Subwavelength imaging of field-effect transistors by focused terahertz radiation

D. B. Veksler, A. V. Muravjov, W. Stillman, F. Guarin, V. Yu. Kachorovskii, T. A. Elkhatib, K. N. Salama, X.-C. Zhang, and M. S. Shur
Rensselaer Polytechnic Institute, U.S.A. and *Ioffe Institute, Russia*

Focused terahertz (THz) beam impinging on a field effect transistor excites plasma oscillations of the two-dimensional electron gas in the device channel. Plasma wave rectification due to nonlinear properties of the FET channel induces a source-drain voltage ΔV_{DS} proportional to the intensity of the THz beam. This ΔV_{DS} voltage also depends on the THz voltages, V_{TGS} and V_{TGD}, induced between the source and gate and between the drain and gate, respectively, and on the electric field values in the channel under the gate edges. The sign of ΔV_{DS} depends on the V_{TGS}/V_{TGD} ratio. The dependence of ΔV_{DS} on the position of the THz beam focus forms a two-dimensional THz transistor image with subwavelenth resolution.

A typical image of a microwave transistor (with asymmetrical drain and source) has two maxima of opposite signs corresponding to the dominant V_{TGS} and V_{TGD}, respectively. In the saturation regime, a change in the drain bias, which affects the electric field distribution of a scale of a few nanometers, shifts the image on the scale of a few tens of microns. For symmetrical transistors, the image has a single polarity peak that shifts with the direction of the current (*i.e.* when the source and drain are exchanged). When several transistors are connected in series, changing the beam position can shift the response peak to different transistors with the shift distance close to the gate separation. The theory of this effect is in good agreement with the measured data for GaAs/AlGaAs and GaN/AlGaN HEMTs and Si CMOS. Terahertz images of nanoscale Si CMOS devices are sensitive to the leakage current and, therefore, can be used for non-destructive device testing under bias.