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## Abstract

We have developed a system that allows compensation of higher order phase terms that limit chirped pulse amplification systems. Results indicate phase can be compensated by a properly adjusted air-spaced doublet within the stretcher.

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## Summary

High intensity, sub-picosecond lasers systems based on the technique of Chirped Pulse Amplification[1] (CPA) in solid state laser materials have recently become quite common. Systems considered developmental just a few years ago have recently become commercially available and are now being used in a broad range of experiments. As these systems grow more powerful and experimental requirements become more stringent, the subtleties involved in stretching, amplifying and recompressing the laser pulses are becoming more critical. In particular, as peak intensities rise, the already strict experimental requirements on contrast ratio and pulse shape, become very restrictive, requiring pulse fidelity over an very broad dynamic range.

Ideally, a short pulse entering a CPA system is stretched by imposing a linear chirp (quadratic phase), which is exactly canceled in a compressor after amplification. However, in reality the stretching does not provide a pure linear chirp, the group velocity dispersion (GVD) of the amplifier system imparts chirp, and the compressor is not capable of exact cancellation of the resulting chirp. The compressed pulse is therefore not transform limited and the residual chirp reduces the pulse fidelity.

We have developed a model of pulse propagation through a chirped pulse amplification system which calculates the complete frequency dependent phase at any point within the system. This model, which can calculate the phase aberrations to arbitrarily high order, has been verified by comparison to analytical and experimental results. Temporal profiles calculated from modeling results are in good agreement with our measured pulse profiles for several different laser system configurations. Once verified, this model was used to investigate the sources of error in CPA systems.

The results of this investigation can be summed up in two important points. First, chromatic aberration in the stretcher lens results in third order phase contributions while spherical aberration results in fourth order phase. Second, the mismatch between the stretcher and compressor caused by the GVD of the amplifier system introduces both third and fourth order phase components. It is therefore important to not just to design a stretcher that perfectly matches the compressor but instead to design a stretcher that has "knobs" that can be used to compensate the higher order phase terms introduced throughout the system. Our design is based on a now standard single-grating, single-lens, multi-pass stretcher[2]. However, by replacing the lens with a properly designed air-spaced doublet it is possible to adjust the higher order phase by manipulating the elements of the lens. Altering the space between the elements of the lens pair changes the spherical aberration of the lens resulting in a change of the fourth order phase. A relative translation of the lens elements within the plane of dispersion changes the chromatic aberration of the lens system, resulting in third order phase changes. Modeling results for this system indicate that even with significant amounts of dispersive material between the stretcher and compressor, the higher order phase can be compensated resulting in transform limited pulses.

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