Plasmonics as an Enabling Technology for 360° THz Phase Shifter at Room Temperature

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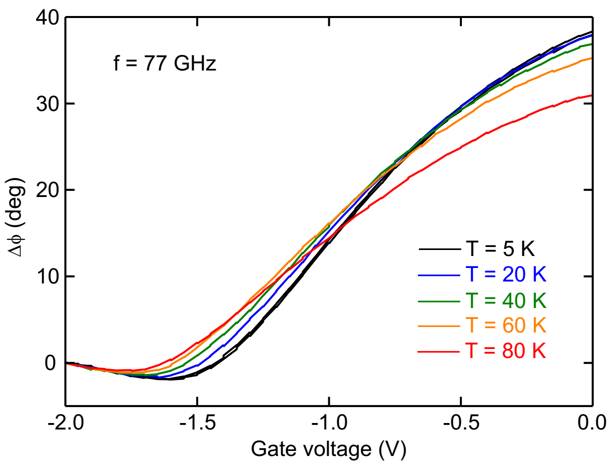
Creating a phased antenna array at terahertz (THz) frequencies is one of the most significant challenges in modern high-frequency electronics. Possible applications of such phased arrays include beam steering and programmable holographic projections ultimately aimed at developing THz communication systems. However, the existing approaches for constructing active THz phase metasurfaces are not without drawbacks. Plasmonics is considered to be one of the methods of advancing electronics into the terahertz frequency range. The key advantage of the 2D plasmonic devices is that their response can be tuned over wide ranges by varying the 2DES electron density n_s.

Different concepts are contributing to the large phase shift with little modulation of the amplitude. First, we have studied the terahertz response of a dielectric membrane with a high-mobility two-dimensional electron system (2DES) on one side [1]. The developed device exhibits electromagnetic transparency above the plasma frequency. We find this phenomenon to be dependent on the 2DES density and membrane thickness. Significantly, we demonstrate the opaque low-frequency region to be highly tunable through an externally applied magnetic field.

Next, we reported on the conceptual development and implementation of an active plasmonic THz phase shifter with the 2DES density tunable through an externally applied gate voltage [2]. The device is designed based on the well-established HEMT technology. We achieve the phase tunability range of up to 41° at the insertion loss of −2.2 dB. We demonstrate the successful operation of the phase shifter at temperatures of up to 80 K (see the figure). Structure-wise, the phase shifter is easily scalable to a planar phased array.



Last, the utilization of higher plasmonic modes of the gated (screened) structure can enable the full 360° phase shift functionality. The shift towards higher frequencies will allow the operation at room temperatures.

[1] A. S. Astrakhanceva, A. Shuvaev, P. A. Gusikhin, et. al, *Appl. Phys. Lett.* **120**, 031104 (2022).

[2] V. M. Muravev, A. Shuvaev, A. S. Astrakhanceva, et. al, *Appl. Phys. Lett.* **121**, 051101 (2022).