Building Bridges 2018

AE-Barcelona Knowledge Hub

28-29 NOVEMBER 2018

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- Graduate in Physics, University of Zaragoza (Spain). **J.M. Saviron** (1979)
- Phd at Max-Planck Institut für Festkörperforscung, Stuutgart (Germany). **M. Cardona** (1980-)
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  Full Professor and Head of Department

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- Department of Material Sciences. Universidad Autonoma of Madri 95-)

  Full Professor and Head of Department

Bose-Einstein condensates in semiconductor microcavities

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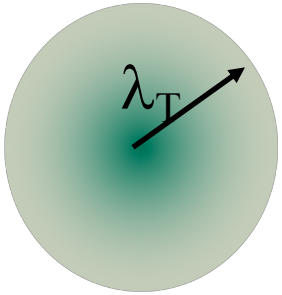
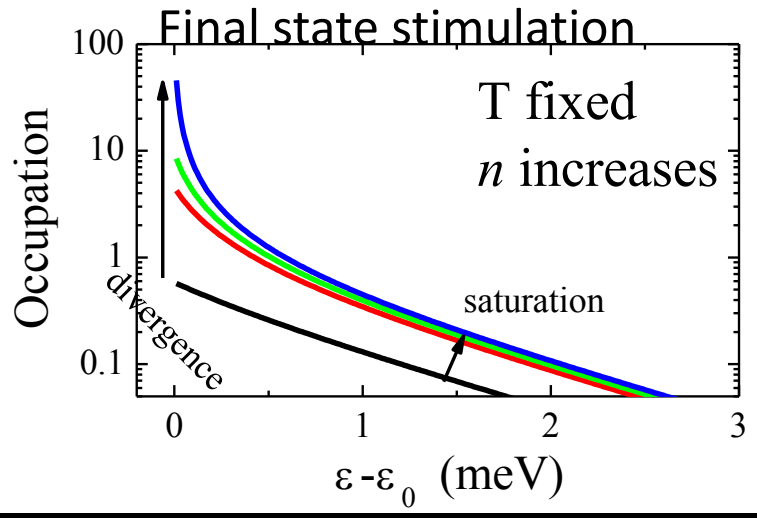
Atomic BECs

$$f_{BE} = \frac{1}{\exp\left(\frac{\varepsilon - \mu}{k_B T}\right) - 1}$$

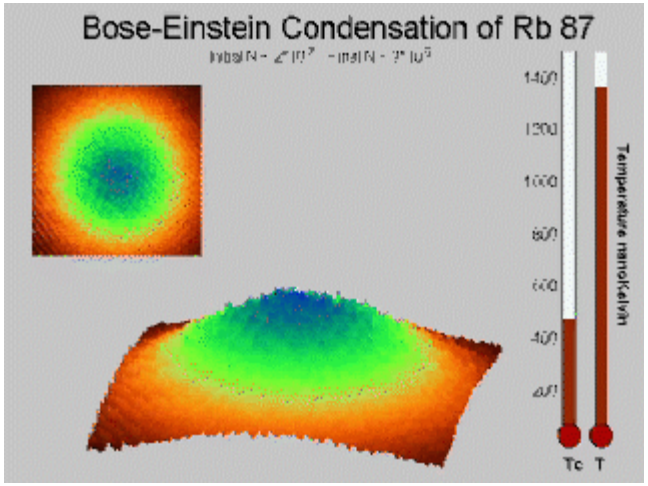
$$\lambda_T = \left(\frac{2\pi\hbar^2}{m k_B T}\right)^{\frac{1}{2}}$$



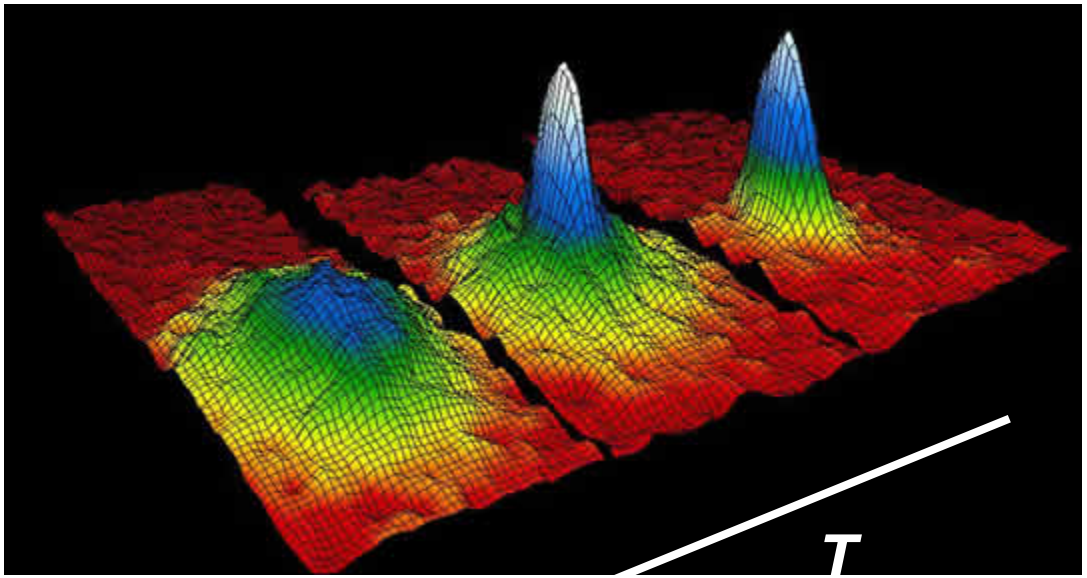
For $T < T_{deg}$
the particles-waves overlap



Long-range order

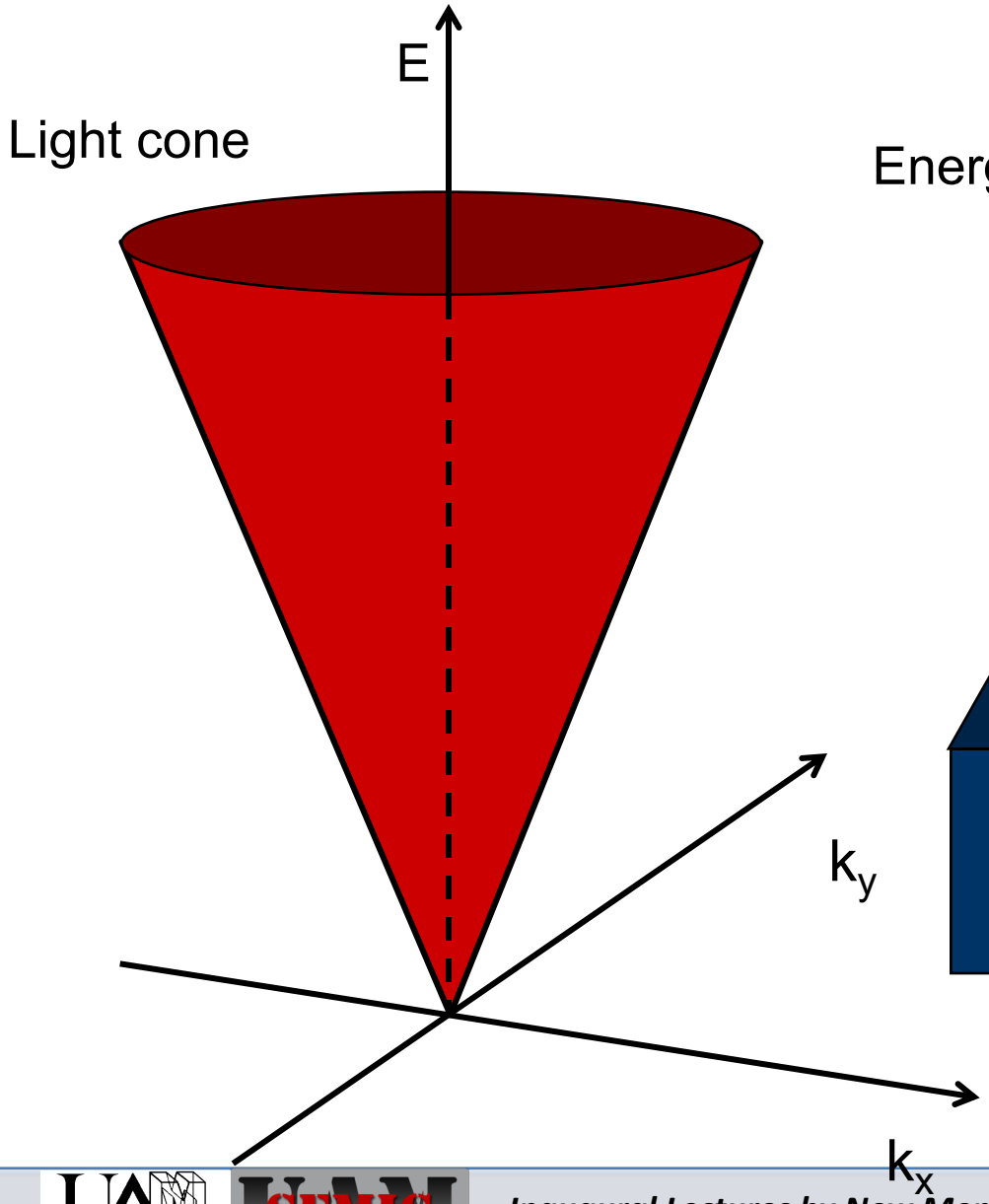


Cornell group (1995)



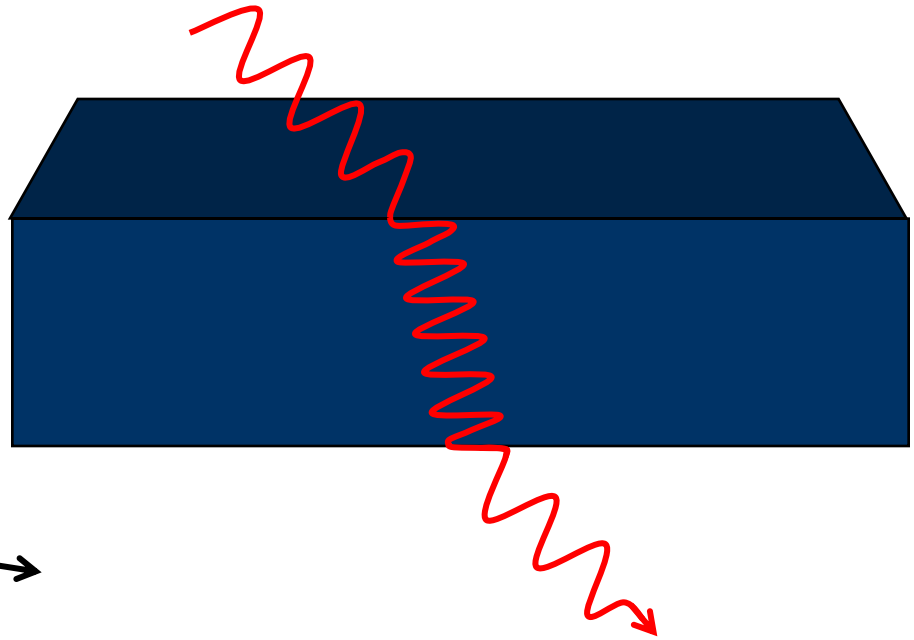
http://jilawww.colorado.edu/bec/

Semiconductor microcavities

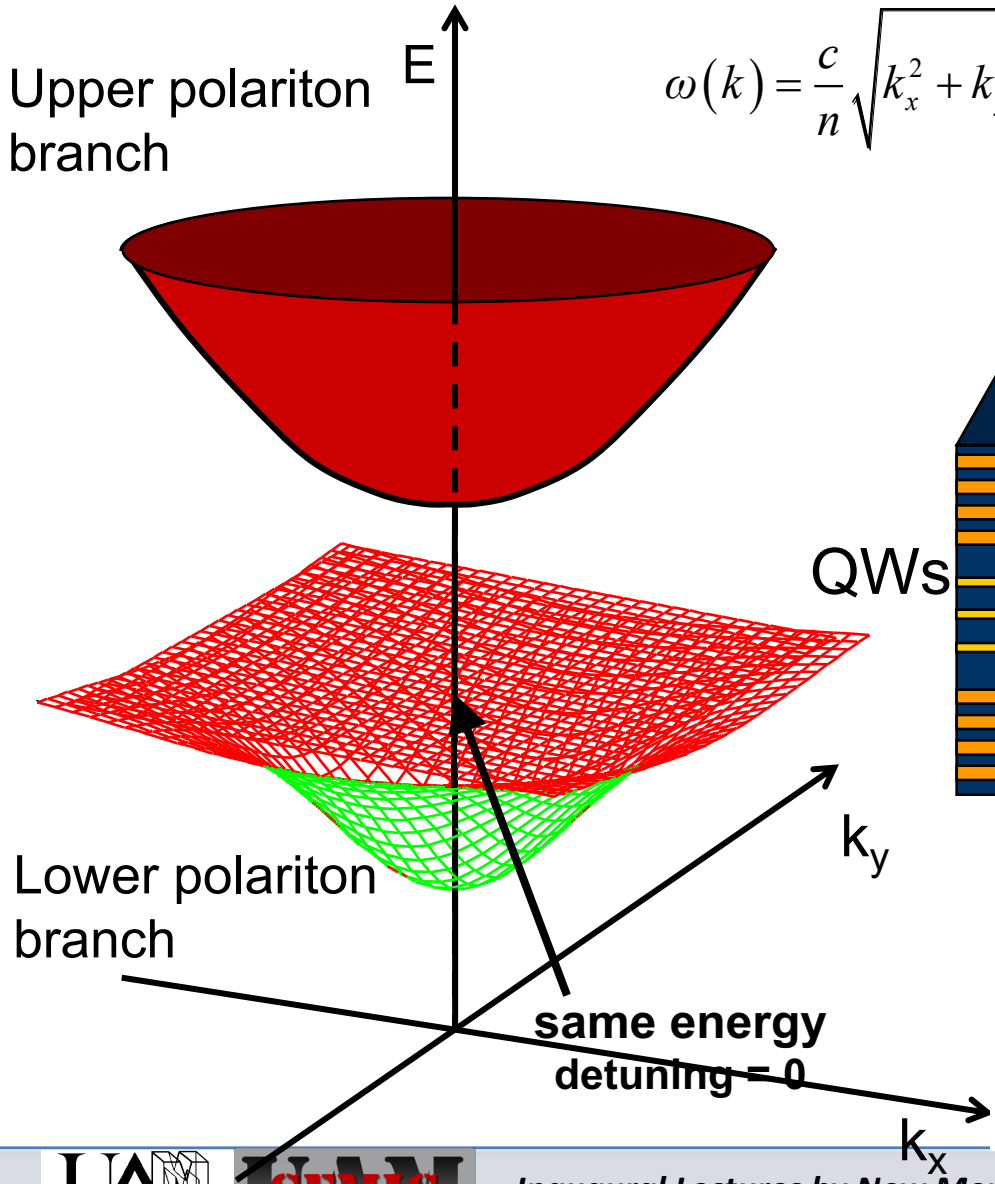


Energy dispersion for a photon in a solid

$$\omega = \frac{c}{n}\left|\vec{k}\right|$$

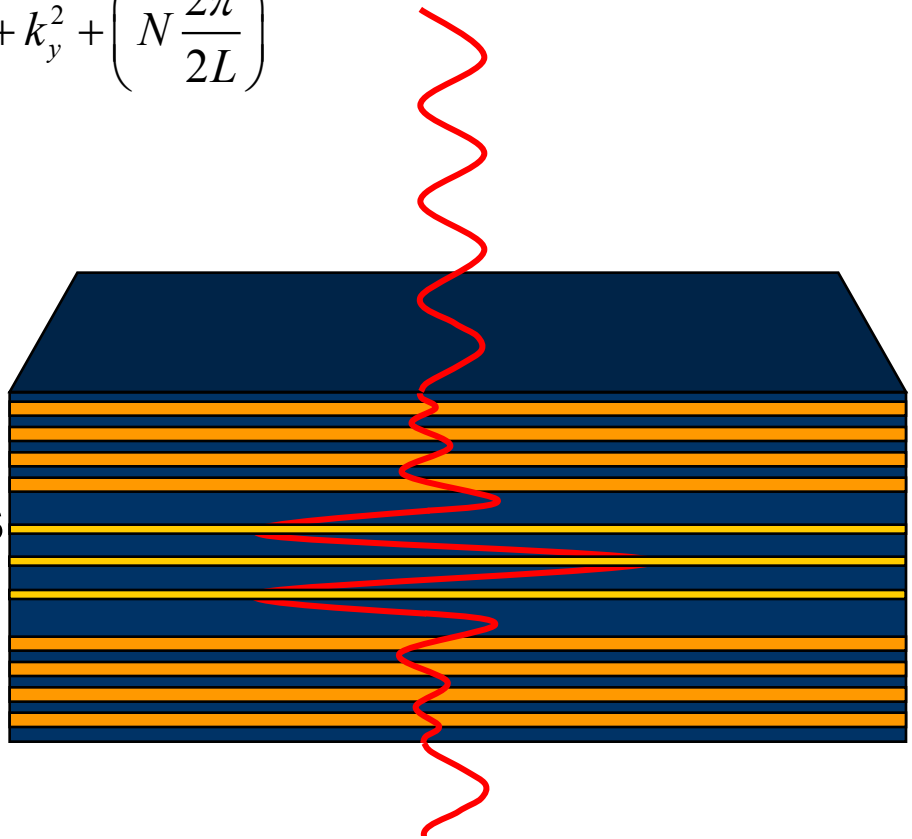


Semiconductor microcavities



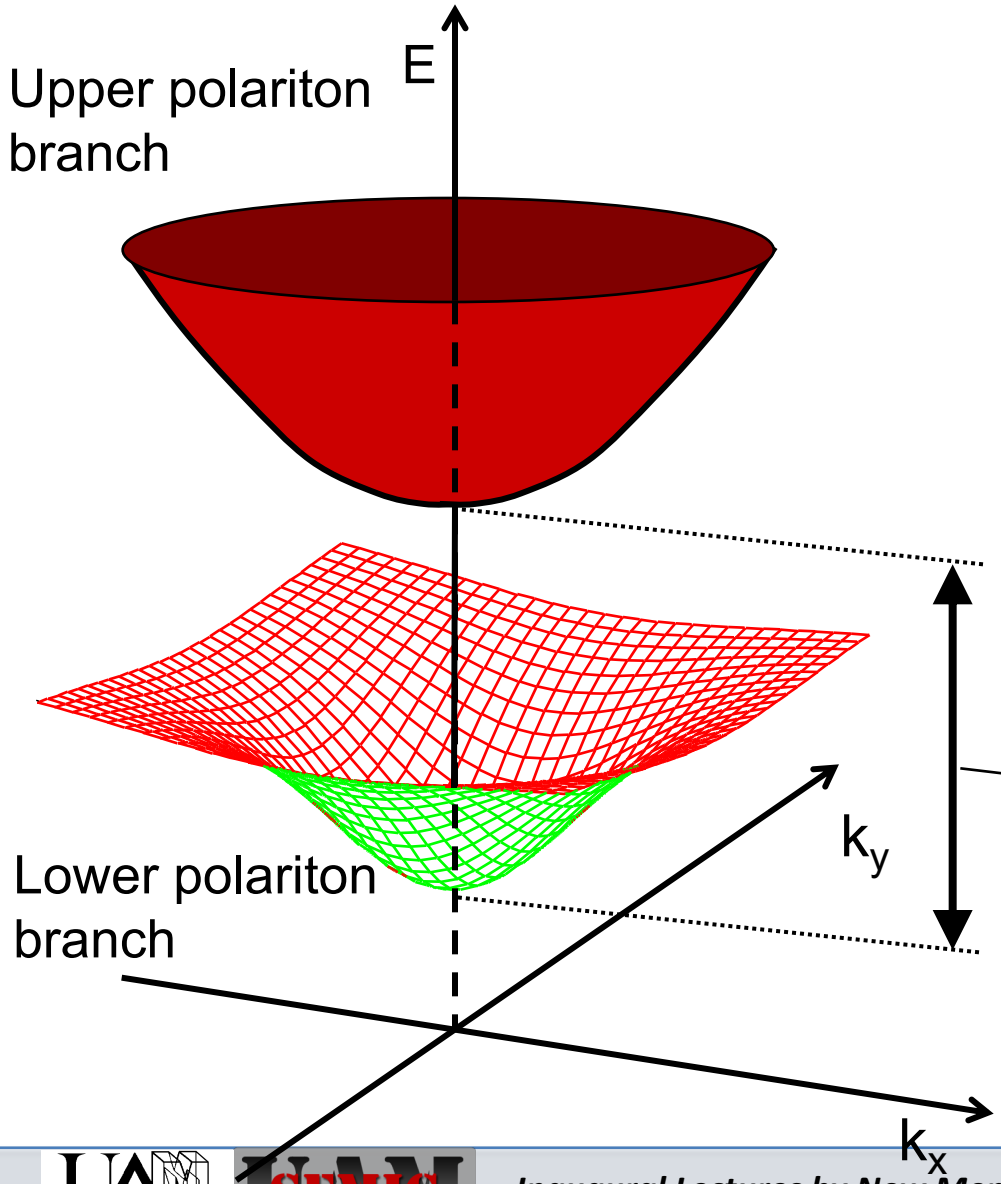
$$\omega(k) = \frac{c}{n}\sqrt{k_x^2 + k_y^2 + \left(N\frac{2\pi}{2L}\right)^2}$$

QWs



$$\mathcal{H}_{pol}\left(k_{\|}\right) = \begin{pmatrix} \hbar\omega_c\left(k_{\|}\right) & \hbar\Omega_R \\ \hbar\Omega_R & \hbar\omega_x\left(k_{\|}\right) \end{pmatrix}$$

Semiconductor microcavities



Strong exciton confinement
Enhanced electromagnetic field

⬇

Strong light-matter coupling

New eigenstates
POLARITONS

$$\hat{Q}_{UPB} = c \cdot \hat{P} + d \cdot \hat{X}$$

$$\hat{Q}_{LPB} = -d \cdot \hat{P} + c \cdot \hat{X}$$

Rabi splitting

$$\Omega_R^2 = \frac{\left(1+\sqrt{R}\right)^2}{2\sqrt{R}} \frac{c\Gamma_0}{n_{cav} L_{eff}}$$

Low polariton mass
"*S*" shaped dispersion
Momentum trap

polaritons

New eigenstates
POLARITONS

$$\hat{Q}_{UPB} = c \cdot \hat{P} + d \cdot \hat{X}$$

$$\hat{Q}_{LPB} = -d \cdot \hat{P} + c \cdot \hat{X}$$

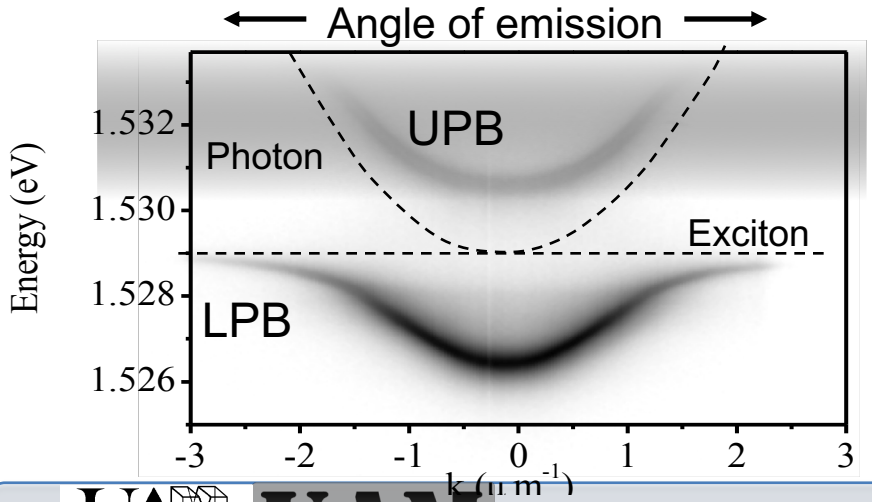
composite BOSONS

photonic content ⟷ very low mass

High condensation temperature
10 K -300 K

$$\lambda_T = \left(\frac{2\pi\hbar^2}{m k_B T} \right)^{\frac{1}{2}}$$

species	atomic gases	polaritons
mass m^*/m_0	10^4	10^{-5}
Bohr radius	10^{-1} Å	10^2 Å
λ_T at T_c	10^3 Å	10^4 Å
T_c	$< 1\mu$K	$10 - 300$K

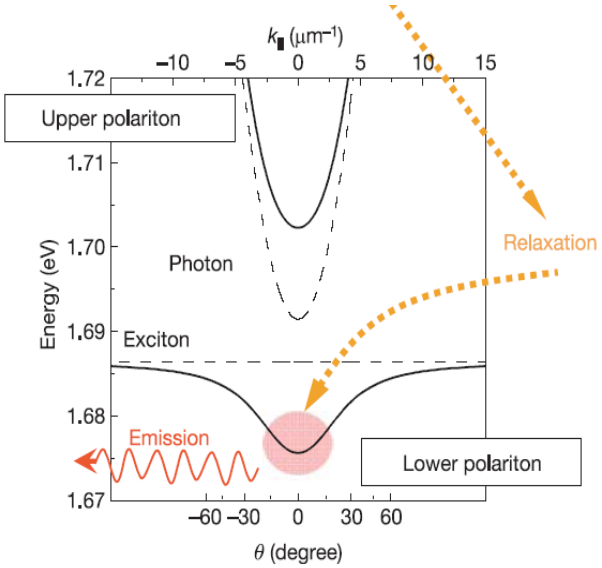


Polariton lifetime: 2-8 ps (at $k = 0$)

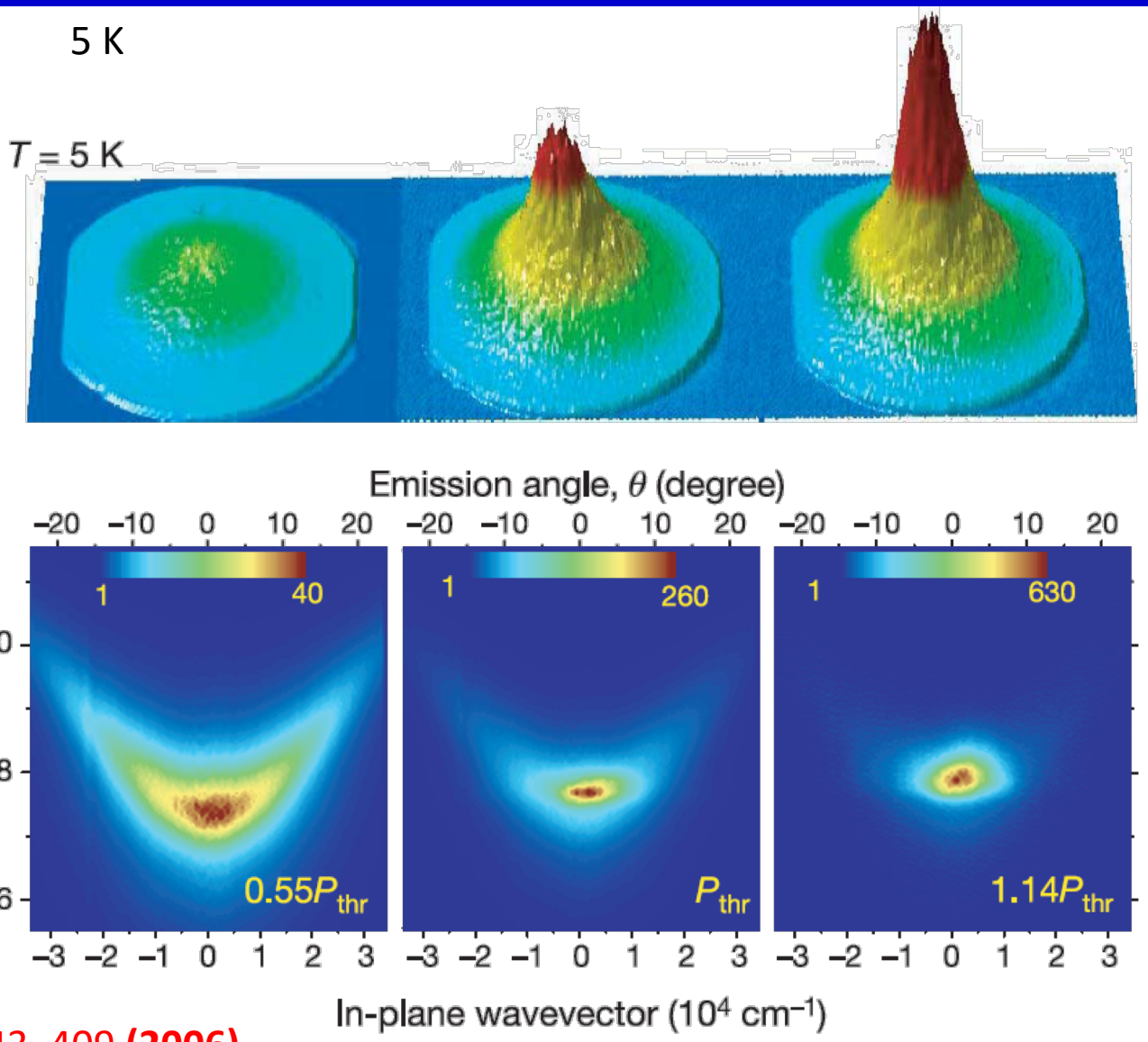
PL experiment

BEC of polaritons

Excitation CW laser 1.755 eV

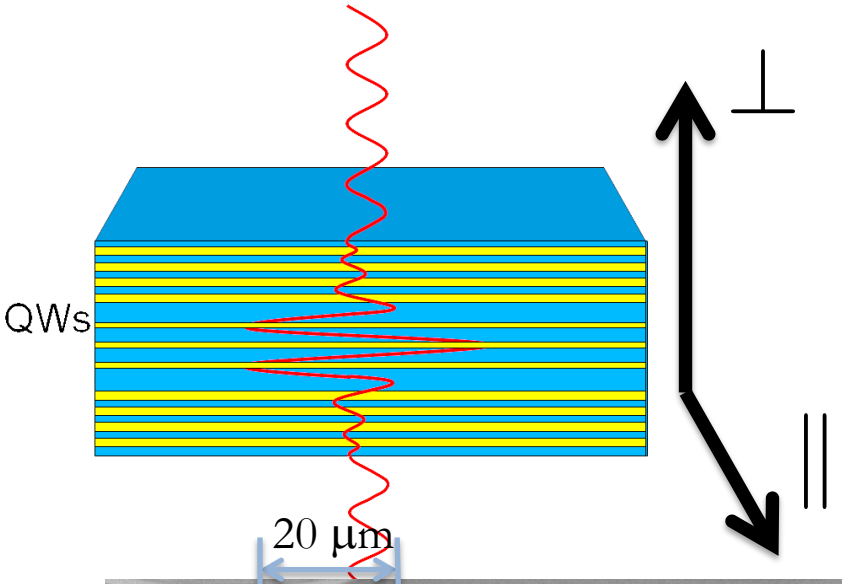


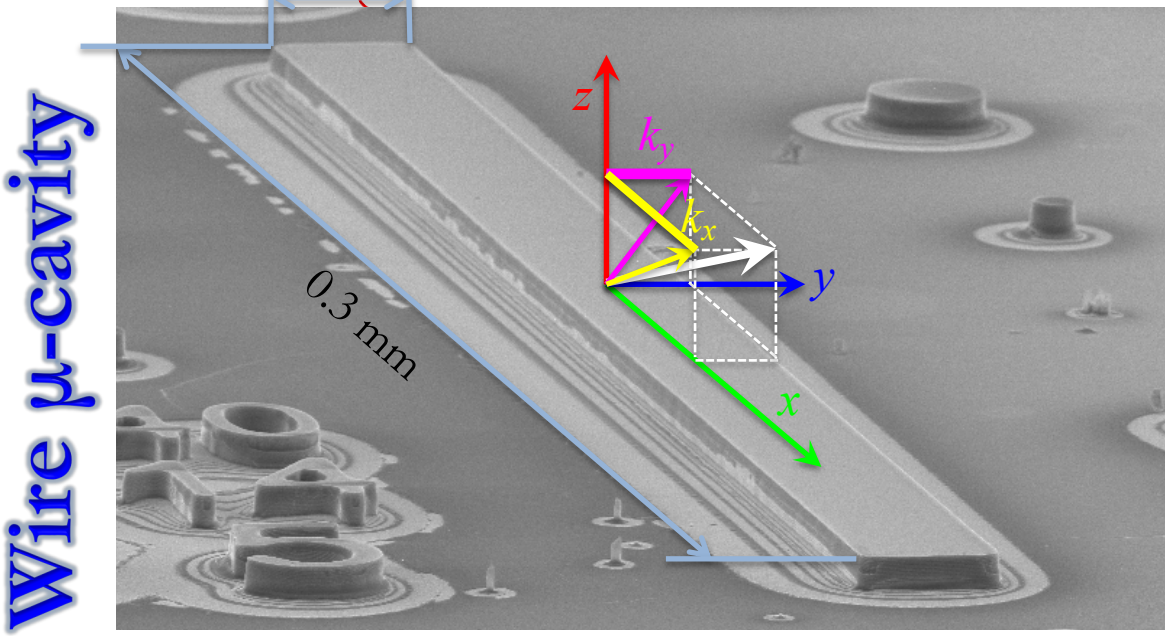
5 K



Kasprzak et al. Nature 443, 409 **(2006)**

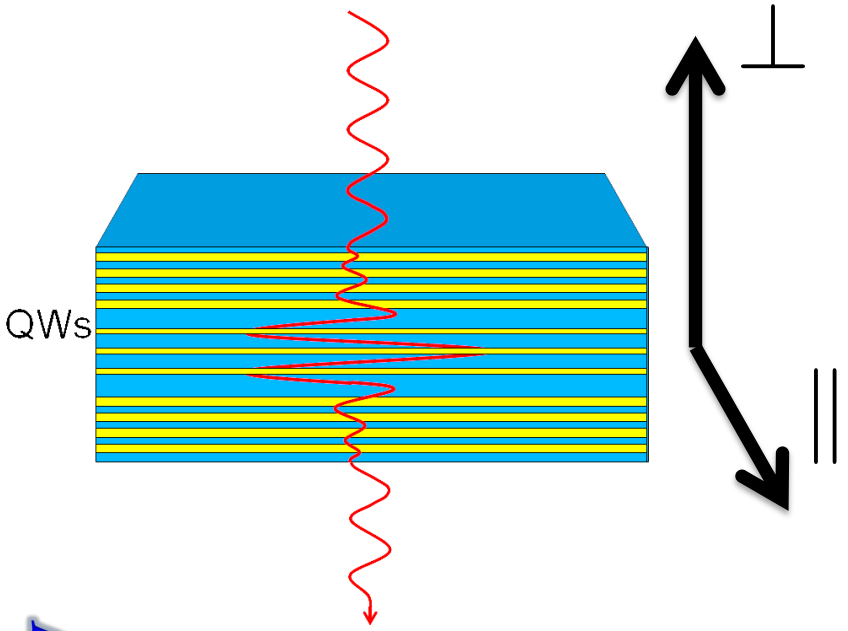
Wire microcavities

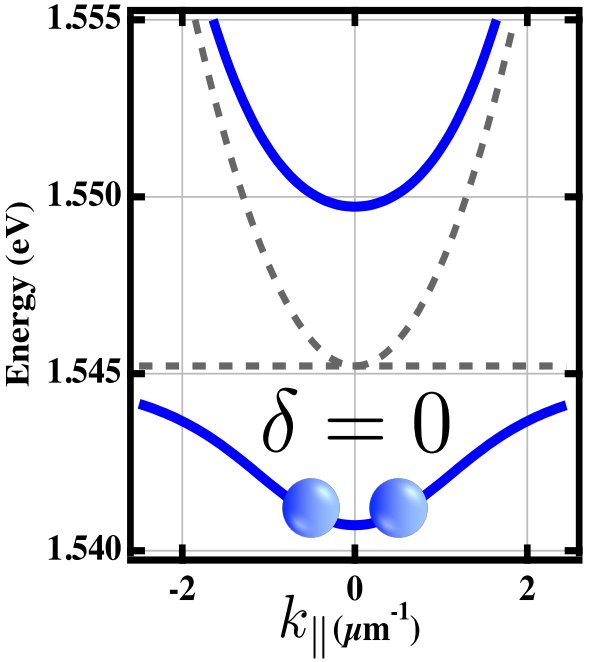




High-quality AlGaAs-based microcavity

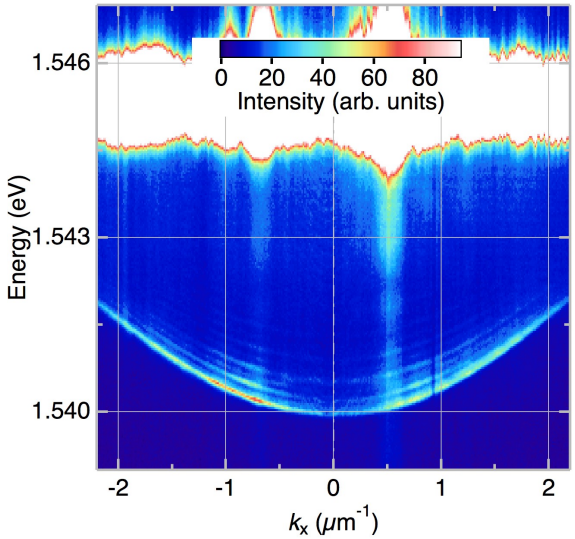
Wire microcavities

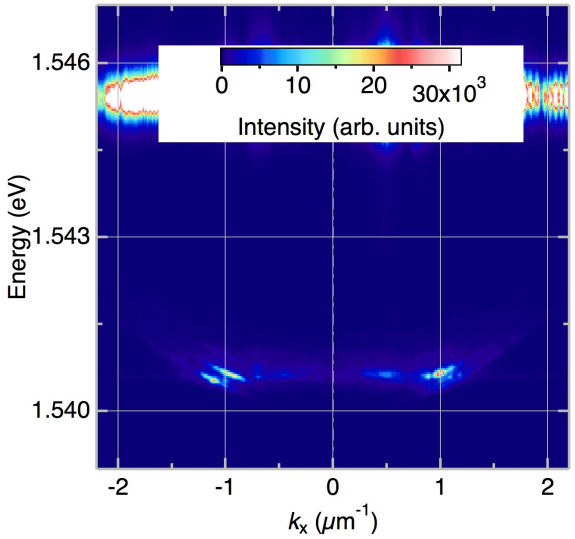




Strong coupling

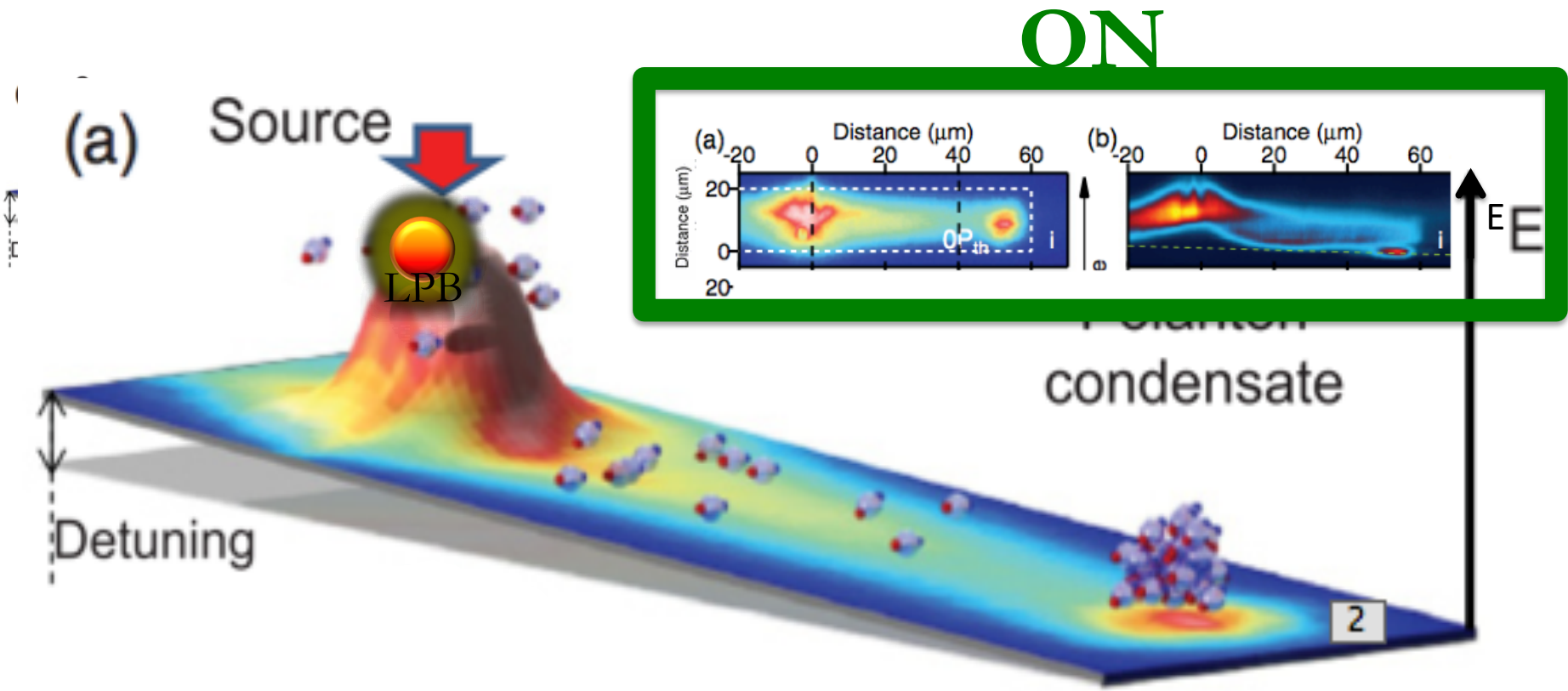
Wire μ-cavity



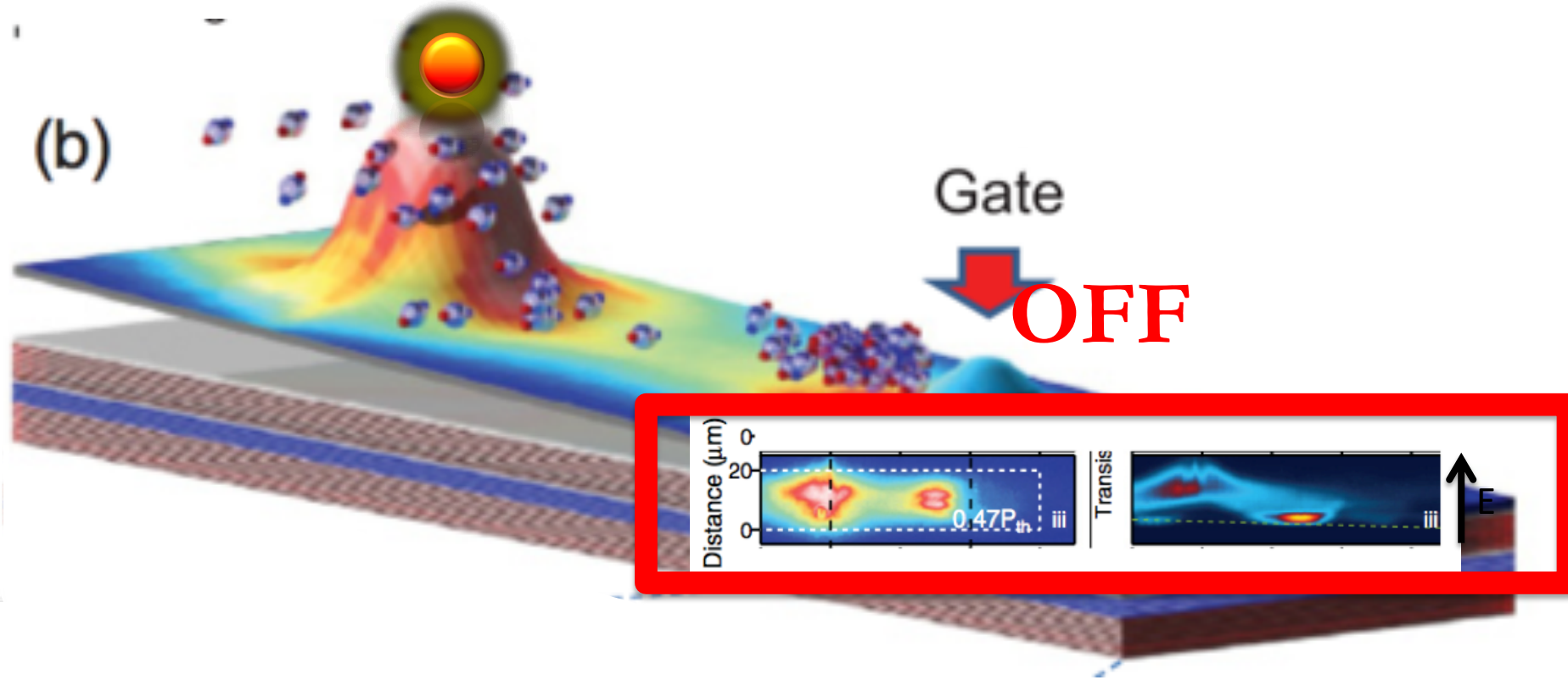


Moving condensates

Polariton condensates transistor switch

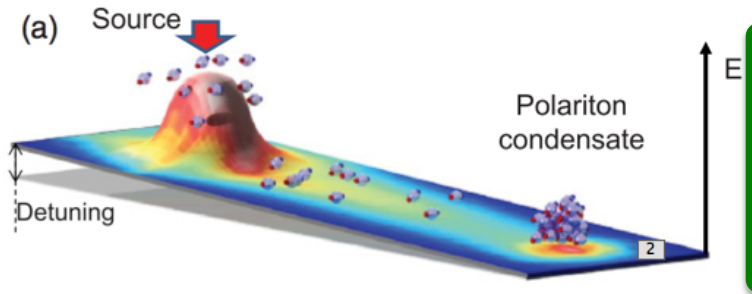


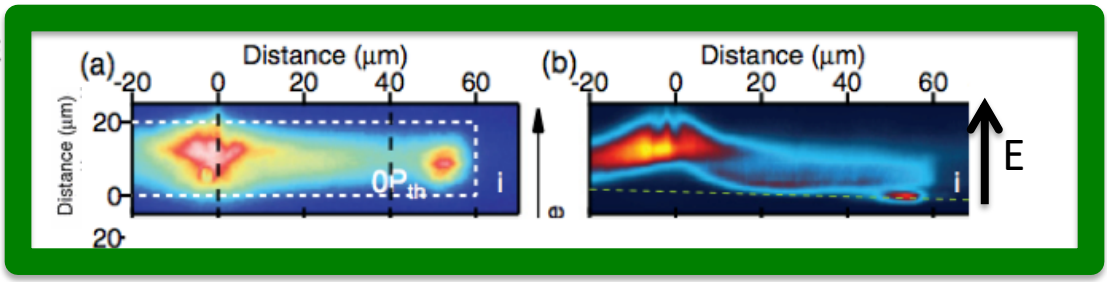
Polariton condensates transistor switch



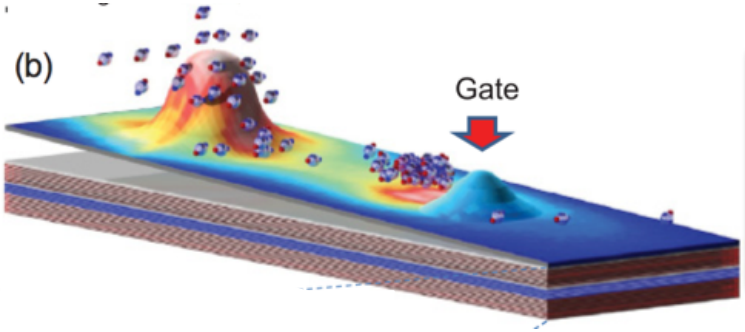
Polariton condensates transistor switch

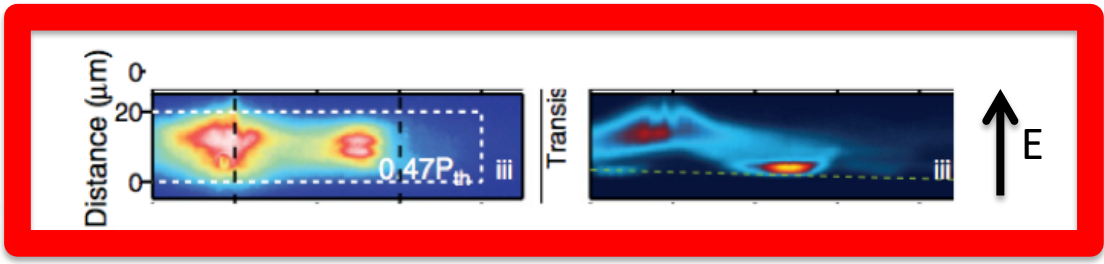
ON



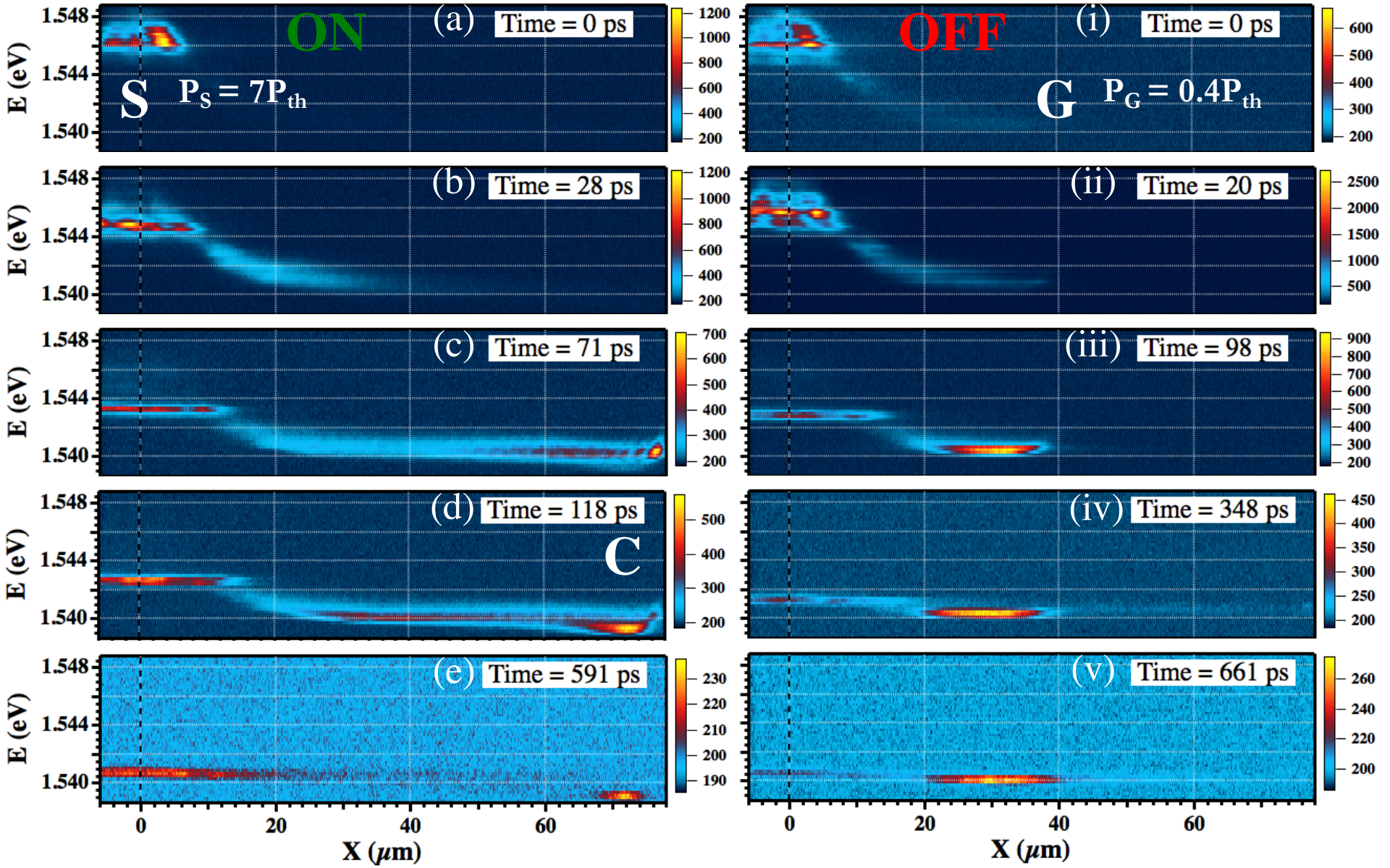


OFF

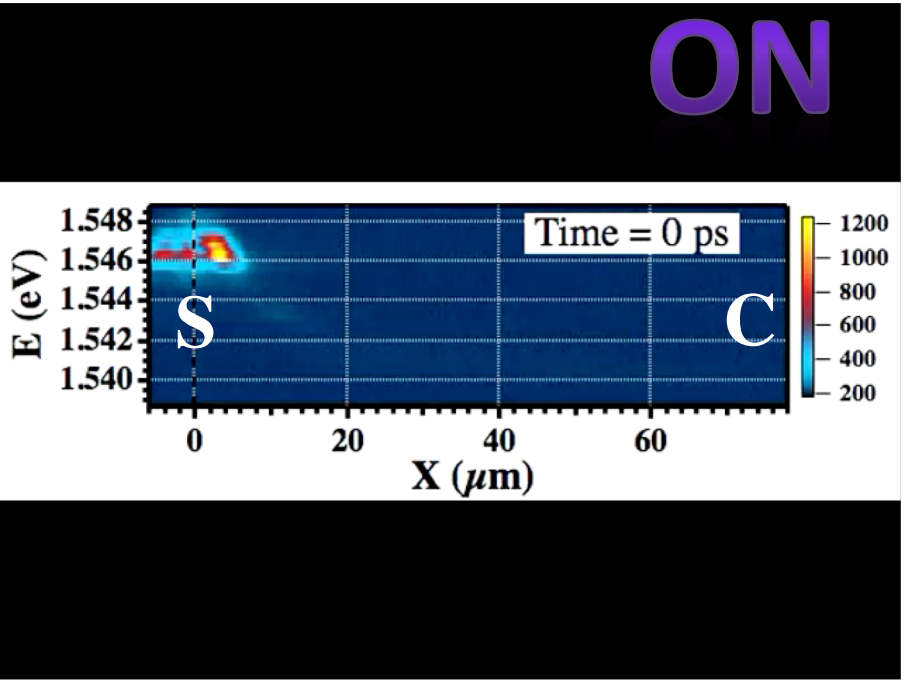


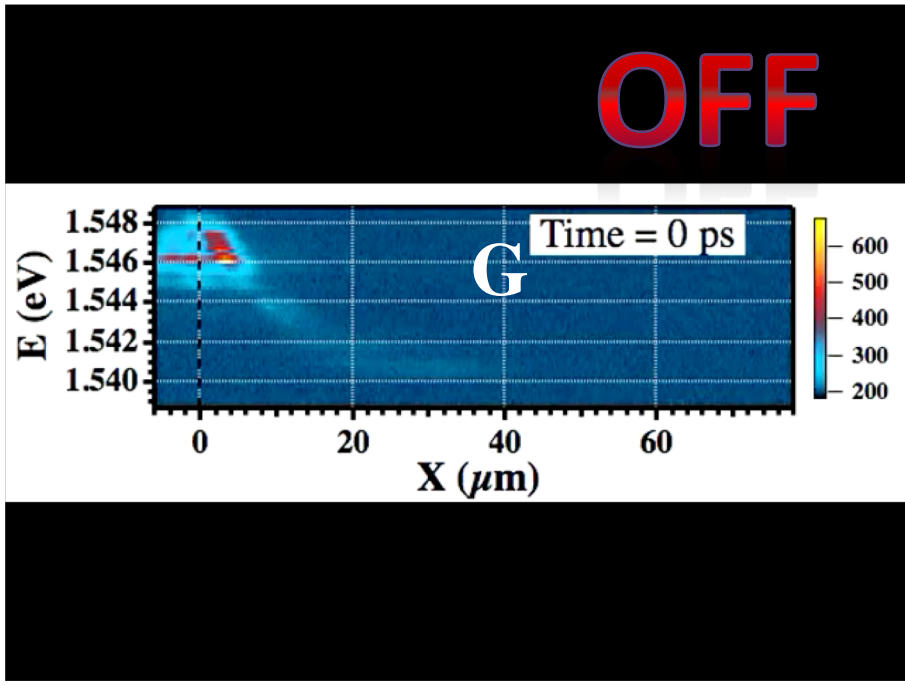


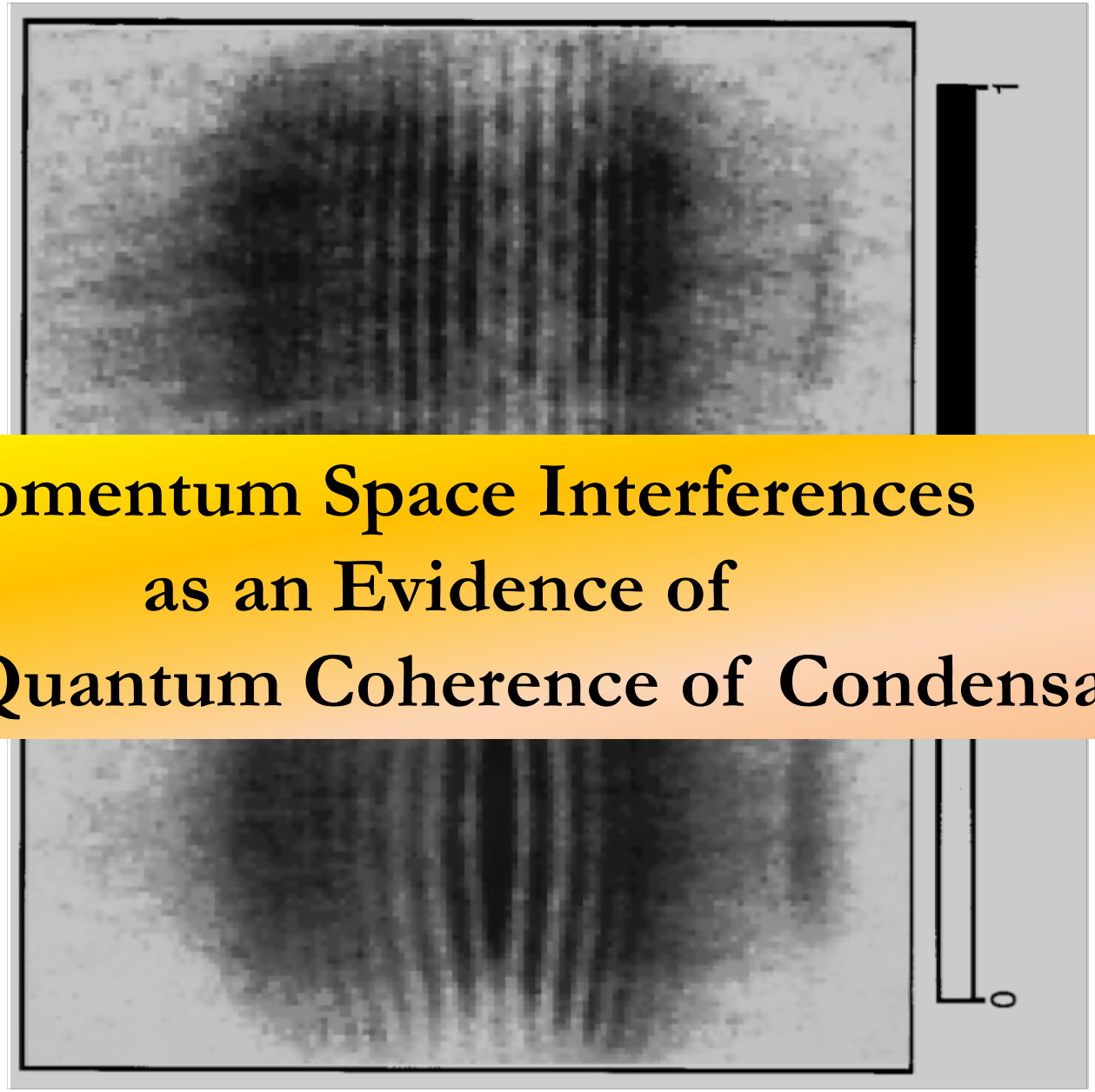
Experiments (snapshots)



Experiments (movies)

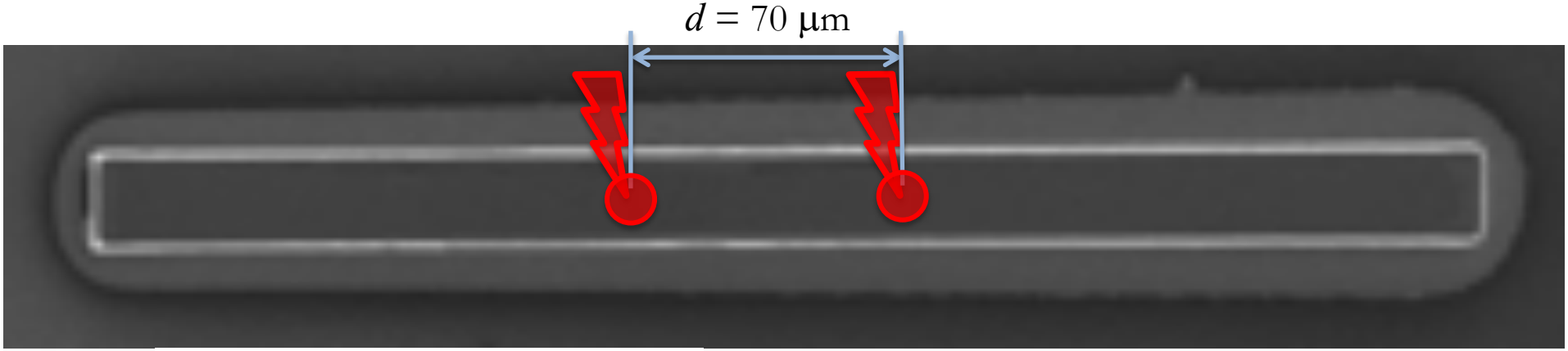


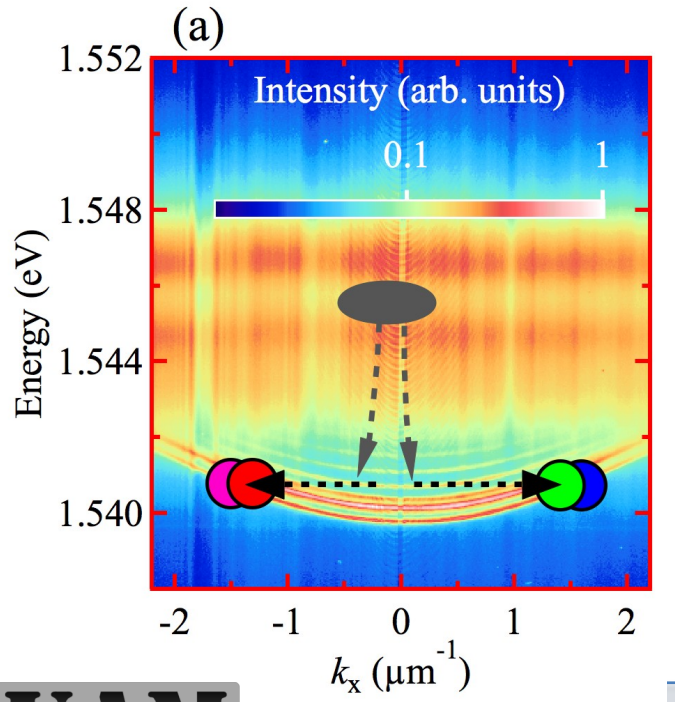


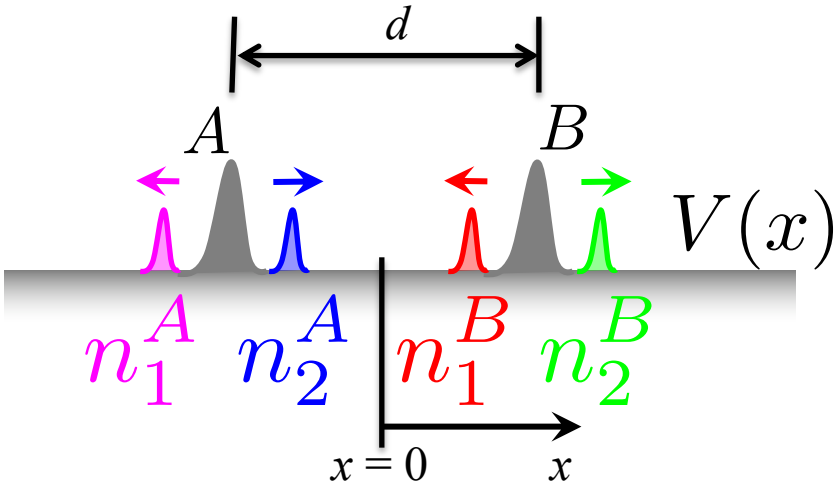


Momentum Space Interferences as an Evidence of Remote Quantum Coherence of Condensates

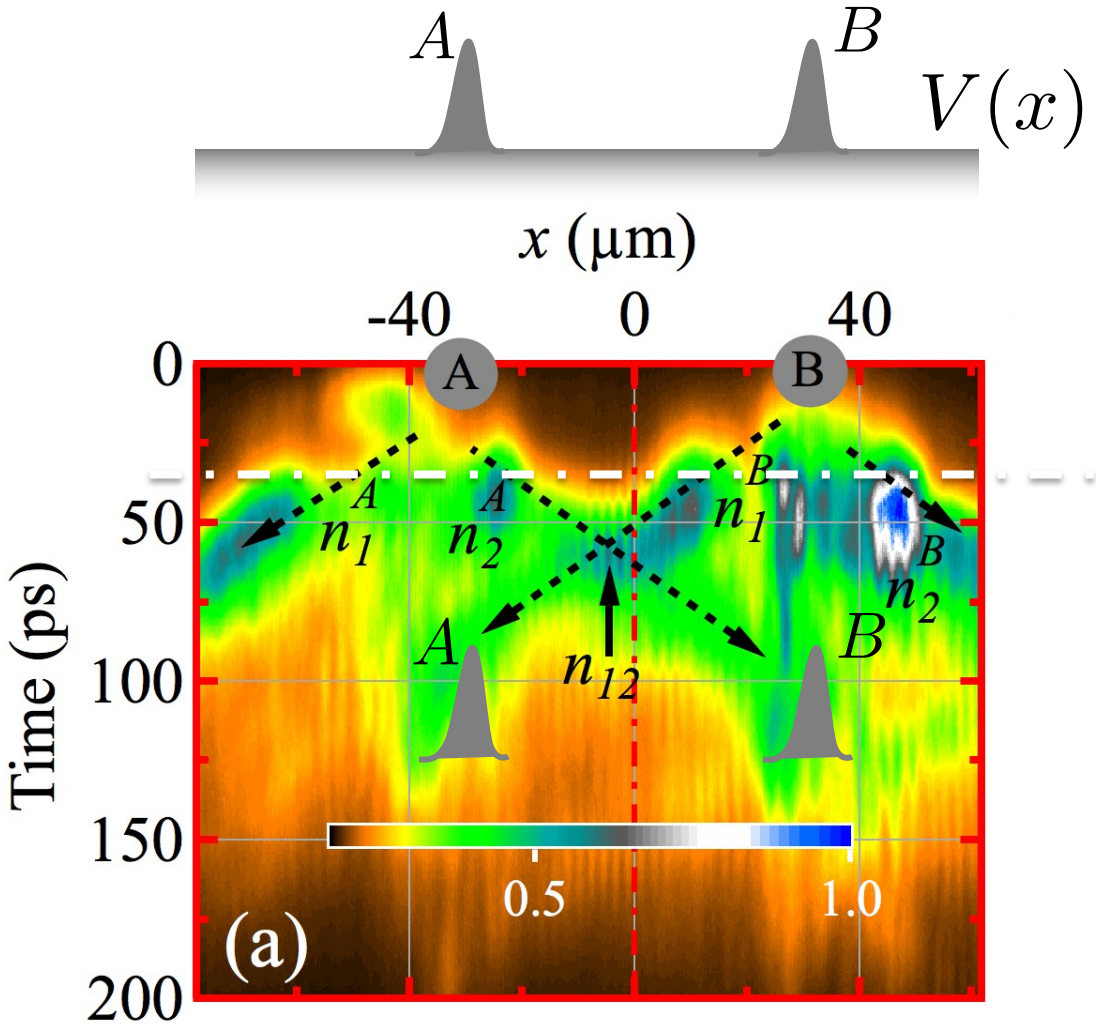
Full observation of the phase-locking in momentum space between polariton condensates





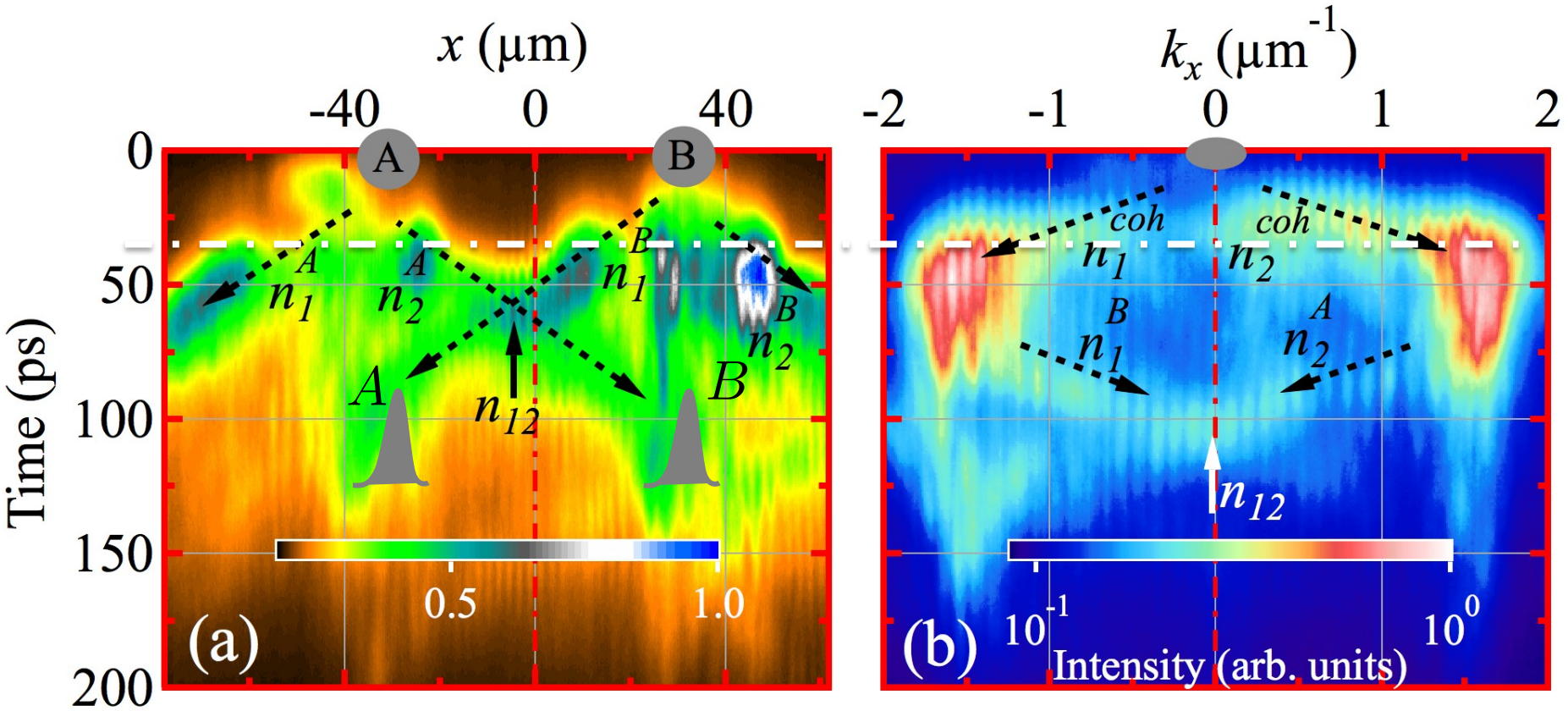


Full observation of the phase-locking in momentum space between polariton condensates



Full observation of the phase-locking in momentum space between polariton condensates

(I) Initial acceleration, t =35 ps



(v) Conclusions

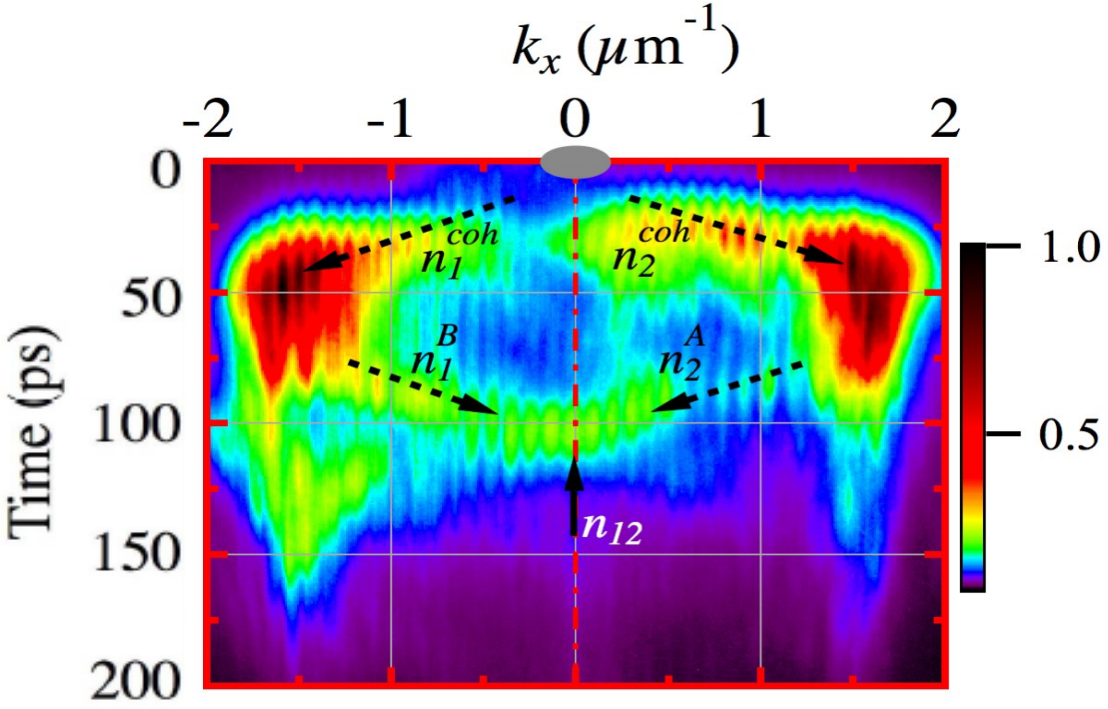
- Semiconductor microcavities:
ideal scenario to observe **Bose-Einstein condensation.**

- Generation of **ultrafast-propagating condensed polariton wave trains** in quasi-1D microcavities.

- Fabrication of **all-optical devices** based on polariton condenstes.

- Affirmative answer to the Anderson´s question: Dynamical observation (picosecond scale) of the **mutual coherence** in **momentum space** of polariton wave trains **that have never been in contact.**

Thank you very much…



…Funding

- ✓ Spanish MEC MAT2014-53119-C2-1-R
- ✓ Spanish MINECO MAT2017-83722-R