Spectral position of minima of exciton reflection of light by a semiconductor microcavity with a SQW

P.Kosoboutski
Department of Physics, Lviv Polytechnic National University
12 Bandery str., 79646 Lviv-13 Ukraine
E-mail: petkosob@polynet.lviv.ua

The paper is devoted to studying the problem of the effect of spectral position of exciton reflection minima of light by a semiconductor microcavity with a single quantum well (SQW). The SQW is bounded by a nonabsorbing layer of thickness d_s and refractive index $n_S = \sqrt{\varepsilon_S}$ at the top and semi-infinite medium with ε_b at the bottom. Excitons can be excited in the SQW of thickness L. Dielectric function $\tilde{\varepsilon}(\omega)$ in the neighborhood of the exciton transition energy is represented by the formula [1]

$$\tilde{\varepsilon}(\omega) = \varepsilon_\infty + \frac{F}{\omega_0^2 - \omega^2 - i\omega\gamma} = (\varepsilon_1 + i\cdot\varepsilon_2) = (n - i\cdot\chi)^2, F = \frac{fq^2}{m\varepsilon_0 L} \quad (1)$$

where f is the strength per area unit, $q(m)$ is the charge (mass) of the electron, ω_0 is the resonant frequency of the 1s exciton, ε_∞ is the high frequency dielectric constant, γ is the damping constant (the exciton linewidth), ε_1 and ε_2 are real and imaginary parts of complex dielectric function $\tilde{\varepsilon}(\omega)$, n i χ are the refractive index and the absorption coefficient in the SQW .

We will consider the four-layer model of reflection comprising vacuum, the boundary layer, the SQW and the semi-infinite medium. In the case of normal incidence of light on the surface SQW, the phase shift of the wave at the interface of layer of the phase thickness $\delta_s = \frac{4\pi\cdot n_s\cdot d_s}{\lambda}$ is presented as [2] $\tan\varphi_{23} = \frac{\mathrm{Im}\,\tilde{r}_{23}}{\mathrm{Re}\,\tilde{r}_{23}} = \frac{2\cdot\chi\cdot n_s}{\varepsilon_s - n^2 - \chi^2}$.

Here index 23 corresponds to layer-SQW interboundary. We shall confine the subsequent analysis to the special case when $\varepsilon_s = \varepsilon_\infty$. For this case, the Eq.(2) has a solution at the frequency $\omega_{\min}$

$$\omega_{\min}^2 = \omega_0^2 + \frac{\gamma^2}{2\tan\delta_S} + \frac{F}{2\varepsilon_\infty} - \sqrt{\left(\frac{F}{2\varepsilon_\infty} + \frac{\gamma^2}{2\tan\delta_S}\right)^2 + \frac{\gamma^2\omega_0^2}{\tan^2\delta_S} - \frac{F^2\sin^2\delta_S}{4\varepsilon_\infty^2}} \quad (2)$$

At the frequency $\omega_{\min}$ the condition of phase compensation $\varphi_{23} + \delta_s = 2\pi$ [2,3] is satisfied.

The relation (2) allows us to determine the layer phase thickness δ_S from the position of the reflection minimum $\omega_{\min}$. When $\gamma \to 0$, the expression (2) has the following form

$$\omega_{\min}^2 \approx \omega_0^2 + \frac{F\sin^2\delta_S}{2\varepsilon_\infty} \quad (3)$$

References

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