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
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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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"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).

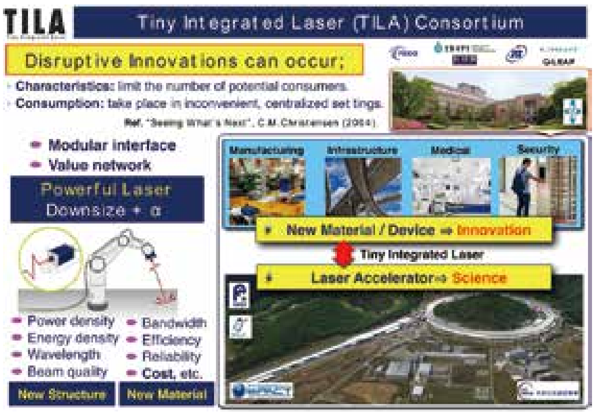

Figure 1. TILA consortium toward "Laser Science and Innovation" by micro solid-state photonics.

Selected Publications

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- S.W. Jolly *et al.*, *Nat. Commun.* **10**, 1 (2019).

1. High Peak Power Nd:YAG/Cr:YAG Ceramic Microchip Laser with Unstable Resonator[1)]

A doughnut mode microchip laser was demonstrated by introducing a monolithic ceramic Nd:YAG/Cr^{4+}:YAG chip in an unstable resonator to deliver laser pulses with an energy of 13.2 mJ and a pulse width of 476 ps, corresponding to a record peak power of 27.7 MW. The laser beam quality was characterized by M^2 ~ 6 at 10 Hz repetition rate. No significant degradation or change of beam pattern, pulse width, and M^2 was confirmed during energy scaling in the case of the unstable cavity, promising for further brightness improving. In comparison with a stable cavity, pulse broadening and M^2 increase was observed up to ~1.2 ns and ~10, respectively, during energy scaling up to 18 mJ due to the beam pattern degradation.

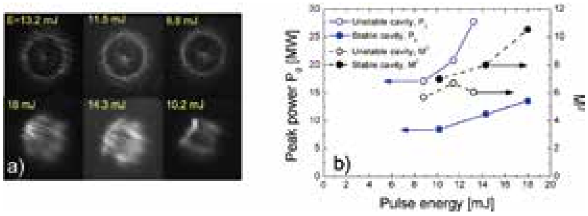

Figure 2. (a) Measured beam patterns and (b) peak power and M^2 at different pulse energies for unstable and stable cavity.

2. High-Brightness 100 Hz 190 mJ Micro-MOPA with the Gain Aperture[2,3)]

High-brigthness 100Hz repetition rate compact MOPA system has been developed. A microchip laser was used as an oscillator whose pulse shape and energy were improved through a Gain Aperture device (GA): After GA, energy was increased from 2.8 mJ to 6.4 mJ, while beam quality factor was reduced from 3.2 to 1.2. The beam was then amplified through double-pass compact high-power amplifier. The strong intrinsic thermal lens of the amplifier has been efficiently compensated by inserting a set of convex-concave lenses between first and second-pass, designed after ABCD matrix calculations. Without compensation, operation was limited to 10 Hz with output beam brightness reaching 18 PW/sr/cm^2, whereas compensation system allowed operation to 100 Hz with a brightness of 11 PW/sr/cm^2.

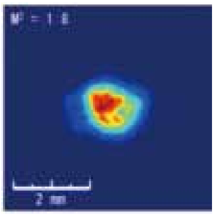

Figure 3. Beam profile under 190 mJ and 100 Hz operation.

3. Spectral Phase Control of Interfering Chirped Pulses for High-Energy Narrowband Terahertz Generation[4)]

We show that high-order spectral phase fundamentally limits the efficiency of narrowband difference-frequency generation using chirped-pulse beating and resolve this limitation by introducing a novel technique based on tuning the relative spectral phase of the pulses. For optical terahertz generation, we demonstrate a 13-fold enhancement in conversion efficiency for 1%-bandwidth, 0.361 THz pulses, yielding a record energy of 0.6 mJ and exceeding previous optically-generated energies by over an order of magnitude. Our results prove the feasibility of millijoule-scale applications like terahertz-based electron accelerators and light sources and solve the long-standing problem of temporal irregularities in the pulse trains generated by interfering chirped pulses.

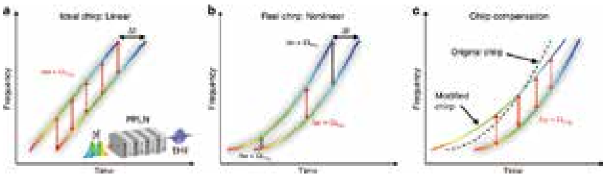

Figure 4. Chirp-and-delay concept. (a) Two broadband but linearly chirped and delayed pulses provide narrow spectral features with constant instantaneous difference frequency. (b) Due to higher order dispersion difference frequency varies along the pulse and limits the range where the provided difference frequency fulfils the phase matching condition in the PPLN. (c) Slightly tilting one of the pulses in time-frequency space regularizes difference frequency and thereby maximizes THz generation.

References

1) H. H. Lim and T. Taira, *Advanced Solid State Lasers 2018*, ATh2A.8, Boston, USA, 4-8 November (2018).
2) V. Yahia and T. Taira, *Opt. Express* **26**, 8609 (2018).
3) T. Kawasaki, V. Yahia and T. Taira, *Opt. Express* **27**, 19555 (2019).
4) S. W. Jolly, H. Ishizuki, T. Taira *et al.*, *Nat. Commun.* **10**, 2591 (2019).

Award

TAIRA, Takunori; Fellow, The Laser Society of Japan (2019).

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