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Quantum GaAs/AlGaAs superlattice: multiphoton and high-frequency gain effects at room temperature

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Semiconductor superlattices – artificial periodic structures consisting of ultrathin layers where by variation of their width, doping level and profile one can tailor their optical and electronic properties in a desirable way – can be found as an attractive environment to investigate various high-frequency phenomena [1,2].
In the given communication, we present the first experimental observation of the cavityless dissipative parametric generation in subcritically doped GaAs/AlGaAs quantum superlattice. The effect, theoretically predicted more than a decade ago [3, 4] and being inherent to optical systems [5], was discovered in molecular beam epitaxy grown silicon doped GaAs/AlGaAs quantum superlattice. To enable uniform electric field in the structure the superlattice was sandwiched between non-ohmic contacts – Schottky contact on the top and heterostructure underneath. The structure was then processed into mezas and placed into a waveguide for microwave excitation of 8.45 GHz pump microwave radiation for DC biased experiment at room temperature. A spectral response associated with both the nondegenerate and degenerate parametric processes and harmonics of the pump frequency was clearly demonstrated; generation at fractional frequencies due to several multiphoton processes occurring simultaneously was revealed. It is shown that the incident transverse electromagnetic microwave is transformed into a longitudinal electrostatic wave which propagates with electron drift velocity experiencing negative absorption due to the Esaki-Tsu nonlinearity. The established slow propagating drift-relaxation mode (with velocity of about 1000 times lower than the speed of light in the material) enables to reach tremendous high-frequency gain levels of 104 cm-1, which can be extended up to THz frequencies [6].

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