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-Power Operation of Diode Edge-Pumped, Composite All-Ceramic Yb: $Y_3Al_5O_{12}$ Microchip Laser

A solid-state laser material of composite all-ceramic Yb: $Y_3Al_5O_{12}$ is applied as a source of a high-power, diode edge-pumped microchip laser. 520 W quasi-continuous-wave and 414 W continuous-wave (cw) output powers were obtained from the 3.7-mm-diameter, Yb doped ceramic core with a 200 µm thickness. The cw output power densities of 3.9 kW/cm^2 and 0.19 MW/cm^3 in the core area and volume, respectively, are the highest for an active-mirror solid-state laser. The maximum thermal stress in the ceramic core is estimated to be 384 MPa at the non-cooled surface and is twice the tensile strength of single-crystal $Y_3Al_5O_{12}$. Figure 1 shows the input and output laser characteristics in quasi-cw (10 ms, 10 Hz) and cw operations of the composite all-ceramic Yb:YAG EPMCL.

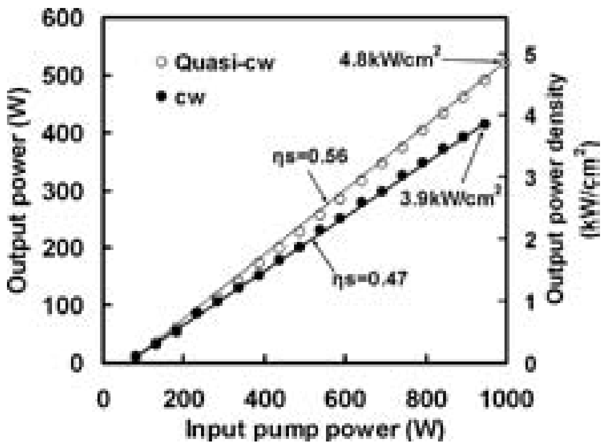

Figure 1. Incident pump power (peak) *vs.* laser output power (peak) of the edge-pumped all-ceramic EPMCL in quasi-cw and cw operations. The right axis shows output power density from the core area.

2. The Studies of Thermal Conductivity in $GdVO_4$, YVO_4, and $Y_3Al_5O_{12}$ Measured by Quasi-One-Dimensional Flash Method

We have measured thermal conductivity of $Y_3Al_5O_{12}$, $GdVO_4$, and YVO_4. In order to avoid the miss leading from three-dimensional (3D) thermal diffusion, we developed the quasi-one-dimensional (q1D) flash method. By taking in account the heat radiation effect in transparent materials for this measurement, YVO_4 was found to have larger thermal conductivity than $GdVO_4$. The measured thermal conductivities were 12.1, 10.5, 10.1, 8.9, and 8.5 W/mK for *c*-cut YVO_4, *c*-cut $GdVO_4$, YAG, *a*-cut YVO_4, and *a*-cut $GdVO_4$, respectively. The measured value in the range from room temperature to 200 °C is shown in Figure 2. The dependence of Nd-conductivity coefficient ($d\kappa/dC_{Nd}$) for convenient evaluation of the doping effect in thermal conductivity is also discussed.

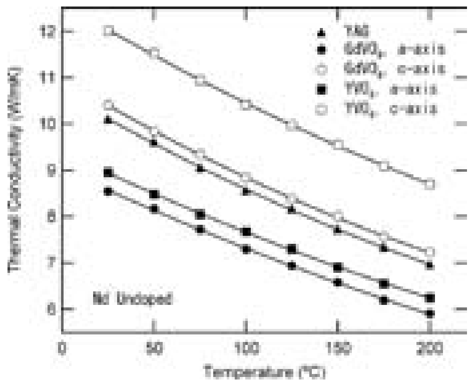

Figure 2. The measured value in the range from room temperature to 200 °C.

3. 52mJ Narrow-Bandwidth Degenerated Optical Parametric System with a Large-Aperture Periodically Poled MgO:LiNbO$_3$ Device

We have demonstrated efficient, high-energy, narrow-spectral-bandwidth 2.128μm pulse generation by use of periodically poled MgO:LiNbO$_3$ devices with a 36 mm length and 5 mm × 5 mm large aperture. A free-running degenerated optical parametric oscillator (OPO) pumped with a Q-switched 1.064μm Nd:YAG laser exhibits a high slope efficiency of 75% and an optical-to-optical conversion efficiency of 70% with a broad spectral bandwidth (> 100 nm). In a configuration with a spectrally narrowed master oscillator followed by a power amplifier, we have achieved an output pulse energy of 52 mJ with a spectral bandwidth of less than 2 nm at the degeneracy point. The total optical-to-optical conversion efficiency of the system reached 50%.

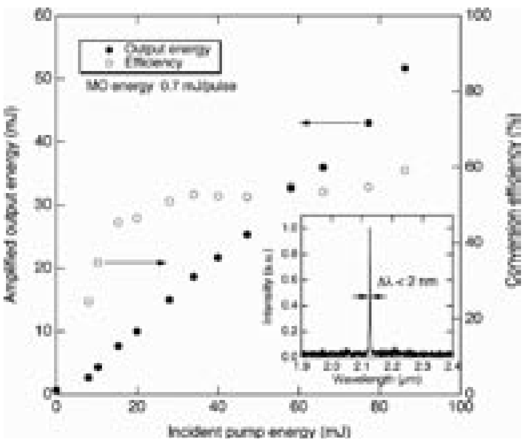

Figure 3. OPA output energy and conversion efficiency versus incident pump energy. The MO energy was 0.7 mJ/pulse. Closed circles, amplified pulse energy; open circles, conversion efficiency.

4. Tailored Spectral Designing of Layer-by-Layer Type Composite Nd:Y$_3$ScAl$_4$O$_{12}$/Nd:Y$_3$Al$_5$O$_{12}$ ceramics

We have fabricated the all-ceramic layered composite device with Nd:YAG and Nd:YSAG, which can perform efficient laser oscillation. From its spectroscopic properties, this layer-by-layer composite device will offer new function of laser oscillation by pump wavelength tuning. For example when pumped from YSAG side at 810.5 nm, it can oscillate at 1064 nm. On the other hand, it will oscillate at 1061 nm when pumped at 808.5 nm.

Due to the difference in the dependence on the wavelength of, the portion of the pumped power absorbed in Nd:YAG-layer and in Nd:YSAG-layer depends on the pumping wavelength. This resulted in the tuning of the component ratio of the Nd:YAG and Nd:YSAG in the fluorescence. The dependence of fluorescence profiles in this composite on the pump wavelength is shown in Figure. 4.

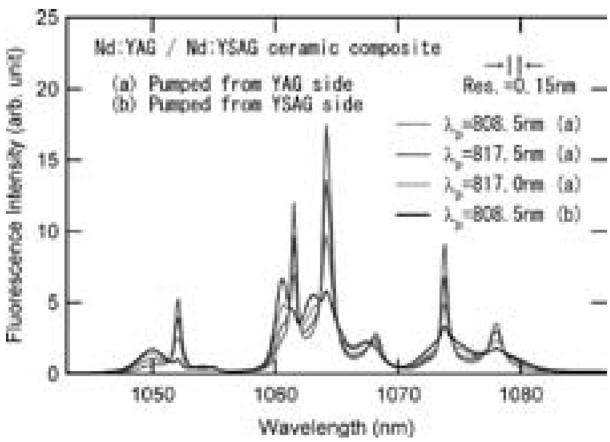

Figure 4. Measured fluorescent spectral profiles by changing pumping wavelength.

References

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