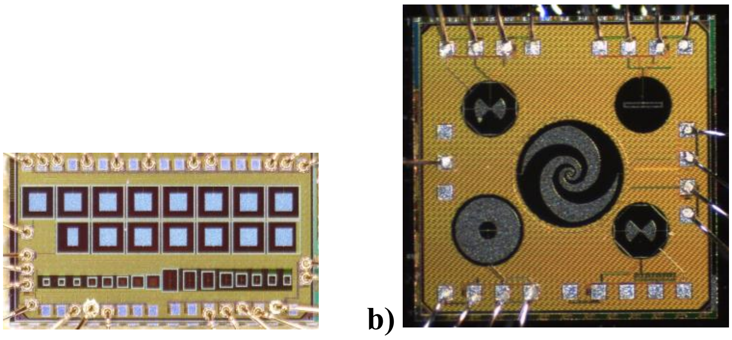
High-performance THz detectors in 90 nm Si CMOS technology

A. Lisauskas[1,2], M. Bauer[2], K. Ikamas[1], J. Zdanevičius[1], D. Voß[2], D. Čibiraitė[2], V. Krozer[2] and H. G. Roskos[2]

[1]*Department of Radiophysics, Vilnius University, 01513 Vilnius, Lithuania*
[2]*Physikalisches Institut, Goethe-Universität Frankfurt, 60438 Frankfurt a.M., Germany*

This paper discusses important aspects of physics-based circuit modelling and design of high-performance field-effect-transistor based terahertz detectors (TeraFETs). TeraFET power detection is based on rectification of THz waves coupled into the channel of a FET. Whereas, at low frequencies, FET-based rectifiers rely on resistive mixing, with rising frequency, charge-density waves in the channel play an increasingly important role and enable detection and mixing far beyond classical cut-off frequencies [1, 2]. The potential of convenient fabrication of TeraFETs by Si CMOS foundry technologies has accelerated developments, which have already led to implementation of real-time camera [2, 3], while detector optimization is still ongoing, gradually leading up to fundamental performance limits for room-temperature operation of the devices.

We have developed a circuit model allowing to evaluate the role of the transistor geometry parameters such as channel length and width taking into account antenna impedance matching and the peculiarities of fabrication technology. Whereas the highest sensitivity is reachable for the shortest, technology defined, gate lengths, there is an optimum value for a gate width. In support of our arguments, we present implementations of several types of narrow-band and broadband detectors using a 90-nm CMOS technology (see micrographs in Fig. 1). At 630 GHz resonant frequency, narrow-band devices reach optical responsivity of 1074 V/W and NEP of 10 pW/√Hz. From 500 GHz to 650 GHz a broad-band bow-tie antenna and hyper-hemispheric lens coupled TeraFETs demonstrate flat device responsivity (taking all available beam power) of 100 V/W with NEP of 75 pW/√Hz.



a) b)

Fig.1. a) Patch antenna coupled narrowband detectors (top row for 630 GHz, bottom row – array of devices from with resonances spanning from 1.2 to 5.6 THz). b) Broad-band (bow-tie and log-spiral) and narrowband (dipole and folded-dipole) devices optimized for substrate-side coupling with hyper-hemispheric Si lens.

References

[1] M. Dyakonov and M. Shur, IEEE Trans. Electron.Dev. **43**, 380 (1996).
[2] A. Lisauskas, U. Pfeiffer, E. Öjefors, P. Haring Bolívar, D. Glaab, and H. G. Roskos, J. Appl. Phys. **105**, 114511 (2009).
[3] R. Al Hadi, H. Sherry, J. Grzyb, Y. Zhao, W. Förster, H. M. Keller, A. Cathelin, A. Kaiser, and U. R. Pfeiffer, IEEE J. Solid-State Circuits **47**, 2999 (2012).
[4] J. Zdanevičius, M. Bauer, S. Boppel, V. Palenskis, A. Lisauskas, V. Krozer, and H. G. Roskos, J. Infrared Millim Terahertz Waves **36**, 986 (2015).