Terahertz Sensing Technology

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The illustrious history of terahertz (THz) imaging and sensing is nearly 50 years long. During this time, photonic and electronic THz technology has developed a lot, but it has not been able yet to bridge the famous THz gap between electronic and photonic devices. In the THz range of frequencies, a low photon energy (smaller than the room temperature thermal energy) makes the development of efficient THz lasers to be a challenge. And the cutoff frequency and maximum frequency of operation of field effect and bipolar transistors struggles to reach one THz. Figure 1 shows the state of THz photonic and optoelectronic technologies competing for applications in THz sensing. Also shown is the expected order of magnitude performance improvement that could be achieved using synchronized arrays of active "plasmonic unit cells" – plasmonic crystals. TeraFETs – short-channel Si CMOS, SOI, FINFETs, GaAs-based and GaN-based HEMTs – operating in a new "plasmonic" regime – form unit cells of such plasmonic crystals. TeraFETs have the potential to become a dominant THz electronics technology. As seen from Fig. 1, deep submicron Si CMOS TeraFET circuits could support THz sensing, which is the key to a dramatic cost reduction of the THz technology deployment.

Many theoretical and modeling papers and a few experimental papers have revealed the enormous potential of the TeraFET plasmonic crystal technology. Reaching this potential requires understanding of new counterintuitive physics of TeraFET plasmonic crystals. This physics involves the propagating, decaying, or growing waves of the electron density – plasma waves" - similar to water and sound waves driven by wind.

THz sensing technology has found applications in industrial controls, the detection of biological and chemical hazardous agents, biology, medicine (including cancer diagnostics), detection of mines and explosives, providing security in buildings, airports, and other public spaces, radioastronomy, space research, and hardware cyber security (detecting tampered with or defective VLSI non-destructive and with or without bias).

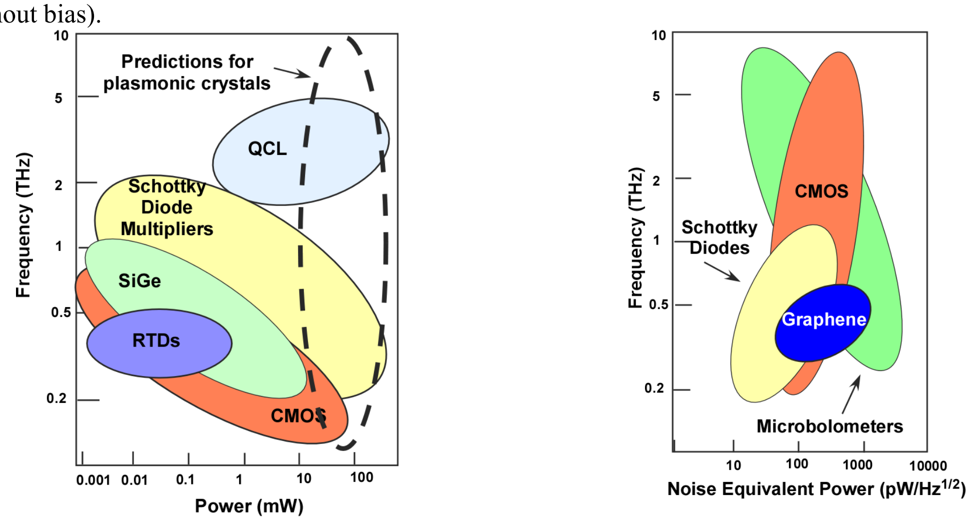

Fig. 1. Performance of THz electronic and photonic technologies (using data from references [1],[2]). Projection for plasmonic crystals based on the theory of reference[3].

[1] Valušis, G.; Lisauskas, A.; Yuan, H.; Knap, W.; Roskos, H.G. Roadmap of Terahertz Imaging 2021, Sensors 2021, 21, 4092. https://doi.org/10.3390/s21124092

[2] Srivastava, G., Agarwal, S. (2022). Terahertz Imaging: Timeline and Future Prospects. In: Das, S., Nella, A., Patel, S.K. (eds) Terahertz Devices, Circuits and Systems. Springer, Singapore. https://doi.org/10.1007/978-981-19-4105-4_16

[3] G. R. Aizin, J. Mikalopas, and M. Shur, Plasmonic Instabilities in Two-Dimensional Electron Channels of Variable Width, Phys. Rev. B 101, 245404 (2020)