Sub-terahertz emission from field-effect transistors

D. Yavorskiy[1], K. Karpierz[1], P. Kopyt[2], M. Grynberg[1], and J. Łusakowski[1]

[1]*Faculty of Physics, University of Warsaw, ul. Pasteura 5, 02-093 Warsaw, Poland*

[2]*Institute of Radioelectronics, Technology University of Warsaw, ul. Nowowiejska 15/19, 00-665 Warsaw, Poland*

A quest for a semiconductor source of terahertz radiation, based on dc current - THz photon conversion, has been lasting for a few decades now and has been always related to a radiative decay of plasmons. A particularly promissing idea was proposed in 1993 in a seminal paper by Dyakonov and Shur [1] who pointed at field-effect transistors (FETs) as THz radiation sources. Within the proposed mechanism, the current flow through a transistor channel is unstable against propagation of plasma waves. Resulting source - drain current oscillations are the source of radiation. The model predicted a THz frequency of radiation for a sub-micrometer transistor's gate length.

Radiation generated by FETs was observed a decade later at cryogenic temperatures from a GaN/AlGaN FET at the band about 50 - 200 GHz (detected by a Fabry-Perot spectrometer) [2] and from a GaInAs/GaAs FET at about 0.2 - 4 THz (detected with a magnetic-field tunable InSb detector) [3]. Both papers pointed at the Dyakonov - Shur mechanism as the source of plasma instability leading to generation of radiation. In spite of these promissing results, the interest in THz emission from FETs seemed to almost vanish as one can judge from the number of only a few important papers in this field during the last decade.

Recently, we have carried out a detailed study on emission from commercially available FETs with the gate lenght of about 100 nm. The emission spectrum was analysed with three different experimental systems: a Michelson interferometer, a high-frequency spectrum analyzer and a magnetic-field-tunable InSb detector. We showed that: a) the emission starts at the saturation of the output characteristics and it is related to a negative differential conductivity, as it was observed in [1] and [2]; b) the fundamental frequency is equal to about 10 GHz and its multiple harmonics up to about 350 GHz were observed; c) parameters of the emission little depend on the particular transistor; d) transistors generate both at room as well liquid helium temperatures; e) emission spectra registered with the Michelson interferometer and the spectrum analyzer are mutually consistent while the InSb detector gives misleading information about spectral characteristics of the emission.

Taking into consideration both the above experimental facts and a theoretical analysis found in the literature we propose that the mechanism responsible for the observed emission is the Gunn effect with a high harmonic content resulting from a pulse-like time dependence of the current.

A financial support from a Polish National Science Centre UMO-2015/17/B/ST7/03630 grant is acknowledged.

[1] M. Dyakonov, and M. Shur, *Phys. Rev. Lett.* **71**, 2465 (1993).
[2] Y. Deng *et al.*, Appl. Phys. Lett. **84**, 70 (2004).
[3] W. Knap *et al.*, Appl. Phys. Lett. **84**, 2331 (2004).