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Introduction

This year's Terahertz Technology and Applications Conference was divided into three general topic areas: (a) Terahertz Sources, Generation and Detection; Terahertz Materials, (b) Metamaterials, and Spectroscopy; and (c) Terahertz Imaging and Instrumentation. Among the more significant contributions to the Terahertz Sources, Generation and Detection topic were papers discussing the inherent advantages of InAs-GaSb bipolar structures for terahertz lasers, terahertz reflection spectroscopy for detecting explosives, widely tunable narrow-band terahertz sources based on frequency down-conversion in periodically structured GaAs devices, power scaling for generation of quasi-single cycle terahertz pulses, and terahertz imaging and spectroscopy based on hot electron bolometer (HEB) heterodyne detection. The Metamaterials and Spectroscopy topic included papers dealing with proton beam writing for metamaterial synthesis, time-resolved terahertz spectroscopy, and a study of the effect of surface scattering on terahertz time-domain spectroscopy of chemicals. Finally, the session on Terahertz Imaging and Instrumentation included papers on analysis of front end receiver software using physical optics, prediction of aberrations in terahertz optical systems, terahertz computational holography processes, Gaussian beam analysis of phase gratings, time-domain terahertz measurements of wet-and dry-paint films, optical phase measurement and dynamic stabilization of 80 GHz microwave photonic ultra-low phase noise in single mode fiber under controlled bending motion, 1.56 THz standoff imaging at 2-frames/sec., and real-time imaging using a 3.4 THz quantum cascade laser and IR microbolometer camera.

These papers represent a cross section of some of the research work that is being pursued in the technically challenging terahertz spectral region. In last year's introduction to the Proceedings of the SPIE 6472, we presented a list of recent technical articles describing significant advances in the terahertz technology. This year, for the interested reader, we point to a recent topical edition of the Proceedings of the IEEE, Special Issue, Vol. 95, No. 8 (August, 2007) in which there are a number of papers of interest to the terahertz community. Reading the general literature dealing with the terahertz technology reveals the fact that there is no consensus as to the precise definition of the terahertz spectral region. It is clear that the terahertz spectral region includes what is referred to as the sub-mm (0.1 mm to 1 mm) wavelength region. Adjacent shorter wavelengths would fall into the "far-infrared" spectral region, and adjacent longer wavelengths would fall into the "mm-wave" spectral region.

Readers who wish to probe more deeply into potential applications of the Terahertz technology for concealed weapon detection may benefit from a recently published report, entitled "Assessment of Millimeter-Wave and Terahertz Technology for Detection and Identification of Concealed Explosives and Weapons," by the Committee on Assessment of Security Technologies for

Transportation, National Research Council, ISBN: 978-0-309-10469-2, paperback (2007). This comprehensive report can be viewed at http://antpac.lib.uci.edu/record=b3716994*eng

In last year's introduction to SPIE Proceedings, Volume 6472, we presented, for the first time, two tables, 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, with updates that became apparent to us during the past year. Readers of this volume are encouraged to send additions, corrections, or specific comments relevant to these tables so that future volumes can continue to provide readers with accurate up-to-date information on the availability of terahertz sources and detectors. Such suggestions can be sent to klinden@spirecorp.com.

Table 1. 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 CO2 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)	creates short across biased spiral antenna gap	Commercially available, CW uW range, $50K-500K
photoconducting (PC) switch	* Also As-doped Si, CO2 laser pump	6 THz stim emission from As, Liq He temp.
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	* 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
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:LiNbO3	200 W pulsed power, room temp., 0.1-5 THz tunable
	non-linear crystal, Phase match GaP	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, 2 to 4 THz	Not commercially available, require cryo-cooling
Josephson junction cascades		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 2. Summary of common terahertz radiation detector types.

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
AlGaAs, InGaAs, & Si FET to 300K	* HEMT with 250 nm gate	Cryo and room temperature
	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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