Terahertz and Optical Spectroscopy on GaAs/AlGaAs Split-Ring Resonator Metamaterial

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Two-dimensional metamaterials are lithographically fabricated periodic arrays of split-ring resonators (SRR) on a surface of a dielectric. Each resonator acts as an LC-circuit responding to the incident radiation with a single or multiple resonances. Typical dimensions of resonators in two-dimensional metamaterials are of the order of a few tens of μm and their resonant frequencies fall within a THz range. Split-ring resonators are THz counterparts of semiconductor microcavities which are resonators for visible or infrared light. In analogy with microcavities, SRR-based metamaterials (SRRMs) allow one to observe a strong light-matter coupling at THz frequencies. An advantage of THz SRRMs is possibility to reach experimentally an ultra-strong light-matter coupling limit (when the Rabi frequency is comparable to that of coupled oscillators involved) which was not observed with microcavities.

We performed a number of spectroscopic measurements on a SRRM fabricated on a modulation doped GaAs/AlGaAs heterostructure in order to study an influence of SRR metalization on optical properties of the metamaterial in THz and VIS ranges of electromagnetic spectrum. Some features of SRR were confronted with a numerical modeling of the metamaterial with a finite difference time domain method.

In order to determine frequency of resonances, we carried out room-temperature time-domain transmission measurements with a control of polarization of the incident radiation. We have found that the frequency of resonances depend on the polarization of the incident radiation which was also revealed in numerical simulations of the metamaterial. A magnetotransmission of 2.54 THz radiation through the SRRM at 2 K showed a cyclotron resonance transition with no evidence of magnetoplasmon excitations. Microluminescence measurements at 2 K indicated that the presence of resonators does not introduces essential changes in spectra in comparision with a reference sample with no SRR. However, such differences were observed in polarization of macroluminescence measurements carried out at magnetic fields up to 10 T.

In conclusion, we have noticed an unexpected difference between results of micro- and macroluminescence from the SRRM which explanation requires further studies. We observed a qualitative agreement in measured and numerically modeled THz response of SRRM.

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