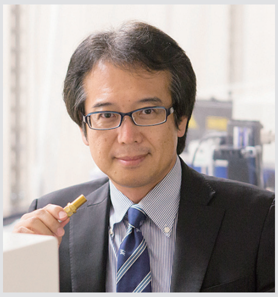
RESEARCH ACTIVITIES

Division of Research Innovation and Collaboration

As the open innovation hub managed by IMS and companies, we conduct the research projects in collaboration with Academia, Industry and Government.

Micro Solid-State Photonics

Division of Research Innovation and Collaboration



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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
2023 Invited Professor, National Institute for Fusion Science
2023 Director, The Amada Foundation

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. With the engineered materials of micro ceramic and single-crystal, solid-state lasers can provide excellent spatial mode quality and narrow linewidths with enough power. The high brightness of these lasers has allowed efficient wavelength extension by nonlinear frequency conversion: The world first laser-ignited car, high efficiency broad frequency conversions from the wavelength of 118nm VUV to 300μm– 1mm THz waves, and so on. In addition, the quasi phase matching (QPM) is an attractive technique for compensating phase velocity dispersion in frequency conversion and is a foundational technology for, *e.g.*, attosecond pulse generation (https://www.nobelprize.org/prizes/physics/2023/krausz/prize-presentation/). 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).

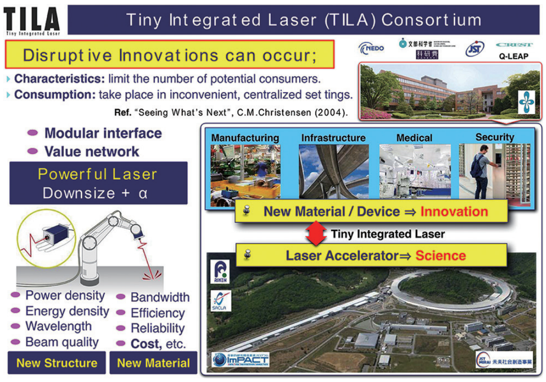

Figure 1. TILA consortium toward "Laser Science and Innovation" by micro solid-state photonics.

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).
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- F. Krausz *et al.*, *Opt. Lett.* **37**, 4973 (2012).
- 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).
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- L. Zheng *et al.*, *Opt. Mater. Express* **7**, 3214 (2017).
- H. Ishizuki *et al.*, *Opt. Mater. Express* **8**, 1259 (2018).
- S.W. Jolly *et al.*, *Nat. Commun.* **10**, 1 (2019).
- K. Tamura *et al.*, *J. Nucl. Sci. Technol.* **58**, 405 (2020).
- Y. Sano *et al.*, *Forces in Mechanics* **7**, 100080 (2022).

1. Widely Tunable Near-Infrared Optical Parametric Oscillator Based on a 5%MgO:PPLN Partial Cylinder Pumped at 1064 nm by a 1-kHz Sub-Nanosecond Microchip Laser[1)]

We report the implementation of a singly resonant optical parametric oscillator using a 5%MgO:PPLN (periodically poled Mg-doped $LiNbO_3$) partial cylinder pumped by a sub-nanosecond microchip laser emitting 1064 nm at a repetition rate of 1 kHz. It is continuously tunable from 1410 nm up to 4330 nm by rotating the cylinder and a total energy of several microjoules is emitted with a beam quality factor M^2 lower than 3.

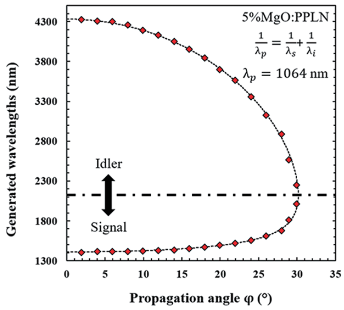

Figure 2. Angular quasi-phase-matching tuning curve of the PPMgLN cylindrical OPO. The horizontal line at 2128 nm stands for degeneracy.

2. Recovery of the Laser-Induced Breakdown Spectroscopy System Using a Ceramic Microchip Deteriorated by Radiation for the Remote Elemental Analysis[2)]

The radiation-induced deterioration of ceramic microchip laser properties limits the applications of laser-induced breakdown spectroscopy (LIBS) systems. The deteriorated properties were recovered through thermal treatment of ceramics as derived by the spectroscopic comparison of ceramics and single crystals (SCs). The absorption in spectra was increased by gamma rays irradiation, which was higher for the ceramics than for the SCs in the infrared radiation region. Although the amount of absorption decreased by heating and increased via cooling ceramics, no significant thermal effects were observed for the SCs. The effects of irradiation on the laser properties of ceramics were examined, and the laser pulse energy loss was well recovered via heating. Although heating reduced the number of generated pulses and affected the burst-mode measurement, the reduction was recovered by increasing the pump laser power. Because the radiation-induced deterioration of the LIBS signal for single-pulse and multiburst mode measurements was well recovered, the procedures are considered effective for the application of LIBS systems using radiation-sensitive ceramics, particularly in harsh radiation environments.

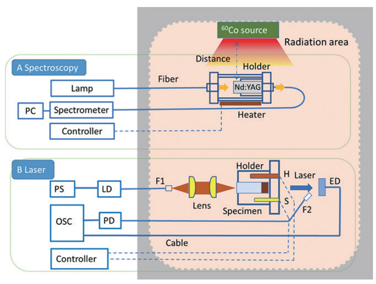

Figure 3. Experimental setup for spectroscopy (A: Spectroscopy), and laser properties measurement (B: Laser). Controller: temperature controller; ED: energy detector; H, Heater: heater; Holder: specimen holder; OSC: oscilloscope; PD 1,2: photodiode; PS: power supply; and S: temperature sensor.

3. >70 MW Peak Power/100 Hz Unstable Cavity Microchip Laser[3)]

We have demonstrated a flat-convex unstable cavity Nd:YAG/Cr^{4+}:YAG ceramic air-cooled microchip laser (MCL) generating a record 37.6 and 59.2 MW peak power pulses with an energy of 17.0 and 24.1 mJ and a width of 452 and 407 ps at 20 Hz by using a uniform power square and hexagon pump, respectively. For hexagon pump, the near field hexagon donut beam was changed in to a Bessel-like beam in far field, whose beam quality was estimated as M^2 of 7.67. The brightness scale of unstable resonator MCL was up to 88.9 TW/(sr·cm^2) in contrast with flat–flat cavity MCL. However, the intense central part of Bessel-like beam increased its brightness effectively more than 8 times, up to 736 TW/(sr·cm^2).

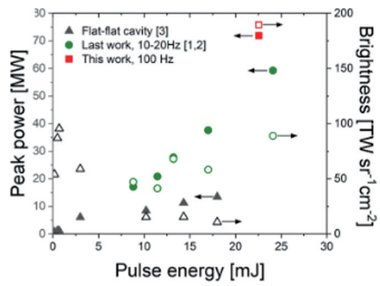

Figure 4. Measured peak power and brightness as a function of pulse energy. The recent results (square) were compared with last results using unstable cavity (circle) [1,2] and flat-flat cavity (triangle) [3]. ([1] *Opt. Express* **27**, 31307 (2019), [2] *Opt. Express* **30**, 5151 (2022), [3] Reference 14–19 of [2])

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1) B. Bruneteau, P. Segonds, H. Ishizuki, T. Taira, B. Boulanger *et. al.*, *Opt. Lett.* **48**, 3669 (2023).

2) K. Tamura, R. Nakanishi, H. Ohba, T. Taira and I. Wakaida, *J. Nucl. Sci. Technol.* **60**, 175–184 (2023).

3) H. H. Lim and T. Taira, *The 25th Congress of the International Commission for Optics (ICO-25), Technische Universität Dresden, Dresden, Germany, September 5-9*, TS 1-7-04 (2022). (Post-Deadline Paper)

* RIKEN SPring-8 Center

† IMS International Internship Program