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. Composite, All-Ceramics, High-Peak Power Nd:YAG/Cr^{4+}:YAG Monolithic Micro-Laser with Three-Beam Output for Engine Ignition

A passively Q-switched Nd:YAG/Cr^{4+}:YAG micro-laser with three-beam output was realized for multi-point ignition of an automobile engine as shown in Figure 1. A single active laser source made of a composite, all-ceramics Nd:YAG/Cr^{4+}:YAG monolithic cavity with a length of 10 mm was pumped by three independent lines. At 5 Hz repetition rate, each line delivered laser pulses with energy of 2.4 mJ and 850-ps pulse duration (2.8-MW peak power). The M^2 factor of a laser beam was 3.7, and stable air breakdowns were realized. The increase of pump repetition rate up to 100 Hz improved the laser pulse energy by 3% and required an increase of the pump pulse energy by only 5%. We confirmed that pulse timing of the laser-array beams could by adjusted by less than 5% tuning of an individual line pump energy, and then simultaneous multi-point ignition is possible.

Figure 1. Microchip laser with three-beam output.

2. Development of Megawatt-Peak-Power UV Microchip Laser

Megawatt peak power, giant pulse microchip lasers are attractive for wavelength conversion, provided their output is linearly polarized. We use a [110] cut Cr^{4+}:YAG for passively Q-switched Nd:YAG microchip laser to obtain a stable, linearly polarized output. Then, we optimize the conditions for second harmonic generation (SHG) using Lithium Triborate (LBO) to achieve > 6 MW peak power, 1.7 mJ, 265 ps, 100 Hz pulses at 532 nm wavelength with a conversion efficiency of 84.71%. Further, using β-Barium Borate (BBO) for fourth harmonic generation (FHG), we obtain > 2 MW peak power, 562 µJ, 260 ps, 100 Hz pulses at 266nm with 51.2% conversion efficiency as shown in Figure 2. These are world records for SHG and FHG using microchip lasers.

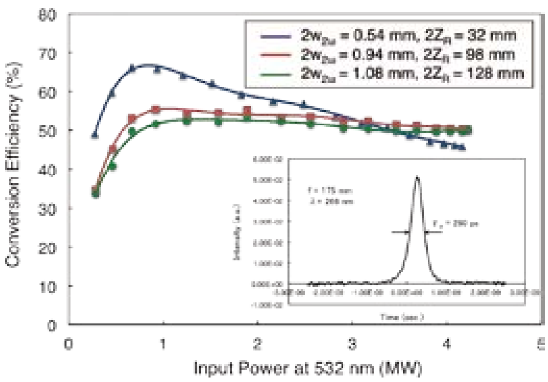

Figure 2. FHG conversion characteristics under different focusing conditions.

3. Variation of the Stimulated Emission Cross Section in Nd:YAG Caused by the Structural Changes of Russell-Saunders Manifolds

It was experimentally found that electronic structures of Russell-Saunders manifolds in Nd:YAG depended on the Nd^{3+}-doping concentration (C_{Nd}) and its fabrication process. Both of the bandwidth and the branching ratio in fluorescent transitions in Nd:YAG varied almost linearly depending on C_{Nd}, and a fabrication process has its own diluted limit of the bandwidth and the branching ratio. Also dependences of Stark splitting in Nd:YAG were also observed. As a result, Nd^{3+}-doping causes 1.9% and 4.5% reduction in the maximum value of the stimulated emission cross section (σ) of Nd:YAG per 1 at.% of C_{Nd} at 1.064 µm and 1.319 µm, respectively. Figure 3 shows the concentration dependence of σ in Nd:YAG at 1.064-µm (a) and 1.319-µm (b).

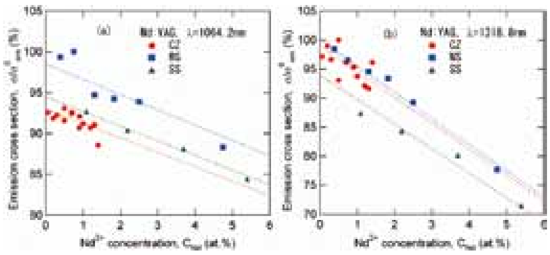

Figure 3. The ratio between σ to the Nd^{3+}-diluted limit (σ_{em}^0) of Nd:YAG at 1.064-µm (a) and 1.319-µm (b). Circle, triangle, and square indicate σ/σ_{em}^0 of CZ, SS, and WS, respectively.

4. Demonstration of Rare-Earth-Doped Anisotropic Ceramic Laser

We succeeded in developing a QCW-diode-pumped "anisotropic ceramic laser" by using micro-domain-controlled neodymium doped hexagonal fluorapatite [Nd_3:$Ca_{10}(PO_4)_6F_2$, Nd:FAP] polycrystalline ceramics as the gain medium, which were fabricated by the rare earth assisted magnetic grain-orientation control method, as a step toward achieving giant micro photonics. The laser delivers 1063.10 and 1063.22 nm output beams when pumped with a central wavelength of 807.5 nm and a 2 nm bandwidth diode laser operating in quasi-continuous-wave (QCW) mode. The resulting slope efficiency with respect to the absorbed power was 2.6% and the oscillation threshold was 12 W when uncoated 2 at.% Nd:FAP material was used as Figure 4.

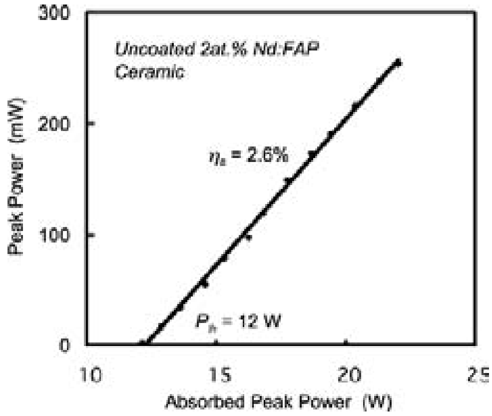

Figure 4. Nd:FAP QCW peak laser output power at 1.06 µm *versus* pump power at 807.5 nm. The pump pulse duration and repetition rate are 420 µs and 6 Hz.

5. PFabrication of Slant Quasi-Phase Matching Structure in Mg-Doped Congruent $LiNbO_3$

We fabricated slant quasi-phase-matching structure in 2-mm-thick Mg-doped $LiNbO_3$ crystal at 65° slant angle with 75-µm surface period as Figure 5. Slant QPM has a possibility of wafer-scale-aperture device, suitable for handling high power/energy lasers.

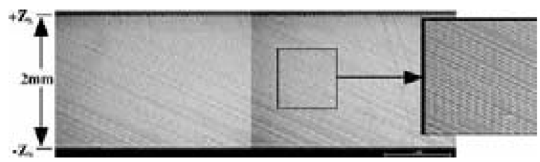

Figure 5. Y-face photograph of obtained slant QPM structure in 65° slant MgLN with thickness d_1 = 2 mm. Surface QPM period Λ_1 = 75 µm.

References

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