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for Short Scale Length Plasma Experiments**

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Production of high contrast ultrashort laser pulses for short scale length plasma experiments

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The production of hot, high density plasmas has been one of the many proposed uses of high intensity ultrashort pulse laser systems since their development began with the introduction of Chirped Pulse Amplification¹ (CPA). Because many of these systems are now capable of producing peak irradiance in excess of 10^{18} W/cm², extremely high pulse fidelity is needed to prevent the temporal wings of the pulse from preionizing a solid target, thus producing a relatively long scale length plasma².

Prepulse in CPA systems is generally the result of Amplified Spontaneous Emission (ASE) and/or imperfect stretching and compressing. While ASE can be controlled by careful amplifier design, removal of the wings that result from frequency dependent phase errors introduced by improper pulse recompression can be more subtle. Because the pulse compressor in a CPA system must not only compensate for the pulse stretcher but must also compensate for the Group Velocity Dispersion (GVD) of the amplifier system, the stretcher and compressor are generally slightly mismatched resulting in higher order phase aberrations which limit the minimum pulse width and introduce significant temporal wings.

We have designed a stretcher³ that provides continuous, independent adjustment of the second, third and fourth order frequency dependent phase. As shown in Figure 1, our design is based on

Figure 1. Diagram of the air-spaced doublet lens pulse stretcher with the. Arrows indicate the adjustments necessary for phase tuning.

the now standard single grating, single lens stretcher with the lens replaced by an air spaced doublet lens. This lens is designed to be spherically and chromatically corrected for the conjugate ratio and wavelength range used in our particular stretcher. If there were no other dispersive elements except for the stretcher and compressor, this would be sufficient for the production of high fidelity compressed pulses. However, as amplifiers and other dispersive elements are added to the system, the higher order phase terms no longer cancel and the compressed pulse contains higher order phase errors. As described in reference 2, these errors can then be compensated by adjusting the relative spatial positions of this lens elements, introducing spatially dependent changes in the imaging system that result in frequency dependent phase compensation.

Experimental and numerical results indicate that high fidelity transform limited pulses can be produced by this chirped pulse amplification system. We have measured the output pulses using high dynamic range crosscorrelations, Frequency Resolved Optical Gating (FROG), and a

technique that provides direct phase measurement. Figure 2 shows the results of high dynamic range crosscorrelations of output pulses with pulses directly from the oscillator as the transverse

Figure 2. Crosscorrelation of compressed pulses with transverse lens position varied in the negative direction.

position of the lens elements are varied in the negative direction. Similarly, positive transverse displacements produce temporal wings of similar magnitude but on the opposite side of the pulse. This clearly allows control of the magnitude and sign of residual third order phase.

Fourth order phase adjustments are accomplished by varying the separation between the individual lens elements. This is shown experimentally as a change in the symmetric temporal wings in Figure 3. Similarly, positive displacements also produce symmetric wings with similar magnitudes.

Figure 3. Crosscorrelation of compressed pulses with the lens separation varied in the negative direction.

By combining the third and fourth order adjustments, diffraction limited pulses can be produced. This is demonstrated in Figure 4, in which crosscorrelations of the initial oscillator pulses are compared to results of third order phase optimization only as well as optimization of both third and fourth order phase. The remaining difference between the optimized pulses and the oscillator pulses is due to the finite bandpass of the stretcher. This result is in very good agreement with the numerical crosscorrelation of the inverse transform of the transmitted spectrum.

Figure 4. Comparison of crosscorrelations of pulses optimized for third order phase only, third and fourth order phase, and pulses directly from the oscillator.

It should also be noted that while these results demonstrate the effectiveness of this stretcher design in producing high fidelity 100 fs pulses, the stretcher can easily be extended to shorter pulses. For example, our numerical model, which agrees very well with the presented experimental results, indicates that the same lenses could be applied to a stretcher based on lower groove density gratings to produce 25 fs pulses. One major advantage of this type of stretcher design is the flexibility to compensate for changes made in the amplifier system or "dial in" a specific amount of prepulse if needed for a particular experiment.

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