LASERS

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Terawatt femtosecond Cr : forsterite laser system

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Abstract. **The development of an IR terawatt Cr : forsterite femtosecond laser system with a pulse energy of 90 mJ and a pulse duration of 80 fs is reported. The laser system is assembled using Russian components only and has no analogues in the world.**

Keywords: *Cr : forsterite, femtosecond laser systems.*

Active elements such as Cr : forsterite ($Cr^{4+}:Mg_2SiO_4$), Cr : garnet (Cr^{4+} : YAG) and several other elements are used for generating femtosecond IR pulses [1 – 4]. The spectral gain bandwidth of Cr : forsterite crystals allows the generation of pulses of duration less than 30 fs at a wavelength of 1250 nm [5]. However, the pulse power of modern lasers does not exceed 0.01 TW [6 – 8].

We have obtained for the first time terawatt femtosecond pulses in the near IR range (at 1240 nm) in a Cr : forsterite laser system [9]. This laser system belongs to the Center for the collective research activity of Russian and foreign scientists 'Femtosecond Laser Complex' of the Institute for High Energy Densities, Joint Institute for High Temperatures, Russian Academy of Sciences. The system was assembled from Russian components, and pulsed lasers (Solar, Belorussia) were used for pumping.

The terawatt femtosecond laser shown in Fig. 1 assembled on an optical table of size 300×120 cm is equipped with a dust-protective system as well as air-purification and temperature stabilisation systems. The chirped-pulse amplification technique, used extensively in Ti : sapphire terawatt lasers [10], was employed for attaining high power levels.

Figure 2 shows the block diagram of the laser and its output parameters. The first module contains the CrF-65 master oscillator (Avesta Project Ltd Company) assembled using the classical scheme with a Z-fold cavity and a pair of SF6 prisms to compensate for the positive dispersion in the active element [5]. Pumping is performed by a 1.064-μm cw ytterbium-doped fibre laser (PYL-10, IRE-Polyus). The oscillator emits a continuous train of 2-nJ, 55-fs pulses at a wavelength of 1260 nm with a repetition rate of 90 MHz at a pump power of 7 W.

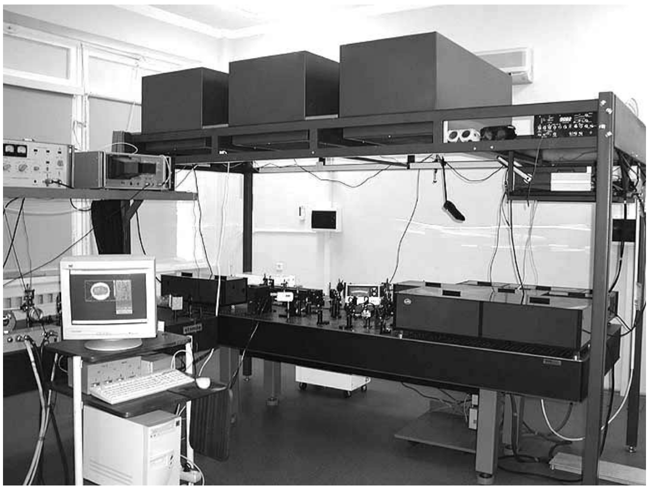

Figure 1. General view of the setup.

Pulses emitted by the master oscillator propagating through a pulse stretcher in the second module are chirped [4, 10]. The pulse stretcher includes a diffraction grating (600 lines mm^{-1}) and a plane mirror and a spherical mirror ($F = 700$ mm) which serve as a telescope that changes negative dispersion into positive one. The pulse stretcher increases the duration of oscillator pulses to 50 ps with an energy efficiency of 60 %.

The chirped pulse is subsequently amplified by a regenerative amplifier with a ring cavity (third module) that does not require a Faraday isolator. The active element is pumped by 12-ns, 15-mJ pulses from a Nd : YAG laser with a pulse repetition rate of 10 Hz. The output pulse energy of the regenerative amplifier is 450 μJ, which corresponds to the gain 3×10^5. The spatial distribution of the beam corresponds to the TEM_{00} mode.

A power amplifier of chirped pulses consists of four multipass amplifiers. Two *Q*-switched Nd : YAG lasers emitting 1.064-μm, 600-mJ, 10-ns pulses with a pulse repetition rate of 10 Hz are used for pumping. The spatial distribution of the pump radiation has a flat-top profile along the abscissa and a nearly Gaussian shape along the ordinate.

The pump radiation was divided by a system of mirrors and focused at the active elements by lenses with focal

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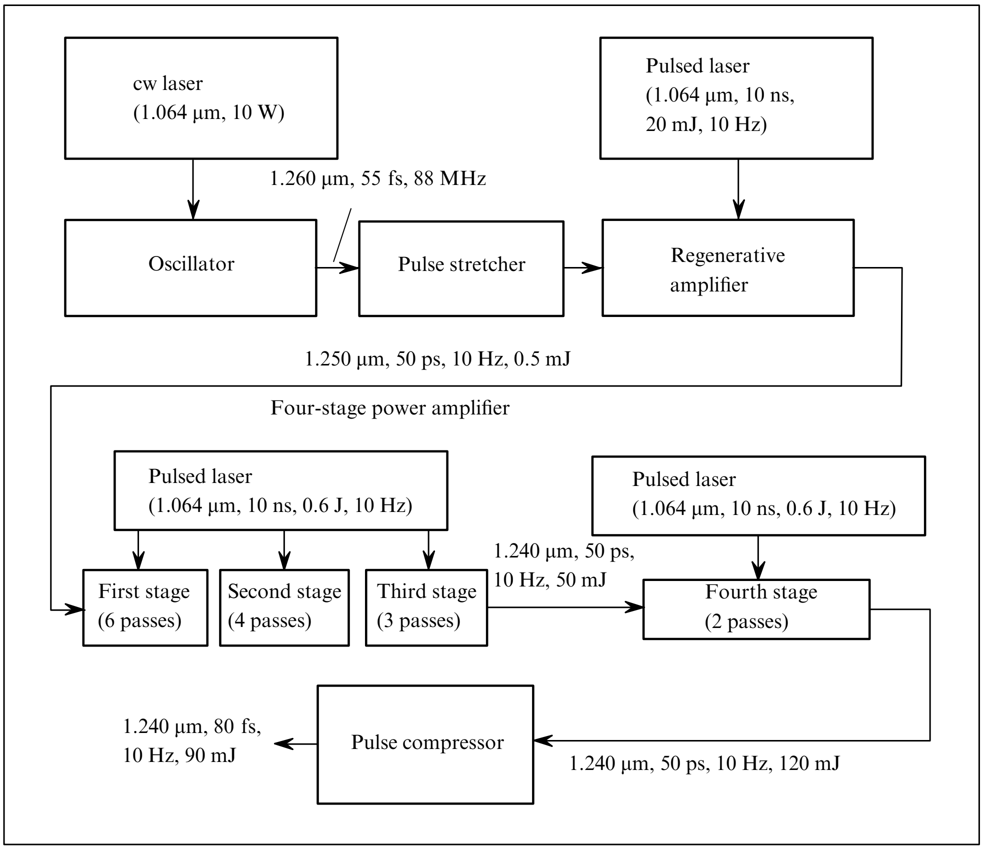

Figure 2. Block diagram and output parameters of the laser.

lengths of 0.5 and 1 m. The pump mode cross section was matched with the mode cross section of the signal being amplified. For an optimal number of passes through the crystal, an efficiency of 10 % was attained for the amplifier. Table 1 shows the main parameters of the multipass amplifiers.

Table 1.

Amplifier stage No.	Number of passes	Pump energy/mJ	Pulse energy/mJ
1	6	90	6
2	4	180	23
3	3	250	50
4	2	600	120

After passing through the power amplifier, the laser pulse was expanded by a telescope and directed to a compressor consisting of two 120×100 mm, 600-lines mm^{-1} diffraction gratings. The total efficiency of the compressor was 75 %. The duration of laser pulses at the compressor output was determined with the help of a single-pulse ASF-20 autocorrelator (Avesta Project Ltd Company). The autocorrelation function and the laser pulse spectrum at the compressor output are shown in Figs 3 and 4. The FWHM pulse duration for the intensity profile sech^2 was 79 fs.

We also estimated the contrast from the third-order autocorrelation function. The signal intensity contrast for the zero and 2 ps delay was no less than 10^6.

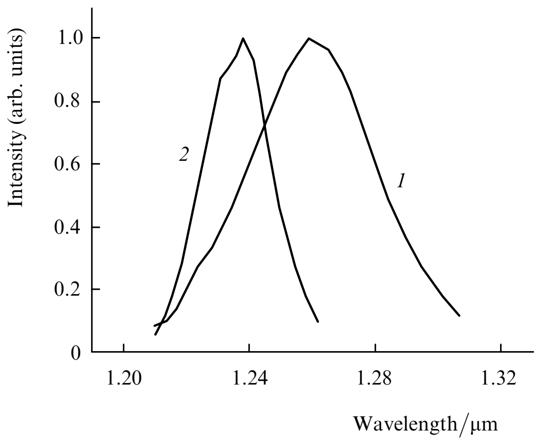

Figure 3. Oscillator spectrum (curve *1*) and emission spectrum (curve *2*) at the compressor output.

Thus, we have built for the first time a terawatt femtosecond Cr : forsterite laser system generating 79-fs, 90-mJ pulses at a wavelength of 1.240 μm with a repetition rate of 10 Hz. The high stability of operation of the entire system and a high conversion efficiency of the pump energy along with a comparatively low cost of the components allows us to hope that such systems will find wide applications for solving many basic and technological problems.

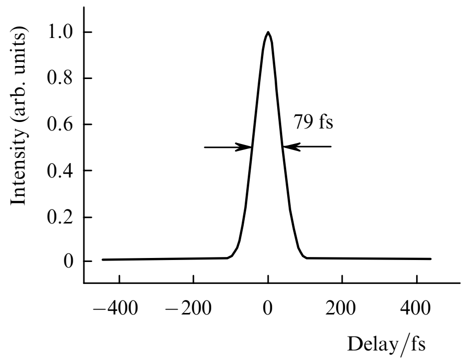

Figure 4. Autocorrelation function of a laser pulse at the compressor output.

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