Bipolariton Axion-like Generation in Ruby

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Abstract. Axion is a hypothetical elementary particle introduced to solve the strong CP-problem of quantum chromodynamics. Nowadays, it is a best candidate for a role of a lightweight dark matter quantum. Axion also helps to solve various astrophysical problems, such as Hubble Space Telescope anomaly (extra-transparency of the Universe), PAMELA one (extra positron flux in cosmic rays), Super-Kamiokande one (traces of a new neutral particle) etc. The paper proposes a way to obtain axion-like particles, bipolaritons, in a crystalline solid by coupling of two polariton into the axion-like bipolariton during Bose-Einstein condensation of light in a transparent crystal (ruby).

INTRODUCTION

Crystalline ruby is a well-known optical medium widely used in lasing. Earlier [1] we reported observation of a polariton Bose-Einstein condensation (BEC) in ruby (Al_2O_3: Cr^{3+}) at the resonance of its dielectric function. Since a local electromagnetic field at BEC rises resonantly, Zeeman splitting overlaps medium's dielectric function nearest resonances' (λ_1 = 694.3 nm and λ_2 = 632.8 nm) BECs resulting to BECs' crossover allowing the pairing

$$\gamma + \gamma \rightarrow a. \tag{1}$$

Here γ is a BEC polariton, a is an axion-like bipolariton.

ANALYSIS

When bipolariton occurs, the dielectric function of a media changes. The total dielectric function ε_Σ becomes

$$\varepsilon_\Sigma = \varepsilon + \varepsilon_a, \tag{2}$$

where ε is dielectric permittivity of a crystal without bipolaritons [2] and ε_a is a bipolariton addition. The last one can be calculated by a following way [3]:

$$\varepsilon_a(k, \omega) = \varepsilon_\infty - |g_k|^2 D_a^R (k, \omega), \tag{3}$$

where retarded Green's function

$$D_a^R (k, \omega) = (\omega - \omega_a(k))^{-1} + (\omega + \omega_a(k))^{-1}, \tag{4}$$

interaction force factor

$$|g_k|^2 = ½ (\varepsilon_0 - \varepsilon_\infty)\, \omega_a(k) \tag{5}$$

and bipolariton self-dispersion

$$\omega_a^2(k) = \omega_{0a}^2 + c^2k^2. \tag{6}$$

In these equations, $\varepsilon_0 = \varepsilon(\omega \rightarrow 0)$ is a low-frequency dielectric function, $\varepsilon_\infty = \varepsilon(\omega \rightarrow \infty)$ is a high-frequency one and $c = 3\times10^8$ m/s is speed of light in a vacuum.

Because of (4) and (6), bipolaritons result to the additional peak of a refractive index of a crystal

$$n_\Sigma(\omega) = (\varepsilon_\Sigma(\omega)\times\mu)^{½} = |\varepsilon_\Sigma(\omega)|^{½} \tag{7}$$

to be registered in a secondary emission spectrum of medium

$$R(\omega) = (n_\Sigma(\omega) - 1)^2 / (n_\Sigma(\omega) + 1)^2 \tag{8}$$

at the unitary polartion spectral line of maximal transparency of a crystal.

RESULTS

In ruby, we observe this bipolariton peak at λ = 532.5 nm when a ruby crystal is irradiated by a powerful nitrogen laser (λ = 337 nm) at liquid nitrogen temperature (T = 77 K).

CONCLUSION

The results makes possible to get axion-like particles at a lab.

REFERENCES

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