NII

The BEC-BCS crossover and highly excited exciton-polariton condensates

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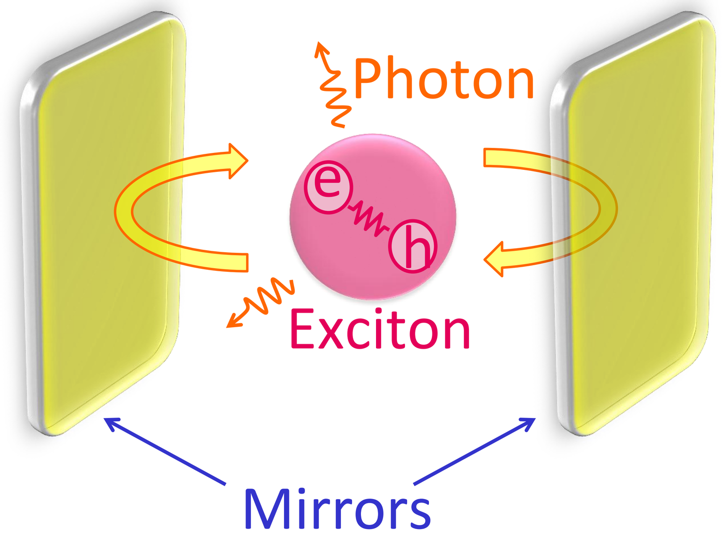
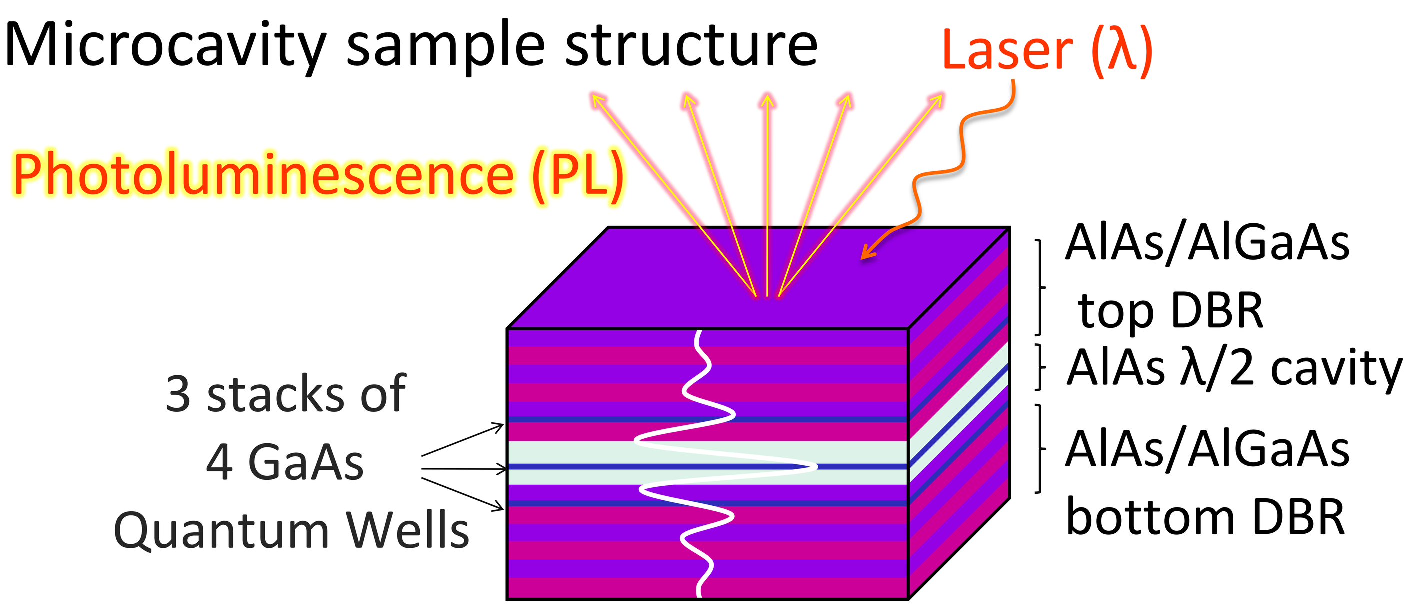
1. Microcavity Exciton Polariton



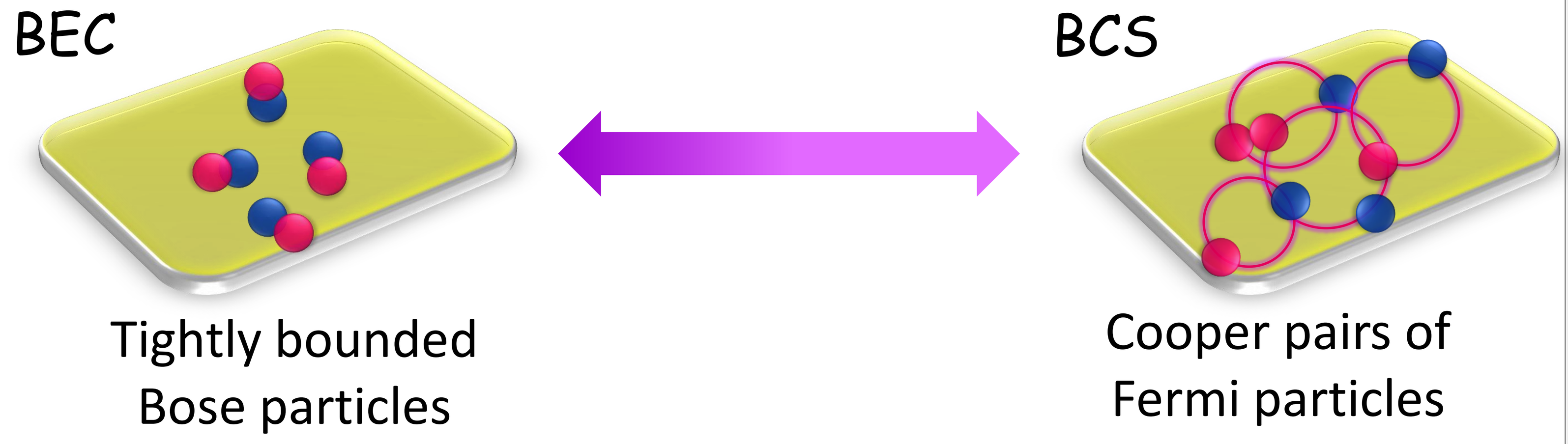
Exciton-polariton: Quasi-particle formed by strong coupling between exciton and photon.

Polaritons have light effective mass
→high T_c >10 K

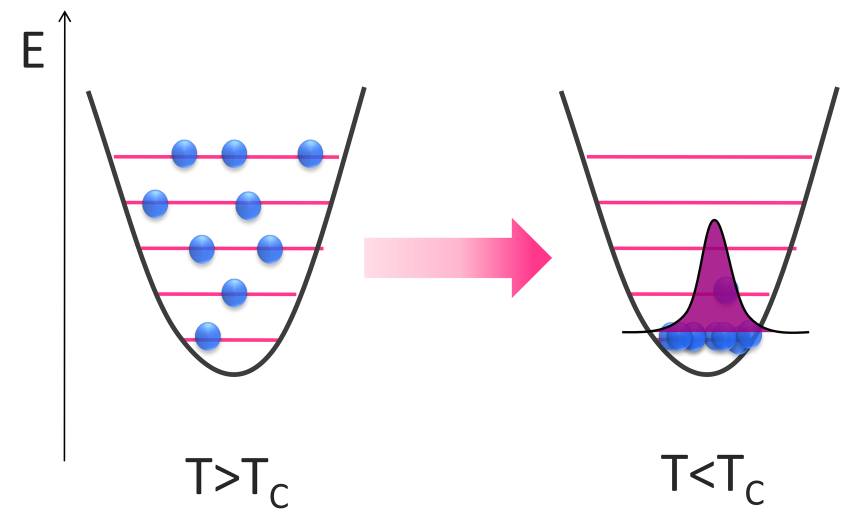
● Microcavity sample structure



2. BEC-BCS crossover



● Bose-Einstein condensation



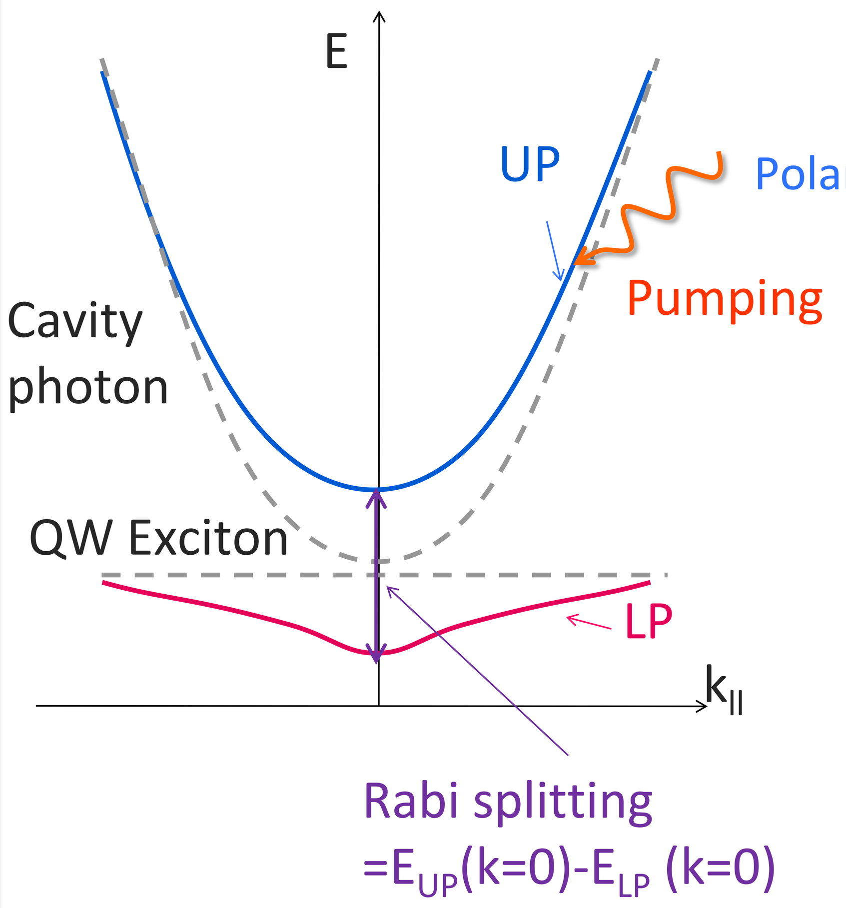
Bose-Einstein distribution:

$$N = \frac{1}{exp\{(\varepsilon-\mu)/k_B T\}-1}$$

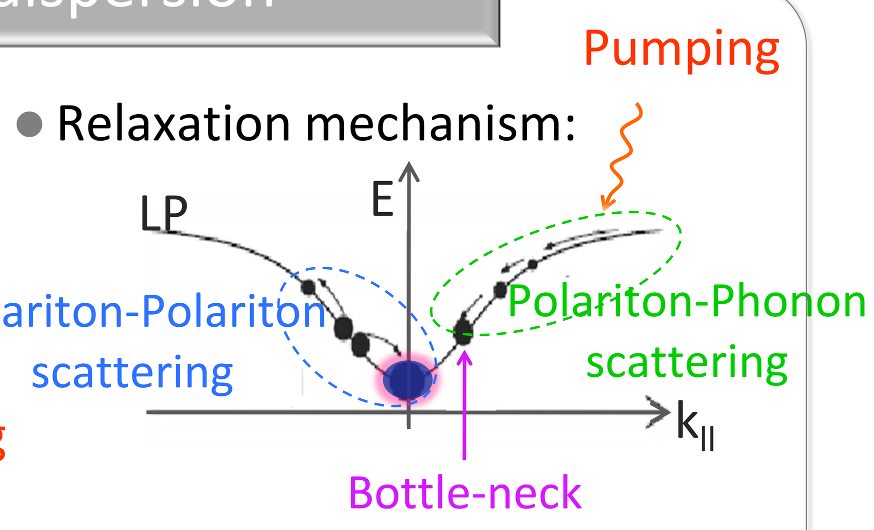
Critical temperature:

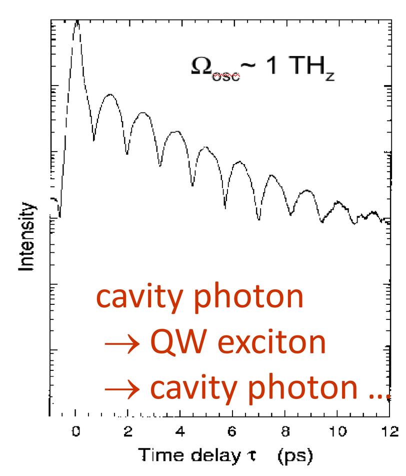
$$k_B T_c = \frac{2\pi\hbar^2}{m}\left(\frac{n}{2.612}\right)^{2/3}$$

3. Energy dispersion



● Relaxation mechanism:

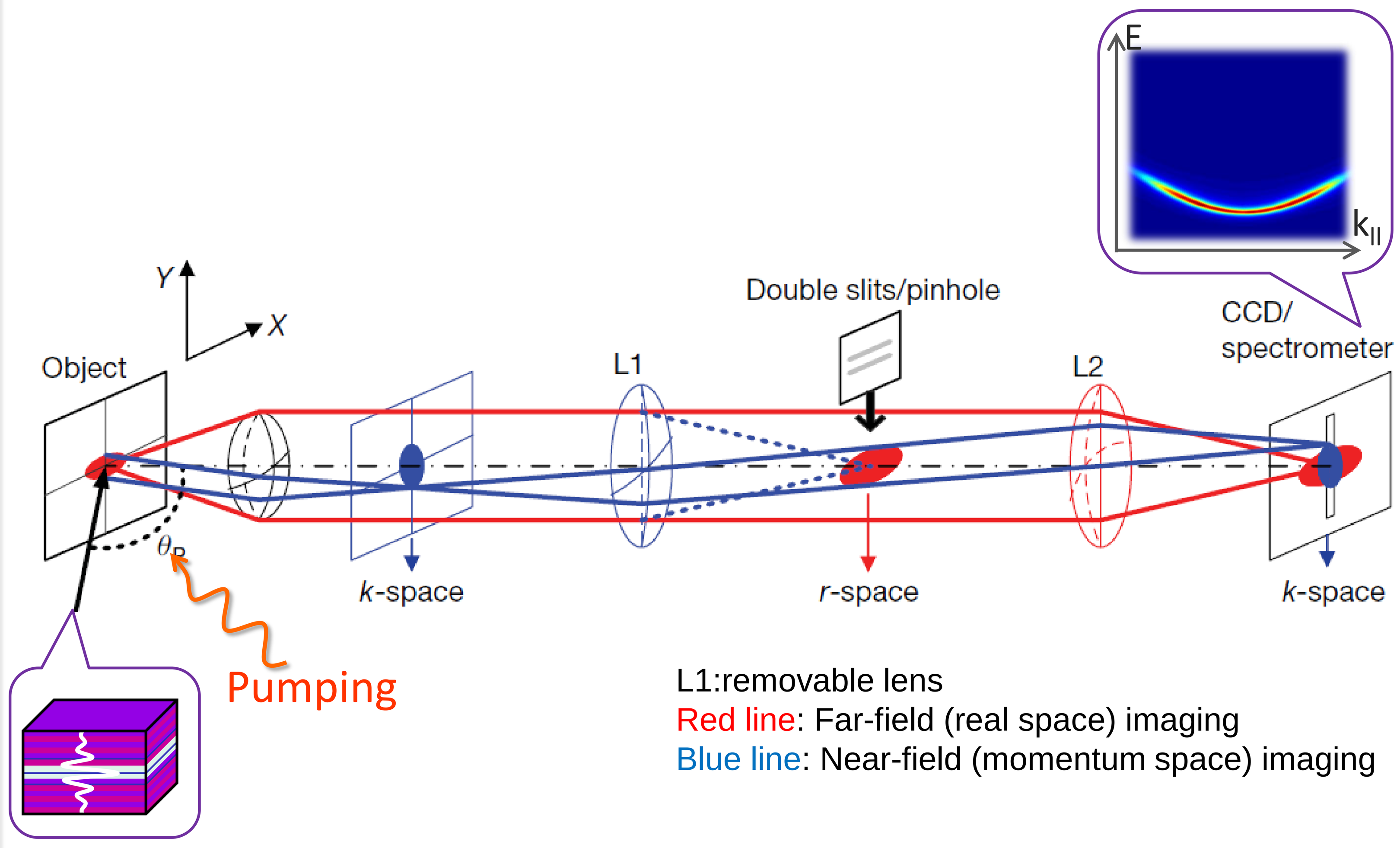




S. Jiang et al., Appl. Phys. Lett. 73, 3031 (1998)

$$E_{LP,UP}(k_{||}) = \frac{1}{2}\left[E_{exc}+E_{cav}\pm\sqrt{4\hbar^2\Omega^2+(E_{exc}-E_{cav})^2}\right]$$

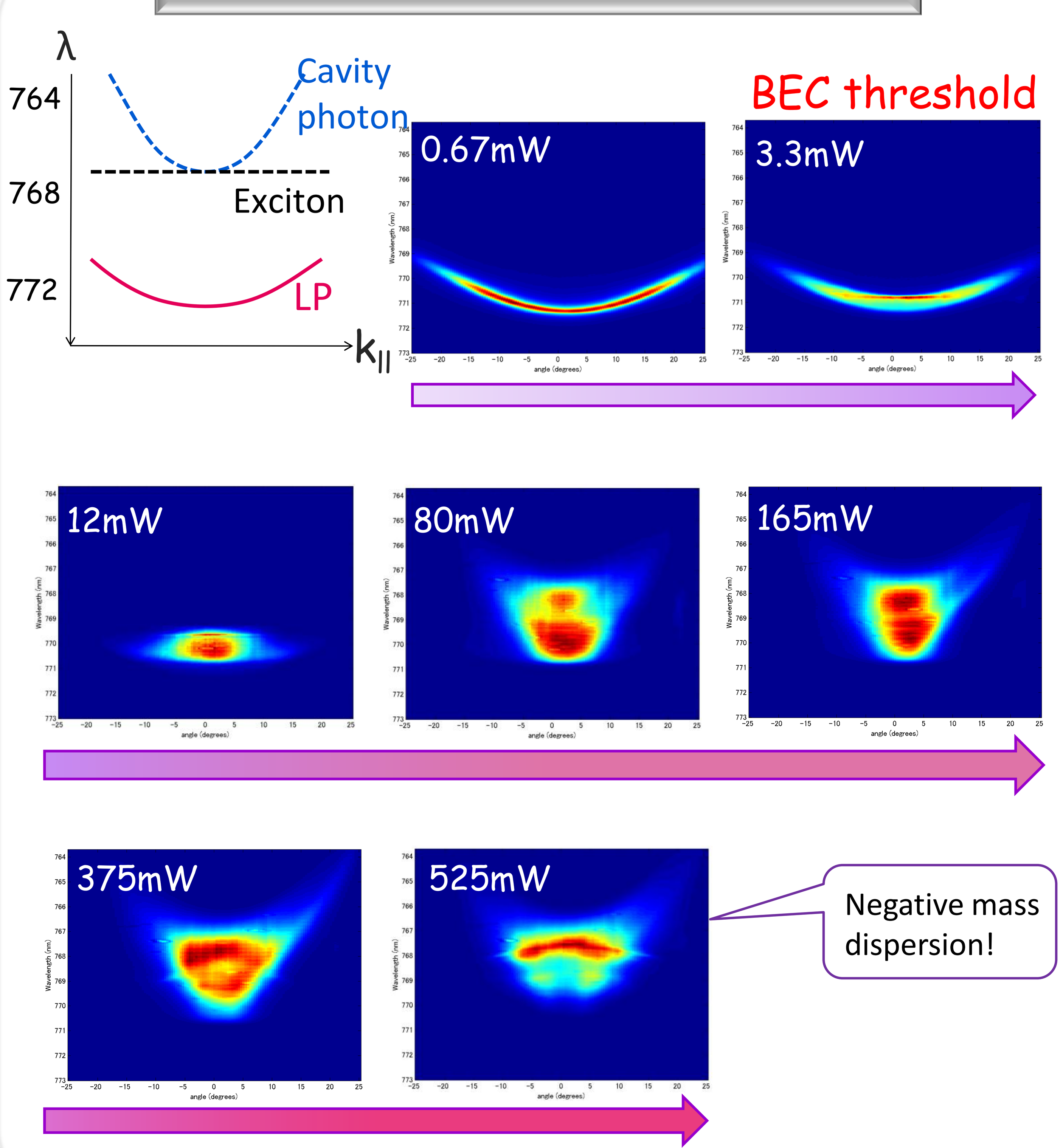
4. Experimental setup



L1:removable lens
Red line: Far-field (real space) imaging
Blue line: Near-field (momentum space) imaging

C.W. Lai et al. Nature **450**, 529-532 (2007)

5. Highly excited polariton BECs



6. Negative mas dispersion due to quantum depletion

Assume particles at condensate scatter into the positive and negative branches to conserve energy and momentum.

Applying the parametric theory [1]

$$i\hbar\frac{d}{dt}\begin{pmatrix}\hat p_k(t)\\ \hat p^\dagger_{-k}(t)e^{-i2\varepsilon_0 t/\hbar}\end{pmatrix} = \hat M_k^{par}\begin{pmatrix}\hat p_k(t)\\ \hat p^\dagger_{-k}(t)e^{-i2\varepsilon_0 t/\hbar}\end{pmatrix} + \begin{pmatrix}\hat F_k(t)\\ -\hat F^\dagger_{-k}(t)e^{-i2\varepsilon_0 t/\hbar}\end{pmatrix}$$

Condensate energy

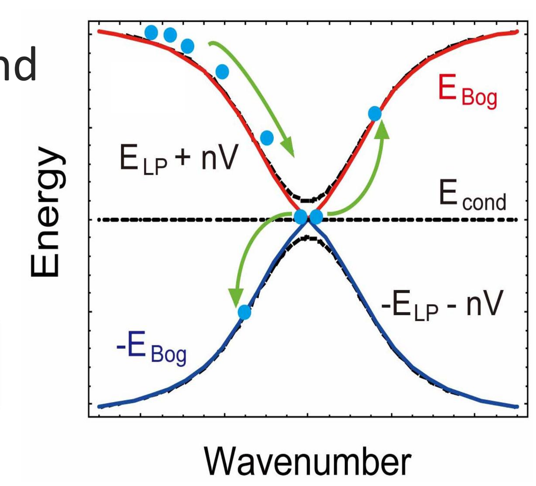
Where

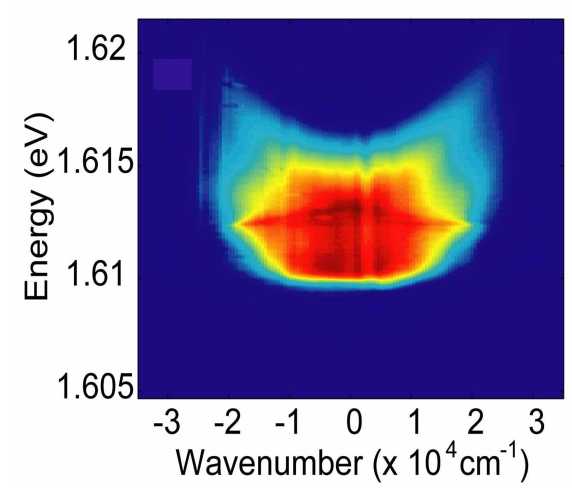
$$\hat M_k^{par} = \begin{pmatrix} E_k(n)+U(n)-i\gamma & U(n)\\ -U(n) & 2\varepsilon_0 - E_k(n)-U(n)-i\gamma\end{pmatrix}$$

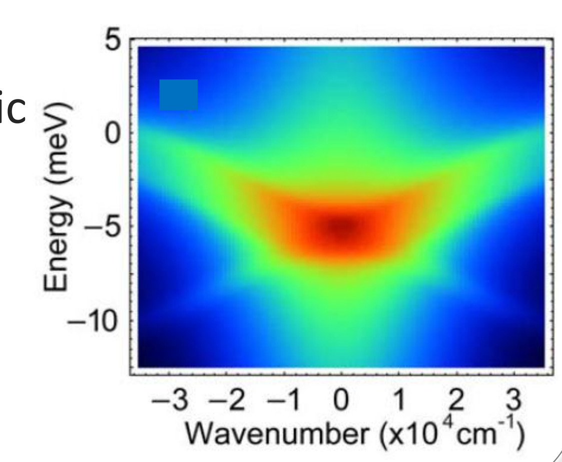
Photoluminescence is then defined by

$$PL(k,t,\omega)\propto |C_k|^2\,\mathrm{Re}\int_0^{+\infty} d\tau e^{-i(\omega-i0^+)\tau}\left\langle \hat p_k^\dagger(t+\tau)\hat p_k(t)\right\rangle$$

Here, we use parameters from BCS model [2] in parametric scattering theory.







[1] C. Ciuti, P. Schwendimann, A. Quattropani, PRB 63, 041303(R) (2001)
[2] T. Byrnes, T. Horikiri. N. Ishida, Y. Yamamoto, PRL 105, 186402 (2010)