correct alignment of single-element grating pairs, and currently the same problem is being considered for multi-element grating arrays for very large aperture beams [6].

On the other hand, an aberration-free, well-collimated beam is usually a requirement for efficient compression. However, even in the case of well-aligned compressors and well-collimated beams, astigmatism will result [6], unless both gratings are operated at Littrow's angle, which is geometrically unpractical in most situations. This leads to coupled distortions in the temporal and spatial domains, or spatio-temporal distortions, a field that is currently a subject of great interest due to both its beneficial applications or harmful consequences of such effects on short pulses [7].

In this work, we study the propagation of spatially and temporally Gaussian beams with wavefront aberrations through grating compressors, using the simple and elegant formalism of Kostenbauder matrices [8]. This approach is particularly adequate in terms of determining the effect of deliberately introducing such perturbations in these beams in terms of the resulting spatio-temporal aberrations and changes to the peak intensity. In particular, we evaluate the use of wavefront-correction schemes at several points of the laser chain and their effect on the compressed pulse spatio-temporal profile.

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