High Power Cryogenic Yb:YAG Disk Laser with Nanosecond Output Pulse Duration

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Abstract—OPCPA amplification of pulses that are several femtosecond order of magnitude requires pumping with picosecond pulses. For a simulation of such pump a laser system for a stretched picosecond pulse amplification has been created in the Institute of Applied Physics RAS: seed laser has been upgraded, a new high average power active cooling cryogenic disk laser head has been developed. New Main amplifier scheme based on this laser heads has been created.

Keywords—pulse laser, disk laser, Yb:YAG, cryogenic cooling

The project of high average and peak power cryogenic Yb:YAG disk laser creation is being implemented at the Institute of Applied Physics RAS. The laser consists of three main parts: seed stage, preamplifier (PA) and the main amplifier (MA). 2-3 mJ pulses from the seed stage are to be amplified in the PA up to 30-40 mJ and then up to ~ 500 mJ in the MA with 1 kHz repetition rate.

One of the main intended purposes of this laser system is the pumping for optical parametrical femtosecond laser amplifiers [1,2]. Our laser should have several picosecond output pulse length. Such pulses are usually amplified by CPA principle with pulse length stretching up to ~ 1 ns. For this reason nanosecond seed laser is enough for the amplification stages testing. That is why it’s necessary to provide broadband amplification for further pulse compression into picosecond range.

Seed stage and MA are modernized. Cryogenic oscillator is changed to the additional amplification stage and new master oscillator is based on a laser head with water cooling. Oscillator pulse duration decreased from 70 ns to 3-7 ns. According to our measurements pulse contrast in nanosecond range was more than 10^5.

Towards the MA average power increasing new disk laser head with cryogenic active cooling and 20 mm active element (AE) aperture is developed. New MA is based on two laser heads of this kind working under the active multipass cell (AMC) scheme, that has proved its success in the PA. Such MA lets us significantly improve laser beam and pump sport alignment on the crystal, compensate thermal lens and organize required number of signal passes through the AE. First experimental results showed beam quality improvement and stable work of the MA up to 1.2 kW CW pumping power (fig. 1). Stored energy is limited due to spurious oscillations across the AE. To solve this problem we plan to produce AE with side cladding. With new laser heads we realized 4 pump V-passes through the AE, that leads to more efficient utilization and let us use thicker AE to reduce negative thermal effects. According to our calculations having removed the spurious oscillations we should achieve 500 mJ at the laser output.

Another one important factor of the stretched pulse amplification is temporal and spectral pulse profile distortions. According to our measurements both profiles stay put by the amplification cascades pulse passing. Spectral width remains 0.7 nm, which corresponds to 2 ps bandwidth-limited pulse. Small-signal gain of the whole scheme equals 10^8.

The first preamplifier, preamplifier and the main amplifier are replaced by the independent cryogenic laser amplifier for the stretched nanosecond pulses.
