Paramagnetic Resonance in Disordered Spin-Polarized Exciton-Polariton Condensate

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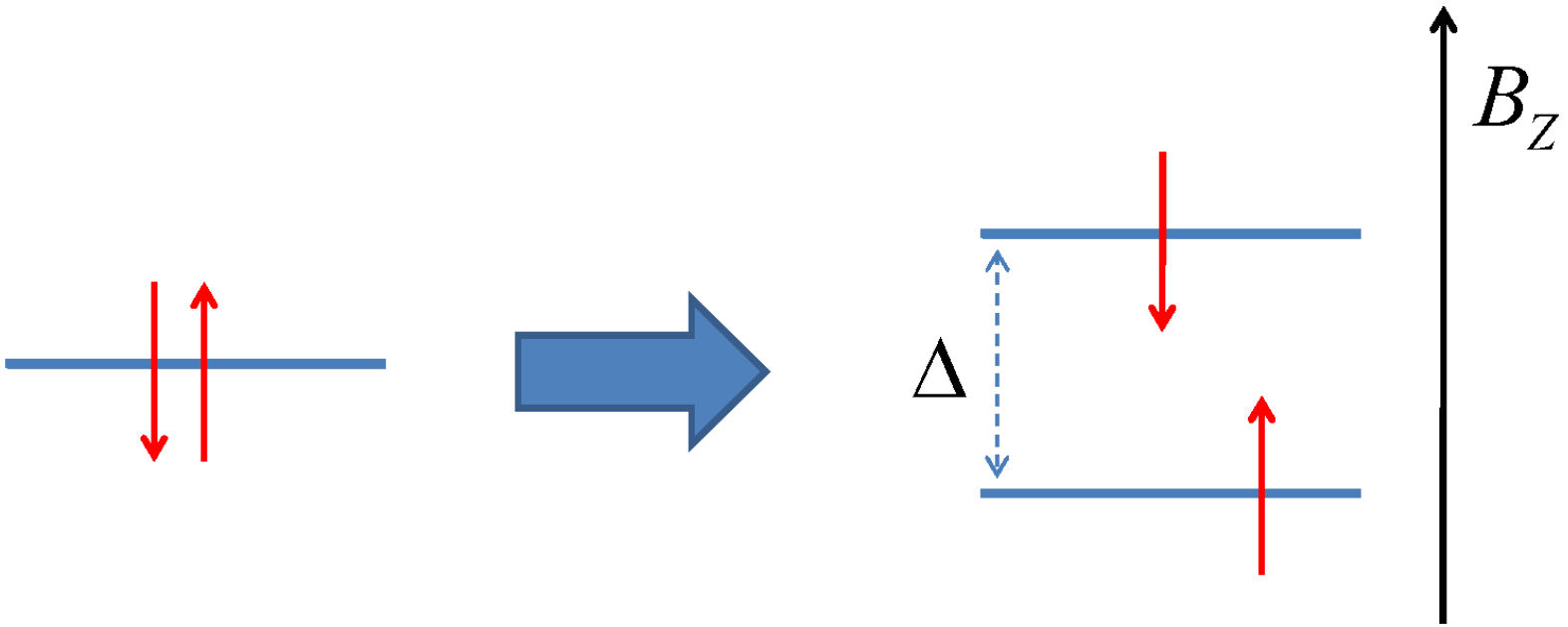
May 15, 2017

Outline

Paramagnetic (Spin) Resonance

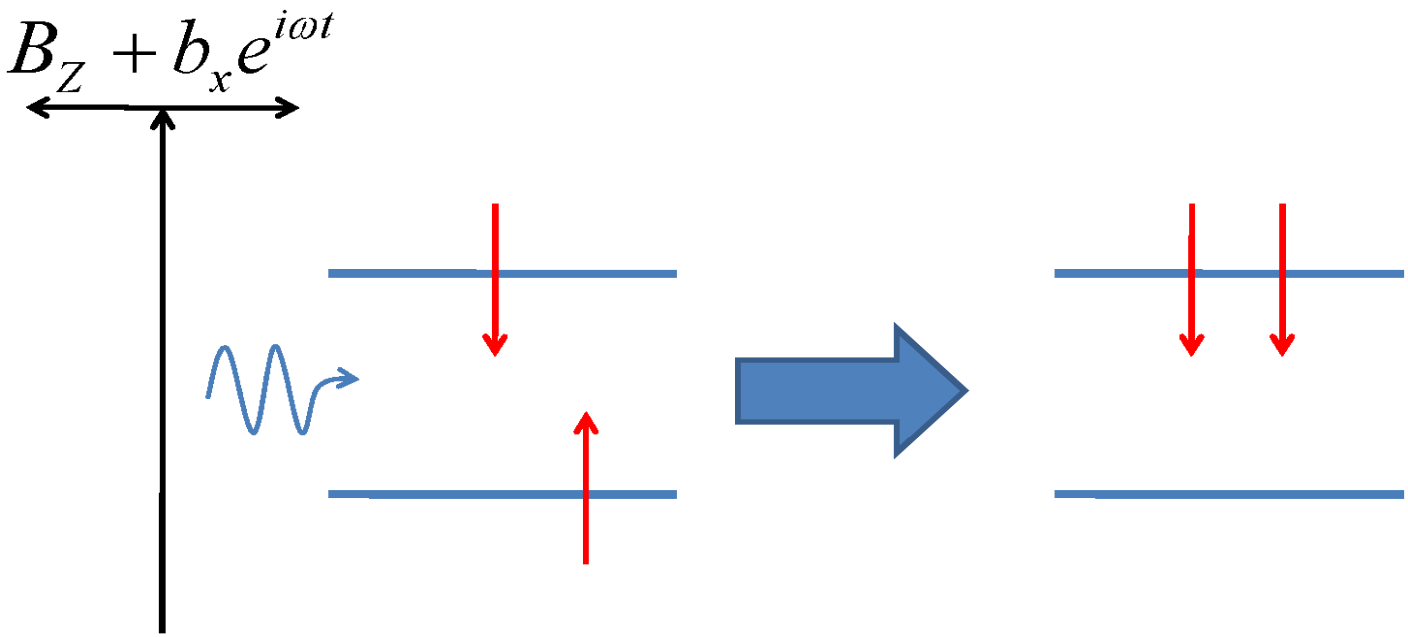
Uniform magnetic field B_Z splits initially degenerate spin levels



Level splitting is $\Delta = g\mu_B B_Z$

Paramagnetic (Spin) Resonance

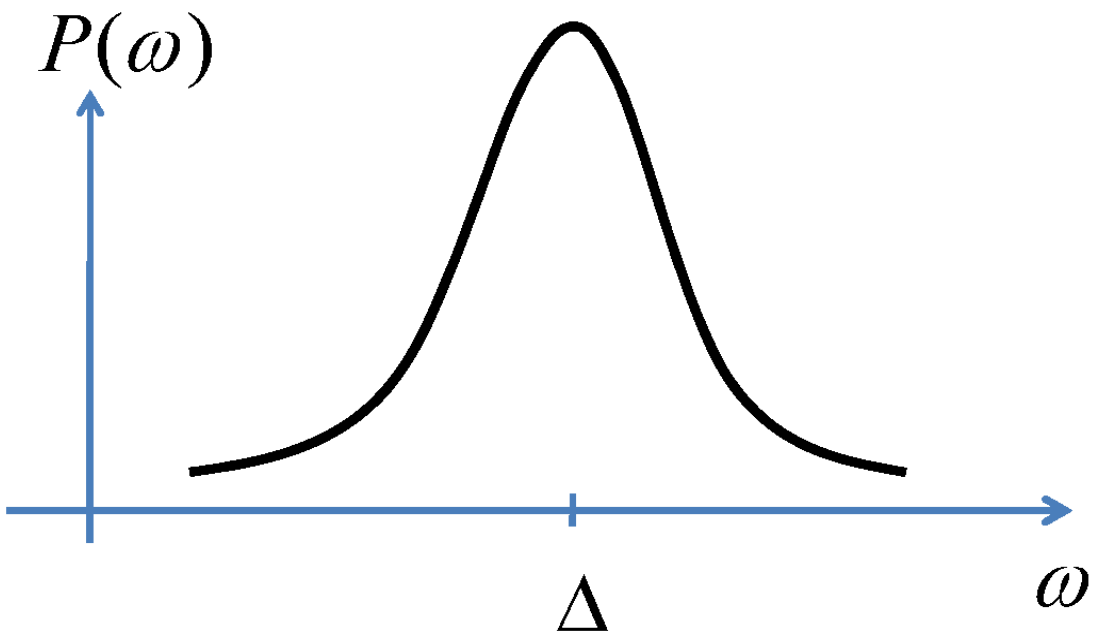
External perturbation $F(t) \sim \sigma_x b_x e^{i\omega t}$ does not conserve spin and results in the spin-flip processes



Spin response of the system is describe by paramagnetic susceptibility $s_\alpha = \chi_{\alpha,\beta}(\omega) b_\beta$ and the absorbed power is expressed via $P(\omega) \sim -\mathrm{Im}\,\chi(\omega)$

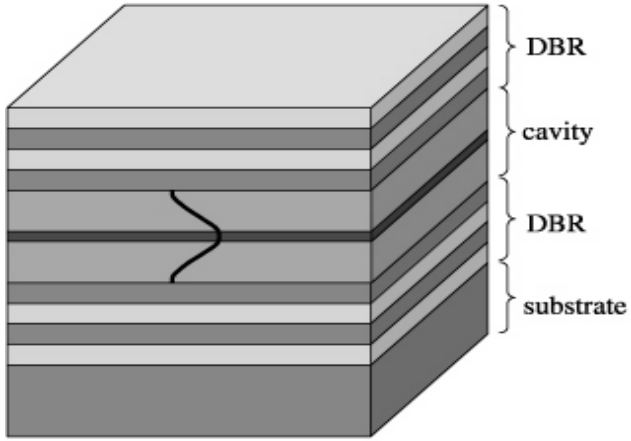
Paramagnetic (Spin) Resonance

Transitions between spin-split states produce resonance at $\omega = \Delta$



- External uniform magnetic field (to split spin states)
- Transverse perturbation (to flip spin)
- Two spin states produce single resonance

Ferromagnetic EP BEC: Hamiltonian



$$H_0 = \begin{pmatrix} \frac{\mathbf{p}^2}{2M} & \alpha p_-^2 \\ \alpha p_+^2 & \frac{\mathbf{p}^2}{2M} \end{pmatrix}, \quad \Psi = \begin{pmatrix} \psi_+ \\ \psi_- \end{pmatrix} \tag{1}$$

$$H_{int} = \frac{U_0}{2}\left(|\psi_+|^2 + |\psi_-|^2\right) + (U_0 - 2U_1)|\psi_+|^2|\psi_-|^2 \tag{2}$$

Ferromagnetic BEC occurs if $U_1 < 0$ and *Antiferromagnetic* if $U_1 > 0$

Ferromagnetic EP BEC: ground state and excitations

Ground state

$$\Psi = \begin{pmatrix} \sqrt{n_c} \\ 0 \end{pmatrix} \tag{3}$$

Excitations

$$\Psi = \begin{pmatrix} \sqrt{n_c} + \delta\psi_+(\mathbf{r}, t) \\ \delta\psi_-(\mathbf{r}, t) \end{pmatrix} \tag{4}$$

Two branches: a) Gapless Boboliubov-type quasiparticles

$$\epsilon_k = sk\sqrt{1 + (k\xi)^2}, \;\; s^2 = U_0 n_c/M, \;\; \xi = 1/2Ms \tag{5}$$

and b) Massive excitations with a gap (produced by exchange interaction)

$$\mathcal{E}_k = 2|U_1|n_c + \frac{\mathbf{k}^2}{2M} \tag{6}$$

Paramagnetic resonance in EP BEC: Absorbed power

External perturbation

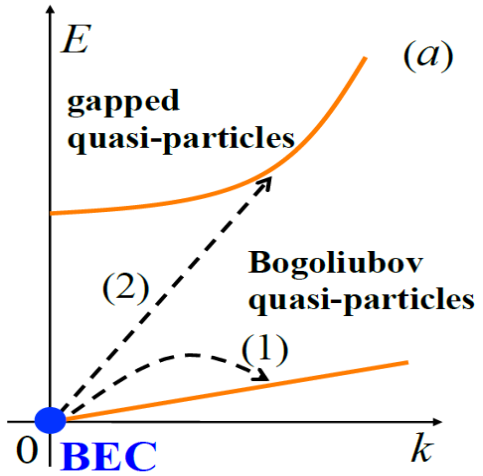
$$\mathcal{F}(\mathbf{r},t)=\frac{1}{2}g_s\mu_B\sigma_z b_z(\mathbf{r},t) \quad (7)$$

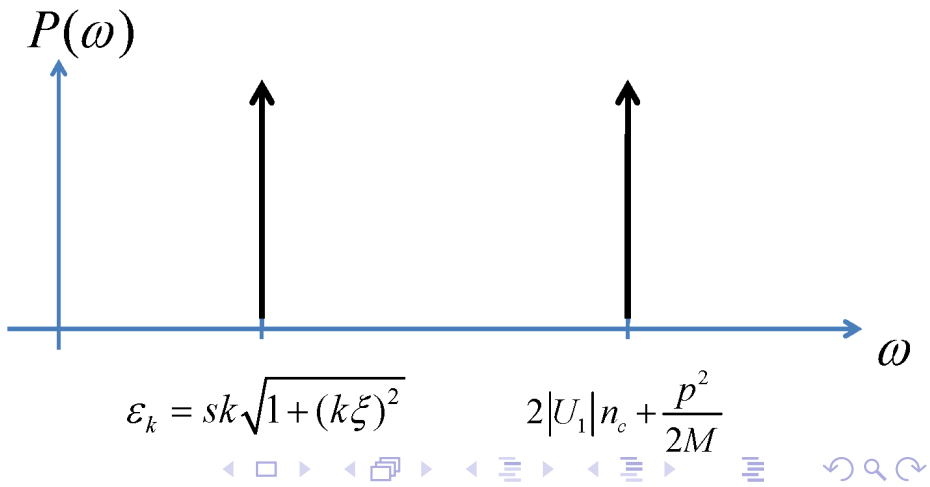
Absorbed power

$$\mathcal{P}_{k\omega}\sim -\omega \mathrm{Im}\chi_{zz}(k,\omega), \quad (8)$$

$$\chi_{zz}(k,\omega)\sim \frac{1}{(\omega+i0)^2-\epsilon_k^2}\times$$

$$\times\left[1+\frac{(2M\alpha)^2}{(\omega+i0)^2-\mathcal{E}_k^2}\right] \quad (9)$$





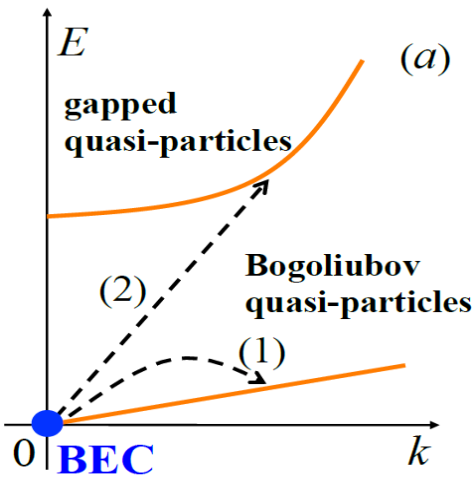
Paramagnetic resonance in EP BEC: Lines broadening

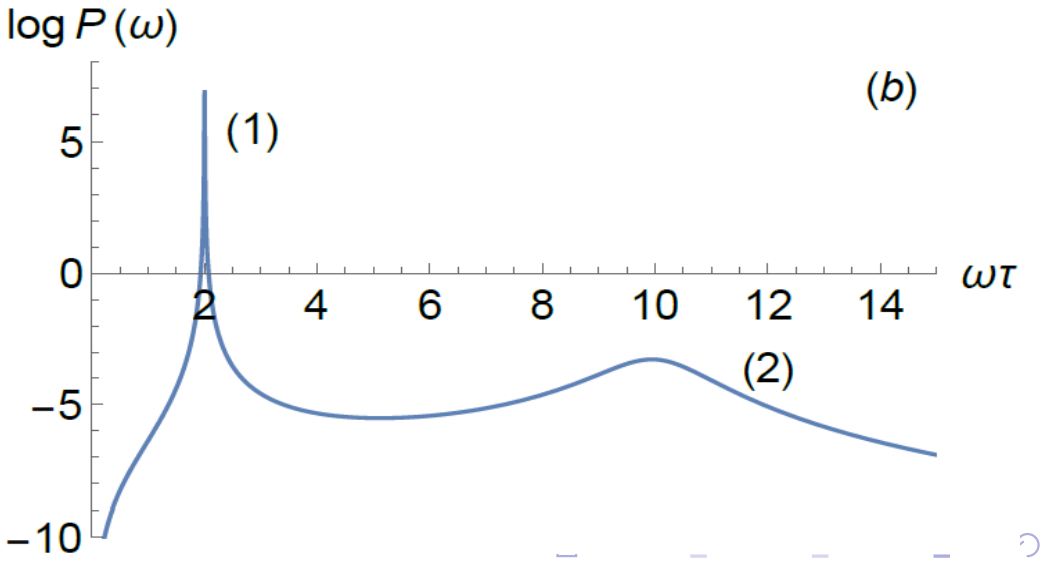
a) Gapless Boboliubov-type quasiparticles scattering via disorder

$$\epsilon_k \to \epsilon_k - i\gamma_k^+, \;\; \gamma_k^+ = \frac{(k\xi)^3}{\tau} << \frac{1}{\tau}$$

b) Massive excitations scattering via disorder

$$\mathcal{E}_k \to \mathcal{E}_k - i\gamma_k^-, \;\; \gamma_k^- = \frac{1}{\tau}\left(\frac{2U_1}{U_0}\right)^2 \approx \frac{1}{\tau}$$





Paramagnetic resonance in EP BEC: Conclusions

- BEC operates as quasi-3-level system: double-line structure of paramagnetic resonance
- no external uniform magnetic field: spin splitting occurs due to exchange interaction
- non-uniform perturbation: transfer of external momentum to excite particle from uniform BEC

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Thank you for your attention!