Final Technical Report

Fundamental Studies of Electronic Properties of Materials and Devices for High Power, Compact Terahertz Vacuum Electron Devices

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The results of this investigation have yielded two major new research capabilities and several important advances in physical understanding of materials and devices at high (THz-regime) frequencies. A quasi-optical cavity THz measurement system was developed with a record-high Q and resolution capable of measuring differences in surface conductivity less than 10% at frequencies between 300 - 1000 GHz. A multiphysics computational model (EMC, FDTD, MD) was developed for electron transport in solid conducting media under electromagnetic radiation driving forces. New discoveries were made about the losses of high frequency THz radiation in conducting media, including the effects of moderate conductivity (semi-conductors) and surface roughness. Experiments were also completed that characterized the effect of water vapor on atmospheric attenuation of THz radiation. Those data were in excellent agreement with the Millimeter-Wave Propagation Model, even though that model was originally developed for the lower millimeter-wave frequencies.

Subject Terms

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Key Accomplishments

- Quasi-optical cavity THz measurement system was developed with a record-high Q and resolution capable of measuring differences in surface conductivity less than 10% at frequencies between 300 – 1000 GHz (currently operational at 400 and 650 GHz) [8,14, 28, 30, 32].
- Multiphysics model (EMC, FDTD, MD) was developed for electron transport under electromagnetic radiation driving forces, validated in comparisons with experimental data [1-3,7, 9-12, 14-16, 18, 24, 26, 28-30]. A determination was made that the Drude model is not sufficiently accurate for describing the high frequency bulk conductivity of semiconducting materials, at least for mobile charge carrier densities up to $10^{14}$ cm$^{-3}$. Probable reason is the inadequacy of the assumption of quasi-static conditions ($\omega\tau<<1$, $\tau$ being the relaxation time) at such high frequencies. [2,3, 7, 9-12, 14-16, 18, 24, 26, 28-30, 34]
- Experiments were completed that characterized the effective conductivity of doped semiconductors, as a function of dopant density [14, 18, 24, 27, 28, 30, 32].
- Experiments were conducted that characterized the effect of surface topography (roughness) on THz radiation losses in metallic conductors [20, 22, 25, 27, 30, 32]. The results revealed that surface roughness losses are generally higher than predicted by available models, and that the losses have different dependencies on the average feature size of the roughness depending on whether the roughness is regular or random.
- Experiments were conducted that characterized the effect of water vapor on atmospheric attenuation of THz radiation [17, 19, 21, 23, 33]. The data reveal that the widely-used Millimeter-Wave Propagation Model (MPM), extrapolated to the THz regime, provides accurate predictions of losses due to water vapor.
- Theoretical model was developed and validating experiments were conducted that explain the reason for step frequency tuning observed with THz regenerative TWT oscillators. [4-6,13].
- Comprehensive assessment was made of high power sources in the THz regime [6, 27].
• Booske was elected Fellow of the American Physical Society “For pioneering contributions to the development of coherent radiation sources in the submillimeter wave and terahertz regime, in particular to the physics of sheet electron beams, advanced cathode, and interaction of high power microwave with materials.”

Archival Publications (published)

Peer reviewed full papers


Conference Abstracts and Talks


[23] Marcus Weber; Benjamin Yang; Mark Kulie; Ralf Bennartz; John Booske, “Analysis of Atmospheric Attenuation due to Water Content at 400 and 650 GHz,” 36th Int’l Conf. Infrared, Millimeter and Terahertz Waves, paper M3B.3 (Houston, TX, Oct 2-7, 2011).


Ph.D. and M.S. Reports and Theses


In Preparation

Peer-reviewed Full Papers:


Changes in research objectives, if any: None
Change in AFOSR program manager, if any: None
Extensions granted or milestones slipped, if any: One No Cost Extension until end of November, 2011.
Include any new discoveries, inventions, or patent disclosures: None