RESEARCH ACTIVITIES

Division of Research Innovation and Collaboration

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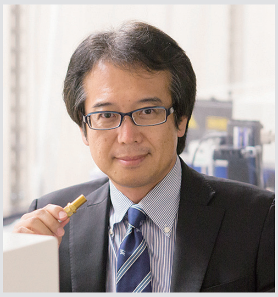
Micro Solid-State Photonics

Division of Research Innovation and Collaboration



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Education
1983 B.A. Fukui University
1985 M.S. Fukui University
1996 Ph.D. Tohoku University

Professional Employment
1985 Researcher, Mitsubishi Electric Corp.
1989 Research Associate, Fukui University
1993 Visiting Researcher, Stanford University (–1994)
1998 Associate Professor, Institute for Molecular Science
Associate Professor, The Graduate University for Advanced Studies
2018 Group Director, RIKEN SPring-8 Center
2019 Project Professor, Institute for Molecular Science

Awards
2004 Persons of Scientific and Technological Research Merits, Commendation by Minister of Education, Culture, Sports, Science and Technology, Japan
2010 OSA Fellow Award, The Optical Society (OSA)
2012 SPIE Fellow Award, The International Society for Optical Engineering (SPIE)
2014 IEEE Fellow Award, The Institute of Electrical and Electronics Engineers (IEEE)
2018 IAPLE (The International Academy of Photonics and Laser Engineering) Fellow
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Keywords Solid-State Lasers, Nonlinear Optics, Micro Solid-State Photonics

"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: The world first laser ignited car, highly efficiency broad frequency conversions from the wavelength of 118nm VUV until 300–500µm THz waves, and so on. In addition, the quasi phase matching (QPM) is an attractive technique for compensating phase velocity dispersion in frequency conversion. Lately, we propose a new architecture to realize a monolithic multi-disk laser by the surface activated bonding (SAB). This multiple thin-disk or chip gain medium for distributed face cooling (DFC) structure can manage the high-power and high-field laser with high-gain compact system. Besides, QPM-structured crystal quartz constructed by multi-plate stacking could be promising as a high-power and reliable VUV frequency conversion devices. These downsized and modularized **tiny integrated lasers** (TILA) promise the extremely high-brightness lasers to open up the new science, such as laser driven electron accelerator toward table-top XFEL, and innovation by the compact power laser (Figure 1).

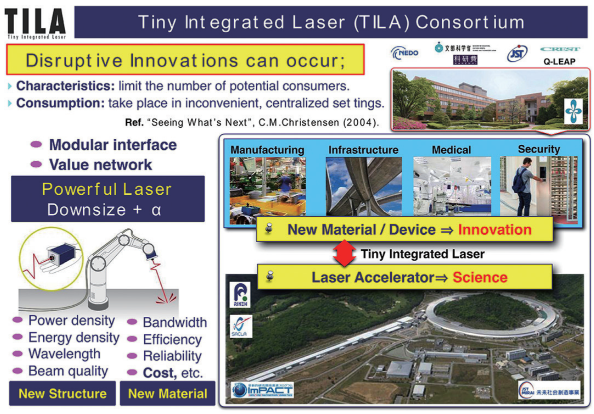

Figure 1. TILA consortium toward "Laser Science and Innovation" by micro solid-state photonics.

Selected Publications

- T. Taira *et al.*, *Opt. Lett.* **16**, 1955 (1991).
- T. Taira *et al.*, *IEEE J. Sel. Top. Quantum Electron.* **3**, 100 (1997).
- T. Taira, *IEEE J. Sel. Top. Quantum Electron.* **13**, 798 (2007).
- T. Taira, *Opt. Mater. Express* **1**, 1040 (2011).
- Y. Sato *et al.*, *Sci. Rep.* **7**, 10732 (2017).
- H. Sakai *et al.*, *Opt. Express* **16**, 19891 (2008).
- M. Tsunekane *et al.*, *IEEE J. Quantum Electron.* **46**, 277 (2010).
- T. Taira *et al.*, *The 1st Laser Ignition Conference '13, OPIC '13, Yokohama, April 23-26*, LIC3-1 (2013).
- R. Bhandari *et al.*, *Opt. Express* **21**, 28849 (2013).
- S. Hayashi *et al.*, *Sci. Rep.* **4**, 5045 (2014).
- L. Zheng *et al.*, *Opt. Mater. Express* **7**, 3214 (2017).
- H. Ishizuki *et al.*, *Opt. Mater. Express* **8**, 1259 (2018).
- N. H. Matlis *et al.*, *Nucl. Instrum. Methods Phys. Res., Sect. A* **909**, 27 (2018).
- S.W. Jolly *et al.*, *Nat. Commun.* **10**, 1 (2019).

1. Polarity Inversion of Crystal Quartz Using a Quasi-Phase Matching Stamp[1)]

Stress-induced polarity inversion of crystal quartz using a quasi-phase matching (QPM) stamp is proposed for a QPM frequency conversion quartz device (Figure 2). Fabrication of QPM structure in x-cut quartz plate could be realized using the periodically patterned QPM stamp. Also, second-harmonic 532 nm generation with 16.8 kW peak intensity was demonstrated using a QPM quartz device with QPM period of 124 μm (3rd-order QPM) to confirm its polarity-inverted structure (Figure 3).

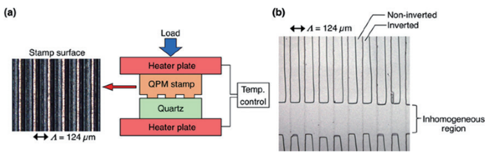

Figure 2. (a) Set up for the QPM stamp method, (b) Etched periodic pattern in *x*-cut plate.

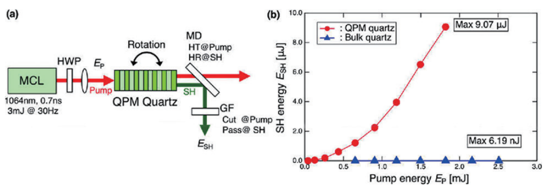

Figure 3. (a) Set up for SHG experiment, (b) SHG characteristics using a QPM quartz.

2. High Peak-Power Near-MW Laser Pulses by Third Harmonic Generation at 355 nm in $Ca_5(BO_3)_3F$ Nonlinear Single Crystals[2)]

In this work, the performance of $Ca_5(BO_3)_3F$ (CBF) single crystals (Figure 4) was investigated for the third harmonic generation at 355 nm. A high energy conversion efficiency of 16.9% at 355 nm was reached using a two-conversion-stage setup. First, using a high peak power, passively Q-switched Nd^{3+}:YAG/Cr^{4+}:YAG microlaser based gain aperture in micro-MOPA, the second harmonic at 532 nm was achieved with lithium triborate (LBO) crystal, reaching 1.35 MW peak power. On a second step, laser pulses at 355 nm were generated using a 5 mm-long CBF crystal growth by TSSG method with energy, pulse duration and peak power of 479 μJ, 568 ps and 0.843 MW, respectively (Figure 5). These results are currently the highest reported for CBF material.

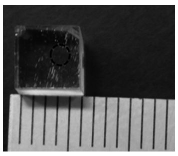

Figure 4. $Ca(BO_3)_3F$ crystal growth by TSSG method using 20 wt% LiF flux.

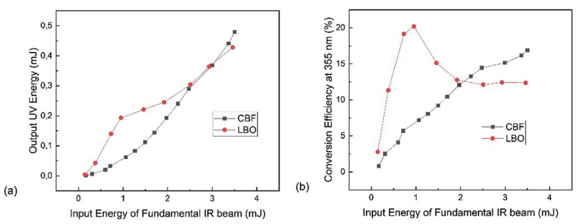

Figure 5. Experimental data on THG for uncoated CBF crystal and comparison with LBO crystal (anti-reflection coating) in terms of output UV energy (a) and of conversion efficiency (b).

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3. Remote Laser Analysis Technique in Harsh Environment[3,4)]

In this study, a compact fiber-optic laser-induced breakdown spectroscopy (LIBS) system was developed using a microchip laser (MCL) with a monolithic Nd:YAG/Cr:YAG composite ceramic, for remote analysis of hazardous environments, such as nuclear reactor cores (Figure 6). Short duration laser pulses exhibiting a near-Gaussian beam profile were obtained. The output properties of the laser, such as pulse energy, repetition rate, temporal shape, and beam profile, were measured in view of their applicability to LIBS analysis and were found suitable for the purpose of this research (Figure 7). Spectra of zirconium metal were obtained, and signal intensity was further enhanced by applying multi-burst mode irradiation to the target. The results of this study reveal that the fiber-optic microchip-laser induced breakdown spectroscopy system is advantageous for efficient remote analysis of hazardous environments and is suitable for analyzing the inside of nuclear reactor cores.

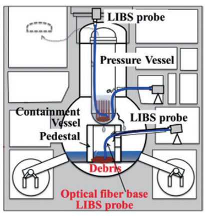

Figure 6. Concept of remote laser analysis technique (LIBS) in harsh environment, such as nuclear reactor cores of Fukushima.

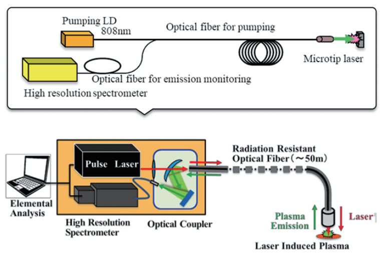

Figure 7. Instead of high power laser fiber delivering system, we have developed a fiber-optic microchip-laser induced breakdown spectroscopy system for efficient remote analysis of hazardous environments.

References

1) H. Ishizuki and T. Taira, *Opt. Express* **28**, 6505 (2020).
2) F. Cassouret, A. Kausas, V. Yahia, G. Aka, P. Loiseau and T. Taira, *Opt. Express* **28**, 10524 (2020). DOI: 10.1364/OE.384281
3) K. Tamura, H. Ohba, M. Saeki, T. Taguchi, H. H. Lim, T. Taira and I. Wakaida, *J. Nucl. Sci. Technol.* **57(10)**, 1189–1198 (2020). DOI: 10.1080/00223131.2020.1776648
4) H. Ohba, I. Wakaida and T. Taira., *ATOMOΣ (The Atomic Energy Society of Japan)*, **62(5)**, 263 (2020).