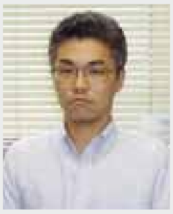
# Micro Solid-State Photonics

**Laser Research Center for Molecular Science**
**Division of Advanced Laser Development**

TAIRA, Takunori
Associate Professor



ISHIZUKI, Hideki
Assistant Professor

| | |
|---|---|
| TSUNEKANE, Masaki | Post-Doctoral Fellow |
| SATO, Yoichi | Post-Doctoral Fellow |
| KAUSAS, Arvydas | Post-Doctoral Fellow |
| BHANDARI, Rakesh | Post-Doctoral Fellow |
| ARZAKANTSYAN, Mikayel | Post-Doctoral Fellow |
| KONG, Weipeng | Graduate Student |
| ONO, Yoko | Secretary |
| INAGAKI, Yayoi | Secretary |


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 Peak Power, Passively Q-Switched Yb:YAG/Cr:YAG Micro-Lasers

High peak power (>MW), passively Q-switched Yb:YAG/Cr:YAG micro-laser end-pumped by fiber-coupled 120 W QCW LDs (Repetition rate < 100 Hz) was developed. The convex output coupler with a curvature of 2 m successfully enlarged the fundamental mode size in the micro-laser cavity, and the output pulse energy increased to 3.6 mJ at a Cr:YAG initial transmission of 89% without optical damage. The $TEM_{00}$ transverse mode and the single-frequency oscillation were confirmed. The pulse duration was 1.3 ns, and then the peak power was estimated as 2.8 MW. To our knowledge, these are the highest pulse energy and peak power ever reported in Yb:YAG/Cr:YAG micro-lasers.

## 2. Palm-Top Size Megawatt Peak Power UV (266 nm) Microlaser

We have developed of a very compact, highly efficient, megawatt peak power, sub-nanosecond pulse width, 266 nm ultraviolet (UV) microlaser.

It contains a specially designed passively Q-switched Nd:YAG/$Cr^{4+}$:YAG microchip laser whose high output peak power of 13 MW enables efficient wavelength conversion without using any optics before the nonlinear crystals. The sub-nanosecond pulse width region, which delivers high peak power of several MW even for a moderate pulse energy of a few mJ, is very useful for efficient wavelength conversion.

We achieved 73% second harmonic generation efficiency using a $LiB_3O_5$ (Lithium Triborate, LBO) crystal and 45% fourth harmonic generation efficiency using a $\beta$-$BaB_2O_4$ ($\beta$-barium borate, BBO) crystal. As a result, we obtained 650 µJ, 4.3 MW peak power, 150 ps, 100 Hz pulse output at 266 nm. We used an original design for the nonlinear crystal holders to reduce the size of the microlaser.

This palm-top size 266 nm UV microlaser will be useful for many applications, such as, photoionization, UV laser induced breakdown spectroscopy (LIBS), pulsed laser deposition and materials microprocessing.

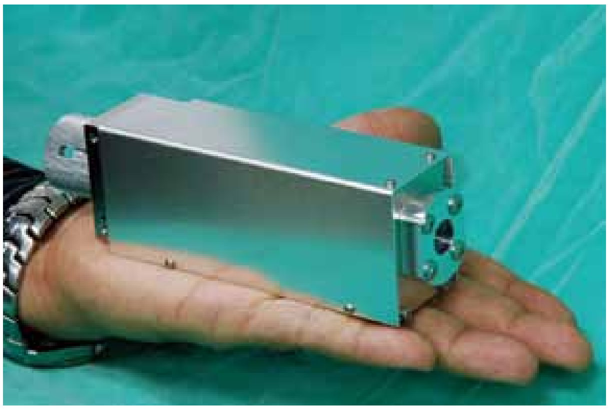


**Figure 1.** Palm-top size 266 nm UV microlaser.

## 3. Fundamental Investigations in Orientation Control Process for Anisotropic Laser Ceramics

We developed theoretical studies on the orientation control of micro-domains in anisotropic laser ceramics. The direction of the crystal axis that is parallel to easy magnetization in each micro-domain can be aligned via two steps of fabrication processes.

In the first step the alignment is performed during the slip-casting under the magnetic field, where directions of easy magnetization in primary particles are forced to align along applied magnetic field. The further orientation control can be processed by the preferential grain growth, where an adequate orientation distribution of primary articles in the casted green body is required for the nearly perfect alignment in sintered ceramics.

However, even though rare-earth trivalent ions doped into primary particles as luminous ions enhance their magnetic moment, the perfect alignment control is not always possible due to Brownian fluctuations by slurry solvent at this stage. By means of the distribution function for the crystal orientation in micro-domains under magnetic field, we confirmed the improvement in the orientation distribution contributed by preferential grain growth from detailed XRD analyses.

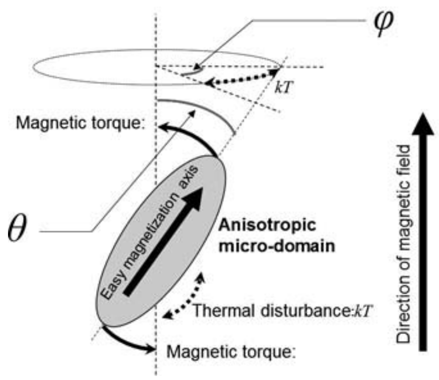



**Figure 2.** Conceptual diagram for the orientation control of anisotropic laser ceramics. Angle θ and φ are the angle between the control axis and the direction of easy magnetization axis and the precession angle of the micro-domain, respectively.

## 4. Half-Joule Output Optical-Parametric Oscillation by Using 10-mm-Thick PPMgLN Device

We presented a next generation of large-aperture periodically poled Mg-doped $LiNbO_3$ (PPMgLN) device with 10-mm thickness. Efficient optical parametric oscillation with 540 mJ output energy at 709 mJ pumping by 1.064 μm laser in 10 ns operation could be demonstrated using the 10-mm-thick PPMgLN with an inversion period of 32.2 μm at total conversion efficiency > 76%. We also confirmed that degradation effect of conversion-efficiency distribution by wedged inversion structures, which is inevitable in current poling condition of the large-aperture PPMgLN, can be ignored in high-intensity operation.

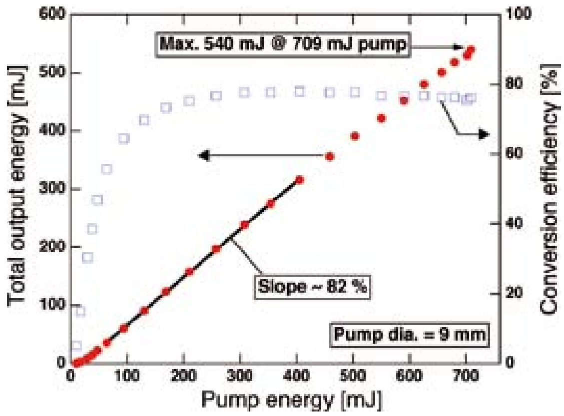



**Figure 3.** Characteristics of 10 nanoseconds OPO by using 10-mm-thick PPMgLN device.

### References


1) M. Tsunekane and T. Taira, *IEEE J. Quantum Electron.* **49**, 454–461 (2013).
2) R. Bhandari and T. Taira, *Opt. Eng.* **52**, 076102 (6 pages) (2013).
3) Y. Sato, J. Akiyama and T. Taira, *Phys. Status Solidi C* **10**, 896 (2013), Y. Sato, J. Akiyama and T. Taira, *Opt. Mater. Express* **3**, 829 (2013).
4) H. Ishizuki and T. Taira, *Opt. Express* **20**, 20002–20010 (2012).