MULTICHANNEL YB:YAG LASER WITH HIGH AVERAGE AND PEAK POWER

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High peak power lasers are widely used today for research in the field of extreme optical field and high energy densities physics. Acceleration of charged particles, generation of secondary X-ray and THz radiation, and much more have been successfully demonstrated. However, practical implementation of these developments requires an increase in the average power of sources, or the pulse repetition rate, which determines the productivity of the processes. For example, to create a laser-plasma X-ray source for lithography, pulsed lasers with a pulse energy of 100 mJ and an average power of up to 10 kW are required. In the laser accelerators, to achieve charged particle flows comparable to traditional accelerators, femtosecond lasers with an energy of more than 30 J and an average power of about 0.5 MW are required. Simultaneous increase in peak and average power is a non-trivial task, since conflicting requirements are imposed on the system. It is necessary to ensure not only efficient storage and extraction of high-energy pulses, but also efficient cooling of the active medium due to the high pulse repetition rate. The geometry of the active element (AE) plays a key role here.

A promising method for increasing the peak and average power of a laser is to use a multi-channel laser scheme with coherent beam combining. The method involves splitting a laser beam into several replicas, amplifying the replicas in different amplifiers, and then coherent combining them into a single beam, which is achieved by controlling the phase of each replica. The method has gained wide popularity in the field of fiber lasers [1], and has been applied in the field of continuous-wave lasers with extremely high average power (>100 kW) [2] and in pulsed laser systems with extremely high peak power [3]. The method can be very effective for lasers with both high peak and average power, however, to date there are only a few pioneering results. The key problem is the creation of identical channels, which is aggravated by the strong influence of thermal effects.

In this paper, we propose a new architecture of a multichannel laser amplifier that allows us to significantly simplify the task of channel multiplication. The idea is to amplify several beams in one AE, when the beams are located symmetrically relative to the AE axis and along its cooled side surface. In this case, the AE is effectively cooled through the side surface, since the heat sources are distributed in close proximity to it. Additionally, all beams are in symmetric conditions, which ensures the equivalence of the channels. Based on the presented geometry, a MOPA laser system with a 4-channel Yb:YAG amplifier and coherent beam combining is implemented, the scheme of which is shown in Fig. 1.

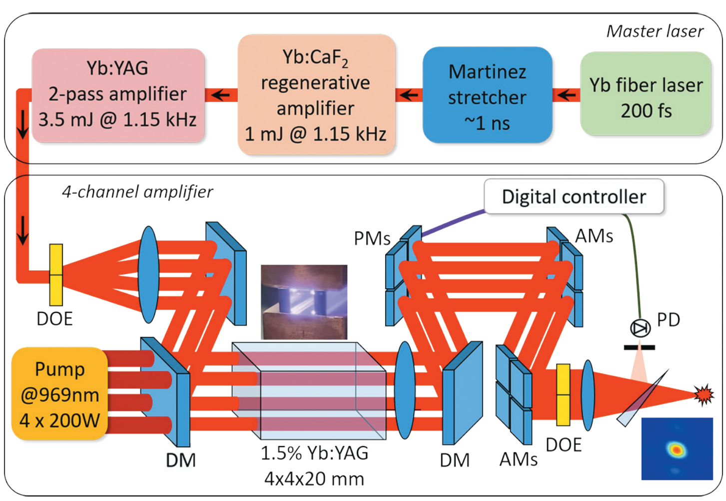

Fig. 1. Optical scheme of laser system:
DOE – diffraction optical element, DM – dichroic mirror, AMs – adjustment mirrors, PMs – mirrors on piezo actuator, PD – photodiode

A diffraction optical element is used to split the signal into 4 replicas. The AE is made of a Yb:YAG crystal in the form of a rectangular parallelepiped, and the signal beams pass along its edges. A 4-channel end-pumping diode system has been developed. A digital controller has been developed for channel phasing, maximizing the power in the central lobe of the total beam using the “hill climbing” algorithm.

To date, such a system has achieved pulse energy >17 mJ at an average power of ~20 W. Coherent channel combining according to the “tiled aperture” principle with 57% power in the central lobe of the beam has been implemented. Phase fluctuations in the channels, mainly concentrated in the band up to 10 Hz, are effectively suppressed by the digital controller. The relative standard deviation of residual fluctuations of the target function was ~1%.

The next step will be to increase the pulse energy in each channel up to ~50 mJ, which was successfully demonstrated in the single-channel rod “diverging beam amplifier” proposed in [4], as well as to increase the number of channels up to 16.

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