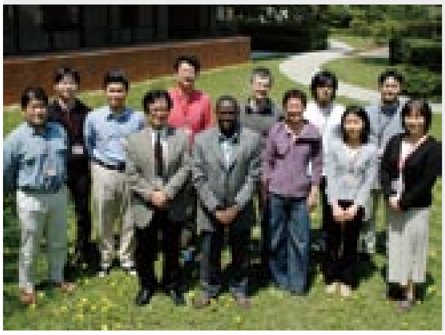
Micro Solid-State Photonics

Laser Research Center for Molecular Science
Division of Advanced Laser Development



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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.

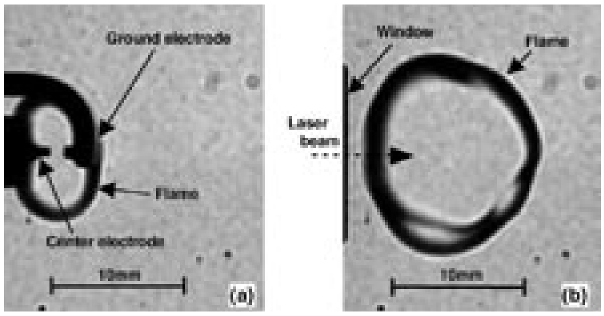

Figure 1. Schlieren photographs of the flame kernel ignited by a spark plug (a) and the micro-laser (b) in a constant volume combustion chamber at 6 ms after ignition trigger.

1. High Peak Power, Passively Q-Switched Cr:YAG/Nd:YAG Micro-Laser for Ignition of Engines

The diode longitudinally pumped, passively Q-switched Nd:YAG/Cr:YAG micro-laser was researched and developed for ignition of automobile's engines. The length of the micro-laser module is 61 mm, comparable to that of a spark plug. The maximum output pulse energy of 2.7 mJ and totally 11 mJ was obtained at the pump duration of 500 µs (70 mJ) of QCW LDs. The pulse width was measured 0.6 ns. The M^2 value was 1.2 and longitudinal mode of the laser was single. The brightness of the micro-laser was calculated 0.3 PW/sr-cm^2. It was understood that the cross-section area of the flame kernel generated by the laser is 3-times larger than a spark plug as shown in Figure 1. The accelerated development of flame kernel due to the absence of quenching effects by electrodes shortens ignition delay and combustion time, and will improve the efficiency of real engines.

2. High-Energy, Broadly Tunable, Narrow-Bandwidth Mid-Infrared Optical Parametric System Pumped by Quasi-Phase-Matched Devices

We have developed a tunable, narrow-bandwidth (< 2 cm^{-1}) mid-infrared (MIR) optical parametric system with a large-aperture periodically poled Mg-doped $LiNbO_3$ (LA-PPMgLN)-based high-energy pump source. The system has a continuously tunable tuning range from 4.6 to 11.2 µm and produces a maximum output energy of 2.0 mJ at 5.1 µm as shown in Figure 2. Practical use of the MIR source is demonstrated by MIR-UV double-resonance spectroscopy of jet-cooled acetanilide.

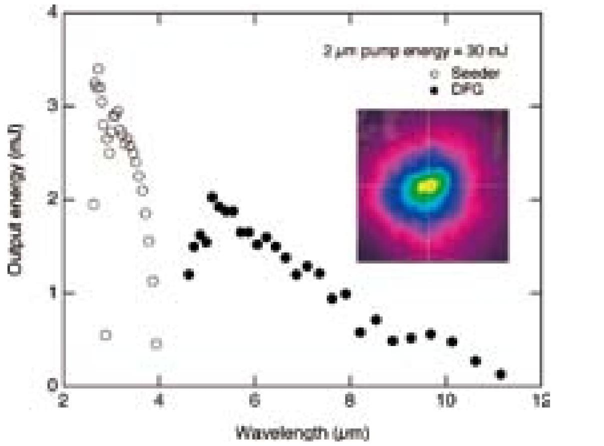

Figure 2. Tuning characteristics of the ZGP-DFG system (closed circle) and the LN-DFG system (open circle). Inset shows the intensity distribution of the ZGP-DFG system at 5.3 μm.

3. Mg-Doped Congruent $LiTaO_3$ Crystal for Large-Aperture Quasi-Phase Matching Device

We have characterized the crystal properties of Mg-doped congruent $LiTaO_3$ (MgLT), and demonstrated the first optical parametric oscillation experiment using periodically poled MgLT (PPMgLT) device. The MgLT could be a candidate for the material of high power quasi phase matching device because of the improved cut off wavelength and the decreased coercive field. The characteristics in the field poling of MgLT is similar to that of MgLN, and the coercive field of MgLT is enough low to realize a large-aperture PPMgLT device for high power applications as shown in Figure 3. We can expect the realization of several-mm-aperture PPMgLT device in near future.

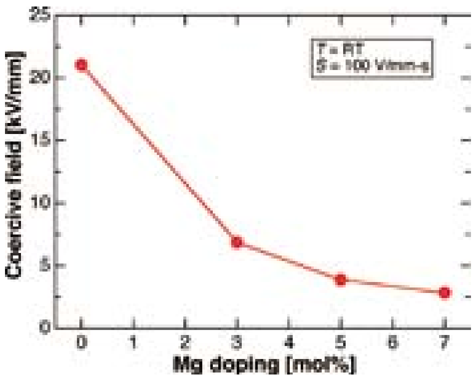

Figure 3. Coercive field of MgLT on Mg-doping (crystal temperature: T = RT, electric-field ramping rate : S = 100 V/mm-s).

4. Dependence of Rare-Earth Doped $Y_3Al_5O_{12}$ Ceramics on Doping Concentration: Electronic Structures of Host and Dopant

We have confirmed experimentally that there is severe dependence of spectral profiles of fluorescence emitted from neodymium doped $Y_3Al_5O_{12}$ (Nd:YAG) ceramics. Figure 4 shows the dependence of fluorescent spectral profile emitted from Nd:YAG on Nd^{3+}-doping concentration. It was found that there was a maximum line-shift of 2 cm^{-1} in fluorescence peaks from 1.0 at.% to 8.9 at.% Nd^{3+}-concentration (C_{Nd}). Maximum line broadening of 1.85 times was also detected due to heavily Nd^{3+}-doping. It directly indicates that heavily Nd^{3+}-doping makes the peaks of stimulated emission cross section.

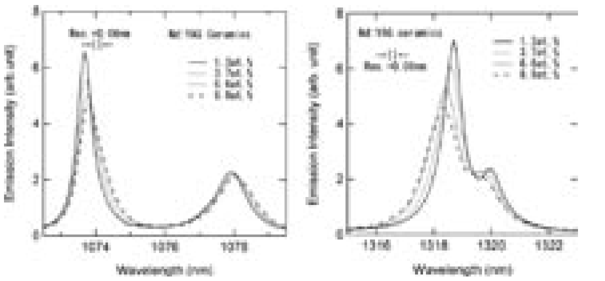

Figure 4. The dependence of fluorescent spectral profile emitted from Nd:YAG on Nd^{3+}-doping concentration. Heavily doping concentration causes both line shift and spectral-broadening.

References

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