>2J Output Energy from Micro-photonics based DFC-chip Amplifier

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Compact size and high-brightness passively Q-switched micro-lasers with sub-ns duration are used for applications such as laser ignition or terahertz generation and can provide several mJ pulses to the user. In order to scale-up the output from such laser, additional micro-laser-based Master Oscillator Power Amplifier (micro-MOPA) system has been developed [1]. However, more than J-class micro-photonics based powerful compact pump lasers could be required to downsize the PW-class large facility of the cutting-edge particle accelerators [2]. If the output energy has to be increased, heat generation inside the active media will cause severe thermal lens and birefringence problems. To suppress these severe effects, another approach for laser component design is required. Recently, it became possible to make a periodic structure consisting of transparent heatsink and active laser media [3]. Materials like sapphire or diamond could be contacted to Nd^{3+}:YAG crystal in a consecutive pattern for removing excess heat generation. Bonding of multiple crystal pairs will produce so called Distributed Face Cooling (DFC) chip. The heat generated in the gain medium will be extracted through the contact with transparent heatsink thus improving heat extraction. In addition, optimization of this design can help to withstand high average powers. To make bonding between crystals possible, we implement Surface Activated Bonding (SAB) technology. The whole bonding process is done at room temperature and stress-free even for materials with different thermal expansion coefficients as compared to the diffusion bonding which is done at several hundred-degree centigrade.

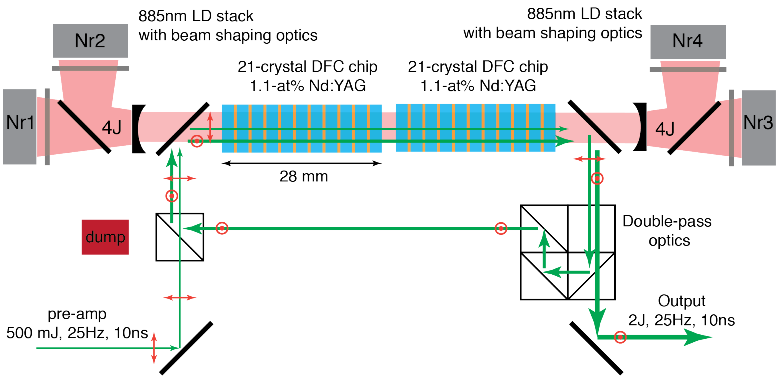

Figure 1. >2J amplifier setup with two 28-mm length each DFC chips

For this work we bonded two DFC chip comprised of sapphire plates with thickness 2 mm (11 pcs) and microchip Nd^{3+}:YAG with thickness 0.5 mm (10 pcs) shown in Fig. 1. The total single DFC chip length reached 27.5 mm. Aperture of both crystals was 10 mm square. Doping level of Nd^{3+}:YAG was 1.1-at.%. In addition, input and output sides of the chips were coated with AR coating for both pump and laser wavelengths. The single pass transmission loss from each of the DFC chips was below 2%. It indicates that such DFC chip is suitable for high-gain and low-loss laser cavity or amplifier system. Two DFC chips were placed one after another with dichroic mirrors separating the pump and laser wavelengths Four pump diode modules 8.8 kW each at 885 nm were put from both ends of DFC chips and used for pumping. The square shape flat-top beam from the diode-modules was collimated and had same size as crystal aperture. The amplifier was based on two-pass configuration. Measured absorption efficiency for two DFC chips was equal to 75%. The preamplifier system was based on rod crystal and experienced instabilities when the repetition rate increased higher than 25 Hz. For this reason, in this experiment the repetition rate was limited to 25 Hz and pulse duration 250 μs. The seed laser after preamplifier was 500 mJ with 10 ns pulse duration. After two-pass amplification we could obtain 2.3 J output. We also used Comsol Multiphysics software to analyze the heat distribution of DFC chip and single rod. Because this experiment shows the validity of amplifier system based on DFC structure, future work will be focused on improving the chip for room temperature operation with 2 J output energy at 100 Hz repetition rate in micro solid-state photonics based compact laser system.

This work was partially supported by ImPACT, and JST-Mirai Program Grant Number JPMJMI17A1, Japan.

References

[1] Taisuke Kawasaki, Vincent Yahia, and Takunori Taira, "100 Hz operation in 10 PW/sr·cm^2 class Nd:YAG Micro-MOPA," *Opt. Express* 27, 19555-19561 (2019).

[2] Couprie, M. E., "Towards compact Free Electron–Laser based on laser plasma accelerators," *Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, *909*, 5–15 (2018).

[3] Lihe Zheng, Arvydas Kausas, and Takunori Taira, "Drastic thermal effects reduction through distributed face cooling in a high-power giant-pulse tiny laser," *Opt. Mater. Express* 7, 3214-3221 (2017).