# Surface Activated Bond properties of Distributed Face Cooling structure for high average power applications

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High-brightness passively Q-switched micro-lasers with sub-ns duration could be used for applications such as laser ignition or terahertz generation [1] and can provide several mJ pulses to the user. To scale-up the output from such laser, additional Master Oscillator Power Amplifier (MOPA) system is necessary. This will increase both the size and price of the setup. Additionally, if the repetition rate to be increased, heat generation inside the active media will cause severe thermal lens and birefringence loss. To avoid these severe effects, another approach for laser cavity design is required. Recently, it became possible to make a periodic structure consisting of transparent heatsink and active laser media. Materials like Sapphire or Diamond could be contacted to $Nd^{3+}$:YAG crystal in a consecutive pattern for removing heat generation. Combination of several units of these crystal pairs will produce so called Distributed Face Cooling (DFC) chip. Optimization of this design can help to withstand high average powers with the change of several parameters such as thickness of both gain and heatsink material, pump laser wavelength, doping of gain crystal, etc.

We are using Surface Activated Bonding (SAB) technology to produce DFC structures. This process was first applied in semiconductor manufacturing [2]. Activation of surface in ultra-high vacuum with fast Ar atoms, will remove oxide layers and creates several nm thick amorphous layer. After, two materials are brought together and mechanically pressed to compensate for the surface flatness difference of two surfaces. By repeating this process several times, multi-chip structure is created. 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 shows the bonding with amorphous layer in between.

By using SAB technology, we produced 9-chip crystal consisting of five Sapphire crystals and four $Nd^{3+}$:YAG crystals [3]. The cavity loss from DFC chip was measured to reach 0.51% which is close to ideal Fresnel loss of 0.2%. It indicates that such DFC chip is suitable for high-gain and low-loss laser cavity or amplifier system. For the pump source we used 100W diode laser at 808 nm. At 86 W CW incident pump power the DFC chip gave an output power of 47.7 W and no roll-off curve was observed. The slope efficiency $\eta_S$ reached 64.6% for the output coupler of 4.46%. In order to understand mechanical strength of the bonded chip, we a additionally stress-test the single pairs of Sapphire and $Nd^{3+}$:YAG crystals for different temperature conditions. By applying increasing temperature the Sapphire/$Nd^{3+}$:YAG bond could withstand up to 1100˚C without any separation. In this work we will present results for mechanical and optical property measurements and provide future direction for over kW-level pump DFC chip optimization.

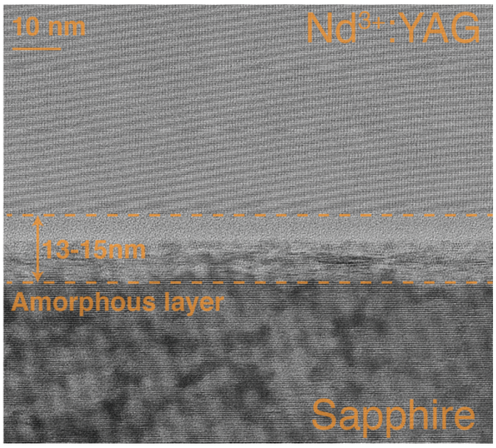


Figure 1. TEM image of Sapphire/ $Nd^{3+}$:YAG crystal bond with amorphous layer created due to Ar atom beam irradiation.

This work was funded by ImPACT Program of Council for Science, Technology and Innovation (Cabinet Office, Government of Japan).

## References

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