Study on the ultrastrong coupling of the cyclotron transition of two dimensional electron gases to THz split ring resonators

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Semiconductor heterostructures have been widely used to study the interaction of electronic transitions with light. The collective character of electronic excitations in semiconductor nanostructures allowed to reach strong light-matter interaction.

Interest in the ultrastrong coupling regime increased recently as new QED-phenomena are expected to appear [1]. We demonstrated ultrastrong coupling between the cylotron transition of two dimensional electron gases (2DEGs) and split ring resonators (SRRs) reaching a normalized Rabi frequency of $\frac{\Omega}{\omega_c} = 0.58$ [2].

The cyclotron transition has a huge electric dipole which scales as $d \sim e l_0 \sqrt{\nu}$, where $l_0 = \sqrt{\hbar/eB}$ is the magnetic length and $\nu = \rho_{2DEG} 2\pi l_0^2$ the filling factor [3]. The transition frequency can be tuned by the magnetic field applied perpendicular to the 2DEG plane as $\omega_c = eB/m^*$. On the other side, SRRs exhibit a LC resonance with strongly subwavelength mode confinement which further enhances the coupling strength. We investigated in more detail the predicted scaling of the normalized Rabi frequency $\frac{\Omega}{\omega_{res}} \sim \sqrt{n_{QW}\nu}$ by optimizing the SRR design. Observations of the polariton frequencies in dependence of the carrier density and number of quantum wells agree well with predictions. In this process we could push the normalized Rabi frequency to $\frac{\Omega}{\omega_{res}} = 0.72$, limited at this stage by the depth of the cavity mode.

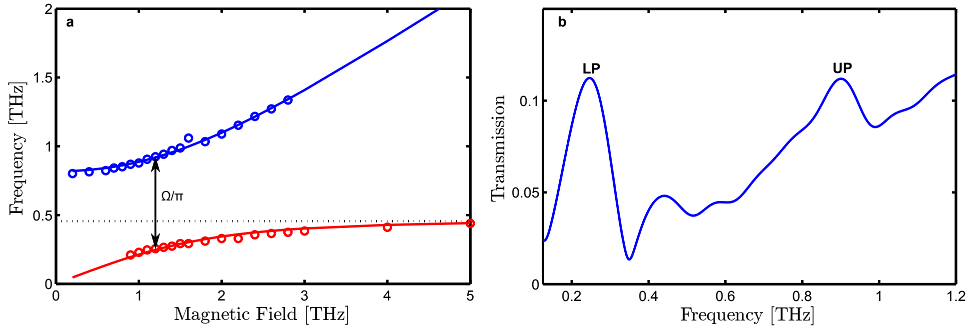

Figure 1: **a**) Transmission maxima (open circles) and best fit (solid line) (as described in [2]) yielding $\Omega/\omega_{res} = 0.72$. The dashed line indicates the frequency of the unperturbed cavity mode. **b**) Transmission spectrum at resonance (B = 1.2 T). The lower and upper polariton (LP,UP) are clearly visible.

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