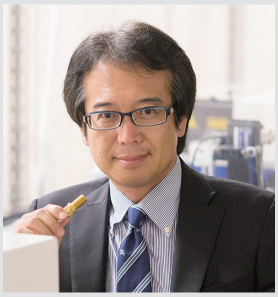
Micro Solid-State Photonics

Division of Research Innovation and Collaboration



TAIRA, Takunori
Project Professor
[taira@ims.ac.jp]

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
2019 LSJ (The Laser Society of Japan) Fellow

Member

Program Manager
SANO, Yuji
TAKIGAMI, Hiroyuki*
Associate Program Manager
SUMIYA, Rie
SUZUKI, Masayo
UEGURI, Atsushi
YOSHIOKA, Takashi
Visiting Professor
KAWASE, Kodo
Visiting Associate Professor
YOSHIDA, Mitsuhiro
Post-Doctoral Fellow
TAKEYA, Kei
ISHIZUKI, Hideki
SATO, Yoichi
YAHIA, Vincent
LIM, Hwanhong
TSUJI, Akihiro
ICHII, Tomoaki
MURATE, Kosuke
Research Fellow
KAUSAS, Arvydas
Visiting Scientist
MOREIRA, Joel†
Technical Fellow
MATSUDA, Miho*
KOBAYASHI, Jun
MIZUSHIMA, Kazuhiko
IBUKI, Takeshi*
JUNG, Heeseob*
Secretary
ONO, Yoko
INAGAKI, Yayoi
OKUHARA, Norie*

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 ceramic and single-crystal, solid-state 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 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. 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).

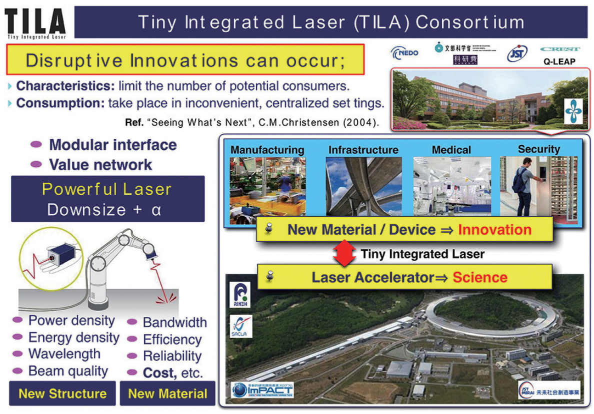


Figure 1. TILA consortium toward "Laser Science and Innovation" by micro solid-state photonics.

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. Laser-Induced Damage Study of Bonded Material for a High-Brightness Laser System[1]

We evaluated the laser-induced damage threshold (LIDT) of the interface between two identical YAG crystals, bonded by an inter-layer assisted surface activated bonding (il-SAB) method. The experimental results indicate slight damage threshold degradation for both single- and polycrystalline trivalent rear-earth (RE^{3+})-ion-doped YAG gain media in the sub-nanosecond pulse regime. Moreover, crystal annealing prior to damage testing could provide additional improvement for the laser damage threshold of the bulk and bonded interface.

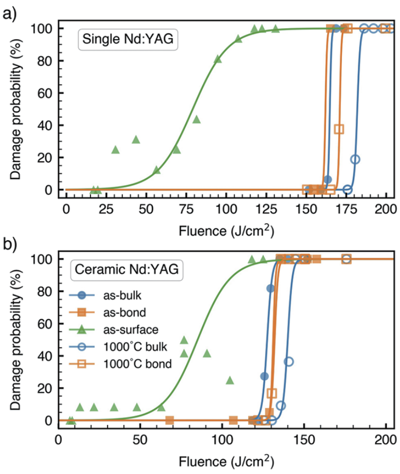


Figure 2. LIDT data for (a) single crystal and (b) ceramic Nd:YAG materials. Both experimental data (points) and fitting (lines) for surface (green), bulk (blue), and bonded interface (orange) are shown. Each data point on the graph represents 16 and 12 measurements for the single crystal and ceramic Nd:YAG, respectively.

2. Development of a Portable Laser Peening Device and Its Effect on the Fatigue Properties of HT780 Butt-Welded Joints[2]

Laser peening (LP) is a well-established technique for introducing compressive residual stress (RS) near the surface of metal components, to improve their high-cycle fatigue properties. The authors have developed a compact LP device with a thumb-sized Nd:YAG microchip laser mounted on a collaborative robot arm. The device was applied to 9-mm-thick HT780 high-strength steel plate samples with irradiated pulse energies of 7.5–8.0 mJ, spot sizes of 0.42–0.58 mm and pulse densities of 100–1,600 pulses/mm^2. X-ray diffraction showed that the maximum compressive RS was over 500 MPa near the surface, and the LP effect reached a depth of approximately 0.1 mm from the surface. Butt-welded HT780 samples were laser-peened with a pulse energy of 7.7 mJ, spot size of 0.49 mm and pulse density of 800 pulses/mm^2. Then, the samples were subjected to a uniaxial fatigue test with a stress ratio of 0.1. The results showed that the fatigue strength at 107 cycles was improved by at least 50 MPa, comparable to the improvement attained by LP in a previous study with a pulse energy of 200 mJ from a conventional Nd:YAG laser.

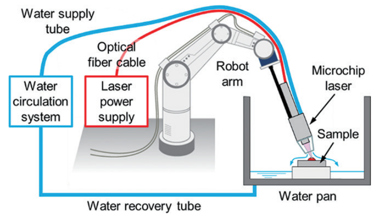


Figure 3. Configuration of the portable laser peening device with an Nd:YAG microchip laser.

3. >50 MW Peak Power, High Brightness Nd:YAG/Cr^{4+}:YAG Microchip Laser with Unstable Resonator[3]

We 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 2nd moment M^2 of 7.67. The brightness scale of unstable resonator MCL was achieved up to 88.9 TW/(sr·cm^2) in contrast with flat-flat cavity MCL. However, the high intense center part of Bessel-like beam increased its brightness effectively more than 8 times, up to 736 TW/(sr·cm^2).

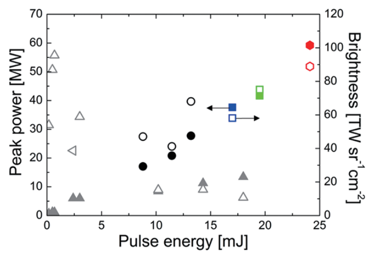


Figure 4. New record peak powers of 37.6, 41.7, and 52.9 MW of Nd:YAG/Cr^{4+}:YAG microchip laser (MCL) using uniform power pump. Successful brightness scale of unstable cavity MCL up to 88.9 TW/(sr·cm^2) in contrast to flat-flat cavity, promising further brightness scale up.

References

1) A. Kausas and T. Taira, *Opt. Lett.* **47**, 3067 (2022).
2) Y. Sano, T. Kato, Y. Mizuta, S. Tamaki, K. Yokofujita, T. Taira, T. Hosokai and Y. Sakino, *Forces in Mechanics* **7**, 100080 (2022).
3) H. H. Lim and T. Taira, *Opt. Express* **30**, 5151 (2022). DOI: 10.1364/OE.450335

* RIKEN SPring-8 Center
† IMS International Internship Program