Micro Solid-State Photonics

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"*Micro Solid-State Photonics*," based on the micro domain structure and boundary controlled materials, opens new horizon in the laser science. The engineered materials of micro and/or microchip solid-state, ceramic and single-crystal, lasers can provide excellent spatial mode quality and narrow linewidths with enough power. High-brightness nature of these lasers has allowed efficient wavelength extension by nonlinear frequency conversion, UV to THz wave generation. Moreover, the quasi phase matching (QPM) is an attractive technique for compensating phase velocity dispersion in frequency conversion. The future may herald new photonics.

Giant pulse > 10 MW was obtained in 1064nm microchip lasers using micro-domain controlled materials. The world first laser ignited gasoline engine vehicle, giant-pulse UV (355 nm, 266 nm) and efficient VUV (118 nm) pulse generations have been successfully demonstrated. Also, few cycle mid-IR pulses for atto-second pulses are demonstrated by LA-PPMgLN. We have developed new theoretical models for the micro-domain control of anisotropic laser ceramics. These functional micro-domain based highly brightness/brightness-temperature compact lasers and nonlinear optics, so to speak "Giant Micro-photonics," are promising. Moreover, the new generation of micro and/or microchip lasers by using orientation-controlled advanced ceramics can provide extreme high performances in photonics.

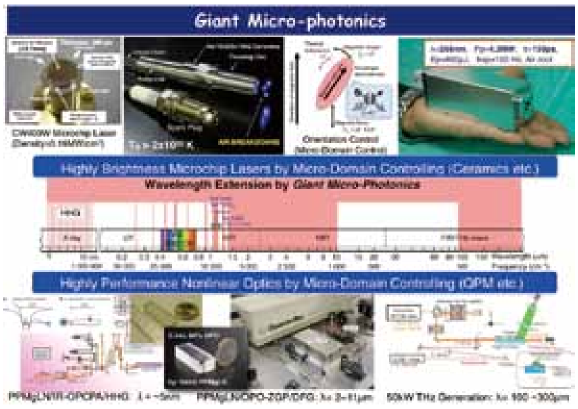

Figure 1. Giant micro-photonics.

Selected Publications

- H. Sakai, H. Kan and T. Taira, ">1 MW Peak Power Single-Mode High-Brightness Passively Q-Switched Nd^{3+}:YAG Microchip Laser," *Opt. Express* **16**, 19891–19899 (2008).
- M. Tsunekane, T. Inohara, A. Ando, N. Kido, K. Kanehara and T. Taira, "High Peak Power, Passively Q-Switched Microlaser for Ignition of Engines," *IEEE J. Quantum Electron.* **46**, 277–284 (2010).
- T. Taira, "Domain-Controlled Laser Ceramics toward Giant Micro-Photonics," *Opt. Mater. Express* **1**, 1040–1050 (2011).
- H. Ishizuki and T. Taira, "Half-Joule Output Optical-Parametric Oscillation by Using 10-mm-Thick Periodically Poled Mg-Doped Congruent $LiNbO_3$," *Opt. Express*, **20**, 20002–20010 (2012).
- R. Bhandari, N. Tsuji, T. Suzuki, M. Nishifuji and T. Taira, "Efficient Second to Ninth Harmonic Generation Using Megawatt Peak Power Microchip Laser," *Opt. Express* **21**, 28849–28855 (2013).

1. Timing Jitter Control of a Passively Q-Switched Nd:YVO$_4$/Cr^{4+}:YAG Laser by the Use of a Coupled Cavity

Timing jitter was measured in Nd:YVO$_4$/Cr:YAG passively Q-switched laser. Primary results with coupled cavity as shown in Figure 2 showed reduction of timing jitter by one order of magnitude down to 450 ns (2σ value), 40 μJ pulse energy and 2.5 ns pulse duration.

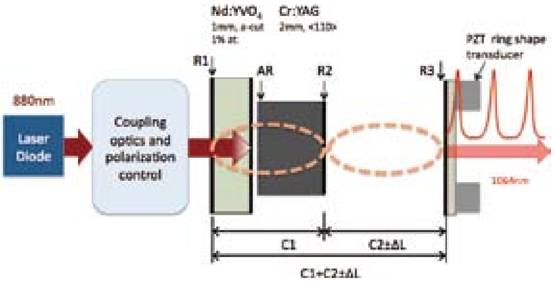

Figure 2. Schematic view of the Nd:YVO$_4$/Cr^{4+}:YAG passively Q-switched laser.

2. Highly Accurate Interferometric Evaluation of Thermal Expansion and *dn*/*dT* of Optical Materials

Thermo-mechanical and -optical properties of $Y_3Al_5O_{12}$ (YAG), YVO$_4$, and GdVO$_4$ were evaluated with high accuracy. Evaluation procedure that was established by authors enabled to suppress evaluation errors less than 2%, by means of the detection of temperature deviations in interferometric fringes on transmittance as shown in Figure 3.

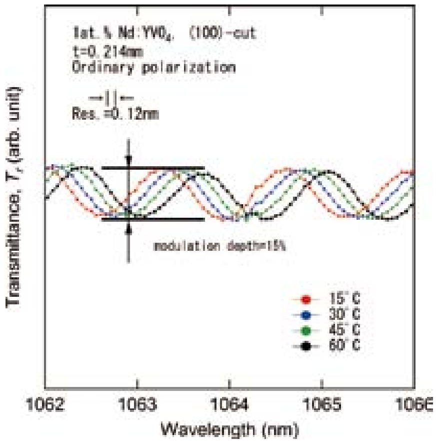

Figure 3. Temperature dependence of interferometric fringes in Nd:YVO$_4$.

Measured thermal expansion coefficient for YAG, [100]-YVO$_4$, [001]-YVO$_4$, [001]-GdVO$_4$, and [001]-GdVO$_4$ were 6.13, 1.76, 8.24, 1.19, and 7.26 × 10^{-6}/K at room temperature. Temperature coefficients of refractive index for YAG, YVO$_4$ in ordinary and extraordinary polarization, and GdVO$_4$ in ordinary and extraordinary polarization at room temperature for the wavelength of 1.06 μm were 12.1, 15.5, 8.41, 15.2, and 9.92 × 10^{-6}/K, respectively.

This work was ranked the fourth place in TOP-10 downloaded articles in June 2014 from OSA's Optical Materials Express.

3. Improvement of Laser-Beam Distortion in Large-Aperture PPMgLN Device by Using *X*-Axis Czochralski-Grown Crystal

Large-aperture periodically poled Mg-doped LiNbO$_3$ device using *X*-axis Czochralski-grown MgLN crystal was proposed to avoid a laser-beam distortion problem, as shown in Figure 4. Availability of periodic poling in 5-mm-thick MgLN and compatibility of wavelength-conversion characteristics in QPM-OPO were evaluated by comparing with conventional arrangement using *Z*-axis-grown crystal.

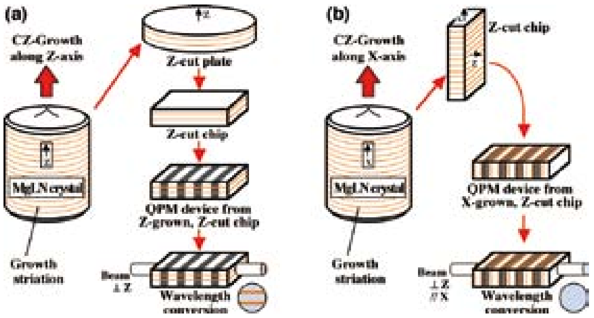

Figure 4. PPMgLN device fabricated from (a) *Z*-axis CZ-grown crystal, and (b) *X*-axis CZ-grown crystal.

References

1) A. Kausas and T. Taira, *The 61st JSAP spring meeting*, 18p-PA3-3 (March 17–20, 2014).
2) Y. Sato and T. Taira, *Opt. Mater. Express* **4**, 876–888 (2014).
3) H. Ishizuki and T. Taira, *Opt. Express* **22**, 19668 (2014).

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