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Ultrastrong light-matter coupling with multisubband plasmons

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Intersubband polaritons are quasi-particles arising from the strong interaction between an excitation of a two-dimensional electron gas and a cavity optical mode [1]. The strength of the interaction, measured by the ratio between the vacuum field Rabi splitting E_R and the intersubband excitation energy E_{ISB} [2], can be optimized by reducing the cavity mode volume and increasing the light-matter interaction oscillator strength. An ultra-subwavelength confinement of the optical mode is provided by Double Metal Cavities (DMCs) [3], while high oscillator strength can be obtained by exploiting Coulomb interaction in highly doped quantum wells. Indeed, it has been recently demonstrated [4] that, in a quantum well with several occupied subbands, all the intersubband transitions can be phase locked by dipole-dipole Coulomb interaction, giving rise to a single sharp absorption resonance. This resonance, which concentrates the whole oscillator strength of the system, is associated to a collective excitation of the electron gas, the *multisubband plasmon* (MSP). In this work we demonstrate the ultrastrong coupling between a MSP in a single quantum well and a DMC mode, with $E_R/E_{ISB}=70\%$ at room temperature.

Our sample consists of a single highly doped (7×10^{18} cm^{-3}) GaInAs/AlInAs quantum well, 148nm thick. Transmission measurements at Brewster angle show a single sharp resonance ($\Delta E/E=6\%$), as presented in the inset of Fig.1. DMCs were realized, with patch widths ranging from 0.5µm to 8µm, and reflectivity measurements were performed at room temperature. The main panel of Fig. 1 shows the energy position of the reflectivity minima as a function of the cavity mode energy. Thanks to the very strong light-matter coupling, reflectivity minima are observed in a wide energy range, spanning the mid and far infrared. The upper and lower polariton branches are separated by a 36meV gap, characteristic of the ultra-strong coupling dispersion. A coupling of the lower branch with optical phonons is also visible in the graph. A Rabi energy of 81meV is deduced from the data, corresponding to 70% of the multisubband plasmon resonance.

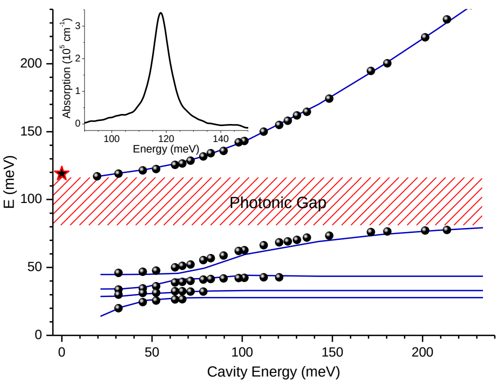

Fig.1. Main panel: Polaritonic dispersion extracted from reflectivity measurements at 300K (symbols) on gratings of different patch widths. Solid lines represent the simulated dispersion. Inset: Absorption coefficient measured at Brewster angle at 300K.

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