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AMPLIFICATION OF ULTRASHORT LASER PULSES BY THE OPCPA METHOD AT SOFIA LABORATORY[1]

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SOFIA laboratory is a test facility for the laser system PALS (Prague Asterix Laser System) and its major task is getting know-how of the OPCPA technique (Optical Parametric Chirped Pulse Amplification), a modern method of the amplification of ultrashort laser pulses. The SOFIA system is a hybrid laser where the oscillator beam is generated in a solid-state optical parametric oscillator (OPO) tuned to 1315 nm (the iodine spectral line) and then amplified in two gaseous iodine amplifiers. The 1315 nm beam is converted to 438 nm in KD*P crystals (4 GW/cm^2) and pumps non-linear crystals (KDP, LBO) as parametric amplifiers. The signal beam for the parametric amplification is produced by Ti:sapphire laser and stretched to 300 ps in a pulse stretcher (single diffraction grating, Öffner telescope).

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Amplification of ultrashort pulses is a rapidly evolving field in the development of high power or high repetition laser systems. Ultrashort pulses render a possibility of attaining ultrahigh peak powers. The well established CPA technique (Chirped Pulse Amplification) is currently used when chirping of the pulse and subsequent amplification are possible. The technique is not applicable for narrow spectral band lasers such as photodissociation iodine lasers ($\lambda = 1315.24$ nm) where the gain bandwidth is only about 0.02 nm. The compression is then limited to about 40 ps [1]. In 1992 a bright combination of CPA and OPA (Optical Parametric Amplification) appeared [2] which removed this disadvantage and the amplification of ultrashort pulses became possible even for narrow band lasers, though at another wavelength. The first realization of the high power OPCPA [3] was followed by other world well-known laboratories [4, 5]. Very soon it was demonstrated theoretically [1] that the implementation of the OPCPA technique would be also beneficial for the PALS (Prague Asterix Laser System) facility and an output power of 5 PW (3 TW at present) is attainable if a compression of the amplified pulse up to 20 fs is realized. The gaseous medium of the iodine laser as a pump for the parametric amplification is particularly suitable as it provides a high spatial homogeneity over the cross-section (close to the ideal top-hat profile) and a smooth temporal profile of the beam [6]. The upgrade of the PALS system to the petawatt level, however, would take a long time without a previous know-how getting and

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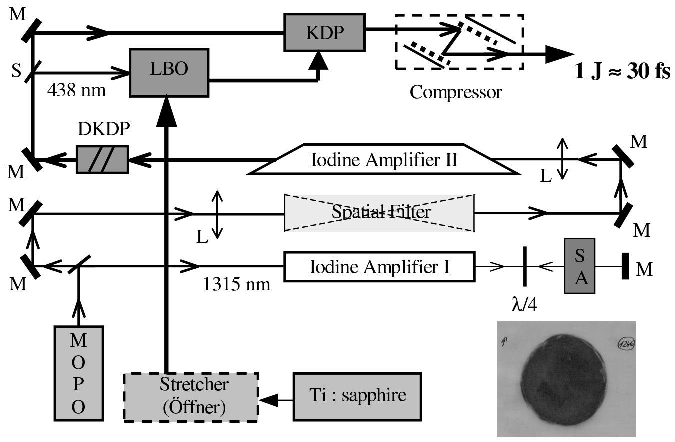

Fig. 1. Scheme of the SOFIA laser system. MOPO-HF...optical parametric oscillator (tuned to 1315 nm); Ti:sapphire laser 10 nJ @ 800 nm; M...mirrors; L...lenses; P...polarizer; SA...saturable absorber; l/4...quarterwave plate; S...beam splitter; DKDP nonlinear crystals for 3ω; LBO and KDP parametric amplifiers. Inset bottom right: a burn pattern of the cross section of the third harmonic frequency (438 nm).

therefore a new laboratory, SOFIA (Solid-state Oscillator Followed by Iodine Amplifiers) [7], was built up as to obtain the necessary experience with this sophisticated technique. The aim of the paper is to introduce the new high power laser system SOFIA and present the status of the OPCPA technique implementation.

The SOFIA hybrid laser system, see Fig. 1, consists of a solid-state parametric oscillator (MOPO-HF, Spectra Physics, pumped by the third harmonic of Nd:YAG laser) tuned to its idler at 1315 nm (the iodine spectral line) and two gaseous iodine amplifiers (from a previous PERUN system [8]). The MOPO-HF generates pulses of 15 mJ at a duration of 4-5 ns. Solid-state oscillators usually form the front-ends of high-power laser systems as gaseous oscillators can hardly be synchronized with some external trigerring device due to a large time jitter in the pulse generation. A system of two fast Pockels cells (risetime of 200 ps) follows the MOPO-HF and enables cutting of different pulse durations and a good pre-pulse suppression. The first three-module iodine amplifier is double-passing. After the amplification in the second amplifier AII the beam is converted to the third harmonic (438 nm, two KD^*P crystals) and pumps the nonlinear crystals (LBO,KDP) as parametric amplifiers. The output energy routinely obtained with SOFIA on the basic wavelength is 25 J with the Pockels cells adjusted to 1 ns gate. The highest energy in the third harmonic was up to now 4 J in a pulse duration of 0.7 ns, for the beam cross section burning pattern see the inset in Fig. 1. The signal wave is produced by Ti:sapphire laser (Femtolasers, 75 MHz, pulse energy of 10 nJ, pulse duration of 12 fs, spectral bandwidth FWHM@800 nm of 75 nm). The pulse is stretched up to 300 ps in a pulse stretcher based on a single diffraction grating and Öffner telescope and retroreflector [9,10,11], see Fig. 2a. The stretcher works at the Littrow geometry and uses a slight off-plane (conical) diffraction. The power transmission of the stretcher is about 50 %, the full spectral transmission about 200 nm. Both these parameters are considered as excellent in comparison with similar systems given in literature. Figure 3

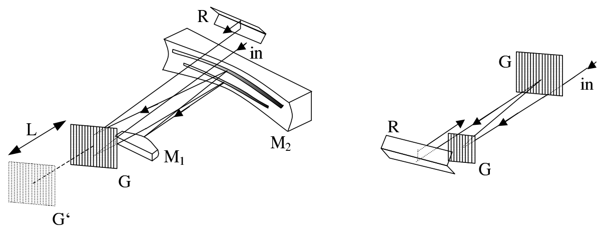

Fig. 2. (a) Pulse stretcher consists of the Öffner telescope (convex mirror M1 and concave mirror M2), producing a virtual image (G') of the single grating (G), and of a retroreflector (R). (b) Complementary pulse compressor with the opposite dispersion consisting of two diffraction gratings (G) and a retroreflector (R).

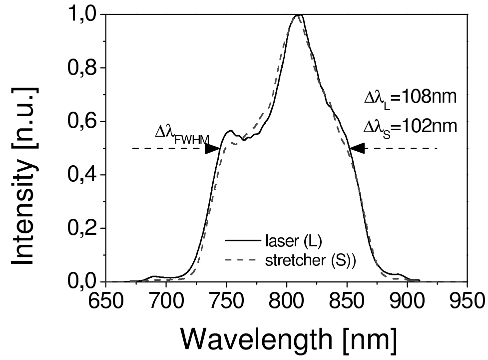

Fig. 3. Spectral bandwidth of the original pulse of Ti:sap laser (full line) and a stretched one (dotted line).

presents the wavelength dependences of the laser beam intensity of Ti:sapphire pulse prior and after stretching. Unamplified stretched pulses were recompressed back to less than 20 fs in a compressor given schematically in Fig. 2b. The recompression was found free from significant distortions of the pulse spectrum.

Following the scheme in Fig. 1, the stretched pulse passes through two parametric amplifiers (nonlinear crystals LBO, KDP). The synchronization of the stretched signal pulse and the pump pulse in the crystals is realized via a home-made trigger resynchronizer. The difficulty of the synchronization consists in the very different repetition rates of the participating devices: 75 MHz (Ti:sap), 10 Hz (Xe flashlamps in MOPO-pumping Nd:YAG and relevant Q-switch timing), 10 Hz (Pockels cells) and finally single shot triggering for the Xe flashlamps in the iodine amplifiers. Some preliminary experiments with the OPCPA technique were already done using MOPO-HF tuned to the third harmonic frequency of the iodine, i.e. 438 nm, as a pump, see Fig. 4. The KDP crystal was used as an amplifier. A successful synchronization of the signal and pump beams is apparent. The amplification attainable at this very low pumping was in a good relation with the calculation. The full scale OPCPA pumping from the SOFIA laser chain is now under progress. The SOFIA laser system is expected to produce laser pulses of tens TW. The

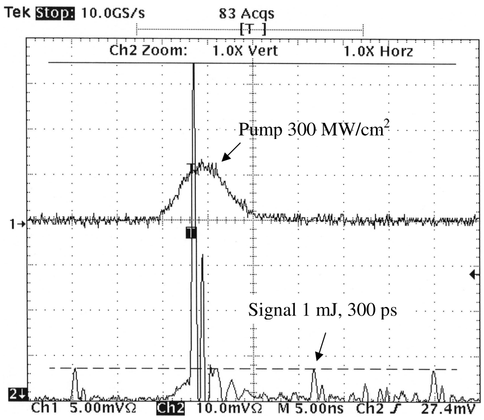

Fig. 4. Record of the pump (438 nm, signal beam from the MOPO-HF) and signal (Ti:sa pulse stretched to 300 ps) pulses at the process of the parametric amplification in KDP crystal. Channel 1: pump power 300 MW/cm^2, Channel 2: $I_S \sim 1$ nJ, $\tau_S \sim 300$ ps.

amplified beam after the compression should be of 1 J energy at a duration of about 30 fs. An evacuated compressor is now under construction. The laser beam is planned to be used for target experiments.

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