Subradiant collective states in the discrete emitter array

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We consider collective polaritonic eigenmodes of a periodic array of N emitters in the waveguide. Similarly to the Fabry-Perot modes, the frequencies polaritonic eigenmodes can be found from an equation (Voronov *et al.*, 2007)

$$1 = r^2(\omega)\mathrm{e}^{2\mathrm{i}K(\omega)(N-1)} \tag{1}$$

where K is the polariton wave vector at the frequency ω, satisfying the equation

$$\cos K = \cos\varphi - \frac{\gamma_{1\mathrm{D}}\sin\varphi}{\omega_0 - \omega} \tag{2}$$

and r is the reflection coefficient of the polariton from the internal boundary of the structure

$$r = -\frac{1 - \mathrm{e}^{\mathrm{i}(K-\varphi)}}{1 - \mathrm{e}^{-\mathrm{i}(K+\varphi)}}\,. \tag{3}$$

Goal: Prove that for $N \gg 1$ the imaginary part of the eigenfrequencies ω with $|K(\omega) - \pi| \ll 1$ can be presented in the form

$$\operatorname{Im}\omega = -\gamma_{1\mathrm{D}}\frac{\pi^2\nu^2\sin^2\frac{\varphi}{2}}{2N^3\cos^4\frac{\varphi}{2}}\,, \nu = 1, 2\ldots \tag{4}$$

Tip: it is instructive to first rewrite the equation for the eigenmodes Eq. (1) in the form (Vladimirova *et al.*, 1998)

$$\tan NK = \frac{\mathrm{i}\sin K\sin\varphi}{\cos K\cos\varphi - 1}\,. \tag{5}$$

References

Vladimirova, M. R., E. L. Ivchenko, and A. V. Kavokin, 1998, Semiconductors **32**(1), 90.

Voronov, M., E. Ivchenko, M. Erementchouk, L. Deych, and A. Lisyansky, 2007, J. of Luminescence **125**, 112.