Abstract—The report presents the basic principles of creation, scheme and the components of multiterawatt laser system at kilohertz repetition rate based on parametric amplification of femtosecond pulses and laser amplification of picosecond pulses for pumping of stages of parametric amplifier. On developed element base in pump channel of laser system, parameters of regenerative amplifier with output energies about 1 mJ at repetition rate of 1 kHz and central wavelength 1030 nm are experimentally investigated. Optical scheme of multispot cryogenic amplifier based on diode pumped Yb:Yb2O3 laser ceramics is developed and parameters for increasing of output energy up to ~0.25-0.35 J are determined.

Keywords—high-intensity laser systems; diode pump; ytterbium ions; femtosecond pulses

Recently, special attention is paid to research on the development of principles and element base of high femtosecond laser systems of multiterawatt power at kilohertz repetition rate. The main objective of this work is the development of laser systems with intensity reaching ultra-relativistic limit - 10^{25} W/cm^{2}, using for the development of the physics of extreme laser fields and experimental studies on nonlinear quantum electrodynamics, as well as for use in fundamentally new technological applications such as laser acceleration of charged particles, laser fusion, etc. [1]. Studies show that the most promising way is the creation of such systems based on OPCPA technique of femtosecond pulses by using for pumping radiation of DPSSL.

The peculiarity of system that is being developed at the ILP SB RAS is that the radiation of one master femtosecond laser at center wavelength 1030 nm splits for amplification into two channels: CPA pump channel, forming picosecond radiation for pumping of the parametric amplifiers and broadband parametric amplification OPCPA-channel, which allows for optical synchronization of the channels [2].

The CPA pump channel includes: a stretcher, regenerative amplifier, a multipass amplifier, compressor and frequency doubling unit based on nonlinear optical crystal of borates group. The OPCPA amplifier channel consists of a photonic crystal fibre, designed to enrich the radiation spectrum of a start femtosecond Yb-laser for formation after amplification output pulses of 10-11 fs, negative dispersion stretcher, sequence of parametric amplifiers based on the nonlinear optical crystals of borates group and compressors based on chirped mirrors and optical materials with positive dispersion. It allows to realize phased development of the system from terawatt to multiterawatt and even petawatt peak power.

Therefore, the goal of the project is the development of this trend on element components, based on large-size nonlinear borate crystals (BBO and LBO) in the channel of parametric amplification and diode-pumped Yb-doped laser crystal and ceramic elements of the aluminium garnet group and sesquioxides in the laser amplification channel.

Numerical modeling of OPCPA-channel with starting spectral width of 300 nm at the central wavelength 1030 nm to the peak power of 100 TW, configuration schemes and the optimal size of nonlinear BBO and LBO crystals were investigated. Stretchers of start generator femtosecond pulses in OPCPA and CPA-channels were developed. The element base of high-intensity solid-state laser system at high repetition rate in optical parametric amplification channel of femtosecond pulses in nonlinear optical crystals and synchronized picosecond pulses pump channel in diode-pumped ytterbium doped crystals and ceramics was carried out. On the basis of the developed elements parameters of picosecond preamplifier with energy of ~ 1 mJ at wavelength of 1030 nm, at repetition rate of 1 kHz in the pump channel of laser system were experimentally investigated. A numerical simulations of diode-pumped Yb:YAG and Yb:LuAG crystal and Yb:Y2O3, Yb:Lu2O3 ceramic multipass amplifier of CPA-channel were obtained. Optimal cascade multipass optical scheme of cryogenic Yb:Y2O3 ceramic amplifier pumped by kilowatt diode lasers was developed and characteristics to achieve the output energy in the range of 0.25-0.35 J was defined.

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