Femtosecond OPCPA in the UV

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Introduction

So far intense femtosecond laser pulses in the spectral range of short wavelength visible (SVIS) and UV have been generated via second harmonic and sum frequency generation. However, due to the dispersion and related problems in nonlinear crystals the requirement of broadband frequency conversion limits the achievable energy of the generated pulse. Also, the narrow spectral gain of the readily available excimer laser amplifiers limits the bandwidth of amplification[1-2] while the relatively broadband newly developed solid state materials exhibit a small gain only[3]. During the past few years papers have been published about successful experiments on optical parametric chirped pulse amplification (OPCPA), in which short pulse NIR and IR laser pulses were efficiently amplified using femtosecond or nanosecond pump lasers[4-9].

In this first experiment we demonstrate efficient amplification of broadband, stretched femtosecond pulses at 400 nm, to our knowledge for the first time, using non-colinear optical parametric amplification pumped by picosecond 267 nm pulses. The effect of saturation and the geometry of the interacting pulses on the spectral gain are also investigated.

Experimental

In our experiment a part of the 800 nm fundamental beam of Astra laser was used (Figure 1). The stretched and amplified pulses with a bandwidth (FWHM) of 20 nm were left slightly over-compressed resulting in a pulse length of 1.85 ps. A small fraction of this beam generated the signal pulse at 400 nm in a 100 µm BBO crystal while the majority was used to obtain the pump pulse at 267 nm in a two-stage frequency converter. The generated pump pulse was further stretched in double pass by a 68° fused silica prism pair and subsequently spectrally filtered providing a smooth spatial profile. Two CCD cameras were used both measuring the beam waist of the pump and signal pulses giving 550 µm and 140 µm, respectively and monitoring their spatial overlap in the 12 mm long BBO amplifier.

The temporal width and phase of the fundamental (800 nm) pulse were established from the spectrum by using a fitting algorithm to a multiple shot autocorrelation measurement (Figure 2). The pump (267 nm) pulses were similarly characterised from their spectra and a cross correlation measurement with the fundamental pulse. The signal (400 nm) pulse was assumed to inherit the phase of the signal pulse[10], so it could be obtained from measuring the spectra only. The temporal width (Figure 2c) and the resulting peak intensity of the negatively stretched signal and pump pulses are 1.2 ps, 0.1 MW/cm^2 and 3.5 ps, 2 GW/cm^2, respectively.

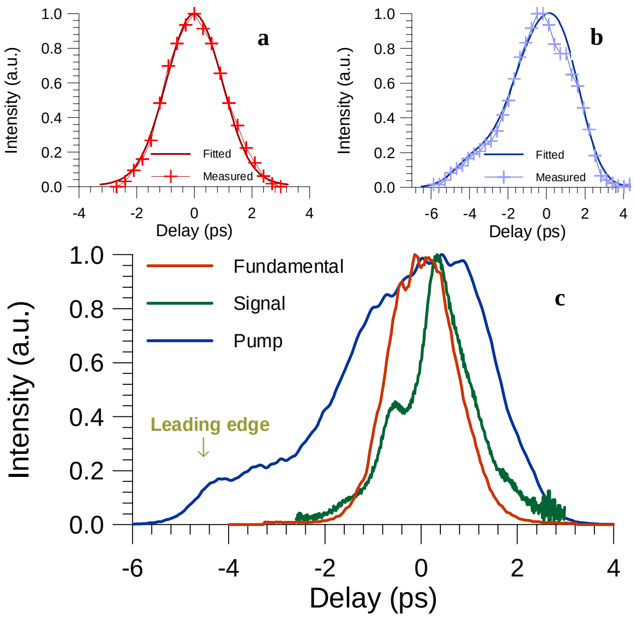

Figure 2. (a) Autocorrelation and (b) crosscorrelation of the fundamental and the pump pulses, respectively, and (c) the temporal shape of the retrieved pulses.

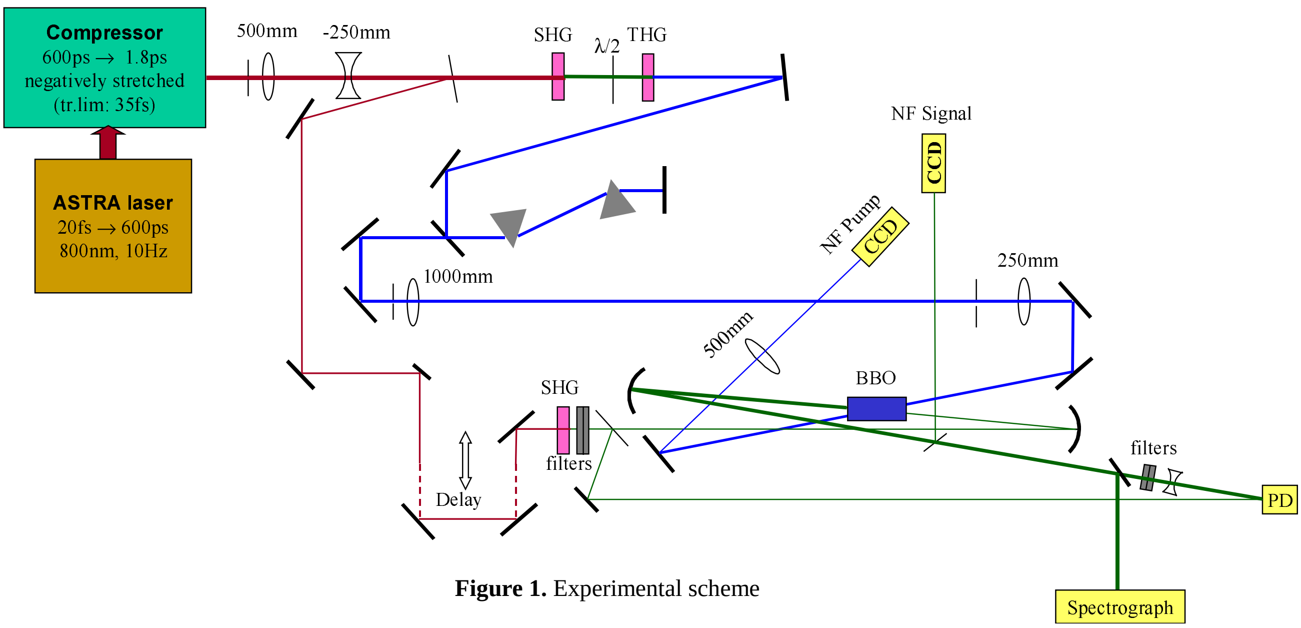

Figure 1. Experimental scheme

Results and discussion

Figure 3 shows the recorded spectra at different intensities of the input signal. The highest gain corresponds to the lowest input signal while the lowest gain was recorded when the pump was depleted (see also Figure 4). When the amplification is not saturated then the amplified spectra fits very well to the input spectrum along the whole spectral range of 392 nm - 408 nm (Figure 3a). In the case of pump depletion, however, the more enhanced shorter wavelength side of the spectrum (Figure 3b) resulted in the 3.8 ps group delay between the pump and signal pulses in the BBO crystal and the inherent feature of optical parametric processes: the peak of the spectrum cannot be amplified further, moreover, its energy is transformed back to the pump. The slight asymmetry in amplification between the shorter and longer wavelength side of the spectrum, which is significant only in the depleted case, corresponds well to the slightly non-flat spectral gain[11].

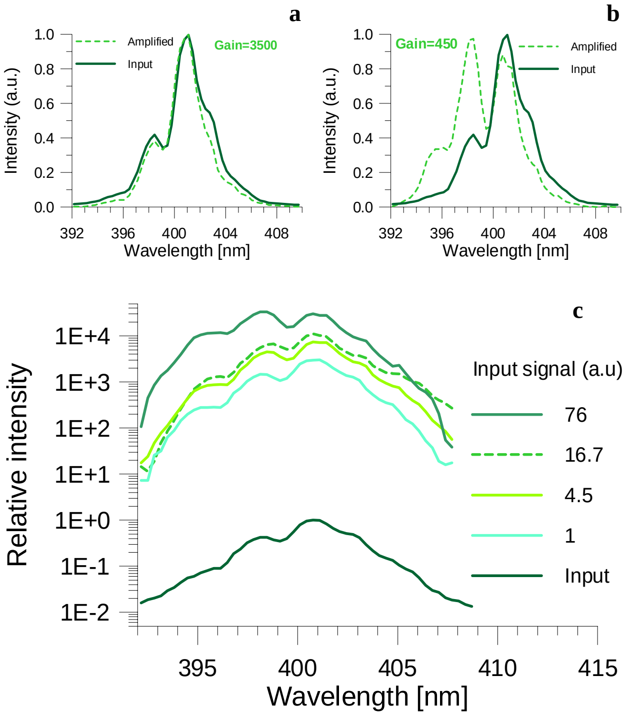

Figure 3. Spectra of the amplified signal at different input powers at a pump intensity of 2 GW/cm^2.

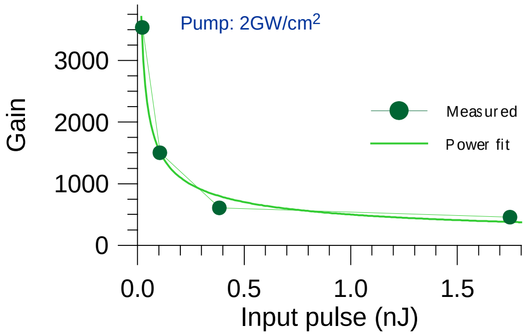

Figure 4. The measured gain vs. input signal.

Because of the shot-to-shot instability of the Astra laser in energy (±10 %), pointing direction (±0.1 mrad) and spectrum especially in the wings, all the spectra displayed above are an average of three measurements. Since the combined effect of these three is not really predictable and hard to distinguish, a way to give an impression for the accuracy of the experiment is to display the spectra of three subsequent amplified signals and their average (Figure 5a).

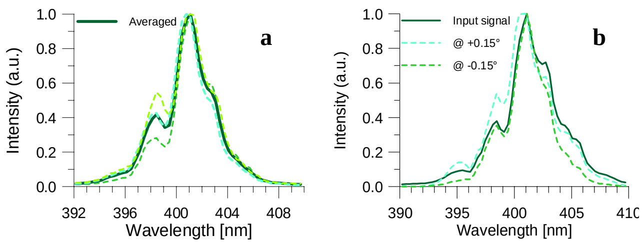

Figure 5. Spectra of the amplified signal at different input powers at a pump intensity of 2 GW/cm^2.

The effect of angular misalignment is shown in Figure 5b. For the available bottom-to-bottom signal bandwidth of 17 nm the theory[11] allows for a deviation of 0.02° for the noncollinear angle from the optimal one. As can be seen, the tolerance of alignment for the amplified spectra is better than could be expected from the theory. One reason for this is that due to group delay difference between the signal and pump pulses the effective crystal length upon amplification is much less than the available physical length of 12 mm.

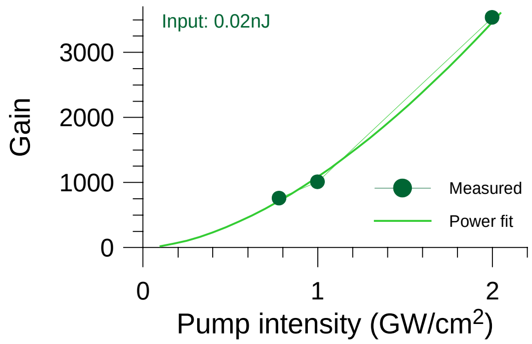

Figure 6. The measured gain vs. pump intensity.

The gain was also recorded at different levels of pump intensity for weak input signals (Figure 6). It has to be mentioned that very strong two photon absorption (TPA) of the pump beam in BBO was observed resulting in only 30% transmission at the peak and hence lower gain. The fact that apart from TPA the gain can, according to the theory, be fitted by the power of pump intensity, gives the other reason for assuming a reduced effective crystal length.

Acknowledgement

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References

1. M J Shaw *et al*., J. Chem. Phys., 105 1815, (1996)
2. S Szatmari *et al*., Appl. Phys. B 58 (1994) 211
3. Z Liu *et al*., Ultrafast Phenomena XII, 99, (Springer 2001)
4. K Osvay and I N Ross, RAL Riport TR-98-080 173, (1998)
5. I N Ross *et al*., Appl. Opt. 39 2422, (2000)
6. G. Dubeitis *et al*., Opt. Commun. 88 437, (1992)
7. G Cerullo *et al*., Opt. Lett. 23 1283, (1998)
8. A Shirakawa *et al*., Appl. Phys. Lett. 74 2268 (1999)
9. E Riedle *et al*., Appl. Phys. B 71 457 (2000)
10. E Sidick *et al*., J.Opt.Soc.Am. B 12 1713 (1995)
11. I N Ross *et al*., Opt. Commun. 144 125, (1997)