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Abstract: We have designed and built an all-reflective pulse stretcher based on an Offner telescope. It uses cylindrical optics to simplify alignment and reduce aberrations. The stretch is ~1x10^5 with a bandwidth of 200 nm. The stretcher is to be part of a 10 Hz repetition rate, high-average-power, femtosecond laser. This new design compensates for dispersion in the laser by using gratings of different groove spacing in the stretcher and compressor and a spectral phase corrector plate, made by magneto-rheological finishing, within the stretcher.

I. Introduction

The Mercury laser [1] project has been developed as a demonstration of a scalable, 10 Hz, high energy diode-pumped solid-state laser for the High Average Power Laser Program. Additional applications of this laser have been considered. For example, when frequency doubled, it is an ideal laser for pumping a Ti:Sapphire based chirped pulse amplifier (CPA) to produce high energy, high peak power pulses at 10 Hz. Such a laser would have a variety of applications in high-energy-density physics research [2]. We are currently building a system that will produce 33 J, 15 fs, near diffraction-limited pulses at 10 Hz [3]. When focused by a fast, off-axis parabola peak irradiances of 10^{23} W/cm^2 can be achieved. One of the most challenging aspects of the design of this system is the control of dispersion over nearly 200 nm of bandwidth. Our approach is to compensate the dispersion of the laser material primarily using different groove densities for the stretcher and compressor gratings [4]. The residual dispersion will be offset using a spectral phase plate inside the stretcher. In this paper we discuss the design and construction of the stretcher.

II. Design and construction of the stretcher

We used a modified Offner triplet telescope [5] for the stretcher. The usefulness of the Offner triplet for ultrashort pulse stretchers has been demonstrated previously [6], but the design used here has a number of unique features. The design, shown in figure 1, uses cylindrical as oppose to spherical mirrors with the benefit of easier alignment.

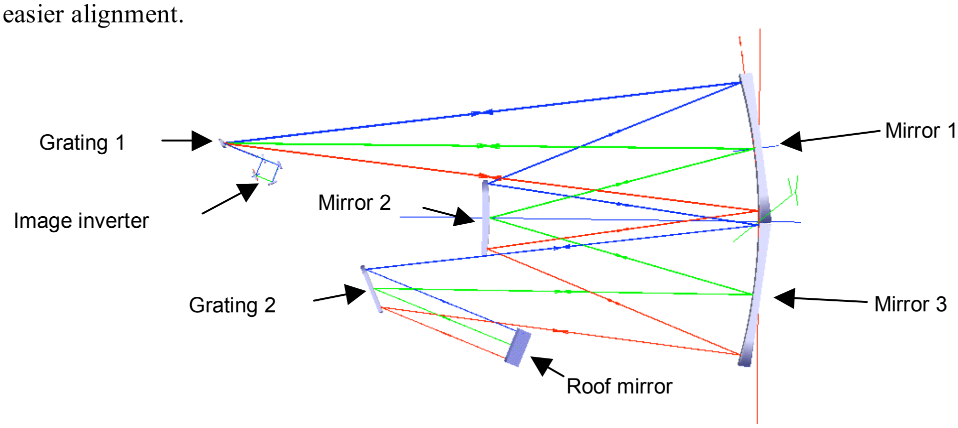

Figure 1. Offner-like stretcher

Starting with a 10 fs input source (Femtosource pro), the pulse is stretched to nearly 1 ns by passing through the stretcher 4 times. The matched gratings are 1357 lines/mm. The second pass is as usual returned with a height offset by a roof mirror. Then the pulse is sent through a four-mirror image inverter [7] which inverts the beam in the horizontal direction before directing it back through the telescope for two

more passes. The horizontal inversion cancels any resulting spatial chirp generated during the first two passes. All the optics, including the gratings, are gold coated to meet the 200nm bandwidth requirement.
The first grating is in the plane perpendicular to the system symmetry axis through the common center of curvature of the mirrors, but it is not at the center of curvature. Therefore, this system is not completely aberration free. As pointed out by Offner, [5, 8] the aberration can be reduced by making the curvature of mirror 2 somewhat longer than half that of mirrors 1 and 3, thus introducing some third order field curvature which offsets the higher order aberrations. Thus the radius of mirrors 1 and 3 is 1134mm and the radius of mirror 2 is 605mm. Based on our models, this design minimizes abberations permitting the recompression of the pulse to 15 fs. Figure 2 shows the setup of the laser front end including the stretcher. The light path through the stretcher is sketched on the figure.

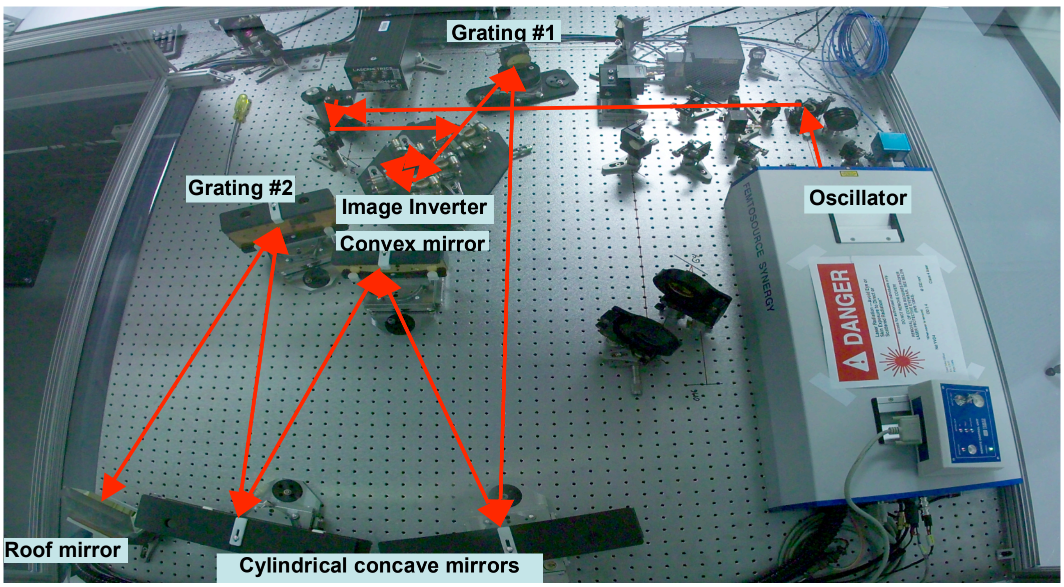

Figure 2. The modified cylindrical Offner stretcher minimizes the aberrations enabling 15 fs pulse lengths.

To accommodate a pass bandwidth without clipping of nearly 200 nm requires large cylindrical mirrors. The aperture in the long axis of mirrors 1 and 3 is 170 mm. Manufacturing and testing cylindrical optics of this size with the required optical quality is very difficult. We use a commercial computer-generated holographic cylinder null (Diffraction International) to test the mirrors. The goal is for a reflected wavefront with an error of no more than λ/10. Currently we have stretched the pulse and are in process of amplifying in a spectrally sculpted regenerative amplifier. Simultaneously we are in the process of fabricating a second set of cylindrical optics to meet this stringent wavefront specification. Figure 4 shows the 0.85 ns (FWHM) stretched output pulse.

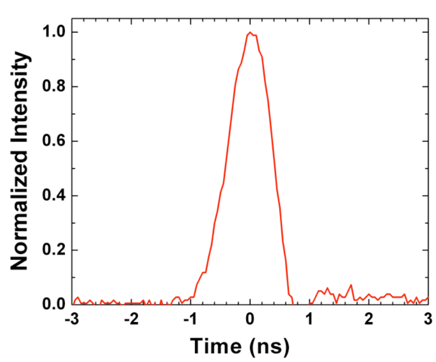

Figure 4. Output pulse from stretcher

III. Dispersion control

We intend to use a unique combination of methods for final compensation of dispersion within the system. The compressor gratings, recently manufactured at LLNL, have a higher groove density (1480 lines/mm) than the stretcher gratings. Modeling of the system dispersion, shown in Figure 3a, shows the group delay for a system composed of the stretcher, compressor, and 1300 mm of fused silica. This pulse, under ideal circumstances, could be recompressed to ~25 fs. However, by placing a precisely manufactured phase plate in the stretcher in front of the roof mirror, we can further reduce the group delay. The phase plate consists a piece of fused silica shaped by magneto-rheological finishing and allows the group delay to be arbitrarily modified – in this case reduced as shown in figure 3b.

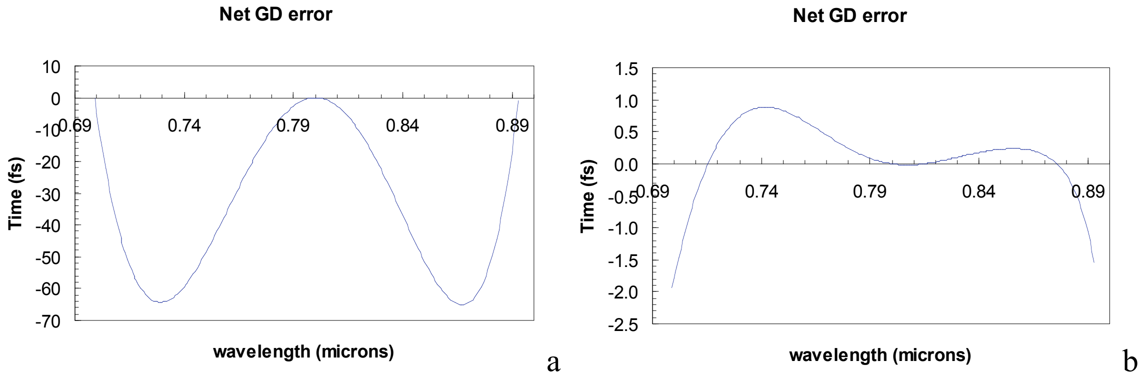

Figure 3. a) Predicted residual group delay (GD) of combination of stretcher, compressor and 1.3 m of fused silica. b) Residual group delay of the system when a compensator plate is placed in the stretcher.

In order to specify the required phase plate for the complete system, an end-to-end ray-trace model of the system has been developed. Finally, to compensate for unknown dispersion present in the real system versus the model, a programmable acousto-optic dispersive filter (Dazzler, Fastlite Inc. [9]) is incorporated in the system.

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