Developing picosecond-pumped OPCPA system for relativistic atto-science

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***Abstract*—key design aspects of an OPCPA system for relativistic laser-matter interaction experiments are discussed as well as the first results of its application to the high harmonics generation.**

Keywords—OPCPA; ultrafast optics; power lasers; high harmonics generation.

Few-cycle pulses with relativistic intensity and excellent temporal contrast are of high demand for laser-matter interaction experiments including the generation of isolated attosecond pulses with unprecedented efficiency by surface high-harmonic generation (SHHG) [1]. Here we report on an optical parametric chirped pulse amplification (OPCPA) system called the "Petawatt Field Synthesizer" (PFS) designed to generate such pulses [2]. The current performance, upgrade plans and first experimental results are presented.

The scheme of the system is shown in Fig. 1. Pump and seed chains start from the same Ti:Sapphire master oscillator to ensure their good temporal synchronization in the OPCPA stages. A home-built diode-pumped Yb:YAG pump chain, consisting of several chirped-pulse amplification stages, delivers 300 mJ sub 1 ps pulses at 515nm central wavelength and 10 Hz repetition rate.

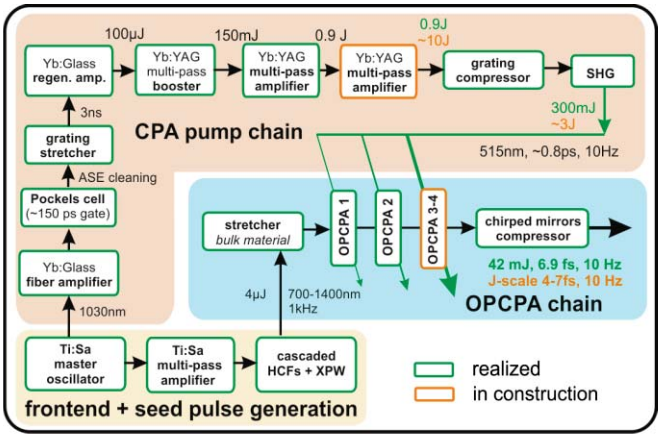

Fig. 1. Schematic layout of the system.

The seed pulses with the spectral range of 700-1400 nm are generated by spectral broadening of the output of a Ti:Sapphire amplifier in two cascaded hollow-core fibers filled with neon, followed by a cross-polarized wave generation stage for temporal pulse cleaning. The seed is then amplified in OPCPA stages using LBO crystals. Two stages being currently in operation deliver more than 40 mJ energy of amplified compressed pulses. The measured after a chirped mirror compressor duration of the amplified pulses is 6.9 fs, corresponding to about 2.5 optical cycles. Using an f/1.3 off-axis parabolic mirror, a relativistic peak intensity of 7×10^{19} W/cm^2 was demonstrated. The temporal contrast of amplified pulses measured with a third order autocorrelator is better than 5×10^{-12} (limited by the detector noise) on >1ps delays before the main pulse. This excellent result is achieved due to the sub-picosecond duration of the pump pulses and doesn't involve any pulse cleaning technique such as a plasma mirror.

The system on the current performance level was applied for SHHG experiments. The harmonics with photon energy exceeding 60 eV and sub-μJ energy scale are detected as well as the dependence of harmonics spectra on the carrier envelope phase (CEP) of the driving field (the detection is based on the CEP tagging technique [3]).

Right now, the system is in the upgrade state. We are building the next pump amplification stage that should provide about 3 J at 515 nm, 10 Hz. On the next J-scale OPCPA stage we will implement the pump recycling technique, that means using the same pump for two stages in sequence, to increase the pump extraction efficiency. In addition, we prepared an optical pulse shaper based on the spatial light modulator, that will be placed before OPCPA stages, to improve pulse compression.

After the upgrade, the system will be a unique and powerful tool for relativistic laser-matter interactions experiments.

References

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