Fundamental phenomena and applications of exciton-polariton condensates (II)

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Outline

1. Motivations

Outline

1. Motivations

2. Samples

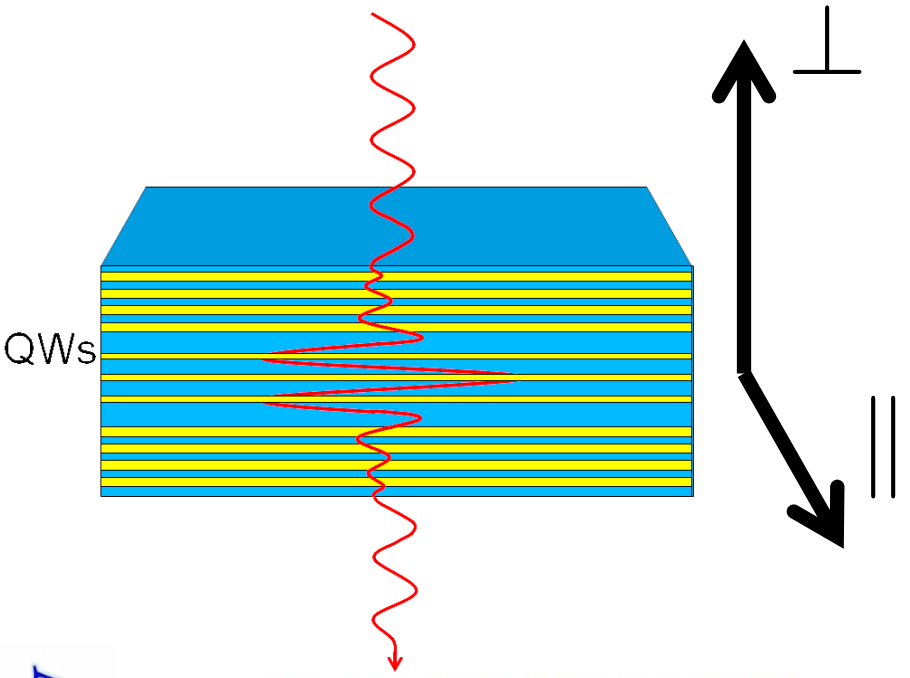
Outline

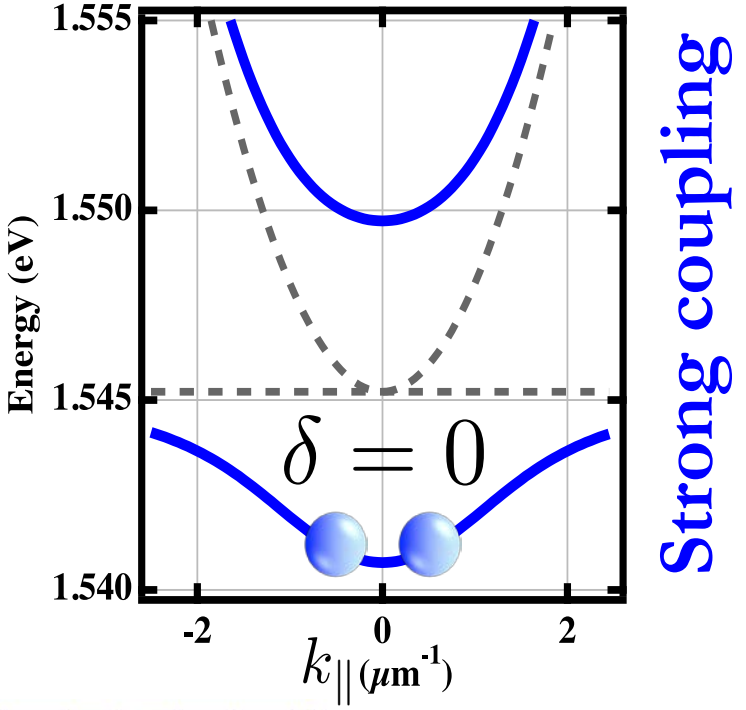
1. Motivations
2. Samples
3. **Devices**

Outline

1. Motivations
2. Samples
3. Devices
4. Coherence in k-space
5. **Summary**

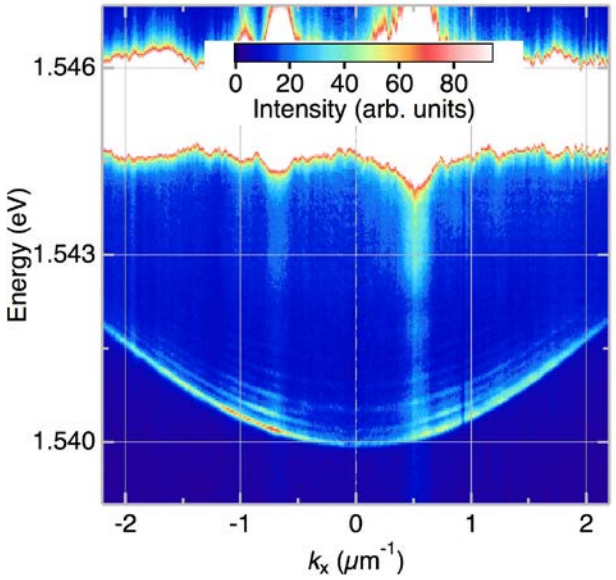
Introduction to polariton condensates

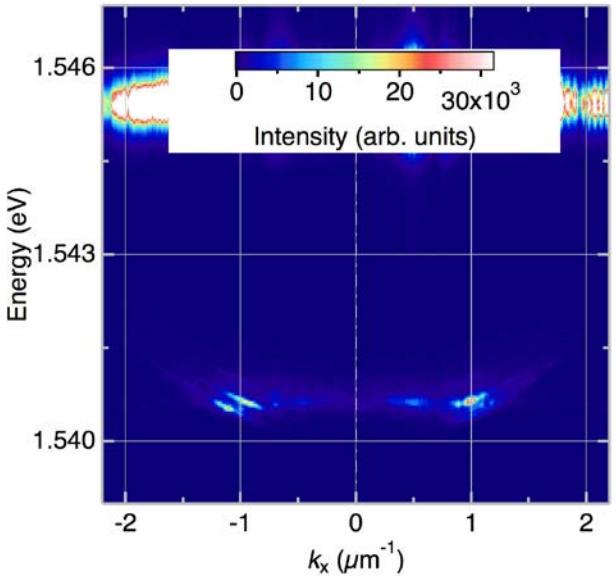




Strong coupling

Wire μ-cavity





Moving condensates

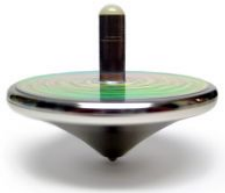
1. Motivations

Motivations

On the polaritronic technology…

Bose-Einstein condensates as a **tool** for technological development

- ✓ Coherence $\Psi_0(r,t)$
- ✓ Superfluid character
- ✓ Spin properties



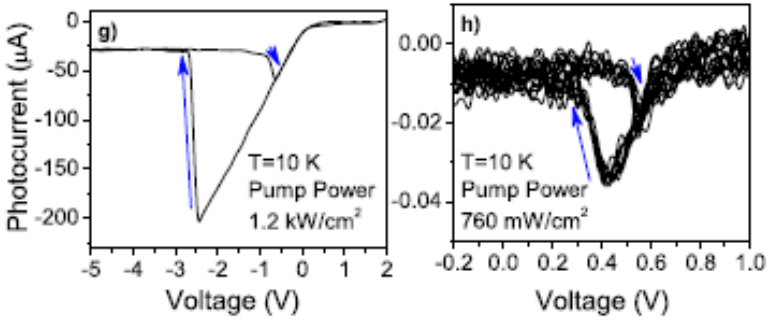
Why use polaritons?

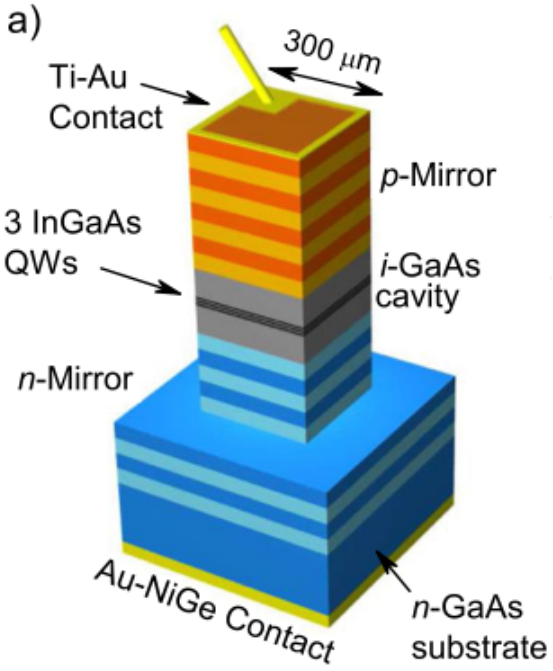
species	atomic gases	polaritons
mass m^*/m_0	10^4	10^{-5}
Bohr radius	10^{-1}Å	10^2Å
λ_T at T_c	10^3Å	10^4Å
T_c	$< 1\mu$K	$10 - 300$K

Motivations

On the polaritronic technology…

✓ Optical gates





PRL 101, 266402 (2008) PHYSICAL REVIEW LETTERS week ending 31 DECEMBER 2008

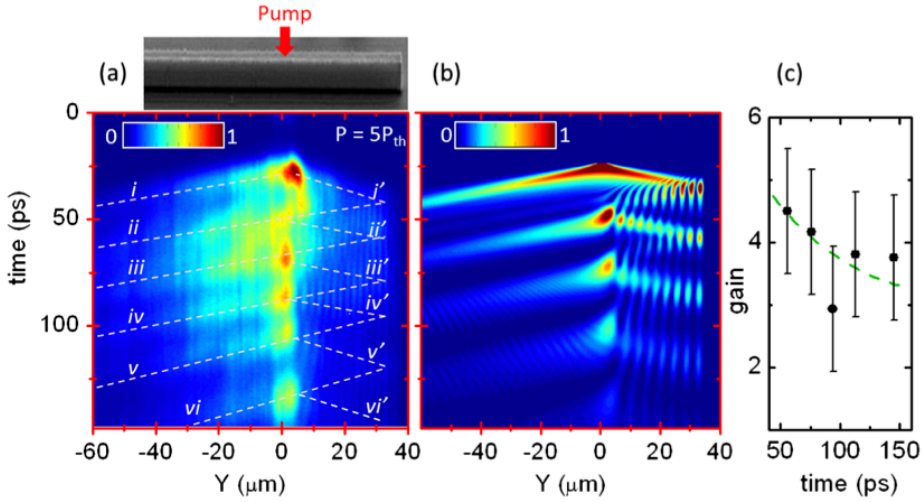
Optical Bistability in a GaAs-Based Polariton Diode

Daniele Bajoni,* Elizaveta Semenova, Aristide Lemaître, Sophie Bouchoule, Esther Wertz, Pascale Senellart, Sylvain Barbay, Robert Kuszelewicz, and Jacqueline Bloch†

Motivations

On the polaritronic technology…

- ✓ Optical amplifiers



PRL 109, 216404 (2012) PHYSICAL REVIEW LETTERS week ending 21 NOVEMBER 2012

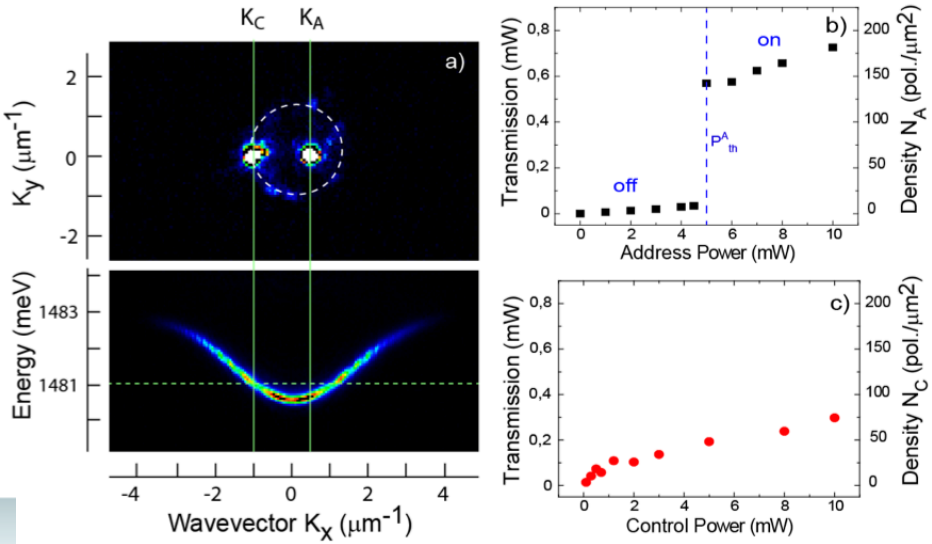
Propagation and Amplification Dynamics of 1D Polariton Condensates

E. Wertz,[1] A. Amo,[1] D. D. Solnyshkov,[2] L. Ferrier,[1] T. C. H. Liew,[3] D. Sanvitto,[4,5] P. Senellart,[1] I. Sagnes,[1] A. Lemaître,[1] A. V. Kavokin,[6,7] G. Malpuech,[2] and J. Bloch[1,*]

Motivations

On the polaritronic technology…

✓ Transistors



nature COMMUNICATIONS 4, 1778 (2013).

ARTICLE

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DOI: 10.1038/ncomms2734

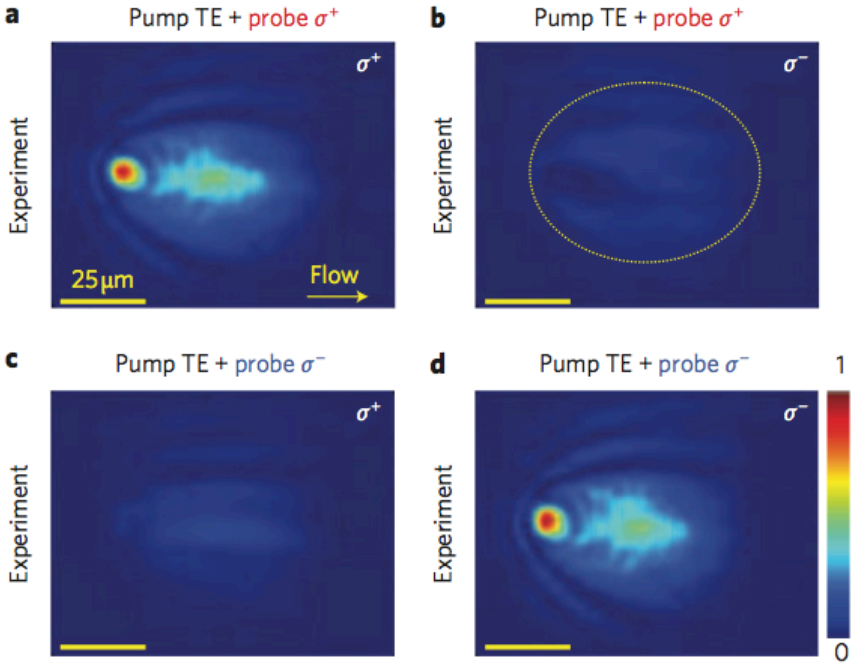
All-optical polariton transistor

D. Ballarini[1,2], M. De Giorgi[1,2], E. Cancellieri[3,4], R. Houdré[5], E. Giacobino[4], R. Cingolani[1], A. Bramati[4], G. Gigli[1,2,6] & D. Sanvitto[1,2]

Motivations

On the polaritronic technology…

- ✓ Spin-switches



PRL 107, 146402 (2011) PHYSICAL REVIEW LETTERS week ending 30 SEPTEMBER 2011

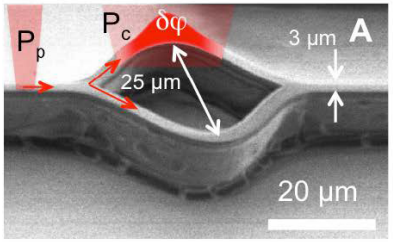
Motion of Spin Polariton Bullets in Semiconductor Microcavities

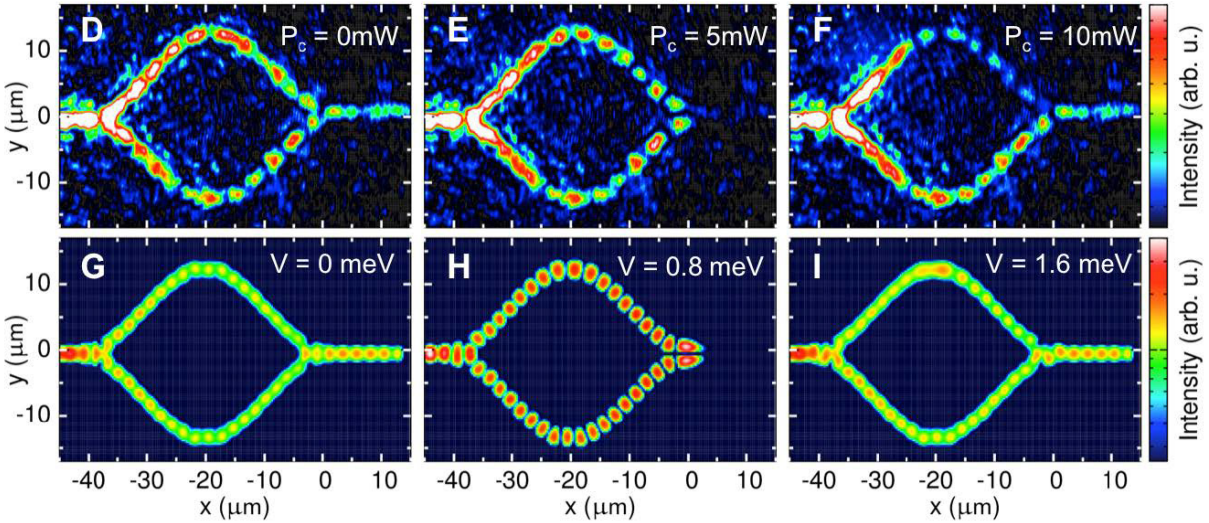
C. Adrados,[1] T. C. H. Liew,[2] A. Amo,[1,3] M. D. Martín,[4] D. Sanvitto,[4,5] C. Antón,[4] E. Giacobino,[1] A. Kavokin,[6,7] A. Bramati,[1] and L. Viña[4]

Motivations

On the polaritronic technology…

✓ Circuits





nature COMMUNICATIONS

ARTICLE

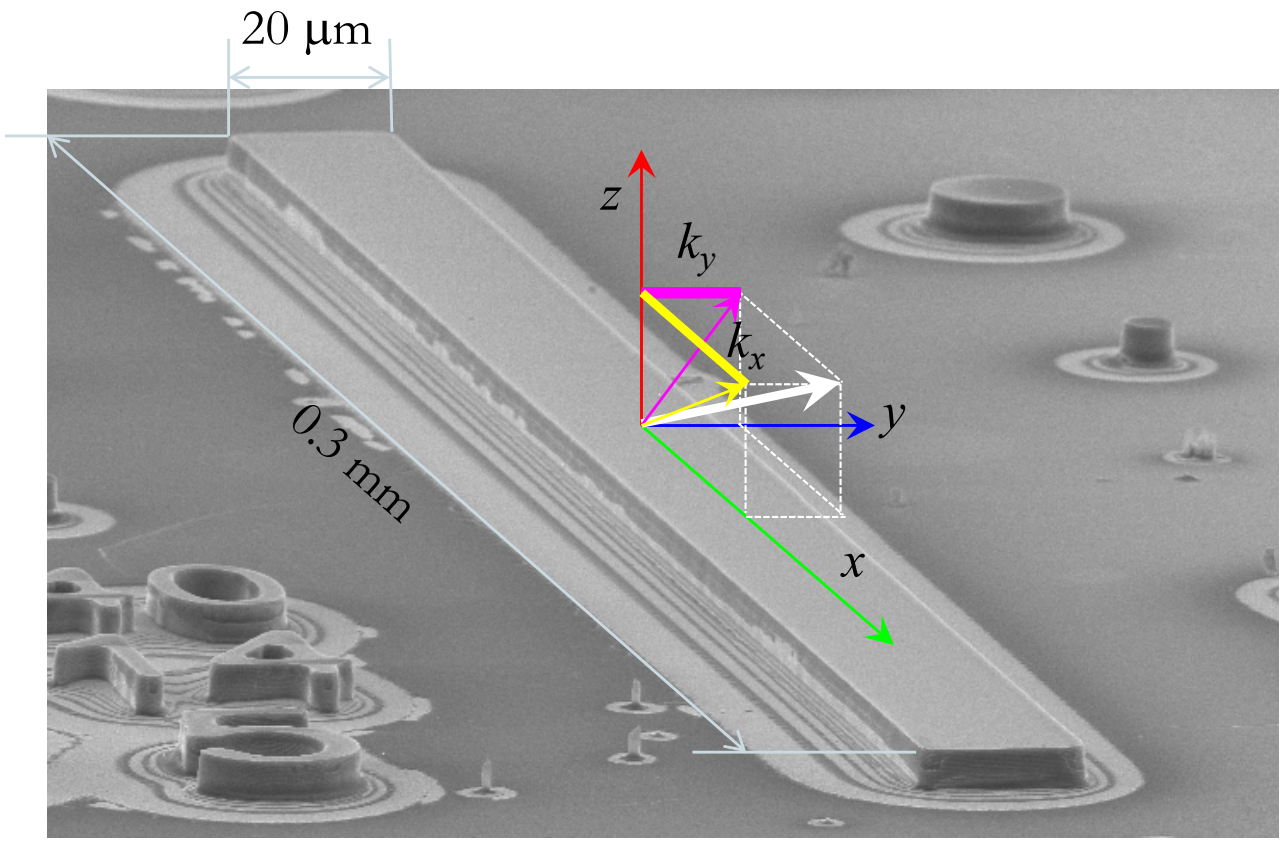
Received 7 May 2013 | Accepted 17 Jan 2014 | Published 11 Feb 2014 DOI: 10.1038/ncomms4278 OPEN

All-optical phase modulation in a cavity-polariton Mach–Zehnder interferometer

C. Sturm[1,2,*], D. Tanese[1,*], H.S. Nguyen[1], H. Flayac[3], E. Galopin[1], A. Lemaître[1], I. Sagnes[1], D. Solnyshkov[3], A. Amo[1], G. Malpuech[3] & J. Bloch[1]

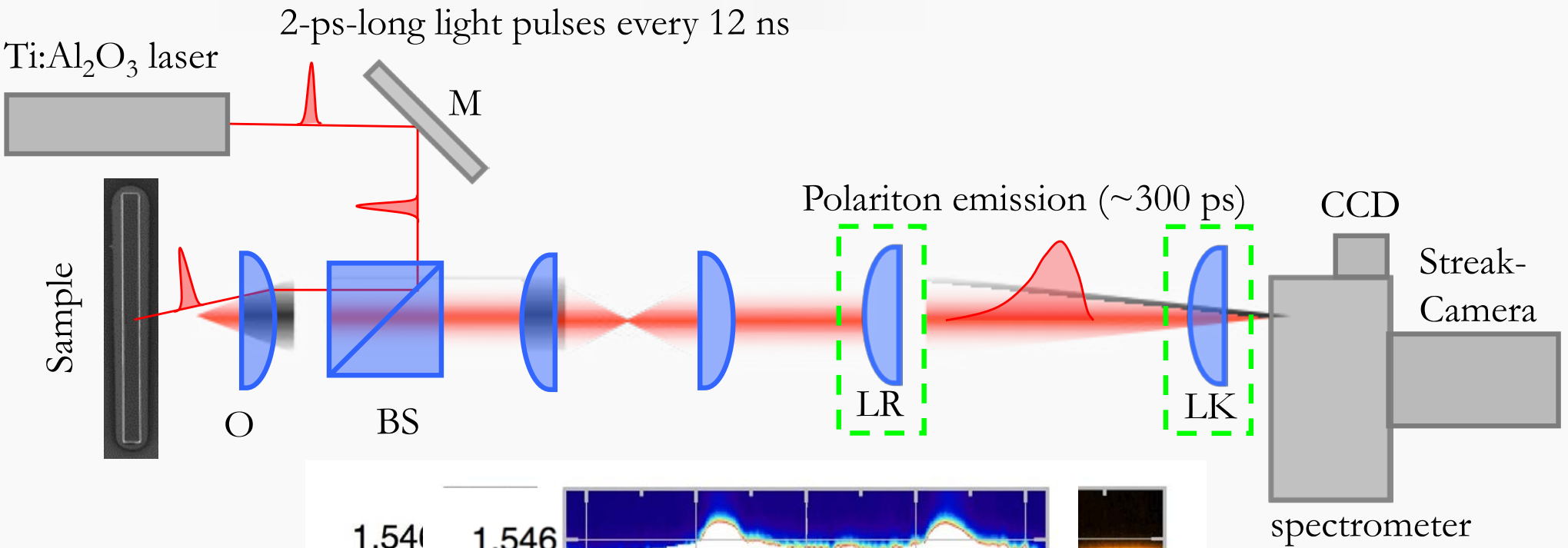
2. Samples

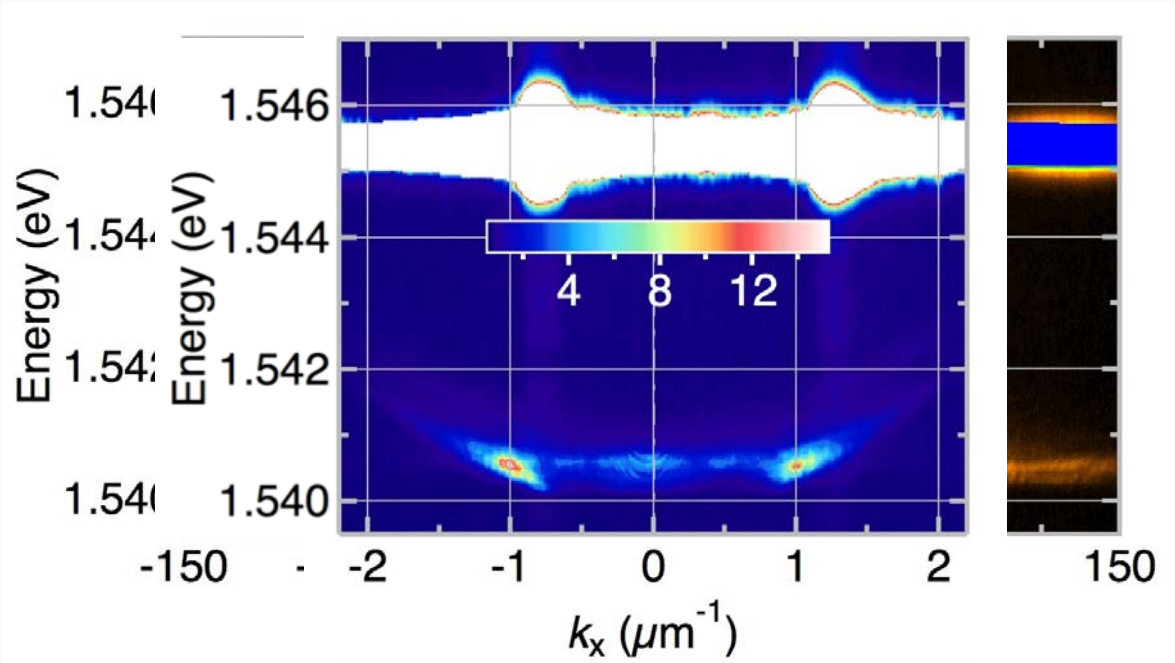
Description of the samples



high-quality AlGaAs-based microcavities

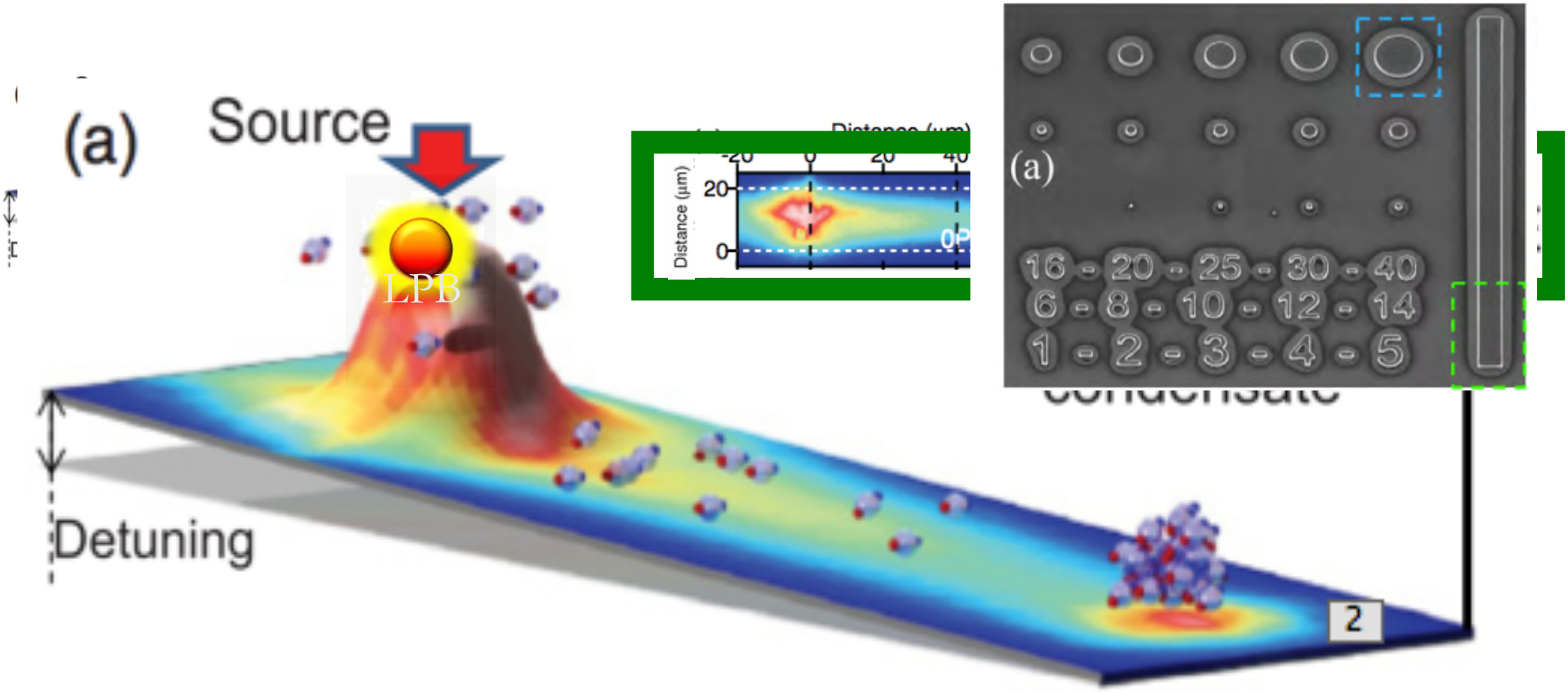
Experimental set-up





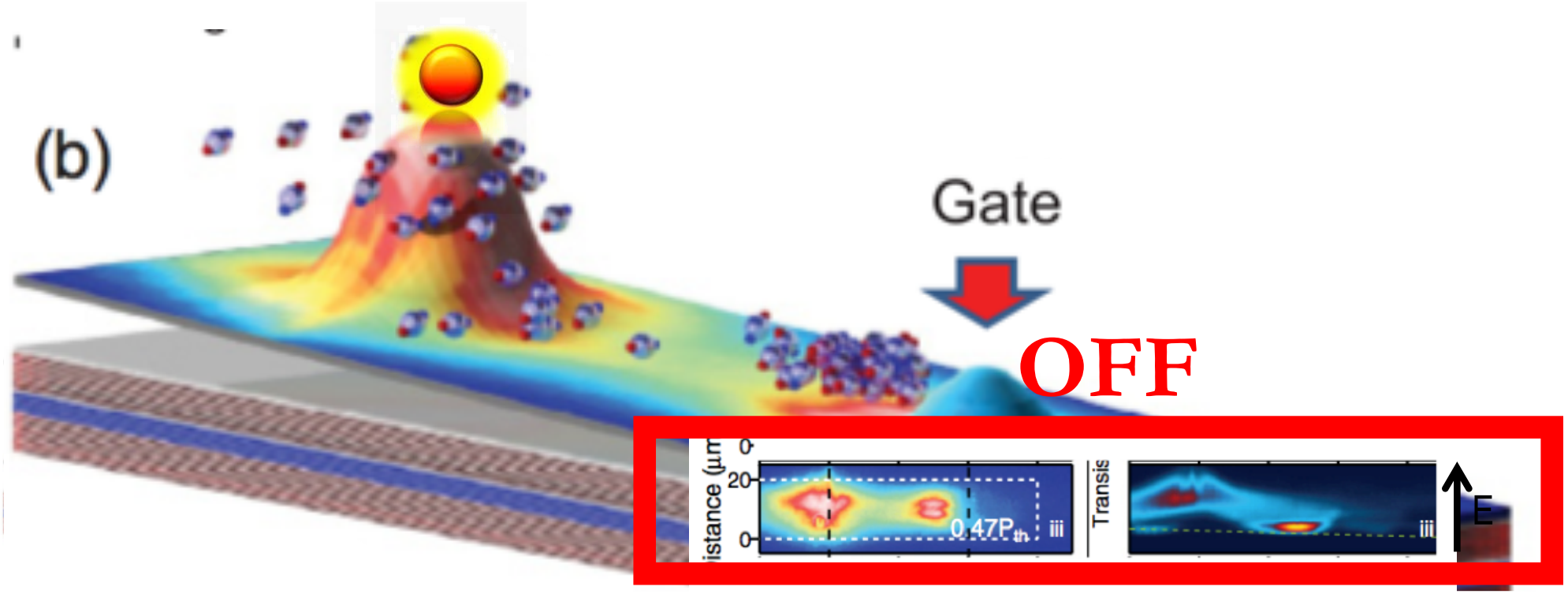
Original work on transistor switch

P Tsotsis et al, New J. Phys. **14**, 023060 (2012)



T. Gao, *et. al.*, "*Polariton condensate transistor switch*", Phys. Rev. B **85**, 235102 (2012).

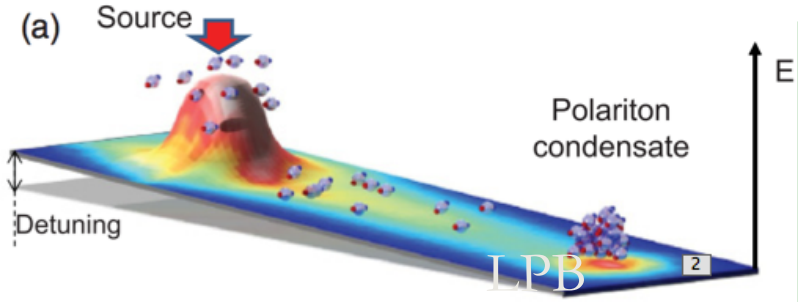
Original work on transistor switch

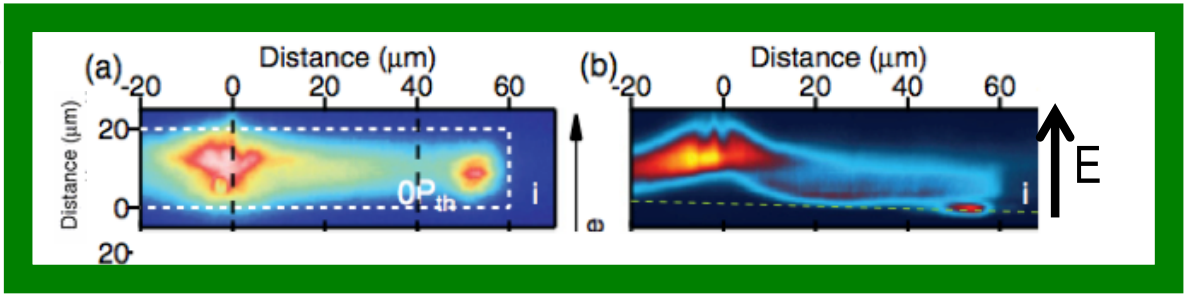


T. Gao, *et. al.*, "*Polariton condensate transistor switch*", Phys. Rev. B **85**, 235102 (2012).

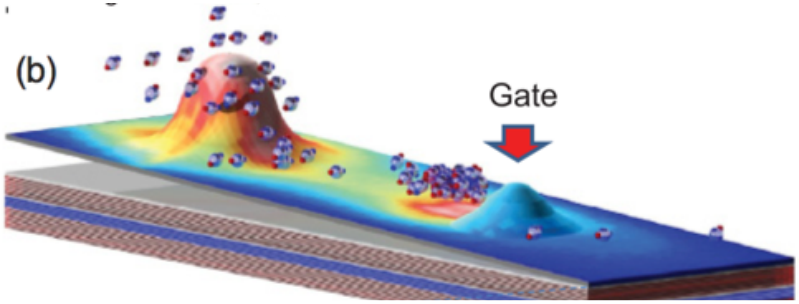
Original work on transistor switch

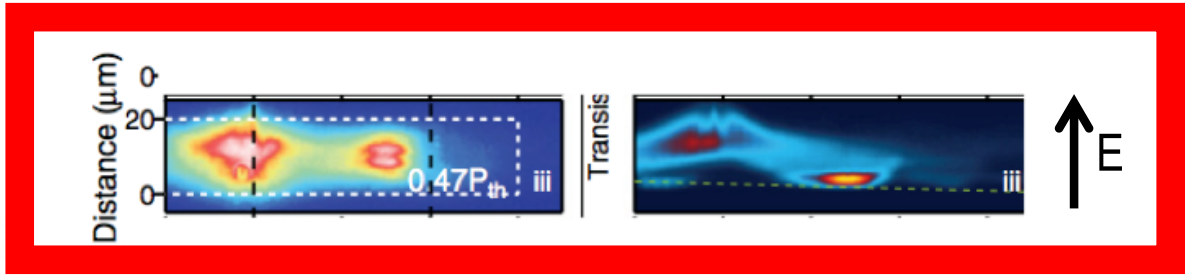
ON





OFF





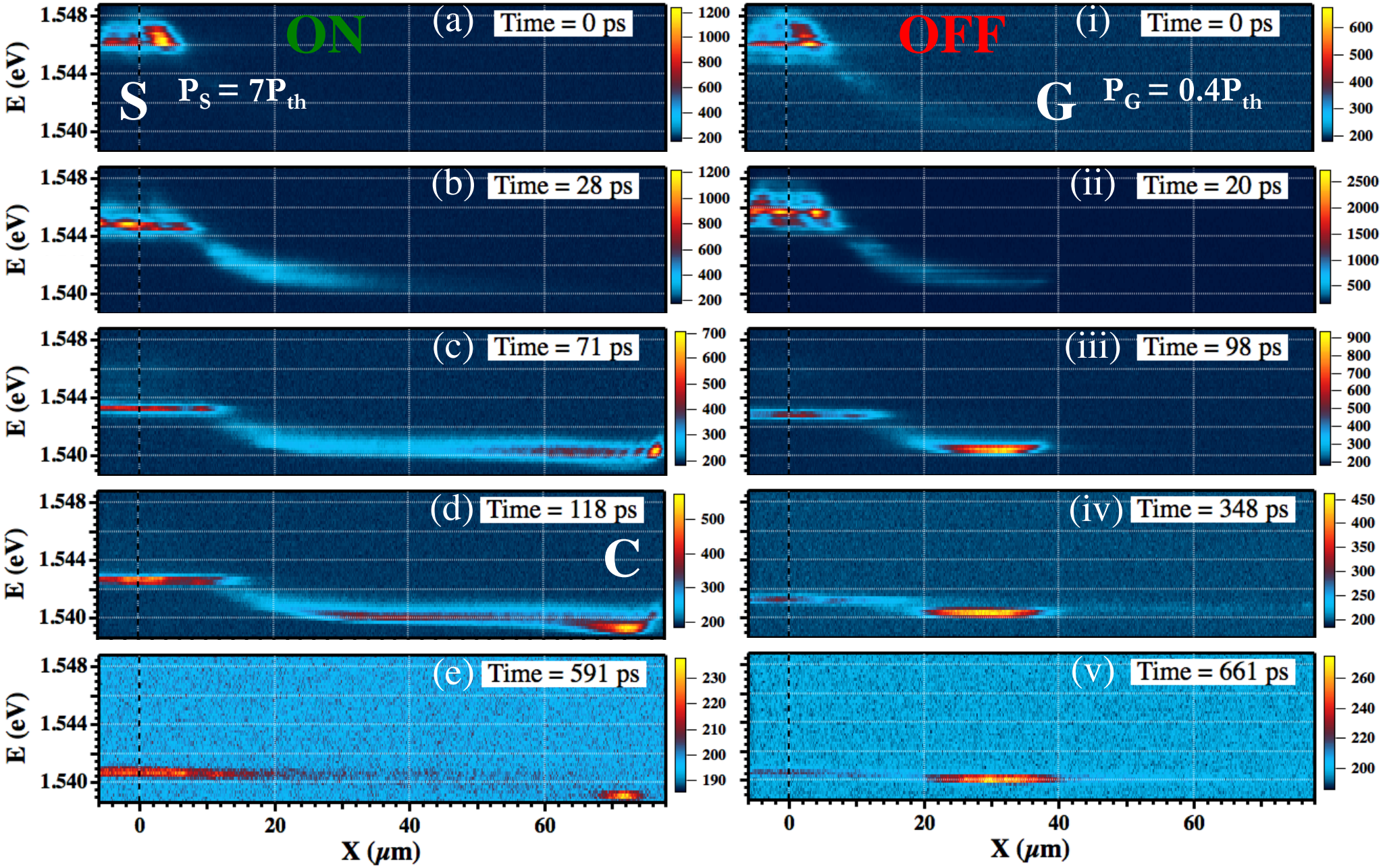
T. Gao, *et. al.*, "*Polariton condensate transistor switch*", Phys. Rev. B **85**, 235102 (2012).

3. Devices

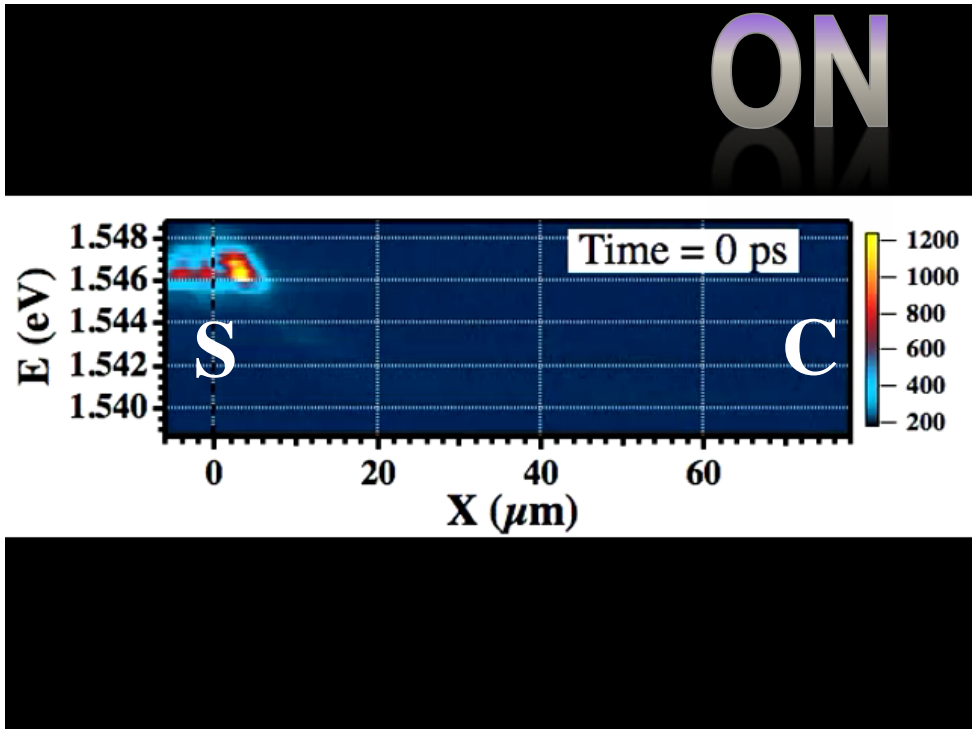
Transistor switch

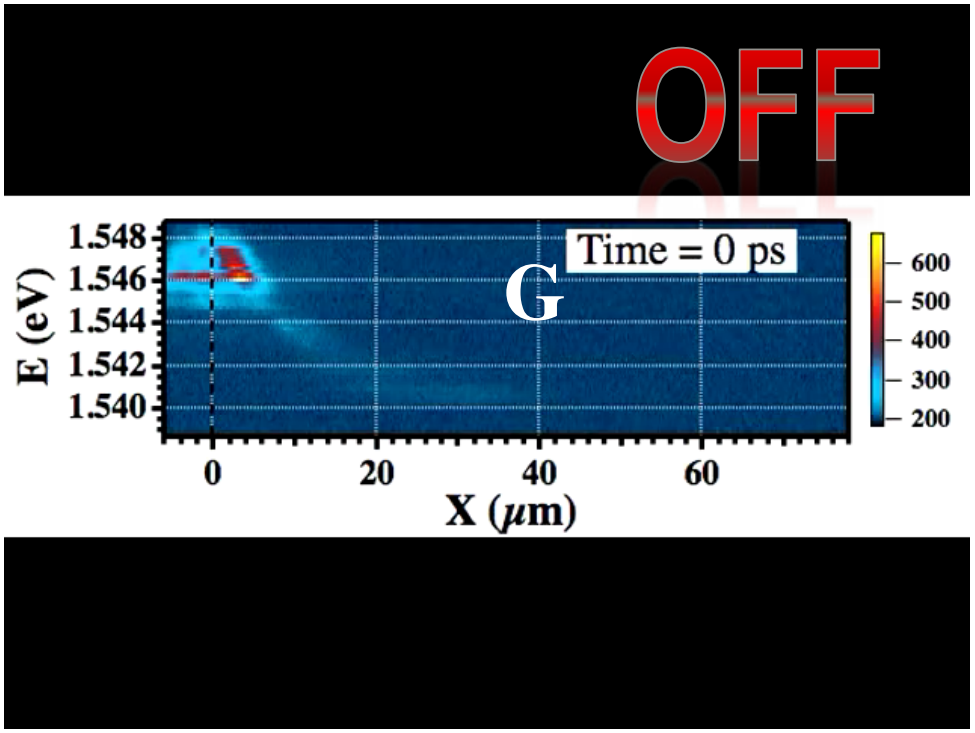
T. Gao, *et. al.*, "*Polariton condensate transistor switch*", Phys. Rev. B **85**, 235102 (2012).
C. Anton, *et. al.*, "*Dynamics of a polariton condensate transistor switch*", App. Phys. Lett. **101**, 261116 (2012).
C. Anton, *et. al.*, "*Energy relaxation of exciton-polariton condensates in quasi-1D microcavities*", Phys. Rev. B **88**, 035313 (2013).
C. Anton, *et. al.*, "*Quantum reflections and shunting of polariton condensate wave trains…*", Phys. Rev. B **88**, 245307 (2013).
C. Anton, *et. al.*, "*Operation speed of polariton condensate switches gated by excitons*" , Phys. Rev. B **89**, 235312 (2014).

Experiments on transistor switch

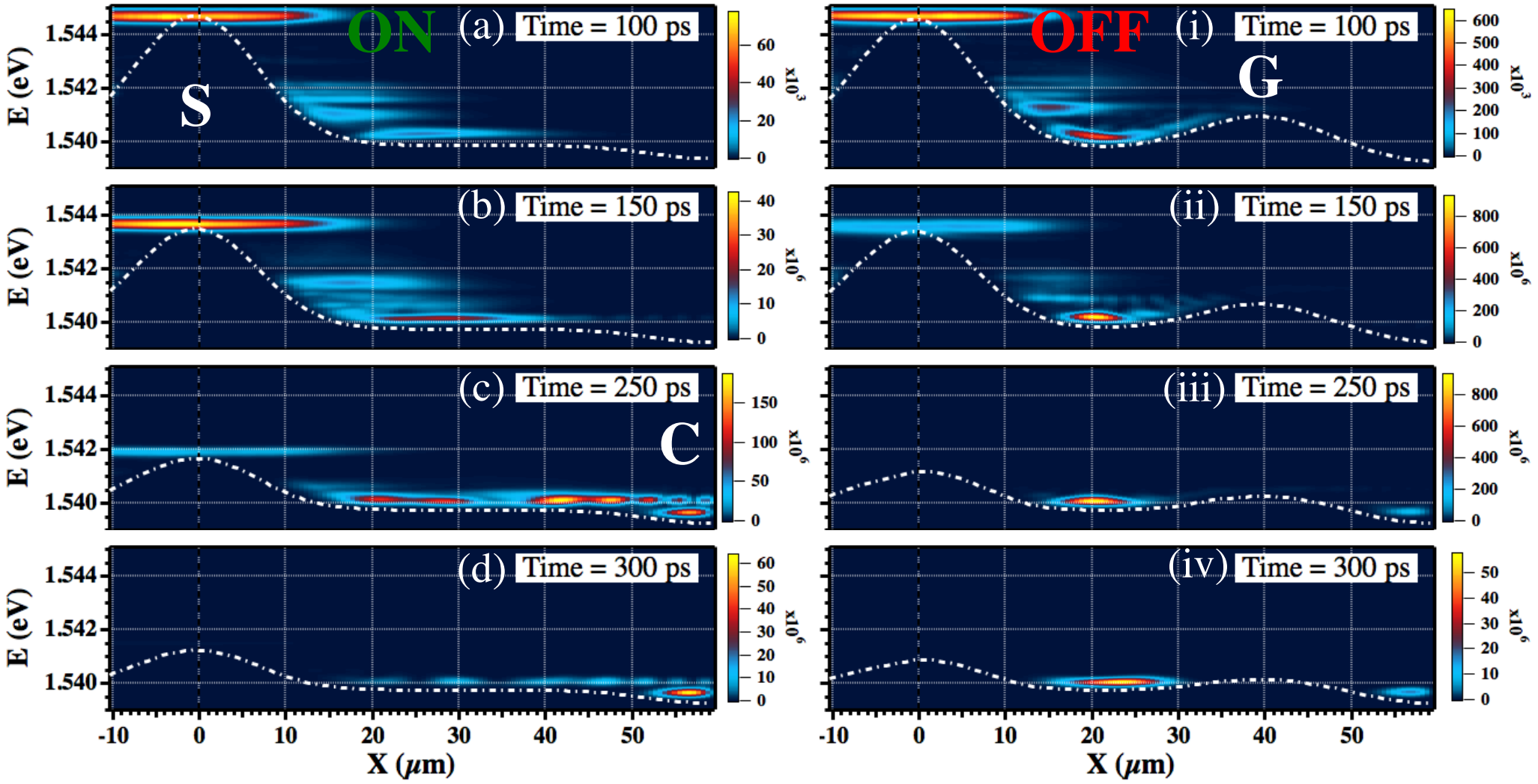


Experiments on transistor switch





Simulations - Gross–Pitaevskii Equation



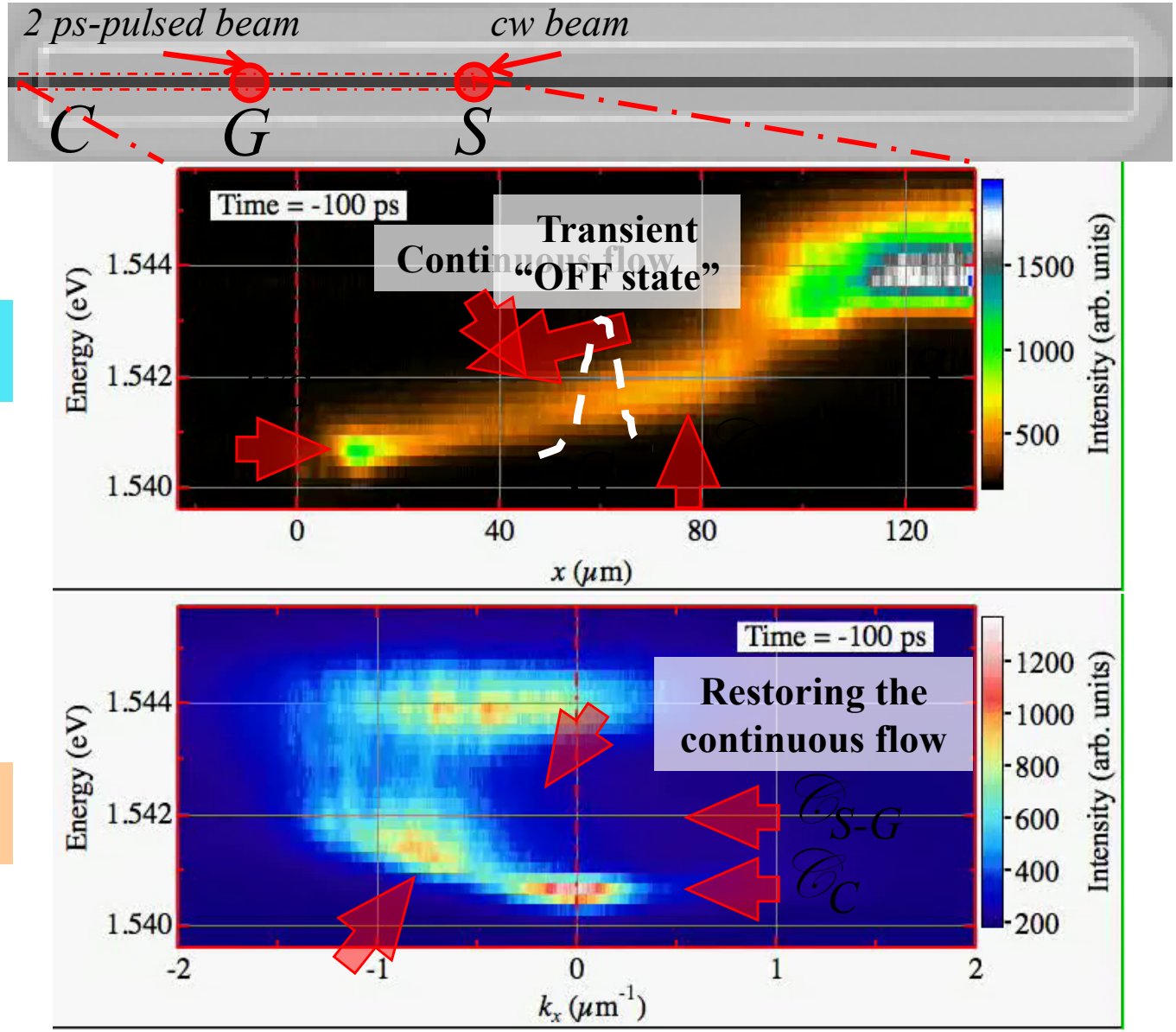
By… **T.C.H. Liew**, *School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore*

Polariton Condensate Transistor Switches

How fast can it work?: Operation speed between the ON-OFF-ON states

Real space dynamics

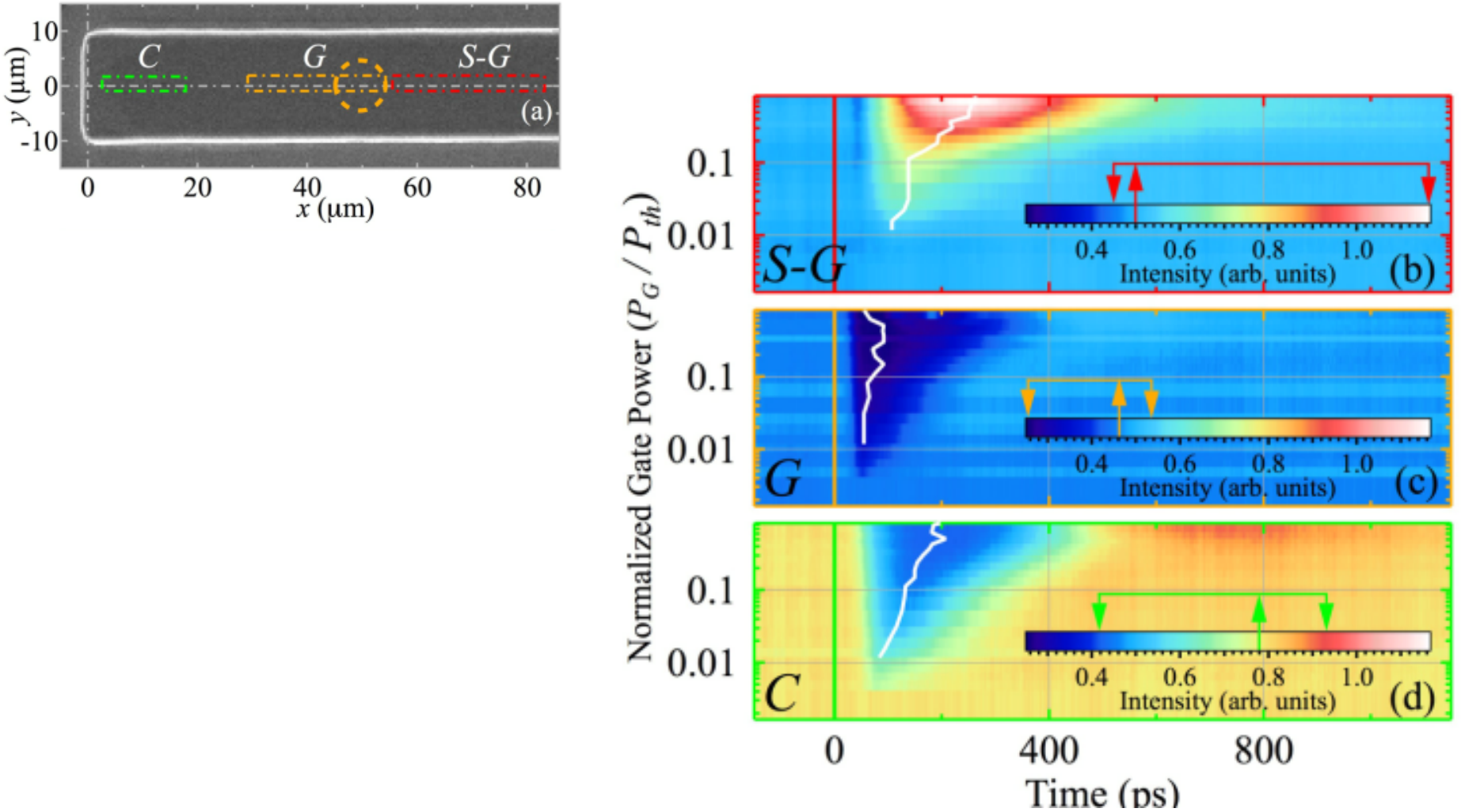
Momentum space dynamics



Polariton Condensate Transistor Switches

Operation speed of the device with excitonic gates

Gate pump power dependence on the operation speed the device

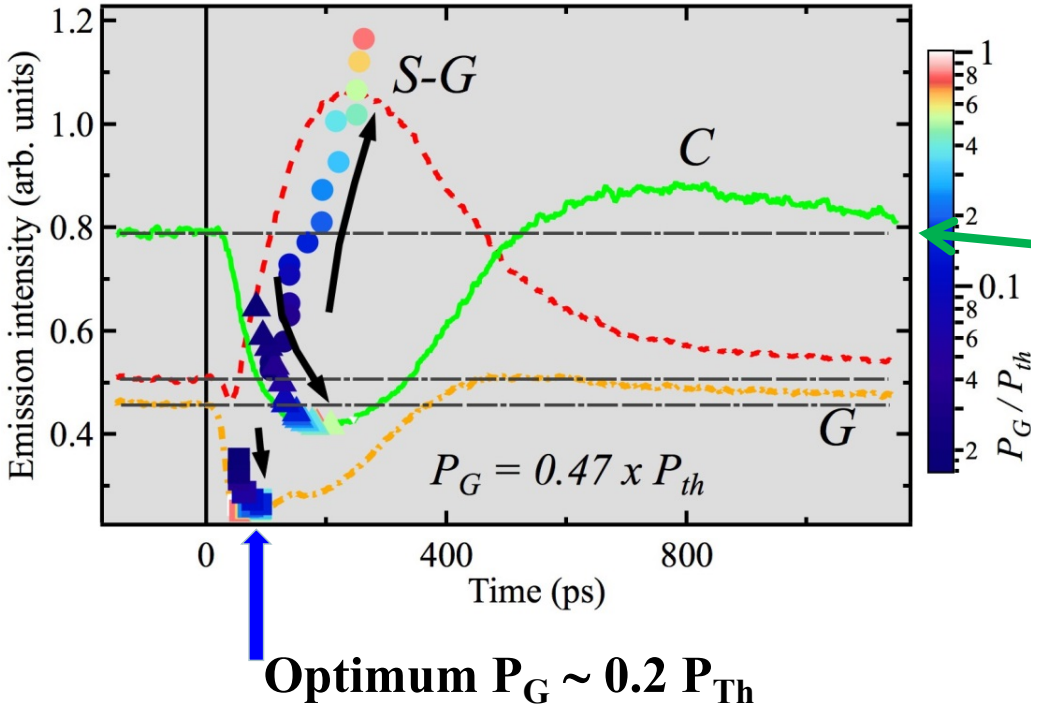


Polariton Condensate Transistor Switches

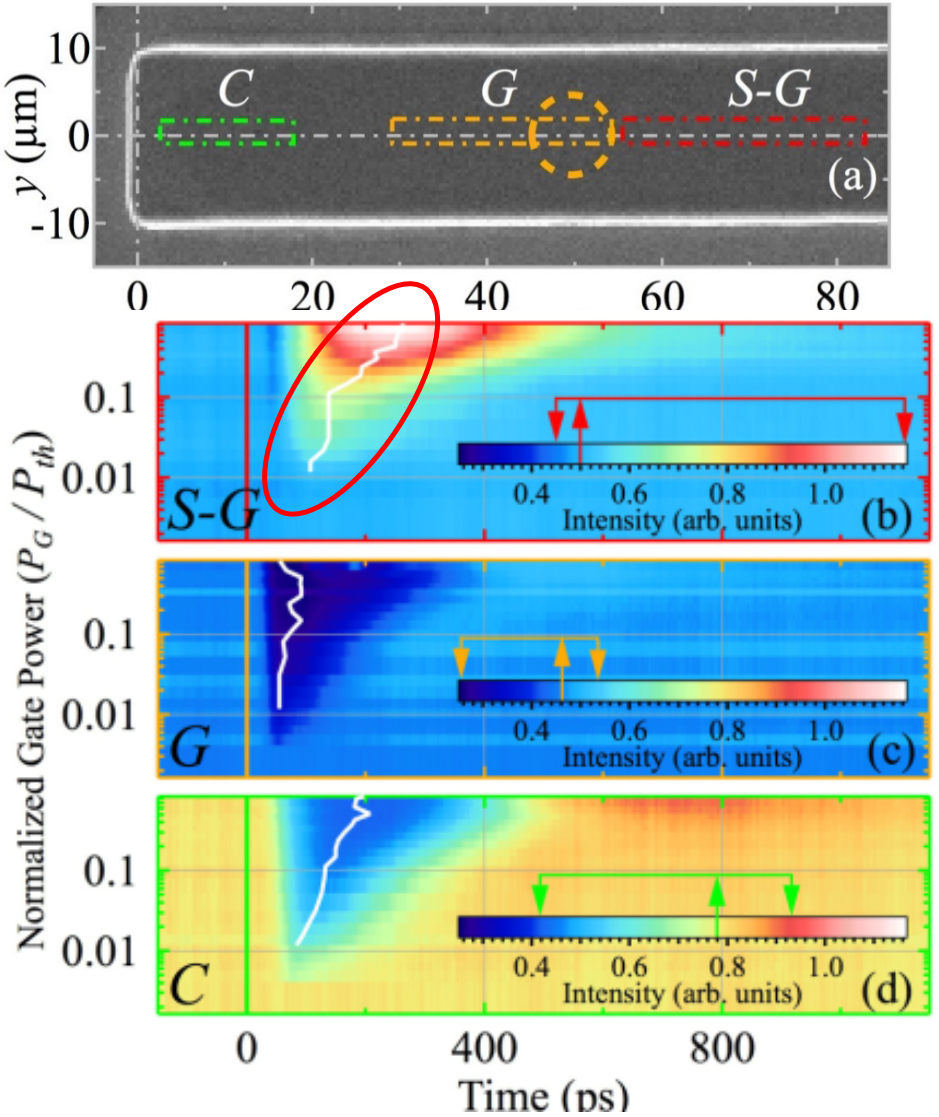
Operation speed of the device with excitonic gates

Gate pump power dependence on the operation speed the device

- ✓ **Maximizing** the ON/OFF ratio at *C*: **~30%**
- ✓ **Minimizing** the temporal interval of the ON-OFF-ON transition at *C*: **~3 GHz**

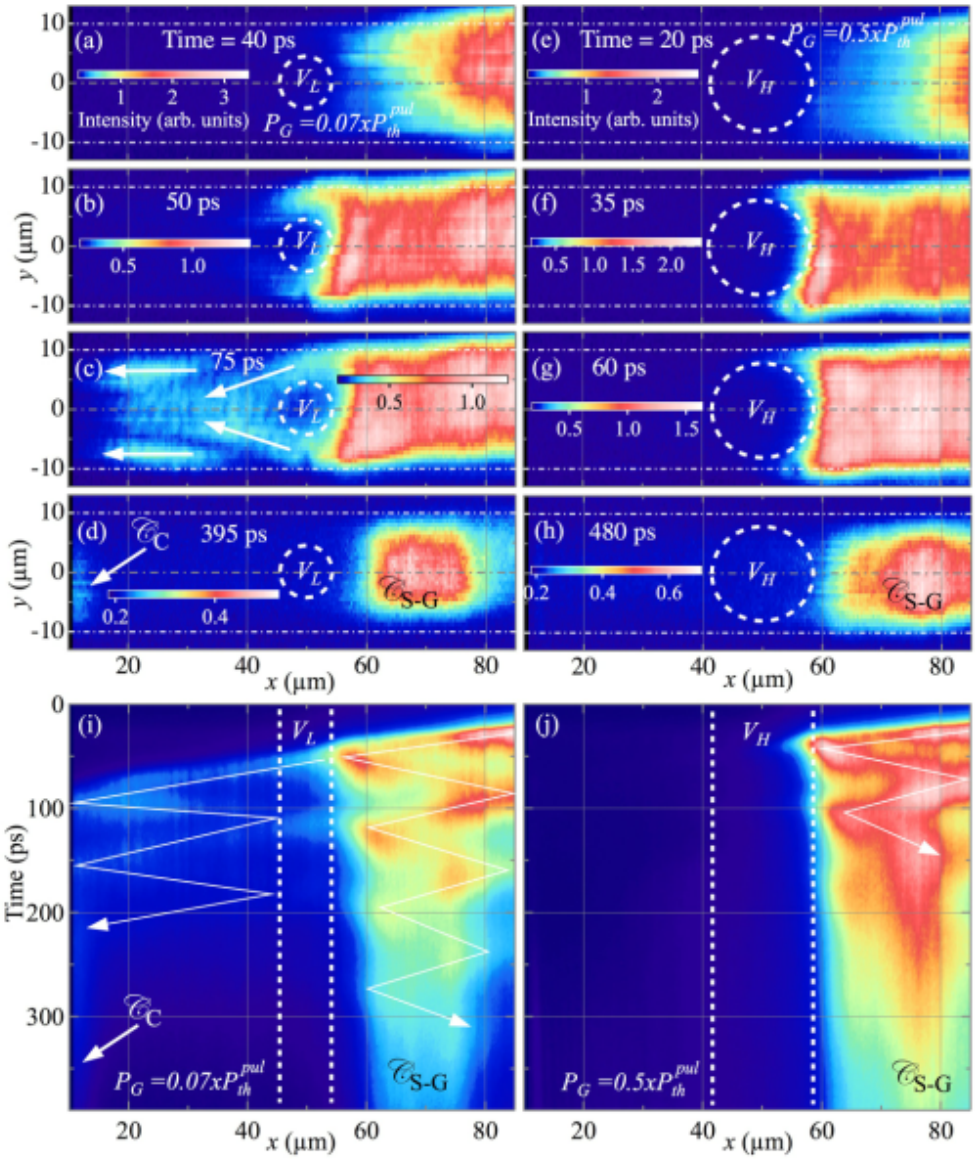


Optimum $P_G \sim 0.2\ P_{Th}$

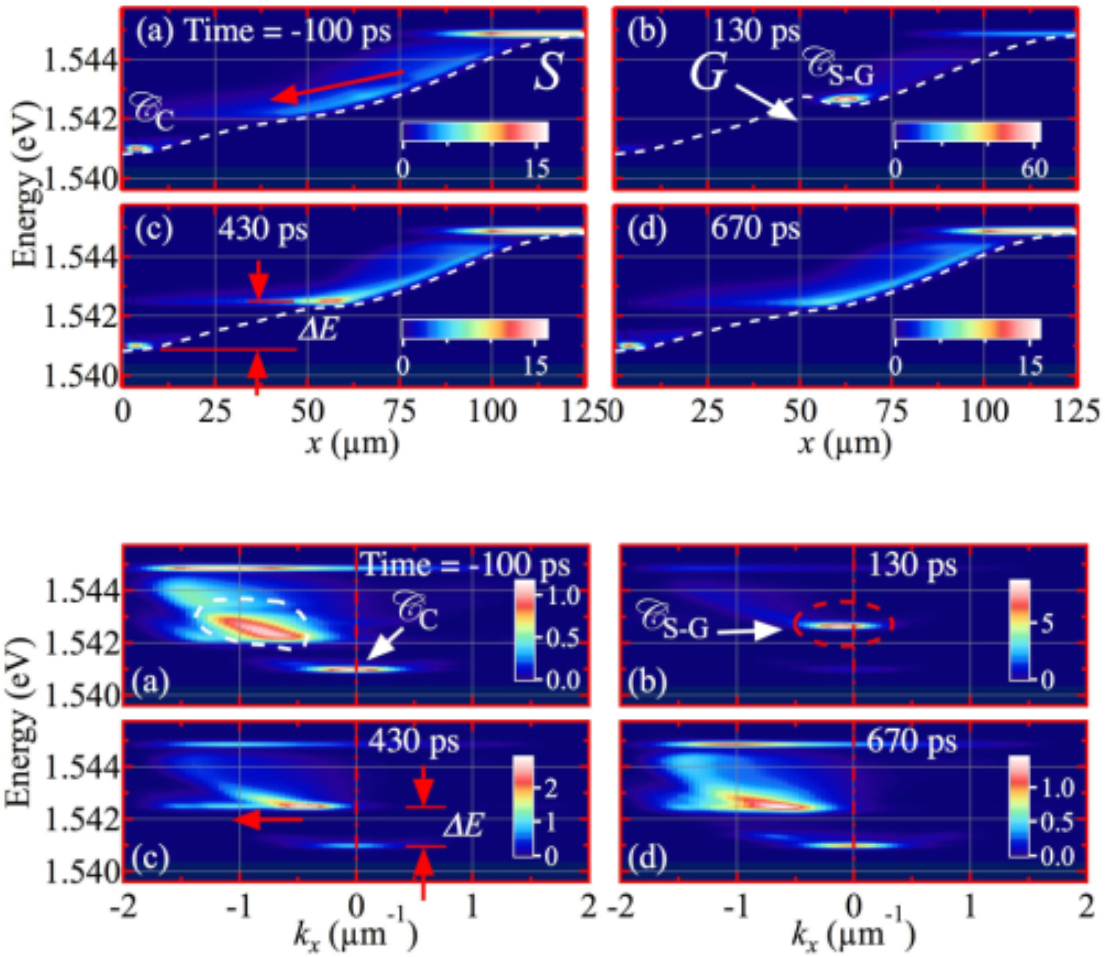


Polariton Condensate Transistor Switches

Leakage effects



Simulations - Gross–Pitaevskii Equation



By… **T.C.H. Liew**, *School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore*

4. Experimental results time-resolved (dynamics)

AND logic gate

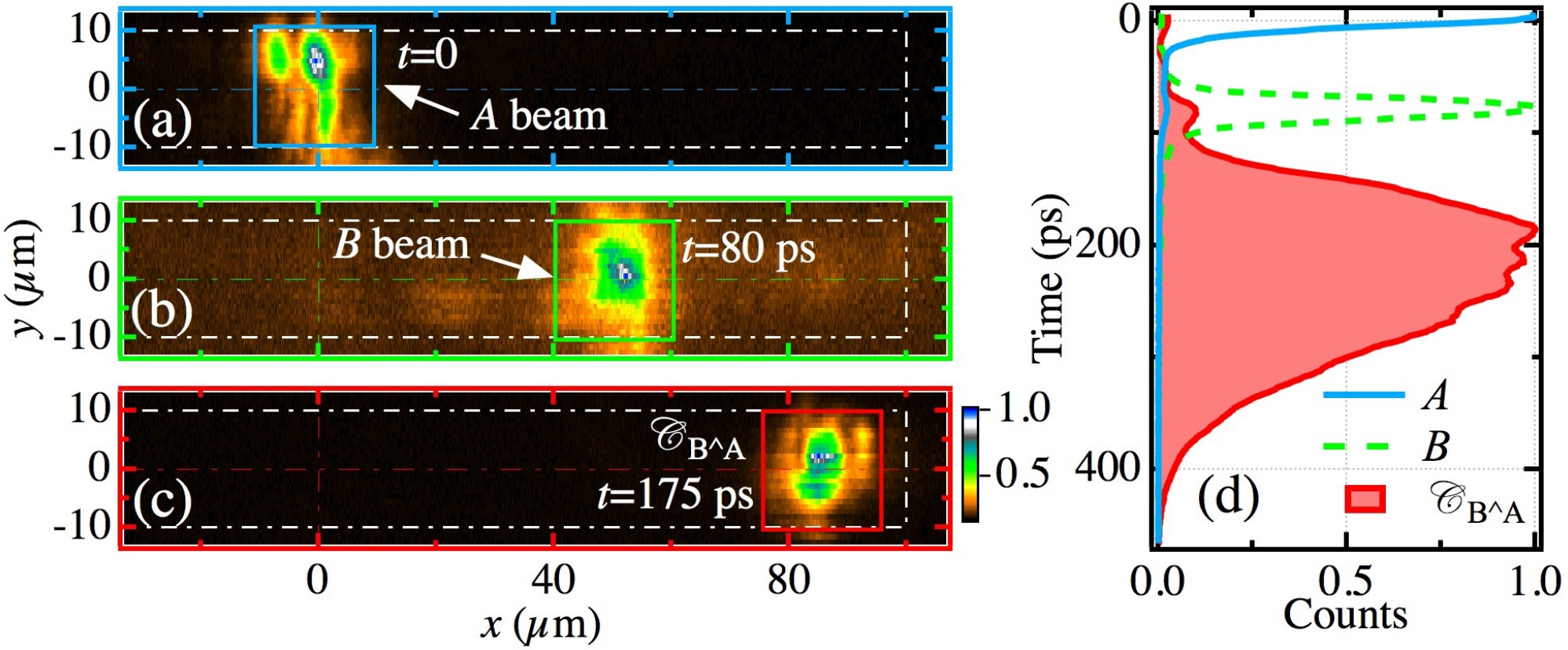
PHYSICAL REVIEW B **88**, 245307 (2013)

Quantum reflections and shunting of polariton condensate wave trains: Implementation of a logic AND gate

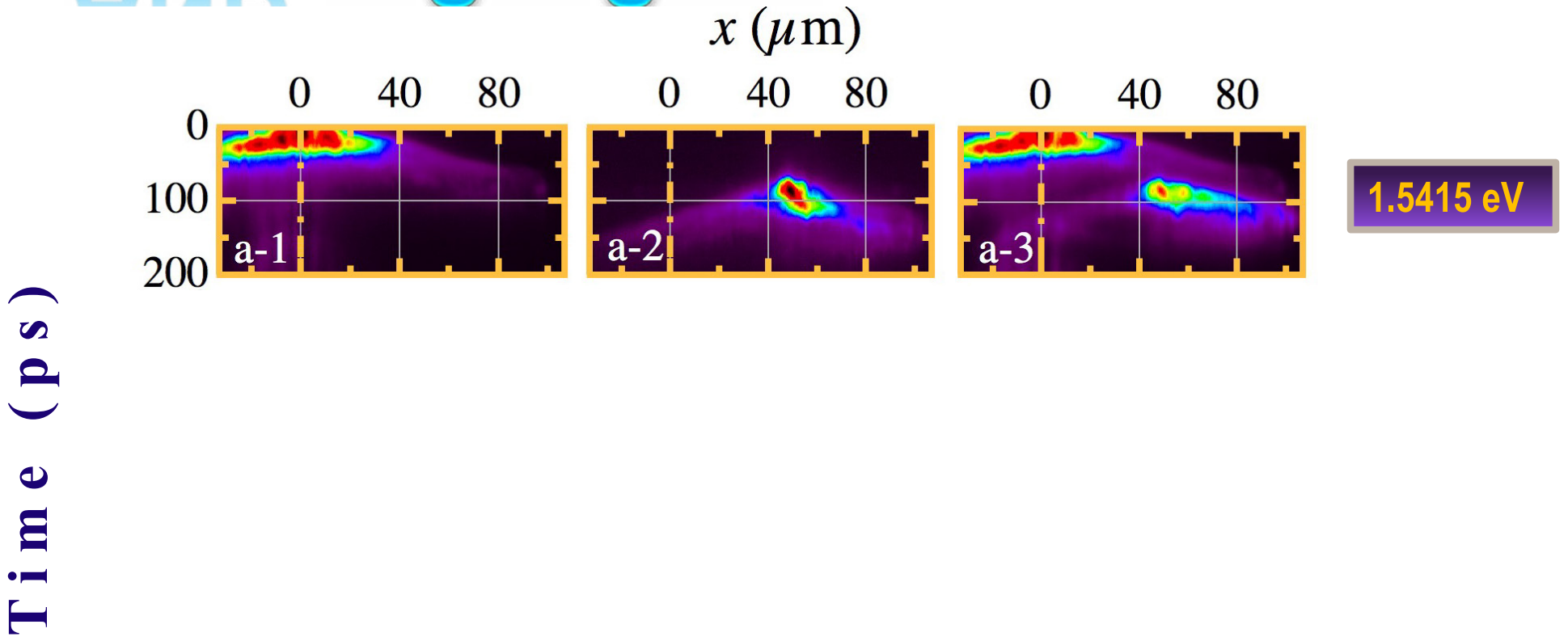
AND

For ballistic propagation ⟹ quasi-resonant excitation

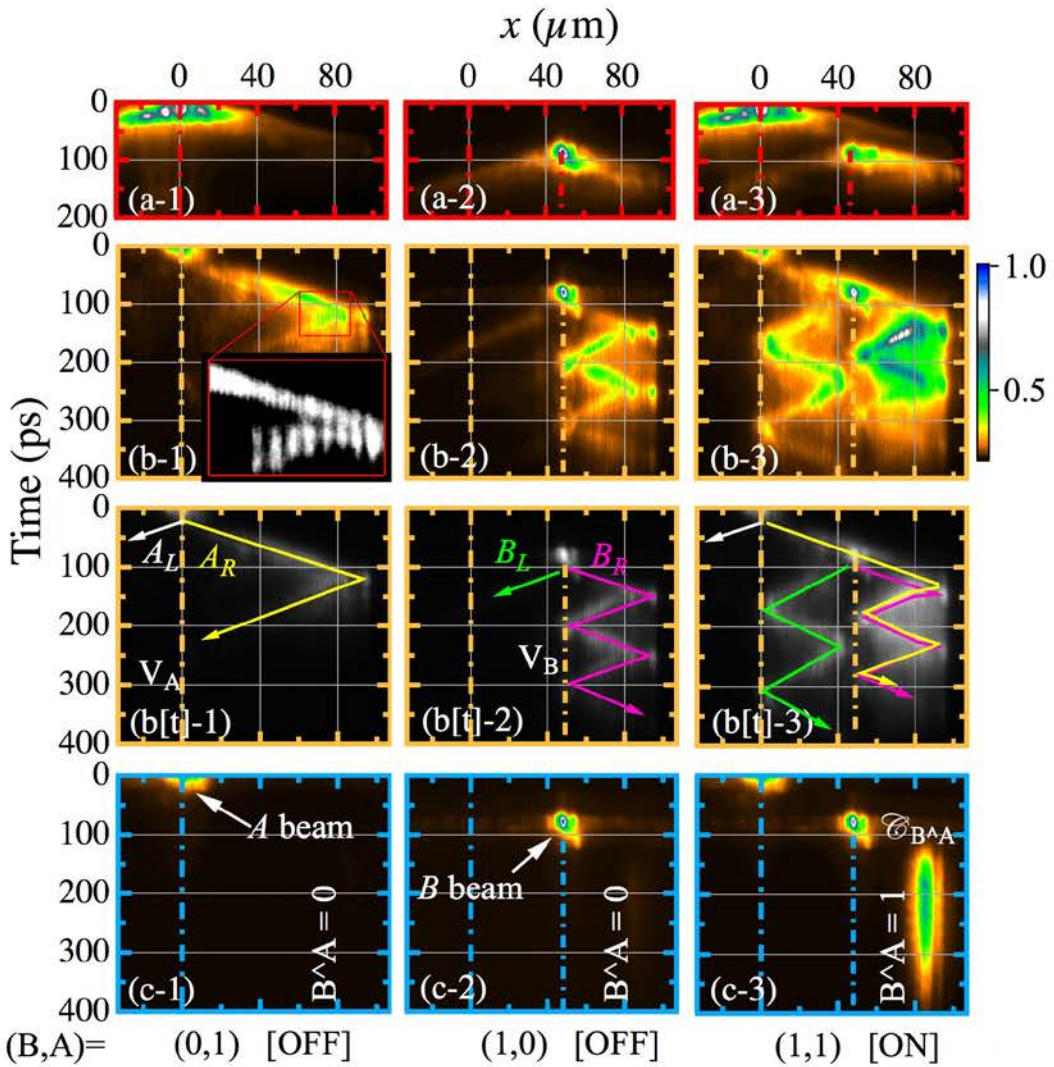
if the pulses don´t arrive simultaneously?



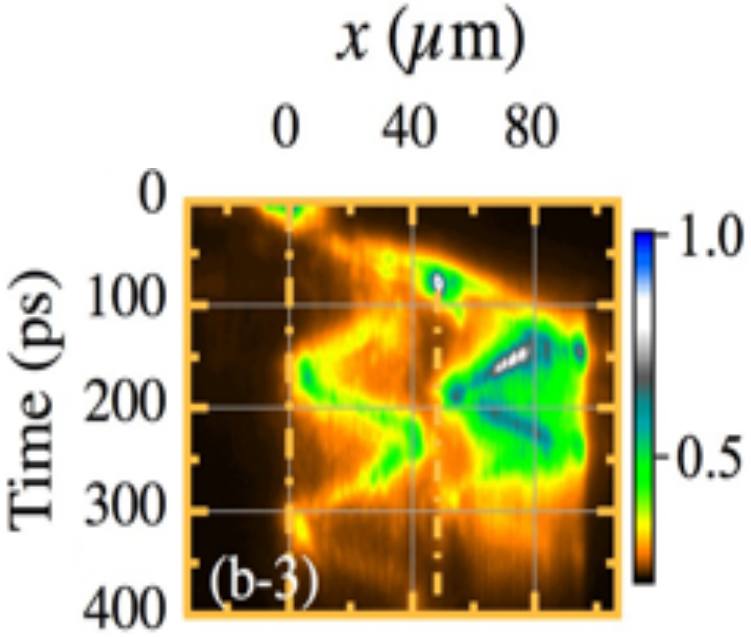
AND logic gate



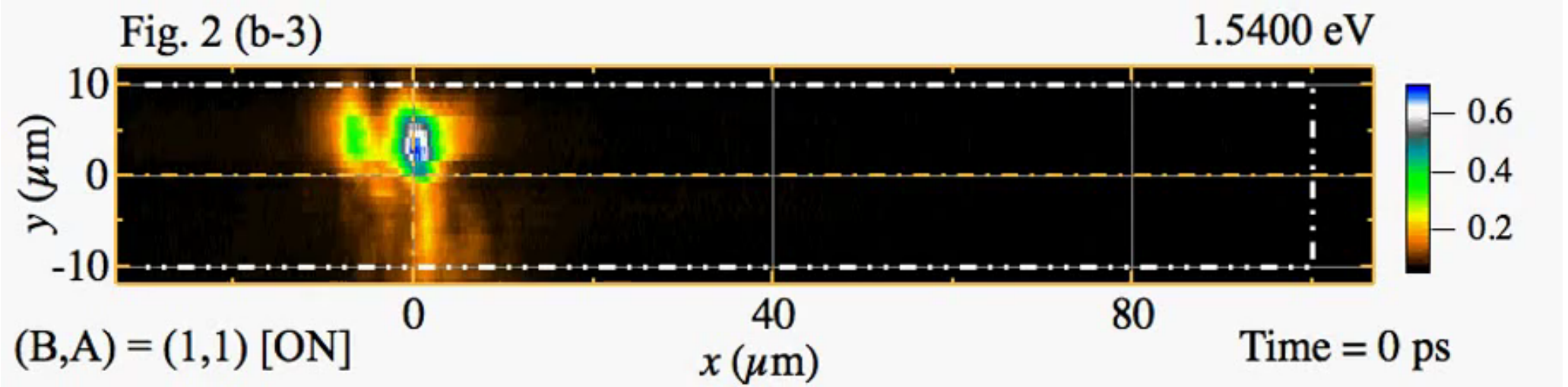
AND logic gate



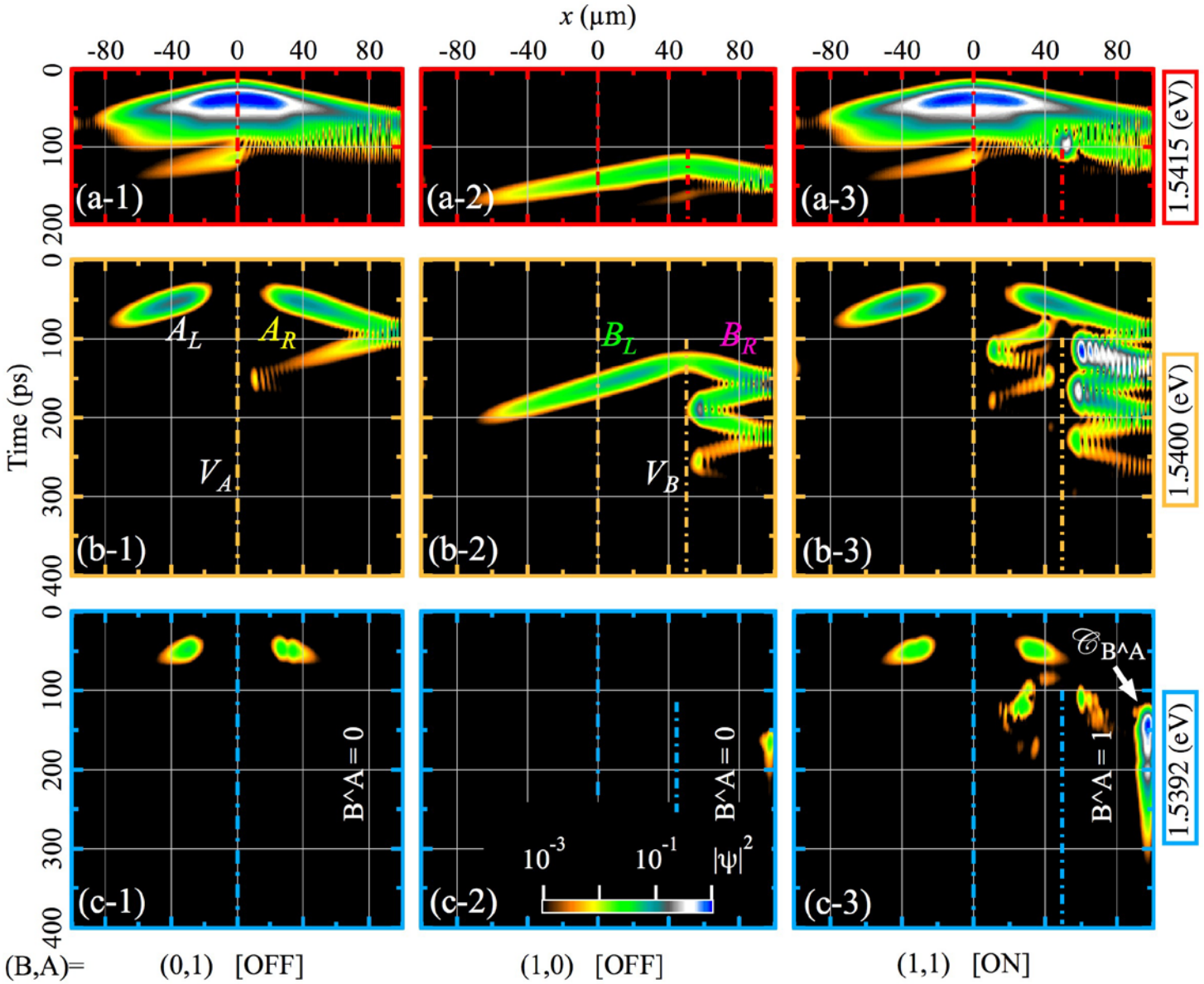
Real space


x (μm)
0
40
80
0
100
200
300
400
Time (ps)
(b-3)
1.0
0.5

AND logic gate



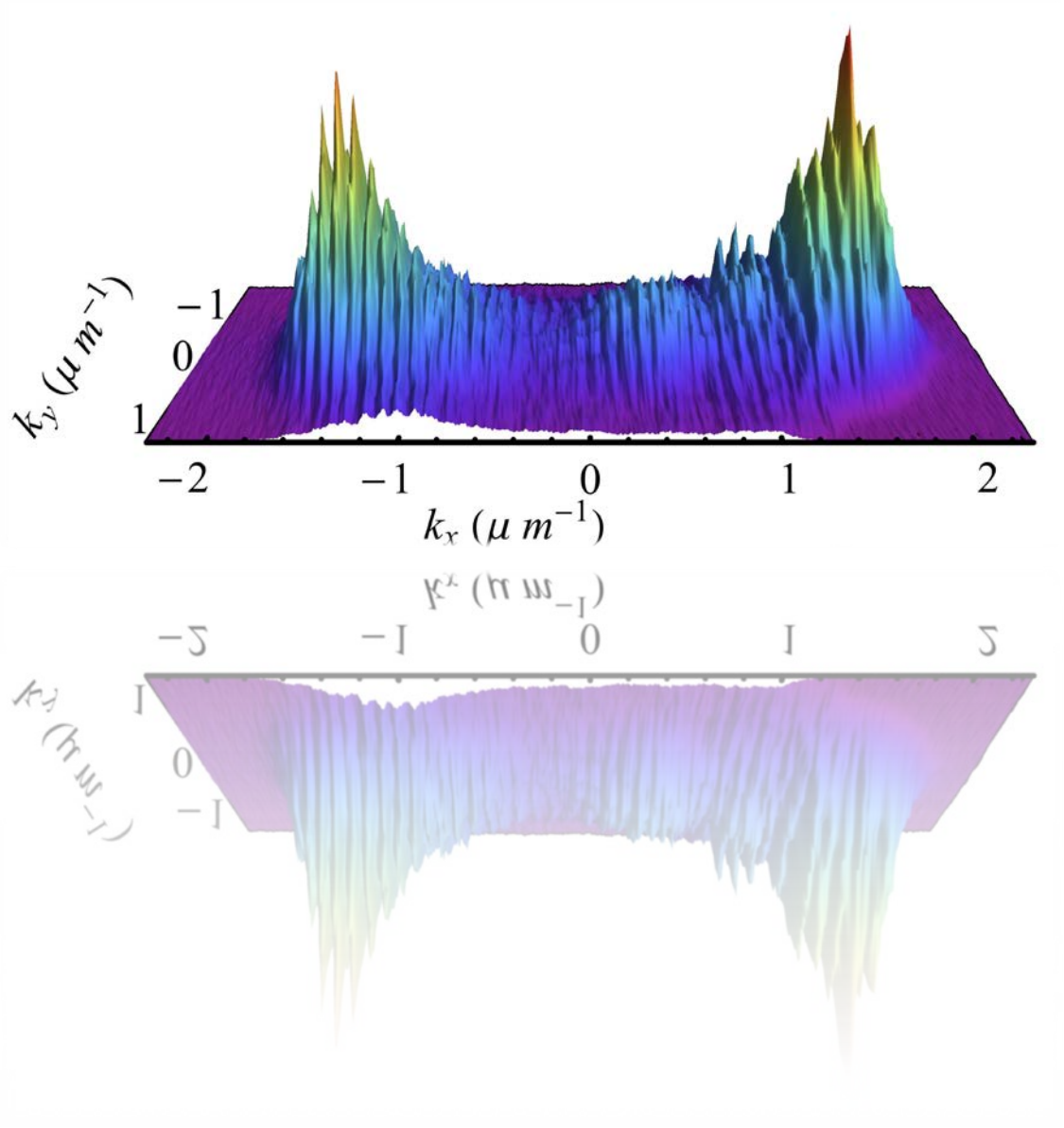
Simulations - Gross–Pitaevskii Equation



5. Summary

- Generation of **ultrafast-propagating condensed polariton wave trains** in quasi-1D microcavities ➔ **devices**
- **Transistor switch**
- **AND optical gate**

Thank you very much…



…Funding

- ✓ Spanish MEC MAT2011-22997 & MAT2014-53119-C2-1-R
- ✓ CAM (*S*-2009/ESP-1503)
- ✓ FP7 ITN's "Clermont4" (235114)
- ✓ "Spin-optronics" (237252)
- ✓ INDEX (289968)