# Optimization of Distributed Face Cooling structure for high average power applications

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The passively Q-switched micro-lasers produce high-brightness, sub-ns duration pulses for applications such as laser ignition or terahertz generation [1] and can provide few mJ pulses to the user. In order to scale-up the output from such laser, additional Master Oscillator Power Amplifier (MOPA) system is required. This increase the size and price of the setup. Additionally, if one will increase the repetition rate, heat generation inside the crystal will cause severe thermal lens and birefringence loss. To avoid these effects, different approach to the design of laser cavity is required. Recently, it became possible to produce a periodic structure of transparent heatsink and gain material. In this new design materials like Sapphire or Diamond could be contacted to $Nd^{3+}$:YAG crystal in a periodic pattern to efficiently remove heat generation. By combining several pieces of these crystal pairs Distributed Face Cooling (DFC) chip is produced. We can optimize this design which can withstand high average powers by change of several parameters such as thickness of both gain and heatsink material, pump laser wavelength, doping of gain crystal, etc.

To produce DFC structures, we are implementing Surface Activated Bonding (SAB) technology which was first applied in semiconductor manufacturing [2]. By activating the surface of crystals in ultra-high vacuum with fast Ar atoms, all oxide layers are removed and dangling bonds are formed. After this, two materials are pressed together to compensate for the surface flatness difference of two surfaces. The pair of the crystals is created. By repeating this process several times, 9- or 11-chip structure is created. The whole bonding process is done at room temperature, and does not produce any stresses due to different thermal expansion of two different materials as compared to the Diffusion Bonding which is done at several hundred-degree centigrade.

By using SAB bonding, we produced 9-chip crystal consisting of five Sapphire crystals and four $Nd^{3+}$:YAG crystals [3]. To determine the cavity loss from DFC chip two different output coupler (OC) mirrors were used to measure the slope efficiency under continuous wave (CW) pump power. Fiber coupled CW diode laser with maximum incident pump power 86 W was used. Fig. 1 gives the schematic diagram of measuring round-trip cavity loss and the output power from 9-chip DFC. The DFC chip gave an output power of 47.7 W under pump power of 86 W and no roll-off curve was observed. The slope efficiencies $\eta_S$ were 64.6% and 61.8% for the output coupler of 4.46% and 3.10%, respectively. The round-trip cavity loss was then calculated to be 0.51%. The total Fresnel loss calculated for 9-chip crystal is 0.2%. It indicates that such DFC chip is suitable for high-gain and low-loss laser cavity or amplifier system. We also measured the performance of $Nd^{3+}$:YAG single crystal. A roll-off for crystal appeared after the incident pump power reached 41.7 W. It could be noted from Fig.1 that $Nd^{3+}$:YAG crystal had thermal fracture at pump power around 54 W partly due to the high pump power induced thermal lens effects, while the 9-chip DFC underwent no damage at pump power of 86 W, indicating a higher capability of thermal reduction.

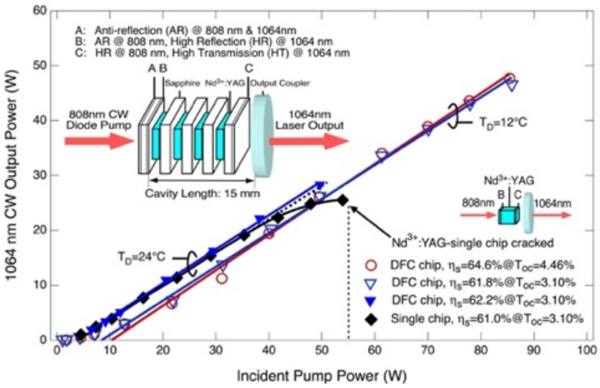


**Fig. 1. Internal loss measurement results for a 9-chip DFC crystal.**

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## References

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