Sub-terahertz emission from a grid-gated GaAs/AlGaAs heterostructure

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A Smith – Purcell effect [1], discovered in electronic vacuum tubes more than 60 years ago, stimulated research aimed at finding a similar source of radiation based on electron transport in solids. In the original experiment [1], a beam of electrons moving in a close proximity to a metallic grating gave the origin to a visible light which wavelength and polarization depended on parameters of the experimental system (the beam velocity, grating period, angle of observation, etc.). A natural candidate to observe the Smith – Purcell effect in solids was a high electron mobility heterostructure with a metallic grid on its surface. Both experimental and theoretical works were undertaken to show that construction of such a source is real but up to now no clear experimental proof has been obtained.

In this paper we present results of our study aimed at generation and characterization of an emission from grid-gated GaAs/AlGaAs high electron mobility heterostructure. A mesa of dimensions of 100 μm x 1000 μm was supplied with ohmic contacts and covered with a grid of Au bars positioned parallel to its shorter edge. The width of each bar and separation between adjacent two was equal to 0.5 μm. The grid did not cover a distance of about 70 μm adjacent to the ohmic contacts. The sample was cooled to liquid helium temperature and supplied with current pulses generated by a low-frequency generator. The radiation was analyzed with a Michelson interferometer positioned outside of the helium cryostat [2].

A current - voltage characteristics showed a steady increase of the current with the voltage applied to the ohmic contacts up to a saturation on the level of 100 mA which appeared at about 15 V. Then, an abrupt increase of the signal (by about two orders of magnitude) was registered by the interferometer's detector. The observed step-like threshold shape proves that the emission resulted from an instability of the current flow. The frequency of emitted signal was found to change between 75.8 GHz to 74.0 GHz with the bias voltage increasing from 16.0 V to 17.5 V. Due to a high power dissipated (on the order of 1 W), we were not able to precisely control temperature of the sample. Considering different mechanisms of current instabilities we propose that the most probable mechanism responsible for the emission is the Gunn effect occurring in a grid-free part of the mesa.

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[1] S. J. Smith and E. M. Purcell, Phys. Rev. **92**, 1069 (1953).
[2] D. Yavorskiy *et al.*, Acta Physical Polonica A **132**, 335 (2017).