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Kurt J. Linden
Laurence P. Sadwick
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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 photon flux, including THz region	E-beam, very broadband source, limited instrument availability, very large size, 20 W pulsed
Free electron laser	* Benchtop design at Univ. Essex, UK Elec beam moves over alternate H-field regions	Tunable over entire THz region, under development 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 "Carcinotron", room temperature, to 1.2 THz	Tunable output possible. Under development and commercially available, 10 mW power level, <1 THz
Mercury lamp	* Water cooled housing, low press. 1E-3 Torr 75-150 W lamp, broad emission	Sciencetech SPS-200,300, low power density Low-cost, used in THz spectroscopy
Optically pumped gas cell laser	* Grating-tuned CO2 laser and far-IR gas cell such as methane. Most mature laser.	> 100 mW, 0.3-10 THz, discrete lines, CW/pulsed Commercially avail - Coherent (\$400K - \$1M)
Opt pump GaAs, p-InAs, Si, ZnTe, InGaAs (fiber laser pump) photoconducting (PC) switch	* Mode locked Nd:YAG or Ti:sapphire laser creates short across biased spiral antenna gap * Also As-doped Si, CO2 laser pump	Imaging apparatus produced, 0.1 to 3 THz Commercially available, CW uW range, \$50K-500K 6 THz stim emission from As, Liq He temp.
Photomixing of near-IR lasers	* Mixing tunable Ti-sapphire laser and diode laser in LT-grown GaAs photomixer. * GaSe crystal, Nd:YAG/OPO difference freq * Single 835 nm diode laser, external cavity * Diff-freq generation with 2 monolith QCLs	Tens of nW, tunable. Requires antenna pattern Not commercial. GaP gave 480 mW @ 1.3 THz Tunable 58-3540um (5-0.1THz),209 W pulse 1.5THz 2-freq mix& 4-wave mixing, RT, sub-nW,0.3-4.2THz 7.6 u & 8.7 u -> 5 THz, 60 nW pulsed output
Electrically pumped Ge	* Electric field injects electrons, magnetic field splits hole levels for low-E transitions	Requires electric and magnetic fields Output up to hundres of mW, cryogenic cooling, 1.5 ~ 4 THz
Electrically pumped Si:B or As	* Transitions between impurity levels 100 x 200 um rectangle mesas, biased	31 uW output at 8.1 THz, slightly polarized Cryogenic cooling needed
Direct multiplied mm waves	* Multiplied to low-THz region up-multiplied from mm-wave	Low power (uW level), available (VA Diodes) Coherent, heterodyne local oscillators in astronomy
Parametric generators	* Q-switched Nd:YAG pumps MgO:LiNbO3 non-linear crystal, Phase match GaP	200 W pulsed power, room temp., 0.1-5 THz tunable Commercially available ~ \$30K
Quantum cascade (QC) laser	* First announced in 2002, semiconductor, AlGaAs/GaAs-based, MBE grown, 2 to 4 THz	Operated at mW power, and up to 164K pulsed Not commercially available, require cryo-cooling
Josephson junction cascades		0.4-0.85 THz, microwatts
Transistor	* InGaAs channel PHEMT with 35 nm gate * InGaAs with 12.5 nm gate, 0.845 THz	1.2 THz, development at Northrop Grumman 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 Hz ^{1/2}) THz detector at liquid He temp., slow response time	Responsivity 2E9V/W, NEP=1E-17 W/Hz ^{1/2} , 100 mK Requires liquid He dewar, commercially avail.
Superconducting hot elec bolom	* Highest sensitivity Fast (1 us) response time	Requires cooling to 0.3 K, NEP=1E-17 W/Hz ^{1/2} Commercially available, expensive, bulky
Pyroelectric detectors	* Slow response t, 220 nW sensitiv at 24 Hz Requires pulsed signals or mechanical chopper	Room temp operation, commercially available, Low cost, imagers available ~ \$10K
Schottky diodes	* ~ 1 THz cutoff frequency Fast response, but low THz sensitivity	Commercially available ((VA Diodes) with corner ref. Room temp operation, good for mixers
PC dipole antennas	* signal gen across biased spiral antenna gap Short pulsed detection only	Analogous to optically pumped THz PC switch but 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 plasma wave-based detection	Cryo and room temperature Univ research, Si NEP to 1E-10 W/Hz ^{1/2} at 300 K
Quantum dot photon detector	* Demo-photon counting terahertz microscopy imaging, requires 0.3 K temp, research only	Under development, 1E-19 W = 100 photons/sec, Tokyo Univ.

Kurt J. Linden
Laurence P. Sadwick

