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Nondegenerate optical parametric chirped pulse amplification

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Abstract: We present the first recompression of amplified pulses in a highly nondegenerate optical parametric chirped pulse amplifier. 60-fs recompressed pulse width and up to 2 mJ pulses were obtained in our experiments.

OCIS codes: (190.4970) Parametric oscillators and amplifiers; (140.7090) Ultrafast lasers

Generation and amplification of ultrashort laser pulses has been at the forefront of laser research in the recent period, driven primarily by newly accessible physics phenomena and commercial applications such as materials processing. The interest in optical parametric chirped pulse amplification (OPCPA) [1] for ultrashort pulse amplification has been motivated by its favorable properties. Large single-pass gain achievable in a ~cm length of nonlinear material pumped by nanosecond pump laser eliminates the need for regenerative amplification. Broad bandwidth capabilities and scalability make OPCPA a possible amplification technology for future multi-PW sources [2]. Absence of thermal load should allow short pulse amplification up to kW-level average power. While the ultrashort amplification capabilities of optical parametric amplifiers (OPAs) have been demonstrated down to 5 fs, the compression of ultrashort (<100 fs) pulses in thick OPCPA crystals remains largely unexplored. Here, we present the first pulse compression in highly nondegenerate OPCPA and obtain the shortest pulses produced in OPCPA to date.

The design of our OPCPA system is presented in Fig. 1. A mode-locked oscillator, which produces 20-fs pulses centered at 820 nm, is used as a seed source. An all-reflective stretcher is used to stretch the seed pulses to 600 ps, with a spectral cut-off width in excess of 100 nm. The OPA consists of two antireflection-coated beta-barium borate (BBO) crystals. The crystals are cut at 23.8° to facilitate type I phase matching at an external noncollinear angle of 3.7°. The noncollinear angle is optimized numerically to maximize the gain bandwidth. The length of each crystal is 15 mm, and they have a wedged output surface to eliminate parasitic oscillation. The pump beam is relay imaged between the two crystals and the beam diameter is adjusted to 3 mm, for a peak intensity near 450 MW/cm^2. We obtained a maximum gain of $4x10^6$ from the OPA when the noncollinear plane was chosen to be perpendicular to the principal plane of the crystal. The result were pulses with energies of up to 2 mJ amplified in a single pass through only 30 mm of gain material. The measured seed and amplified signal spectra are shown in Fig 2. We observe a shift of the center wavelength to 830 nm, which is consistent with the gain bandwidth in nondegenerate BBO OPA, which is centered at longer wavelengths (near 850 nm). The small bandwidth narrowing (<2 nm) at the FWHM observed when the OPA operates far below saturation (0.5 mJ) can be attributed to this spectral shift. At the point near saturation (2 mJ), the spectrum is modified further and the amplified FWHM is increased to 35 nm. Spectral broadening is the result of different rate of nonlinear conversion for the spectral components of different initial intensity. We recompressed our pulses in a single-grating compressor, and the autocorrelation trace is shown in Fig. 3. The measured FWHM autocorrelation of the recompressed pulse is 104 fs, which is nearly 2 times longer than the FWHM of the calculated autocorrelation of the transform-limited pulse with the measured spectrum (Fig. 2). With the inclusion of the spectral phase in the system, the calculated FWHM of the autocorrelation is 108 fs, which is within our experimental error, indicating that we produced 60-fs pulses.

In summary, we report for the first time the compression of pulses amplified in nondegenerate OPCPA. The reported 60-fs pulses are the shortest pulses reported to date produced in an OPCPA system. A careful compensation of spectral phase in our system should enable 30-fs transform-limited pulses.

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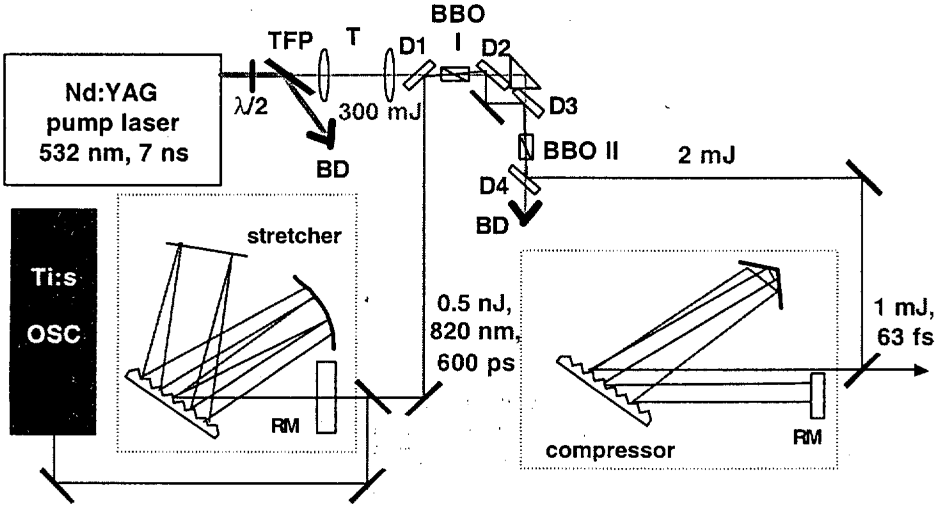

Fig. 1. Experimental setup. TFP-thin film polarizer, T-telescope, D-dichroic. λ/2-waveplate, TFP-thin film polarizer, BD-beam dump, RM-roof mirror.

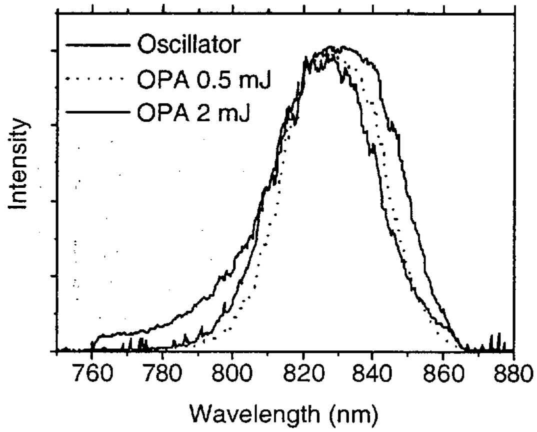

Fig. 2. Seed and amplified signal spectra from the nondegenerate OPCPA system

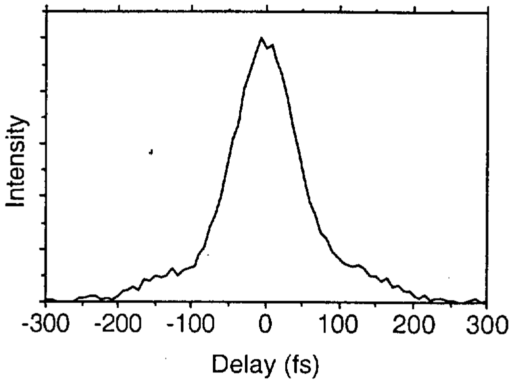

Fig.3. Recompressed pulse autocorrelation