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Magnetoplasmonic Crystals

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Plasmonic crystals, consisting of periodic plasmonic cavities with subwavelength periodicity, enable engineering of plasmonic band structures and strong confinement of terahertz (THz) radiation. While electrical and structural tuning of plasmonic crystals has been extensively investigated [1,2], the impact of magnetic fields on their band structure remains largely unexplored. Here, we report studies on high magnetic field influence on plasmonic crystals formed by periodic arrangements of carrier cavities in grating-gate AlGaN/GaN with high-mobility two-dimensional electron gas (2DEG). We show strong modification of the crystal structures related to interaction of plasmonic collective excitation with harmonics of single particle cyclotron resonance (CR) electron excitations. The investigated structures were fabricated from AlGaN/GaN heterostructures grown on semi-insulating SiC substrates, with sub-micron grating gates patterned by electron-beam lithography. A schematic cross-section of the device is shown in Fig. 1(a). Magnetotransmission measurements were performed using Fourier-transform infrared spectroscopy in magnetic fields up to 16 T at 4.2 K.

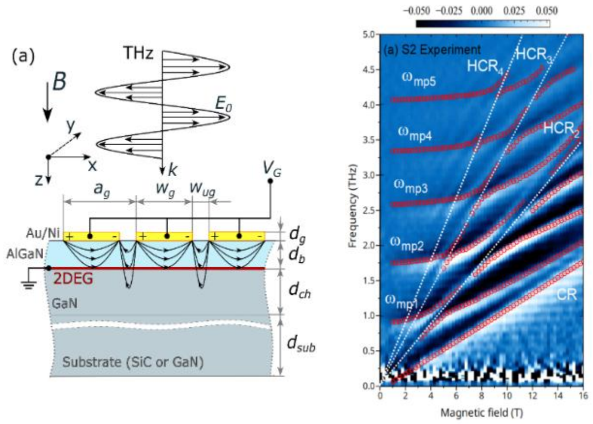

Fig.1. (a) Schematic view of AlGaN/GaN-based plasmonic crystal integrated with metal grating. (b) Magneto transmission of sample with 87% grating filling factor.

The key parameter that decides about the plasmonic crystal band structure is the filling factor (ratio of metalized and uncovered crystal surface). AlGaN/GaN grating-gate plasmonic crystals with different filling factors were investigated. We show that for plasmonic crystals with low grating filling factor, the fundamental plasmon mode exhibits anticrossing with higher harmonics of CR – HCR, leading to the formation of Bernstein modes and magnetic-field-induced band splitting. Increasing the grating filling factor results in excitation of multiple magnetoplasmon modes with energies up to 5 THz. As shown in Fig.1(b), these modes (ω_{mp}) strongly hybridize with HCR up to the fourth order modifying plasmonic crystal energy band structure by appearance of a complex spectrum of Bernstein modes.

The experimental observations are accurately reproduced by our electrodynamic model incorporating the magnetic-field-dependent conductivity tensor of the 2DEG without fitting parameters. The results demonstrate that plasmonic crystals provide a versatile platform for engineering tunable THz excitations in strong magnetic fields and open prospects for magnetoplasmonic THz devices.

1. P. Sai, et al., Phys. Rev. X 13, 041003 (2023).
2. P. Sai, et al., Advanced Optical Materials 13(21), 2500716 (2025).