Room-Temperature Direct and Heterodyne Detectors Based on Field-Effect Transistors

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Field-effect transistors (FETs) based on high-electron-mobility two-dimensional electron gas provide a unique nonlinear element for frequency mixing and hence detection of terahertz electromagnetic wave. To achieve high detection frequency far beyond the cut-off frequency of the field-effect transistor, on-chip antennas have to be integrated with the field-effect gate so that the terahertz electromagnetic wave is transferred to the gate-controlled electron channel. Such a near-field effect is essential for making high-sensitivity FET-based terahertz mixers without suffering from the parasitic device parameters such as the drain-ground capacitance, drain-gate capacitance or the resistance of the leads.

In this talk, we present progresses on the direct (homodyne) detectors and the heterodyne detectors based on either GaN/AlGaN heterostructure or single-layer graphene. The direct detectors are developed for four frequency bands centering at 220 GHz, 340 GHz, 650 GHz and 850 GHz, respectively. The noise equivalent power is below 50 $pW/Hz^{1/2}$ for room-temperature operation and about 1 $pW/Hz^{1/2}$ for operation at 77 K. Heterodyne detection based on GaN/AlGaN FETs and graphene FETs have been successfully demonstrated at 216 GHz and 648 GHz. Sub-harmonic mixing has also been achieved at 432 GHz and 648 GHz with the local oscillator frequency at 216 GHz. The heterodyne mixing is currently realized in a quasi-optic configuration, however, FET detectors integrated in waveguides can be foreseen. Detailed characterization on the sensitivity and the noise performance of the heterodyne detectors will be carried out in the near future.

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