Micro Solid-State Photonics

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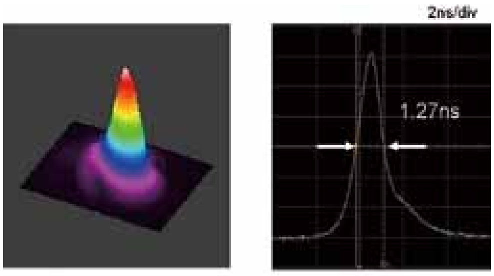
The artistic optical devices should be compact, reliable, efficient and high power light sources. With the approaches of domain structures and boundaries engineering, it is possible to bring the new interaction in their coherent radiation. The high-brightness nature of Yb or Nd doped single crystal or ceramic microchip lasers can realize efficient nonlinear wavelength conversion. In addition, designed nonlinear polarization under coherent length level allows us new function, such as the quasi phase matching (QPM). The development of "***Micro Solid-State Photonics***," which is based on the micro domain structure and boundary controlled materials, opens new horizon in the laser science.

1. High Brightness, Passively Q-Switched Yb:YAG/Cr:YAG Micro-Laser

A QCW diode end-pumped, high peak power passively Q-switched Yb:YAG/Cr:YAG micro-laser was demonstrated as shown in Figure 1. An output pulse energy of 3.6 mJ was obtained with a duration of 1.3 ns. The peak power is 2.8 MW. An M^2 value was nearly 1.



(a) Beam profile (b) Pulse duration

Figure 1. Beam profile and pulse duration at 3.6 mJ.

2. 60% FHG Efficiency from Fluxless-Grown BBO Using Nd:YAG/Cr^{4+}:YAG Microchip Laser

High-efficiency, compact ultra-violet (UV) sources are desirable for many applications, such as, ultrafast UV spectroscopy, photolithography, micromachining, *etc*.

We have developed a Nd:YAG/Cr^{4+}:YAG microchip laser which gives > 8 MW peak power at 100 Hz. We used LBO crystal to obtain 85% second harmonic generation (SHG) and a BBO crystal, grown by a new fluxless method, to obtain 60% fourth harmonic generation (FHG) as shown in Figure 2. A BBO crystal grown by the conventional flux technique can give only 40% FHG under identical conditions. We can obtain a stable pulse train having 3.4 MW peak power with 250 ps pulse width and 100 Hz repetition rate at 266 nm wavelength. We believe that this is the highest conversion efficiency reported so far for the BBO crystal in the generation of deep ultraviolet light.

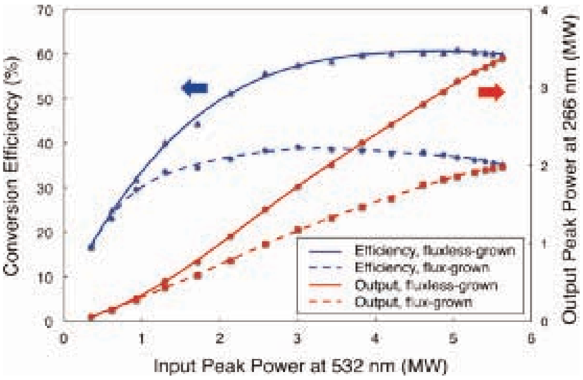


Figure 2. FHG conversion characteristics by different BBO crystal.

3. Lens-Less Edge-Pumped High Power Microchip Laser

A lens-less edge-pumped microchip laser was realized, which is directly pumped by single-emitter diode chips from multiple directions. Figure 3 shows the scheme of this laser head. The lens-less design makes the microchip laser more compact; the multi-direction designable pump schemes can realize desired pump shape. As a preliminary result, continuous wave output power of 32.5 W and slope efficiency of 45% was obtained by 9-direction pumped Yb:YAG ceramic microchip. Further, 27.2 W single peak Gaussian beam was obtained by a small adjustment of the output mirror. Besides, watt-level high-order Hermite–Gaussian mode, doughnut-shape mode and vortex arrays were demonstrated as an evidence of designable pump scheme. Power scalability is easy by increasing the number of pump diodes to achieve hundred-watt-level high power microchip laser.

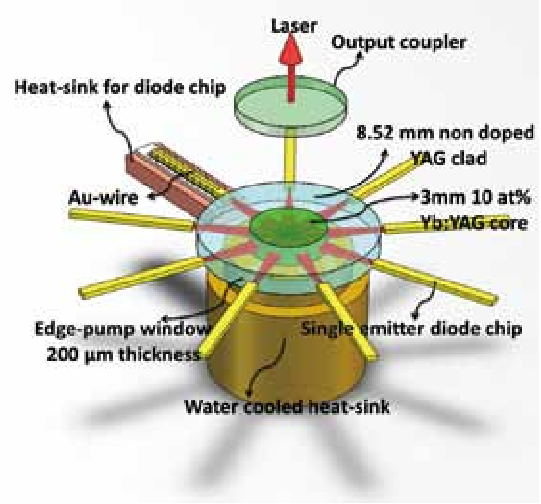


Figure 3. The scheme of lens-less edge-pumped microchip laser.

4. Temperature Dependencies of Stimulated Emission Cross Section for Nd-Doped Solid-State Laser Materials

Temperature dependencies of stimulated emission cross section for Nd:YAG, Nd:YVO_4, and Nd:$GdVO_4$ were carefully evaluated. Our spectral evaluations with fine spectral resolution were carried out under the condition that the population inversion was induced into samples by a weak pumping field. Within the temperature range from 15 °C to 65 °C, the variation of emission cross section at 1.06 μm in Nd:YAG was –0.20%/°C, while those in Nd:YVO_4 and Nd:$GdVO_4$ for π-polarization were –0.50%/°C and –0.48%/°C, respectively. Consideration of measured temperature dependence gave the numerical model for temperature dependent emission cross sections of Nd-doped solid-state laser materials. We have also presented numerical approximations of this model for our samples by a simple polynomial, which can be applicable as shown in Figure 4.

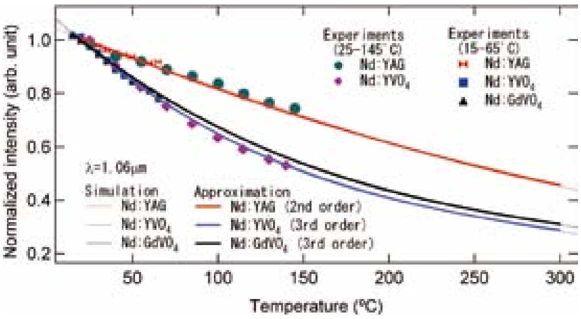


Figure 4. Temperature dependence of emission intensity of various Nd-doped laser media.

5. Fabrication of 10-mm-Thick Periodically Poled Mg-Doped Congruent $LiNbO_3$ Device for High-Energy Wavelength Conversion

Periodically poled Mg-doped congruent $LiNbO_3$ device with 10mm thickness of 32.2 μm period was fabricated by 33 kV pulse application. High-energy optical-parametric oscillation with half-joule-class output energy can be expected by joule-class pumping source in 10 ns pulse region.

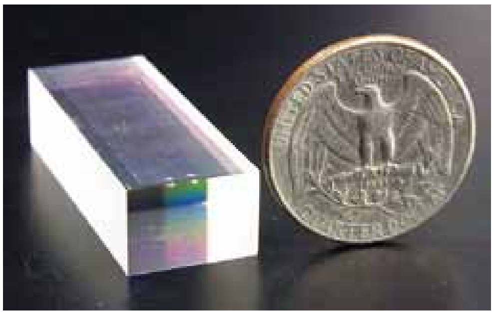


Figure 5. 10-mm-thick PPMgLN device with QPM period Λ = 32.2 μm.

References

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