Grism based stretcher/compressor system for amplified, femtosecond kilohertz lasers

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Abstract: We demonstrate a simple and efficient grism based stretcher/compression system for the first time. 40 fs, 300 µJ pulses are generated at 5 kHz using this unique amplifier design.

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Grisms have the interesting property that they can be designed such that the ratio of third order dispersion (TOD) to second order dispersion, or group velocity dispersion, (GVD) is equal in magnitude to that of most dispersive materials [1]. In addition, both the TOD and GVD terms are opposite in sign to material dispersion; thus, grisms are better optimized for compressing femtosecond pulses than either grating or prism pairs. In this work we demonstrate the first broadband grism with a flat diffraction profile (> 100 nm), making it suitable for either tunable or ultra-broadband femtosecond laser applications. In this demonstration, a grism pair is used to stretch the pulses prior to amplification. The stretched pulses are amplified and then recompressed by simply passing the amplified, negatively chirped beam through a block of glass using the downchirped pulse amplification (DPA) scheme [2].

![Diagram of amplifier system layout](image)

Figure 1. Amplifier system layout.

The basic amplifier system is shown in figure 1. The output of a cavity-dumped Ti:sapphire oscillator (cavity dumped at 5 kHz to match the amplifier) is directed through a grism pair, designed and produced by Horiba Jobin Yvon Inc., that stretches the pulse to approximately 30 ps. There are several important features that make this stretcher design notable. First, the system is not complicated through the addition of lenses or curved mirrors, as is the case with traditional grating based pulse stretchers. Second, the grisms are extremely easy to align – the angle of incidence is normal incidence. Third, the arrangement is extremely compact, as the grism separation is only 2.8 cm. The grisms are constructed using 600 l/mm gratings cemented to a prism substrate. The effective dispersion from a single grism is equivalent to a 1000 l/mm grating. Details on the grism design are described in [3]. Finally, note that simultaneous second and third order dispersion compensation of most materials is accomplished simply by adjusting the separation of the grism pair. In traditional grating based stretcher/compressor systems, the GVD is adjusted by the grating separation and TOD by adjusting the angle. This traditional method is a complicated and unforgiving process.

Spectra of the pulses out of the oscillator, after the grism stretcher, and after amplification, are shown in figure 2. There is moderate reshaping, but no spectral clipping from the stretcher. After stretching, the pulses are amplified using a cryogenically-cooled, Q-switched YAG pumped multipass Ti:sapphire amplifier system operated at 5 kHz.
[4]. The pulses are amplified to 300 μJ per pulse. The amplified spectrum is narrower and shifted to shorter wavelengths due to the wavelength-dependent gain of the Ti:sapphire crystal at 50 K.

![Figure 2. Comparison of spectra of the output from oscillator (black), after stretcher (red), and amplified (blue).](image)

The amplified, chirped pulses are then recompressed by simply passing the amplified beam through 1 m of SF18 glass after a beam expander. The broadband anti-reflection coating on the glass allows compression with negligible power loss. The reconstructed field, measured with a Grenouille-FROG (Newport Corp.), of the compressed, amplified pulse is shown in figure 3. The pulse has a very nice flat phase profile over our spectrum. To date, we have produced 40 fs pulses with very small GVD and TOD using this setup.

![Figure 3a. Reconstructed pulse spectrum (black) and spectral phase (red) and b. reconstructed temporal profile of the compressed, amplified pulse.](image)

In conclusion, we have demonstrated a novel pulse stretcher configuration for the DPA scheme that is well-suited for use in multikilohertz, microjoule femtosecond amplifiers. The 40 fs pulse duration is the shortest ever produced using grisms. Grism based stretching and compression allows compact, easy to align, efficient dispersion management in femtosecond laser amplifier systems. The grism stretcher/compressor setup is designed to operate over a very broad wavelength range allowing compression of tunable lasers and ultra-broadband pulses.

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References