Hybrid intersubband-intrasubband cavity polaritons

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In the nonretarded limit the *n*-doped MQW slab supports the intersubband and intrasubband Coulomb modes [1]. When the MQW is embedded into a microcavity (MC), the resonant coupling between the ground cavity mode (c_1) and the intersubband Coulomb mode (with the frequency ω_{IT}) can be achieved. In this limit the formation of the intersubband cavity polariton (ICP) branches is possible [2,3]. In typical systems the frequency ω_{IT} is much larger than the MQW plasma frequency ω_p. Consequently, the influence of the intrasubband plasmon modes (located below ω_p) on the behavior of the ICP branches can be omitted. We show that when condition $(\omega_p/\omega_{IT})^2 << 1$ is not well fulfilled in the MQW-MC systems (see e.g. Ref. 3), the formation of the hybrid intersubband–intrasubband polariton branches becomes possible, provided that the mirrors are of the dielectric type.

Our approach is based on the “microscopic” implementation of the effective medium approximation [4]. For simplicity the dissipation and the dielectric mismatch are neglected. The results of the numerical calculations performed for the system with perfect dielectric mirrors are presented in Fig.1 [5].

The simultaneous coupling of the c_1 mode with the intersubband and intrasubband Coulomb modes can be equivalently considered as the photon mediated coupling between the intersubband and intrasubband plasmonic modes [6]. The inspection of Fig. 1 shows that the above mentioned coupling creates the hybrid ICP branch with an admixture of the intrasubband plasmon. The hybrid branch is blueshifted with respect to the "pure" ICP branch. As one can expect, practically only the lower ICP branch is affected by the intrasubband plasmons. At $k_x \approx 0.6\, k_{1,x}^{res}$ and $\omega \approx 0.7\, \omega_{IT}$ the considered branch crosses the c_1 mode and transforms into the upper intrasubband polariton branch with decreasing k_x.[5]. (k_x is the in-plane wave vector. Moreover, at $k_x = k_{1,x}^{res}$ the frequency of the ground cavity mode $\omega_{c1}(k_x)$ coincides with the intersubband frequency ω_{IT}.)

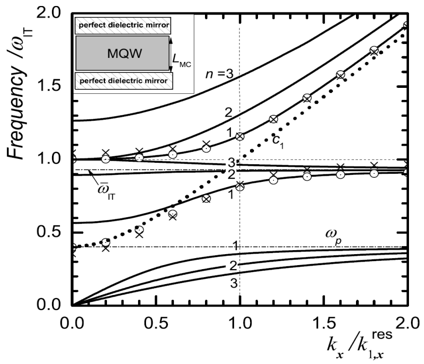

Fig. 1. The frequency of the three lowest order polaritonic branches (solid lines) and the ground photonic mode c_1 (dotted line) supported by the MQW-MC uniform system, with perfect dielectric mirrors, as a function of k_x. The geometry of the system is shown in the insert. The circles correspond to the lower and upper ICP branches calculated neglecting the presence of the intrasubband plasmons. The behavior of the above mentioned branches predicted by a well known two-oscillator model is also presented (crosses). The calculations have been performed for the system with $\omega_{c1}(k_x = 0) = \omega_p = 0.4\, \omega_{IT}$.

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