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Introduction

The 2010 Terahertz Technology and Applications conference was divided into four sessions reflecting specific categories as follows: Session 1 – THz Imaging, Spectroscopy, and Instrumentation, Session 2 – THz Modeling and Simulation, Sessions 3 – THz Sources, Generation, and Detection, and Session 4 – THz Materials and Configurations.

Session 1 included papers covering terahertz pulsed imaging in quality control, improved terahertz imaging with a sparse synthetic aperture array, terahertz imaging of non-melanoma skin cancers, coherent imaging at 2.4 THz with a CW quantum cascade laser transmitter, wavelet transforms in terahertz spectroscopy of rough surface targets, and a paper on terahertz pulse time-domain holography.

Session 2 included papers on measurement and modeling of rough surface effects on terahertz spectroscopy, modeling of an electrically tunable quantum dot photodetector for terahertz detection, a paper on optical requirements and modeling of coupling devices for future far-infrared space missions, and a new set of simulations for magnetic-field enhancement beyond the skin depth limit.

Session 3 began with a paper on stimulated emission of terahertz radiation from electro-optic dendrimer, optically synchronized dual-channel terahertz signals for high-performance transmitter/receiver system, and included a paper on handheld terahertz systems based on telecom technologies, terahertz photonic transmitters with a high-gain open-ended rampart slot array antenna, and concluded with a paper on extended spectral coverage of BWO combined with frequency multipliers in which BWOs combined with solid state multipliers were able to achieve output power up to about 2.2 THz.

Session 4 began with a paper on terahertz dynamics of ionic liquids from a combined dielectric relaxation, terahertz, and optical Kerr effect study, and included additional papers on electric coupling resonance variation in THz metamaterials, a floating gate double quantum well far-infrared photoconductor, design and performance of reflective ultra-broadband terahertz time-domain spectroscopy with air-biased-coherent-detection, and concluded with a paper on the design of hybrid GaAs waveguide emitters for generation of terahertz radiation based on phase-matched optical rectification process pumped by 1550-nm fiber lasers.

As in prior Terahertz Technology and Applications conferences, these papers represent a cross section of much of the research work that is being pursued in the technically challenging terahertz spectral region.

In the prior three years of the Proceedings of this conference (conferences 6472, 6893 and 7215), we (including Dr. Kurt Linden) presented a list of recent technical articles describing significant advances in the terahertz technology. This year, for the interested reader, we also include a list that points to a rather extensive and growing database on the terahertz absorption characteristics of a large number of chemicals given on the website www.thzdb.org. That website, in turn, provides links to related terahertz technology database websites as shown in Table 1.

Table 1 List of terahertz technology database websites as found at www.thzdb.org

THz-BRIDGE Spectral Database
http://www.frascati.enea.it/THz-BRIDGE/

NIST THz Spectral Database
http://webbook.nist.gov/chemistry/thz-ir/

RIKEN THz Spectral Database
http://www.riken.jp/THzdatabase/

THz Links from Rice University
http://www-ece.rice.edu/~daniel/groups.html

Terahertz Technology Forum
http://www.terahertzjapan.com/lang_english/index.html

Terahertz Science & Technology Network
http://www.thznetwork.org/wordpress/

RIKEN Tera-Photonics Laboratory
http://www.riken.go.jp/lab-www/tera/TP_HP/index_en.html

Quantum Semiconductor Electronics Laboratory, University of Tokyo
http://thz.iis.u-tokyo.ac.jp/top-e.html

Teraherts Photonics Laboratory, Osaka University
http://www.ile.osaka-u.ac.jp/research/THP/indexeng.html

Solid State Spectroscopy Group, Kyoto University
http://www.hikari.scphys.kyoto-u.ac.jp/e_home.html

Kawase Laboratory "Tera health", Nagoya University
http://www.nuee.nagoya-u.ac.jp/labs/optlab/kawase/index.html

NICT Terahertz Project
http://act.nict.go.jp/thz/en/main_e.html

Laboratory of Terahertz Bioengineering, Tohoku University
http://www.agri.tohoku.ac.jp/thz/jp/index_e.htm

Infrared and Raman Users Group
http://www.irug.org/

In the last three years' introduction to SPIE Proceedings, volumes 6472, 6893, and 7215 two tables were included, one summarizing the more common terahertz radiation sources, and the other summarizing the more common terahertz detector types. For the interest of the general reader we again include these tables without updates other than to note that recent advancements in vacuum electronics BWOs coupled with solid state multipliers have now produced usable power above 2 THz and that devices such as quantum cascade lasers continue to make improvements that encroach upon established high power sources such as carbon dioxide lasers. Due to such advancements, any values listed in Tables 2 and 3 are likely to be bested by new records in a very short time period; however the sources and detectors listed in Tables 2 and 3 still comprise the majority of those used in the THz regime. Readers of this volume may send additions and enhancements to these tables so that future volumes can continue to provide readers with relevant information on the availability of terahertz sources and detectors. Such suggestions can be sent to sadwick@innosystech.com.

Table 2 Summary of common terahertz sources

THz source type	Details	Characteristics
Synchrotron	* Coherent synchrotron produces very high	E-beam, very broadband source, limited instrument
	photon flux, including THz region	availability, very large size, 20 W pulsed
Free electron laser	* Benchtop design at Univ. Essex, UK	Tunable over entire THz region, under development
	Elec beam moves over alternate H-field regions	0.1 - 4.8 THz, 0.5 - 5 kW, 1 - 20 us pulses at 1 Hz
Smith-Purcell emitters	* E-beam travels over metal grating surface,	Requires vacuum, has low efficiency
Backward-wave oscillators	* Vacuum tube, requires homog H-field~10 kG	Tunable output possible. Under development and
	"Carcinotron", room temperature, to 1.2 Thz	commercially available, 10 mW power level, <1 THz
Mercury lamp	* Water cooled housing, low press. 1E-3 Torr	Sciencetech SPS-200,300, low power density
	75-150 W lamp, broad emission	Low-cost, used in THz spectroscopy
Optically pumped gas cell laser	* Grating-tuned CO_2 laser and far-IR gas	> 100 mW, 0.3-10 THz, discrete lines, CW/pulsed
	cell such as methane. Most mature laser.	Commercially avail - Coherent ($400K - $1M)
Opt pump GaAs, p-InAs, Si, ZnTe,	* Mode locked Nd:YAG or Ti:sapphire laser	Imaging apparatus produced, 0.1 to 3 THz
InGaAs (fiber laser pump), Ge	creates short across biased spiral antenna gap	Commercially available, CW uW range, $50K-500K
photoconducting (PC) switch	* Also As-doped Si, CO_2 laser pump	6 THz stim emission from As, Liq He temp.
Laser-induced air plasma	* Ti-saph laser induces air plasma	Remote THz generatiion possible, very low power
		Possibility of power increase in multiple plasmas
Photomixing of near-IR lasers	* Mixing tunable Ti-sapphire laser and diode	Tens of nW, tunable. Requires antenna pattern
	laser in LT-grown GaAs photomixer.	Not commercial. GaP gave 480 mW @ 1.3 THz
	* GaSe crystal, Nd:YAG/OPO difference freq	Tunable 58-3540um (5-0.1THz),209 W pulse 1.5THz
	* Single 835 nm diode laser, external cavity	2-freq mix& 4-wave mixing, RT, sub-nW,0.3-4.2THz
	* Diff-freq generation with 2 monolith QCLs	7.6 u & 8.7 u -> 5 THz, 60 nW puled output
Electrically pumped Ge in H-field	* Electric field injects electrons, magnetic	Requires electric and magnetic fields Output up to
	field splits hole levels for low-E transitions	hundres of mW, cryogenic cooling, 1.5 ~ 4 THz
Electrically pumped Si:B or As	* Transitions between impurity levels	31 uW output at 8.1 THz, slightly polarized
	100 x 200 um rectangle mesas, biased	Cryogenic cooling needed
Electrically pulsed InGaAs RTD	* Harmonically generated by electrical pulses	0.6 uW, 1.02 THz harmonic from InGaAs/AlAs RTD
	RTD integrated into slot antenna	pulsed at 300 Hz
Direct multiplied mm waves	* Multiplied to low-THz region	Low power (uW level), available (VA Diodes)
	up-multiplied from mm-wave	Coherent, heterodyne local oscillators in astronomy
Parametric generators	* Q-switched Nd:YAG pumps $MgO:LiNbO_3$	200 W pulsed power, room temp., 0.1-5 THz tunable
	non-linear crystal, Phase matched GaAs, GaP	some commercially available ~ $30K
Quantum cascade (QC) laser	* First announced in 2002, semiconductor,	Operated at mW power, and up to 164K pulsed
	AlGaAs/GaAs-based, MBE grown, 1.6 to 4 THz	THz not commercially available, require cryo-cooling
Josephson junction cascades	Research stage	0.4-0.85 THz, microwatts
Transistor	* InGaAs channel PHEMT with 35 nm gate	1.2 THz, development at Northrop Grumman
	* InGaAs with 12.5 nm gate, 0.845 THz	Univ. Ill (Dec 2006)
Grating-bicoupled plasmon-FET	* GaAs based double interdigitated grating	with 1.5um laser illum., Tohoku/Hokkaido Univ.

Table 3 Summary of common terahertz radiation detectors

THz detector type	Details	Characteristics
Si bolometer	* Most sensitive (10 pW Hz1/2) THz detector	Responsivity 2E9V/W,NEP=1E-17 WHz1/2,100 mK
	at liquid He temp., slow response time	Requires liquid He dewar, commercially avail.
Superconducting hot elec bolom	* Highest sensitivity	Requires cooling to 0.3 K, NEP=1E-17 WHz1/2
	Fast (1 us) response time	Commercially available, expensive, bulky
Pyroelectric detectors	* Slow response t, 220 nW sensitiv at 24 Hz	Room temp operation, commercially available,
	Requires pulsed signals or mechanical chopper	Low cost, imagers available ~ $10K
Schottky diodes	* ~ 1 THz cutoff frequency	Commercially available ((VA Diodes) with corner ref.
	Fast response, but low THz sensitivity	Room temp operation, good for mixers
PC dipole antennas	* signal gen across biased spiral antenna gap	Analogous to optically pumped THz PC switch but
	Short pulsed detection only	in detection mode. Commercially available
Antenna coupled inter-subband	* 4-terminal phototransistor, 1.6 THz	Under development UCSB
III-V HEMT & Si FET to 300K	* HEMT with 250 nm gate	20 K, 50 mV/W at 420 GHz, still in development
	plasma wave-based detection	Univ research, Si NEP to 1E-10 W/Hz1/2 at 300 K
Quantum dot photon detector	* Demo-photon counting terahertz microscopy	Under development, 1E-19 W = 100 photons/sec,
	imaging, requires 0.3 K temp, research only	Tokyo Univ.

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