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Self Phase Modulation in a Femtosecond Pulse Amplifier with Subsequent Compression

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Abstract. The pulses from a colliding-pulse mode-locked dye laser (100 fs, 20 pJ) are amplified to 0.2 mJ and self phase modulated in an excimer laser pumped dye amplifier. Suitable chirp compensation leads to nearly bandwidth-limited pulses of about 50 fs duration.

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The amplification of femtosecond light pulses in a multi-stage amplifier chain is mostly accompanied by a drastical pulse broadening due to group-velocity dispersion (GVD). Therefore these amplifiers are terminated by suitable linear optical elements exhibiting GVD with the opposite sign (e.g., prisms or grating sequences) which allow to recompress the pulses to almost their initial duration [1]. Another concept [2] makes use of self-phase modulation (SPM) and GVD in fibers for spectrally broadening as well as temporally lengthening the pulse before it enters the amplifier, where after appropriate chirp compensation behind the amplifier the pulse duration can be considerably smaller compared to the input pulse.

Here we report on pulse amplification that is accompanied by a suitable self-phase modulation. The pulses from a CPM dye laser (100 fs, 20 pJ) are amplified in a four-stage dye amplifier (Sulphorhodamine B) pumped by an excimer laser (EMG 150, Lambda Physik) which is synchronized to the dye laser pulse sequence [3]. To reduce amplified spontaneous emission (ASE) the amplifier stages are decoupled by semiconductor-doped color glass filters (RG 645, thickness 1 mm) acting as saturable absorbers. At the output of the amplifier the pulse spectrum was about two times broader than that of the CPM laser pulses (Fig. 1) while the pulses were broadened to about 230 fs. Through appropriate chirp compensation nearly bandwidth limited pulses have been obtained, which indicates that the spectral broadening can be attributed almost exclusively to SPM. The amplifier caused an upchirp with a relative frequency change of 4% over the pulse width. The chirp compensation was performed using a pair of prisms made of high dispersive F 2 glass in a double-pass configuration [4] so that it was effectively a four-prism arrangement. The distance was varied to get the appropriate negative

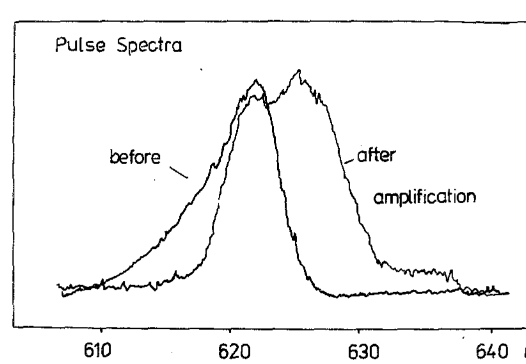

Fig. 1. Spectra of the pulses of the CPM laser (before amplification) and at the output of the amplifier (after amplification)

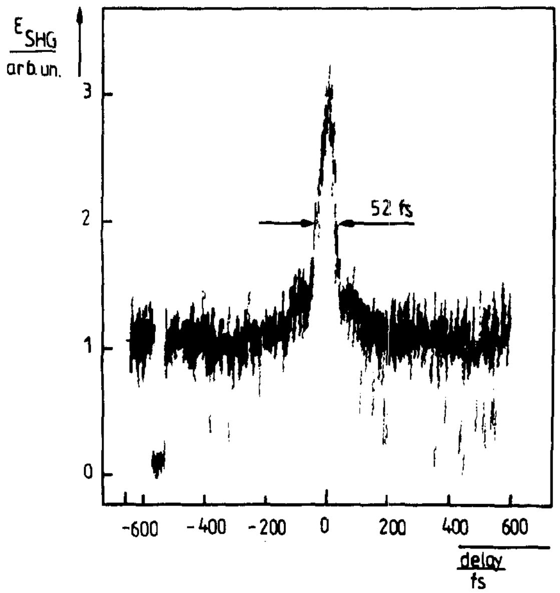

Fig. 2. Autocorrelation trace of the compressed pulse (52 fs duration assuming a sech pulse shape)

GVD for compensating the initial chirp. The resulting pulse duration was 52 fs (Fig. 2) which means a total compression of a factor of two as compared to the input pulses. Note that there was not applied any averaging procedure. By Fourier transformation of the square root of the measured spectrum a pulse duration of 48 fs was obtained. This is to our knowledge the first observation of such drastic pulse shortening in an amplifier system on this time scale.

The pulse coherence was also checked by means of fringe-resolved autocorrelation.

The origin of the SPM is under investigation and is likely due to SPM in the glass filters by Kerr-effect-type nonlinearity in the host medium and refractive index changes induced by the excitation of their doping material (CdSSe) [5]. Due to the relatively long dye cells (2...4 cm) the SPM is accompanied by GVD which may be the reason for the development of favourable chirp with respect to pulse compression. A spectral broadening which could be attributed to the action of colour glass filters was also observed recently in another amplifier arrangement for femtosecond pulses [6]. A second possible reason for SPM is the chirp generation in the amplifying media [7] which was recently investigated experimentally [8] and which in combination with the GVD of the dye solvent may result in a favourable shaping of both pulse envelope and phase.

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