Photon interactions using a single Rydberg dipole blockade

David Paredes
YAO, 27/03/12

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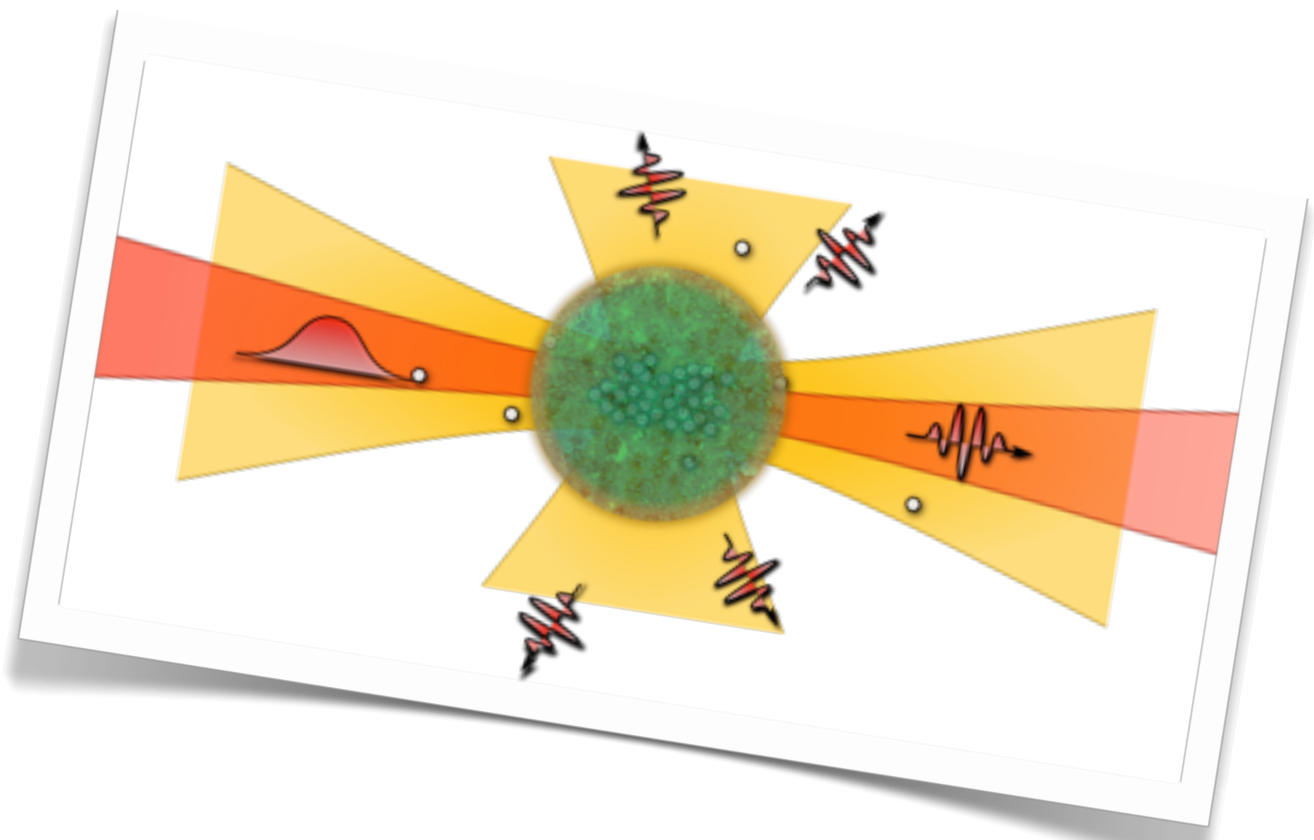

Charles Adams

Matthew Jones

David Szwer

Daniel Maxwell

Hannes Busche

EPSRC

Pioneering research and skills

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A

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What do we do?

- Exploit nonlinear properties of interacting Rydberg atoms
- Study basic interactions

  Atom/photon & photon/photon

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Rydberg atoms

High principal quantum number, **n**

Physically "large"

$$r = \frac{a_0 n^2}{Z}$$

Dipole moment	$\mu \propto n^2$
Polarisability	$\alpha \propto n^7$
Radiative lifetime	$\tau \propto n^3$

Strong dipole-dipole interactions

$$V(r) \propto \frac{C_6}{R^6}$$

$C_6 \propto n^{11}$

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Gallagher, 1994

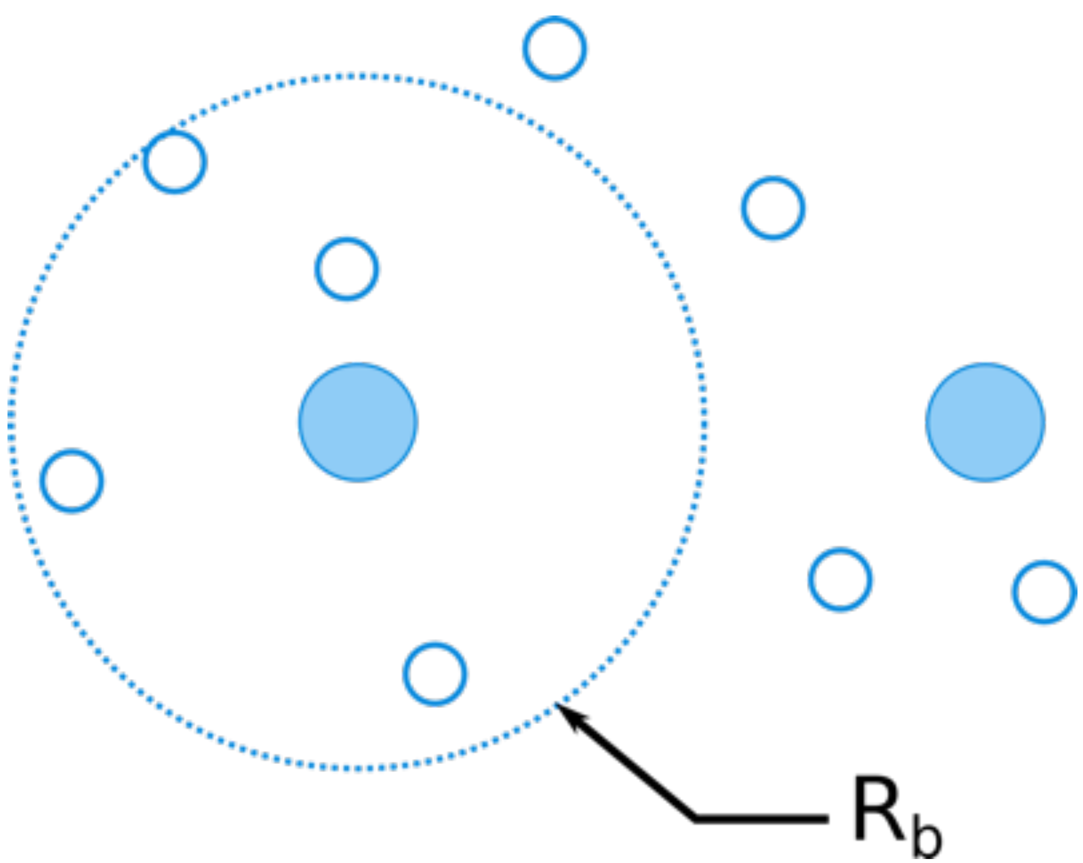
Interesting effects

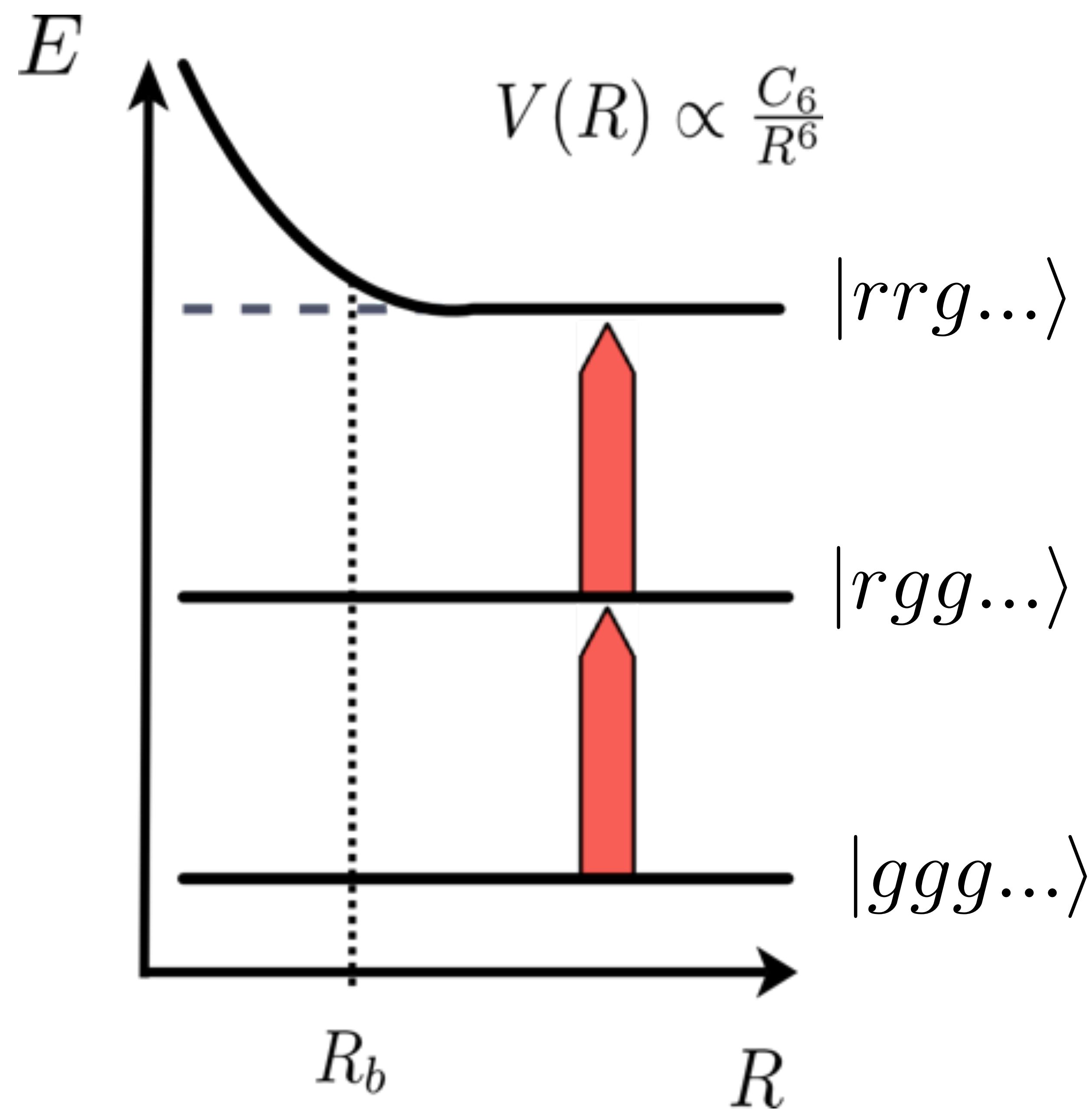
Dipole blockade

↘

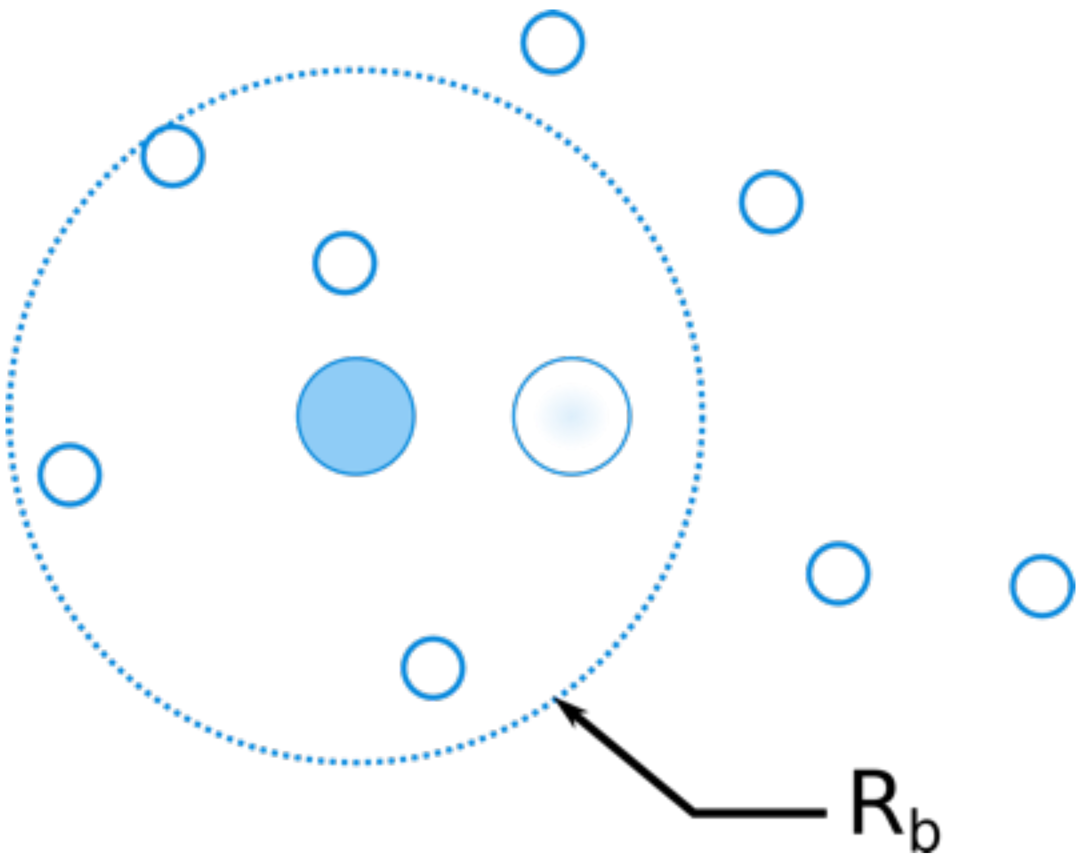
Rydberg Electromagnetically induced transparency (EIT)

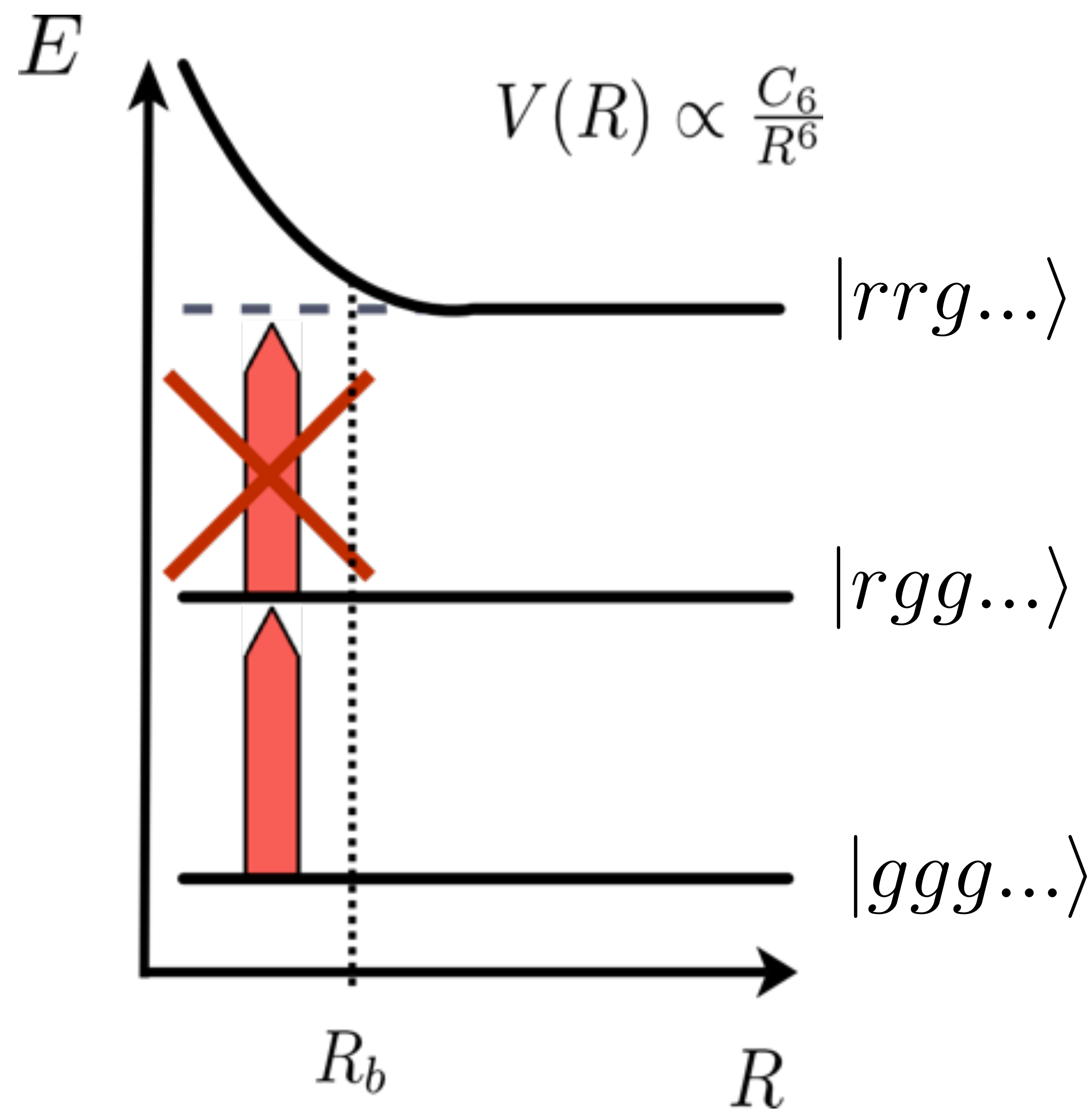
Dipole blockade



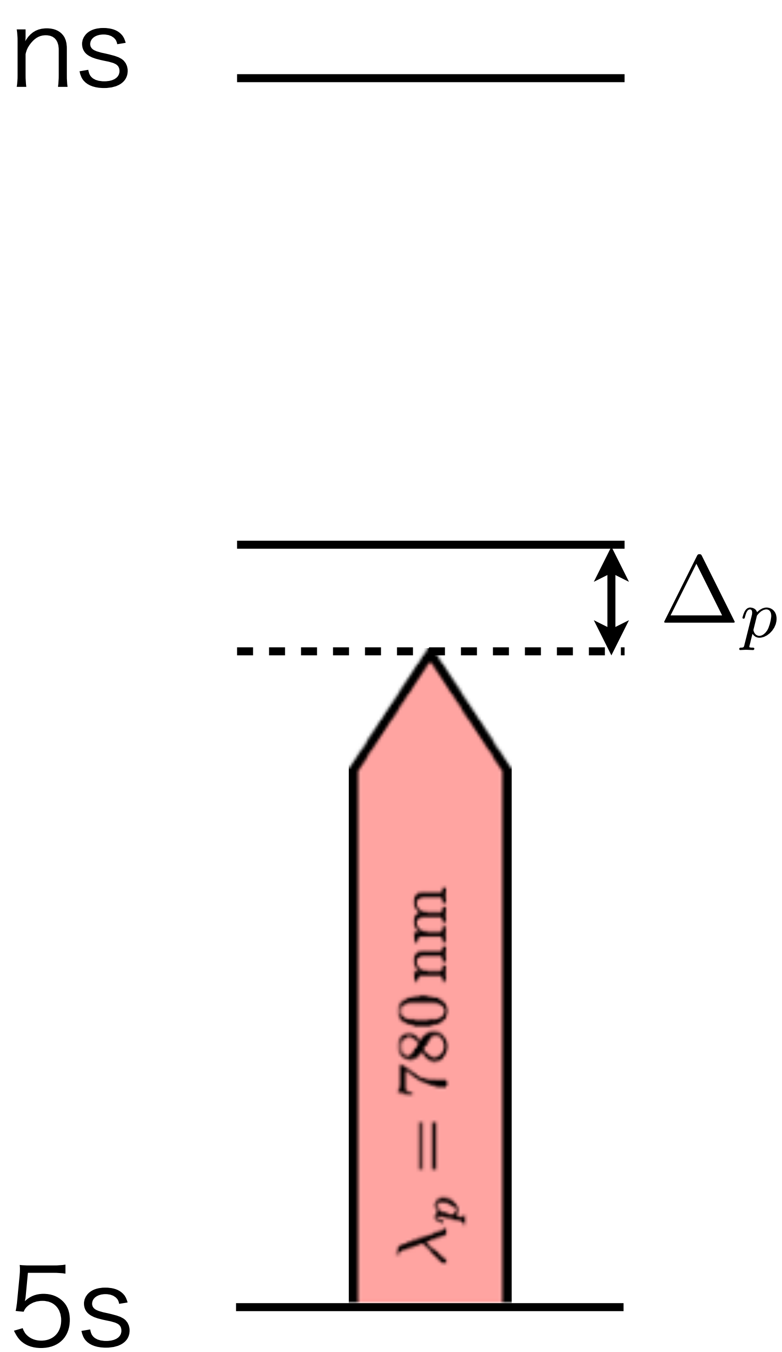


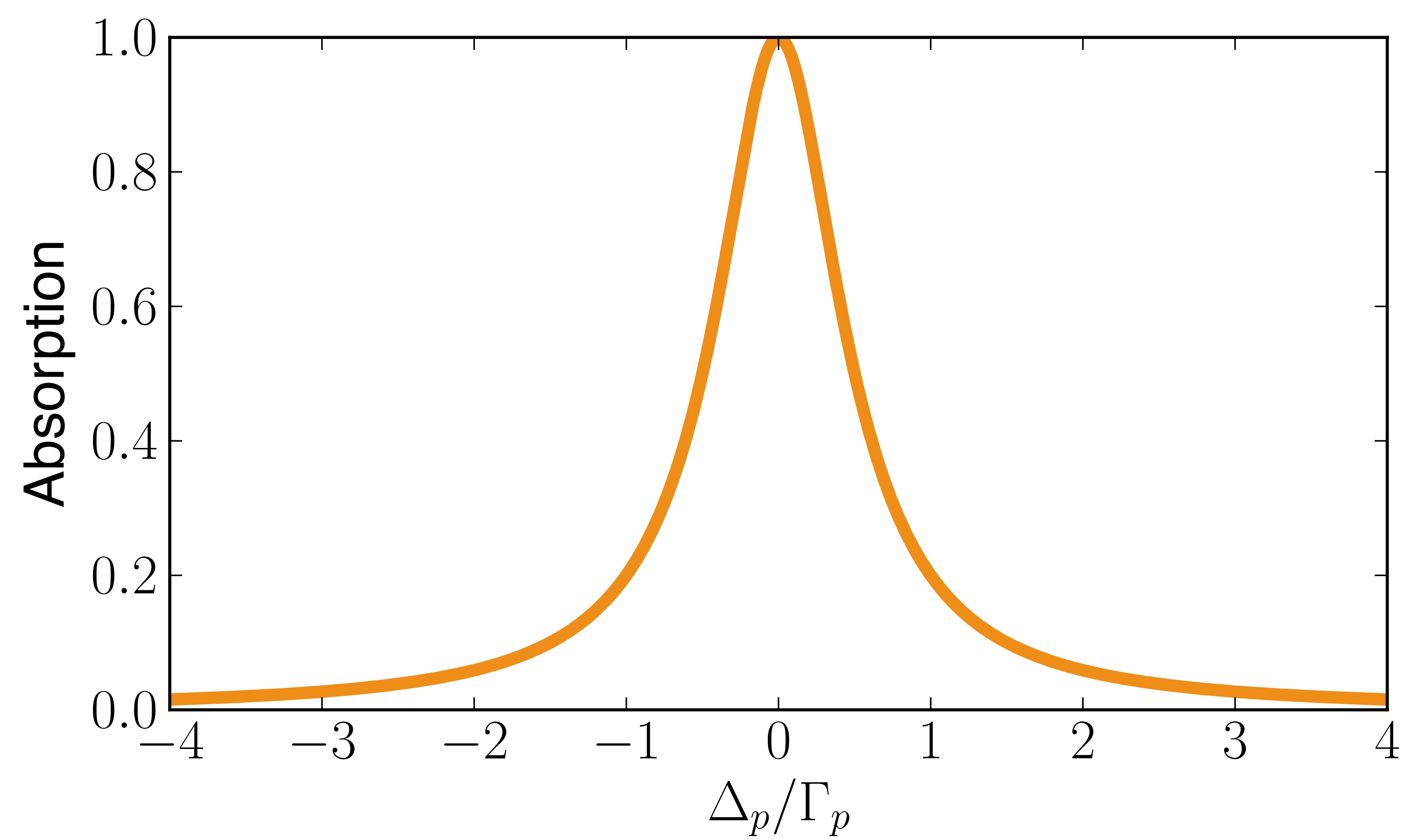
Dipole blockade





EIT





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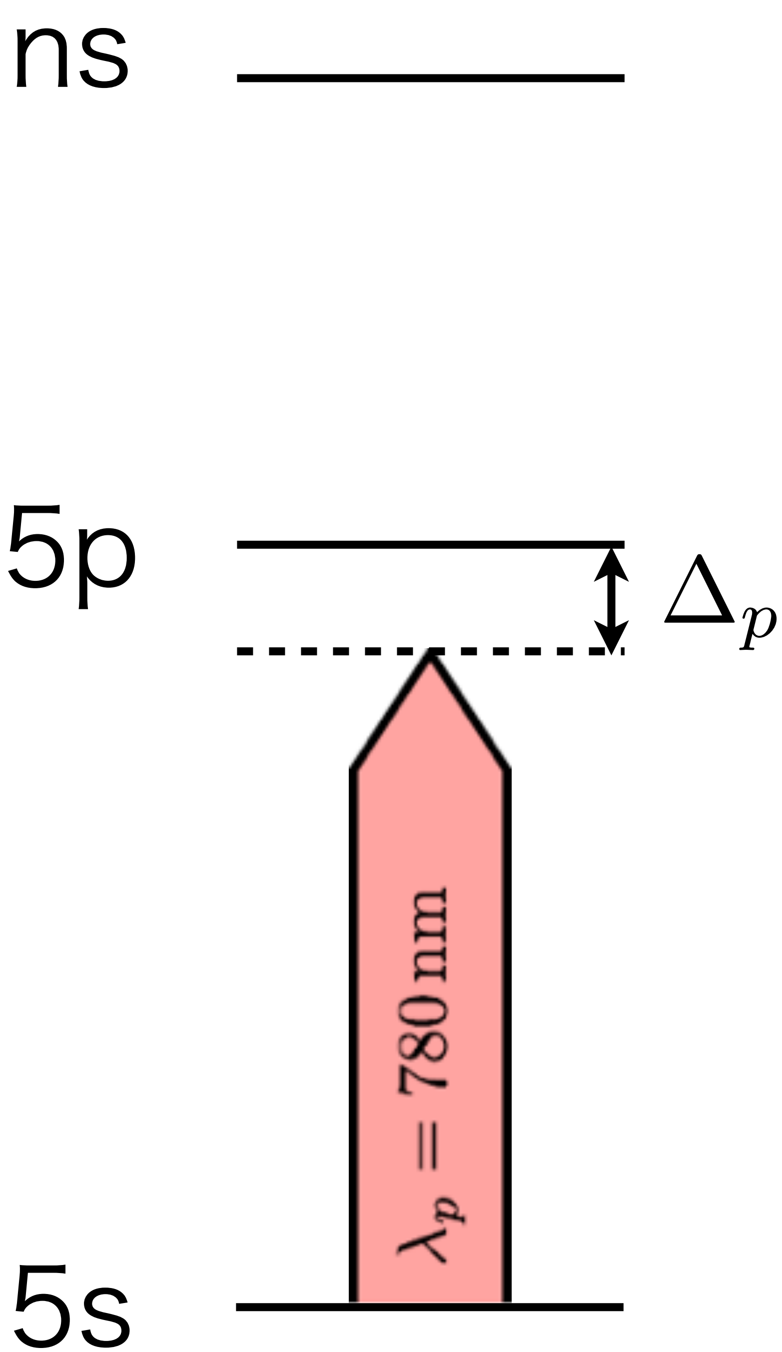
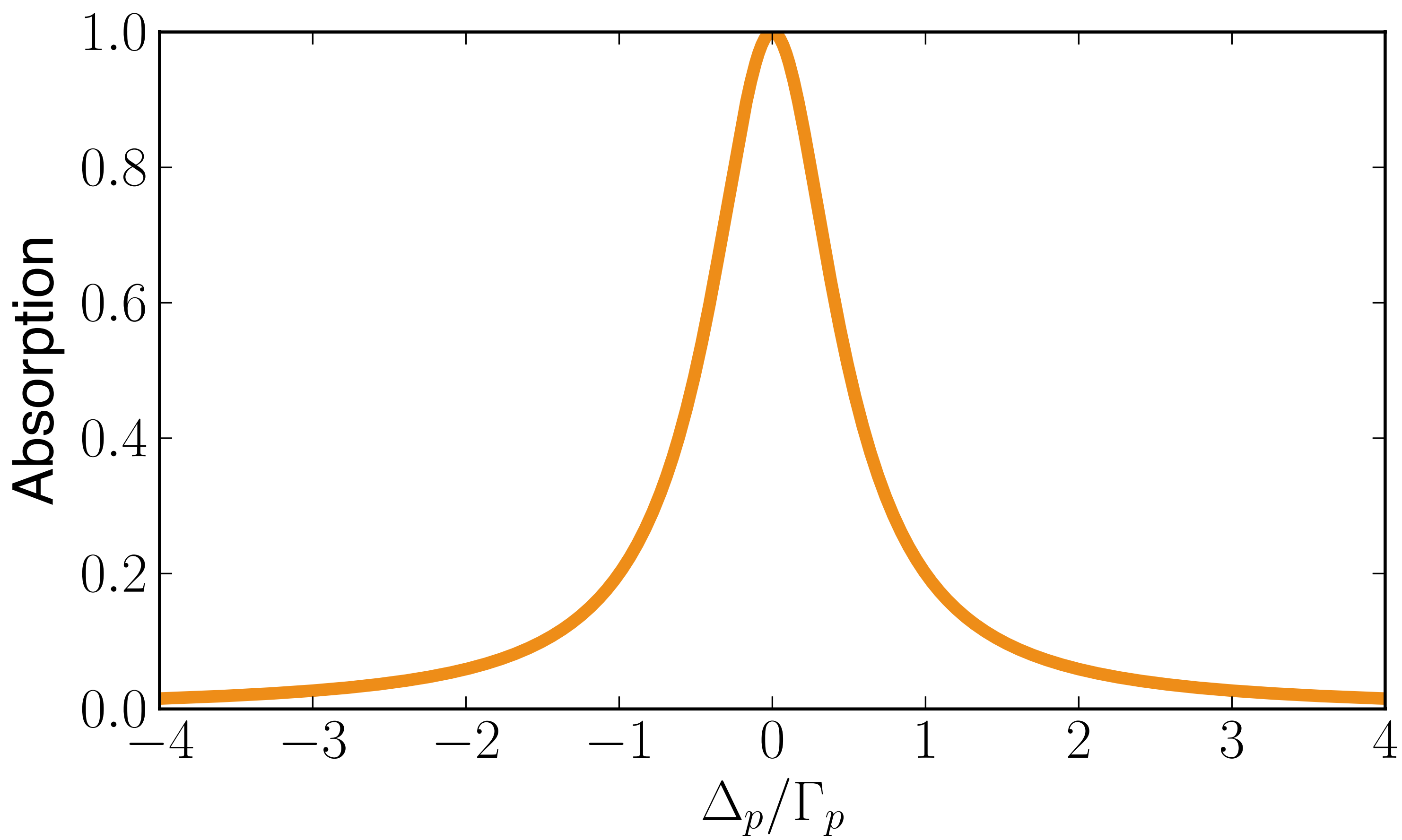
EIT





Fleischhauer et al., Rev. Mod. Phys. 77, 633 (2005)

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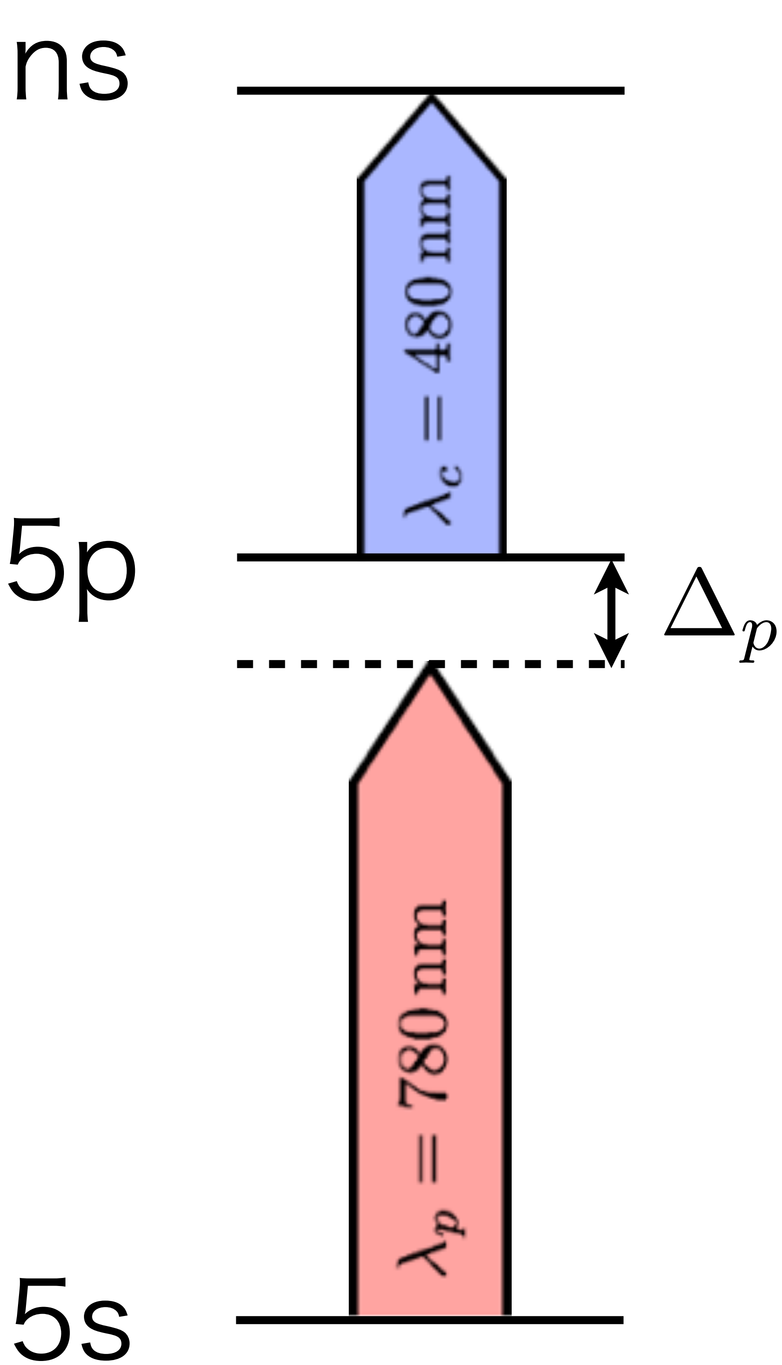
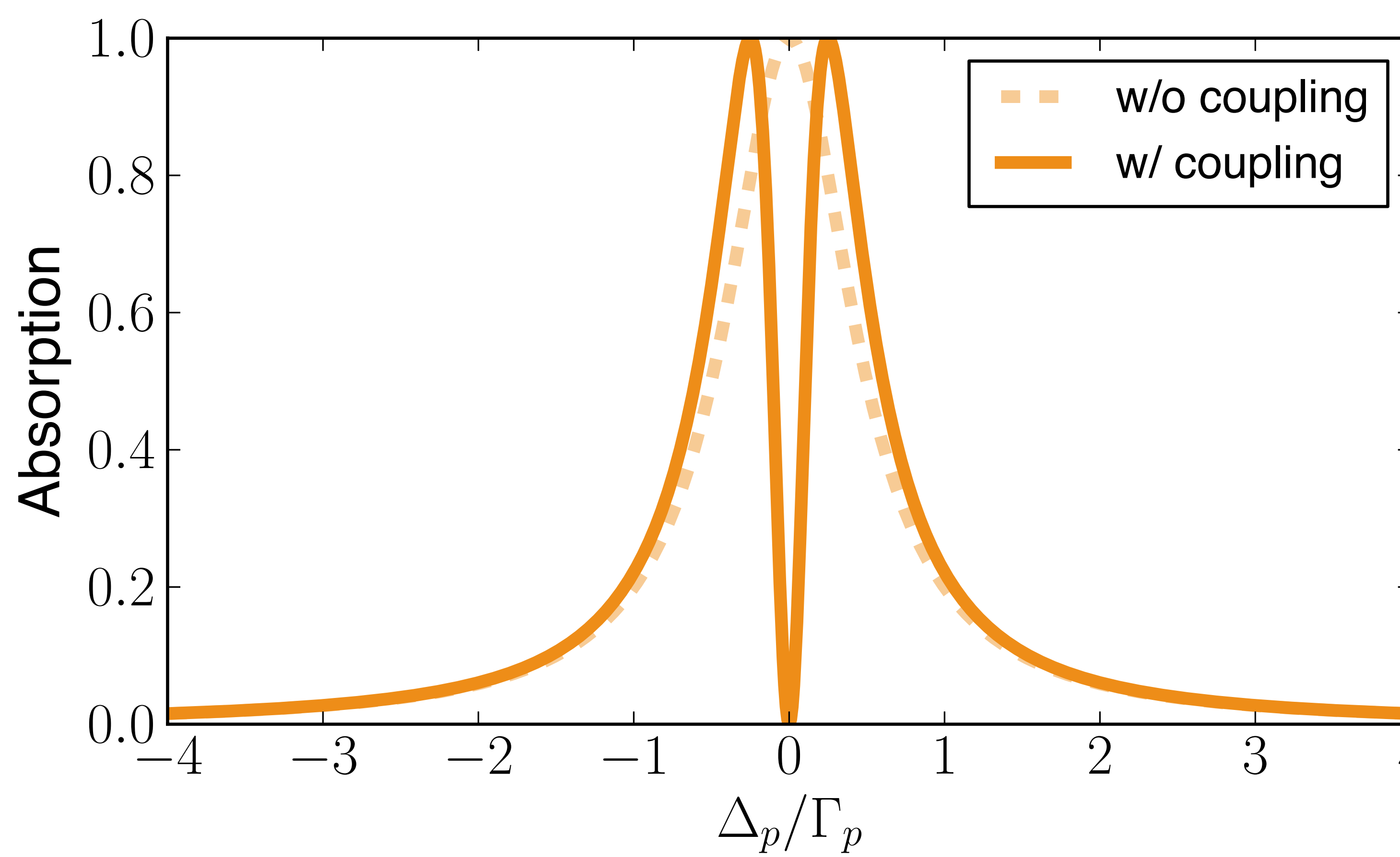
EIT





Fleischhauer et al., Rev. Mod. Phys. 77, 633 (2005)

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“Dark” Polaritons

Photons propagating through matter polarize it

Maxwell-Bloch equations ⟶ EM field + matter

Particular solution: Polariton

$$\Psi(z,t) = \cos\theta(t) E(z,t) - \sin\theta(t)\sqrt{N}\sigma_{gr}(z,t)$$

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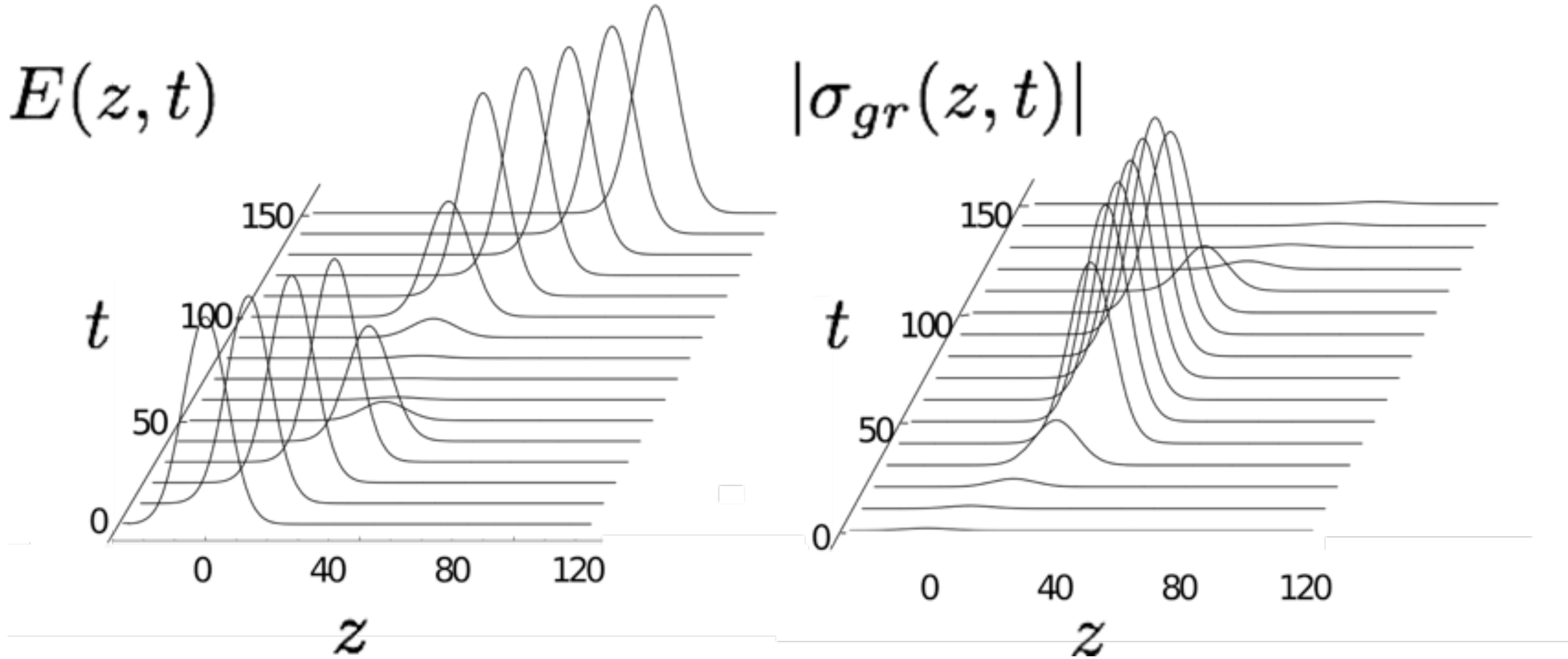
Fleischhauer & Lukin, PRL 84, 5094 (2000)

Dark Polaritons

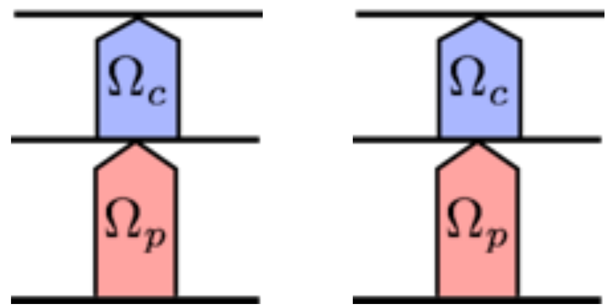


Fleischhauer & Lukin, PRL 84, 5094 (2000)

Combine effects

Combine effects

Non-interacting system



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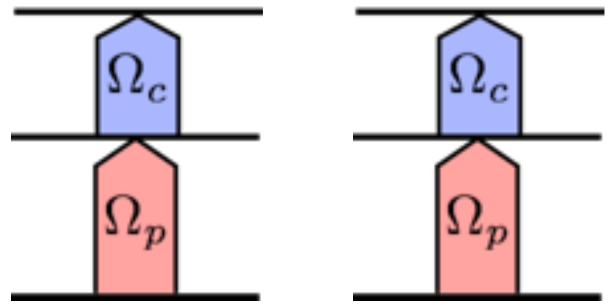
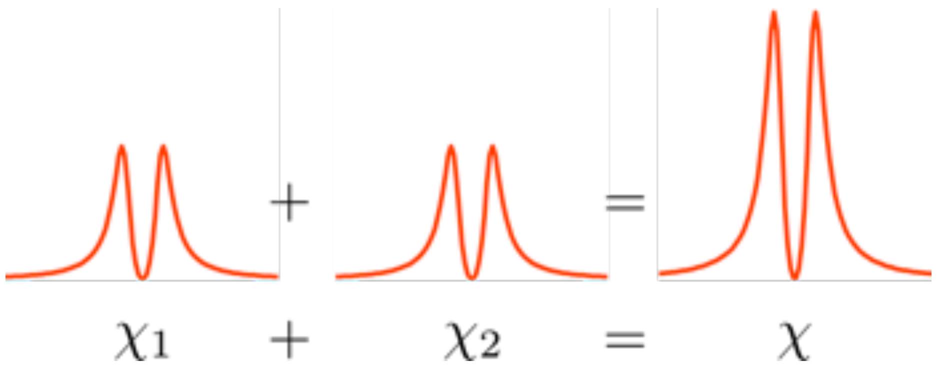
Combine effects

Non-interacting system





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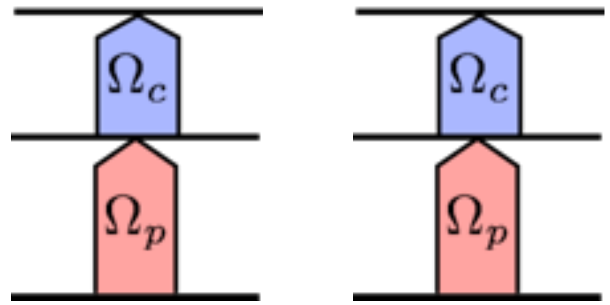
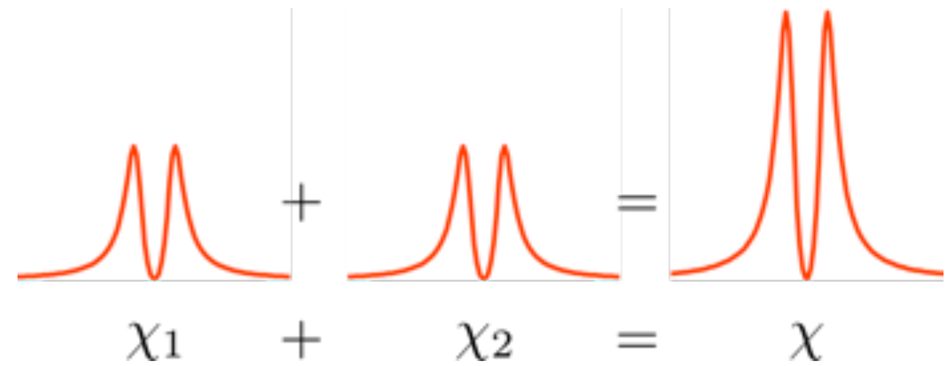
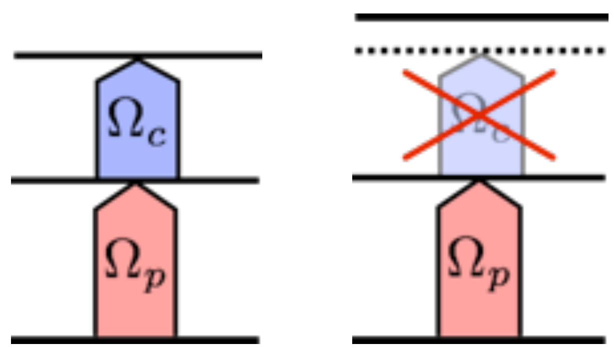


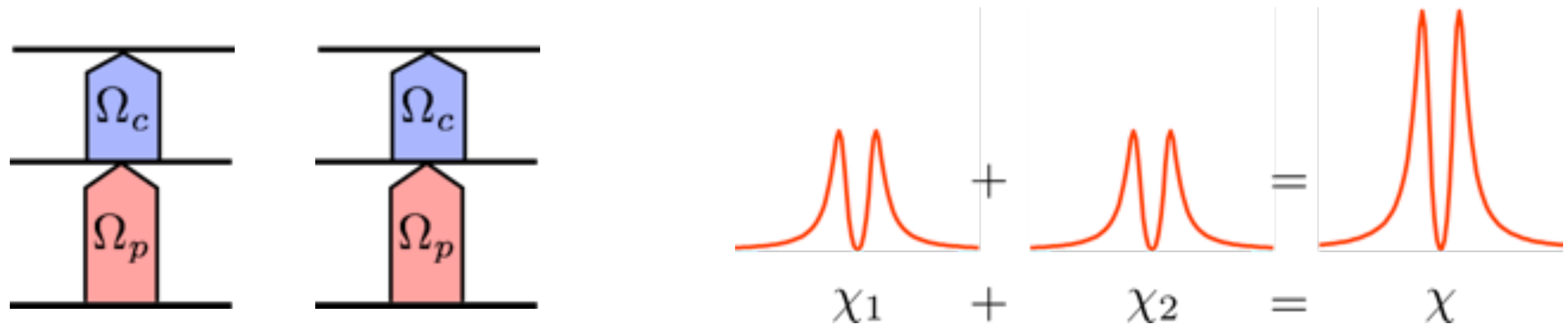


Blockaded system



Combine effects

Non-interacting system



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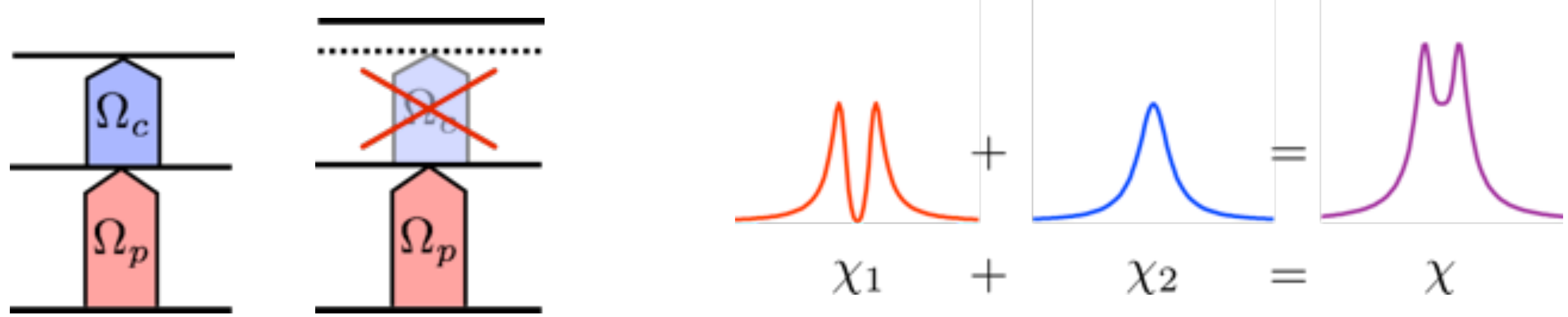

Combine effects

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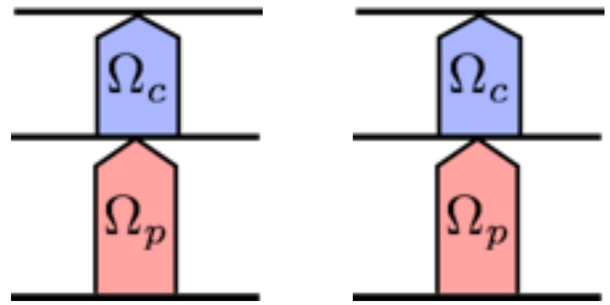

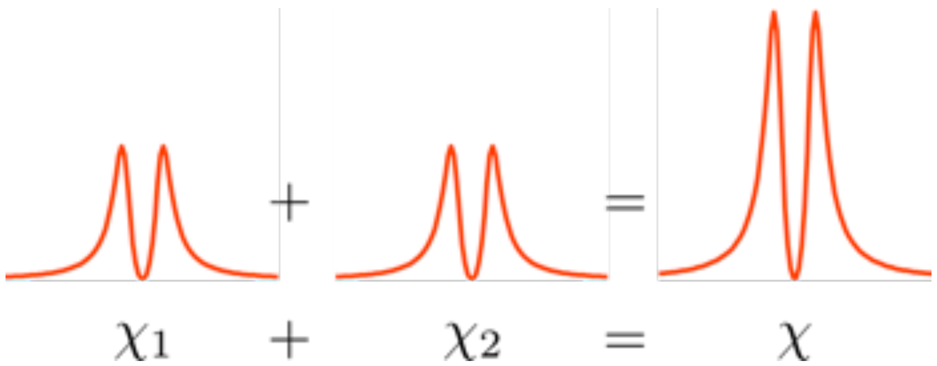

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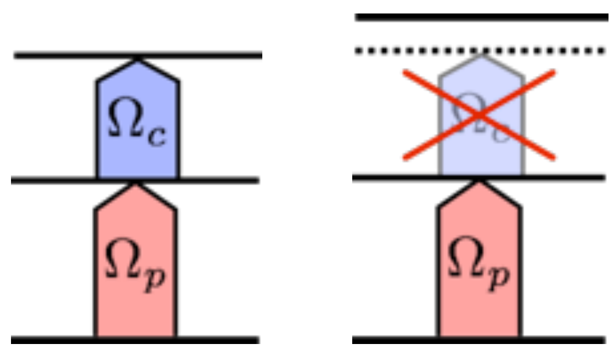
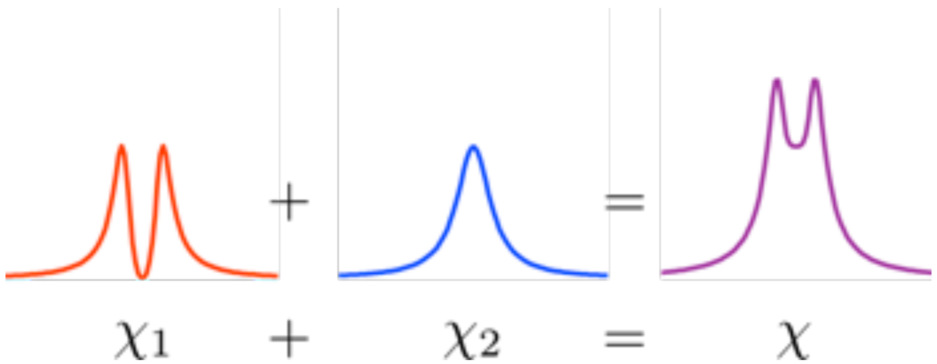


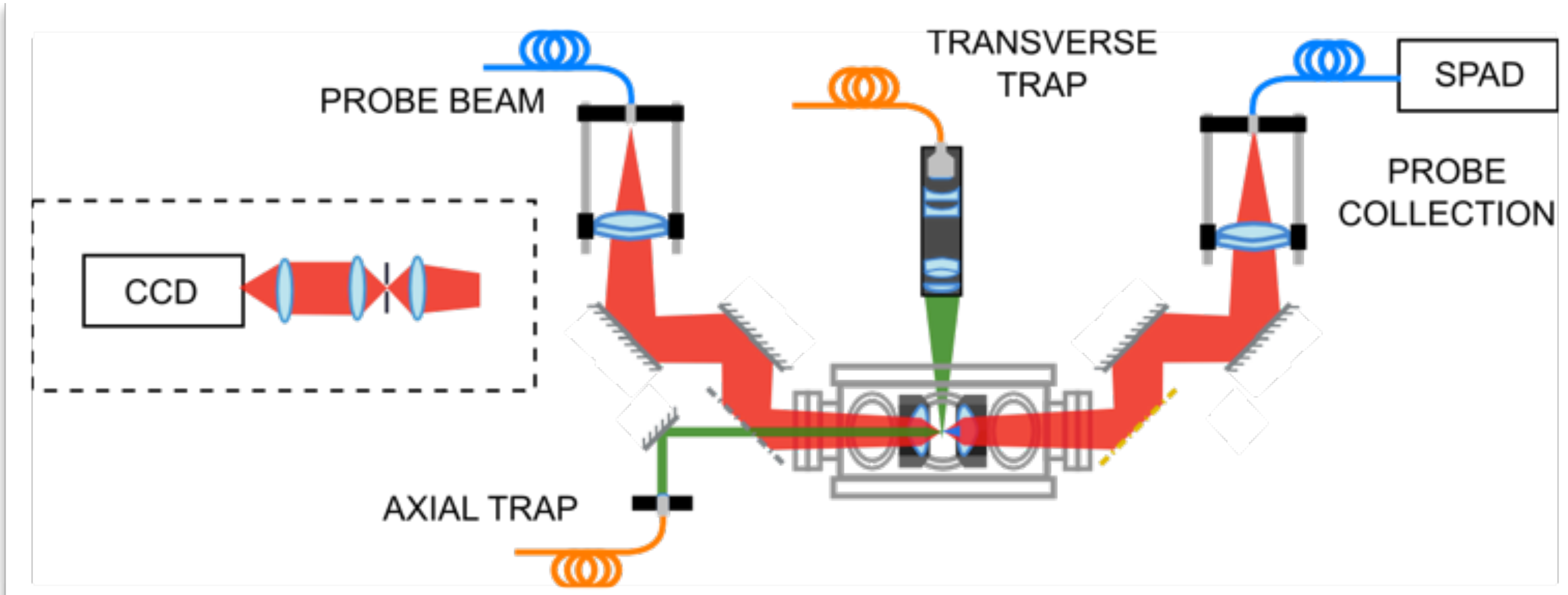


EIT supression

Requirements

Single excitation Small volume

High absorption Good optical depth + Cloud/probe mode matching



Cold ^{87}Rb **T ~ 150μK**

Tightly focused, cross-dipole trap (aspheric lenses in vacuum). Cloud size **R_c < 5μm**

Optical depth **OD ~0.5**

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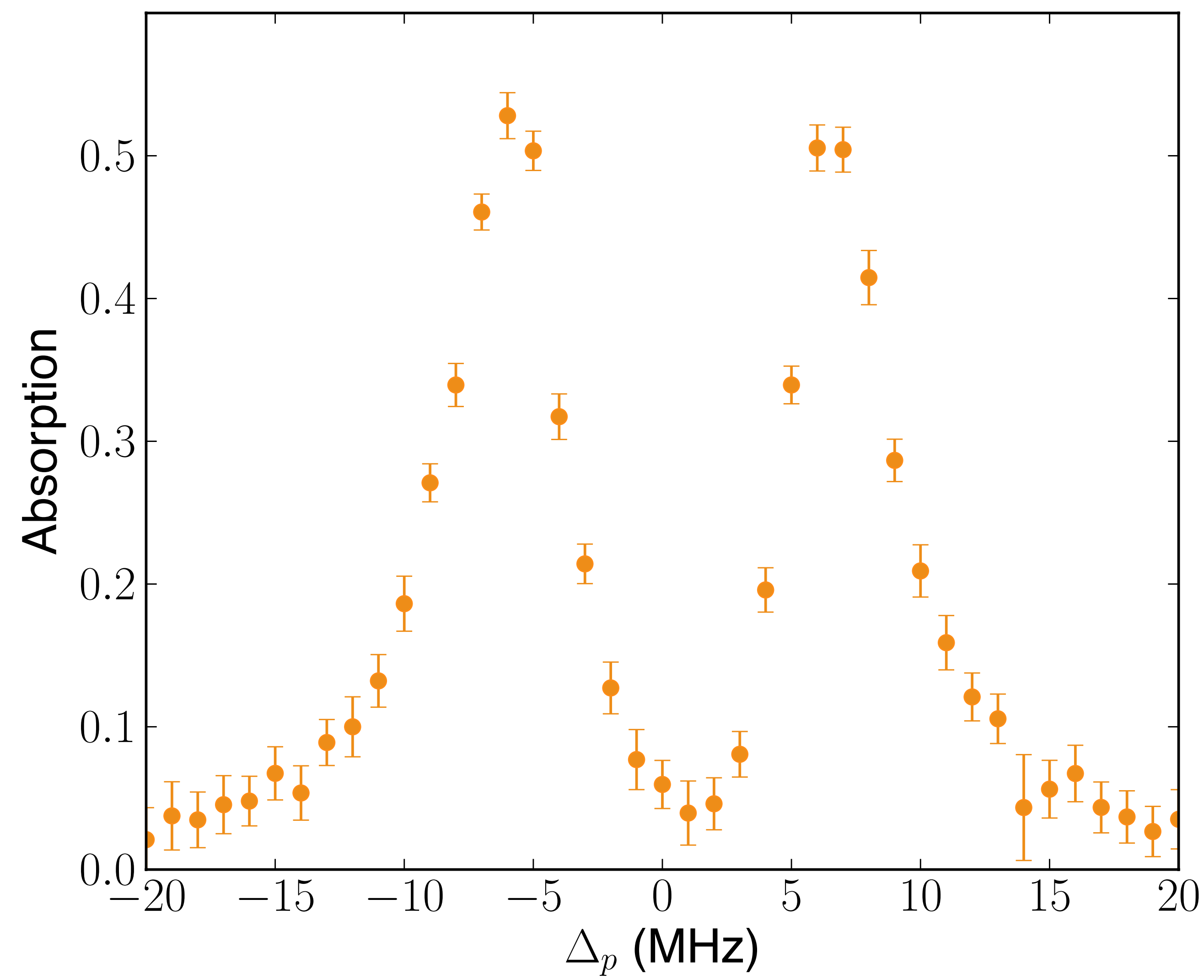
Experimental progress

EIT at high coupling power

5s-5p-42s of ^{87}Rb

$$\Omega_p = 2\pi \times 0.5\,\mathrm{MHz}$$

$$\Omega_c = 2\pi \times 12\,\mathrm{MHz}$$



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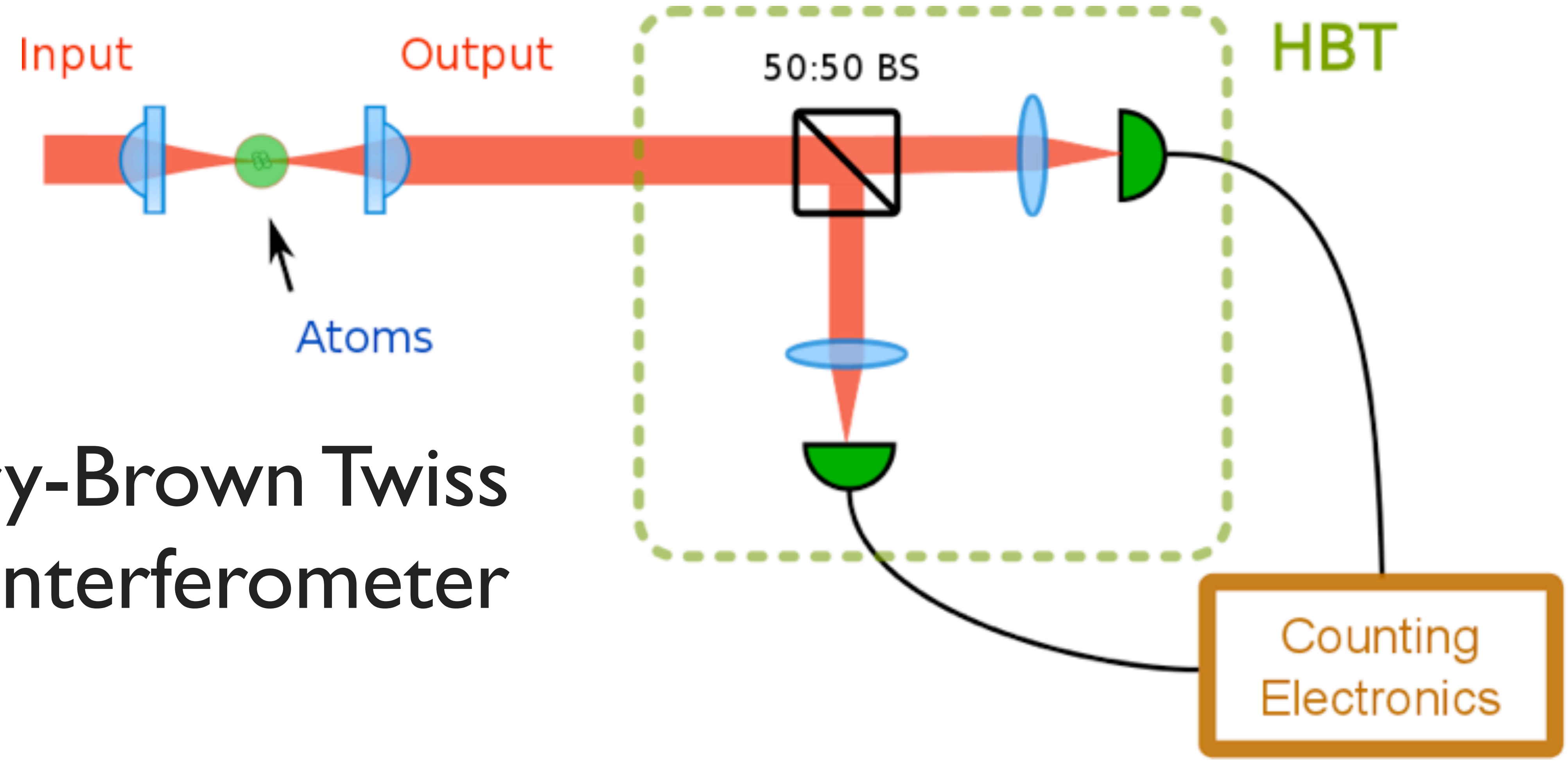
Autocorrelation measurement



Hanbury-Brown Twiss (HBT) interferometer

$$g^{(2)}(\tau)$$

Probability of detecting two photons with a time difference τ in different detectors

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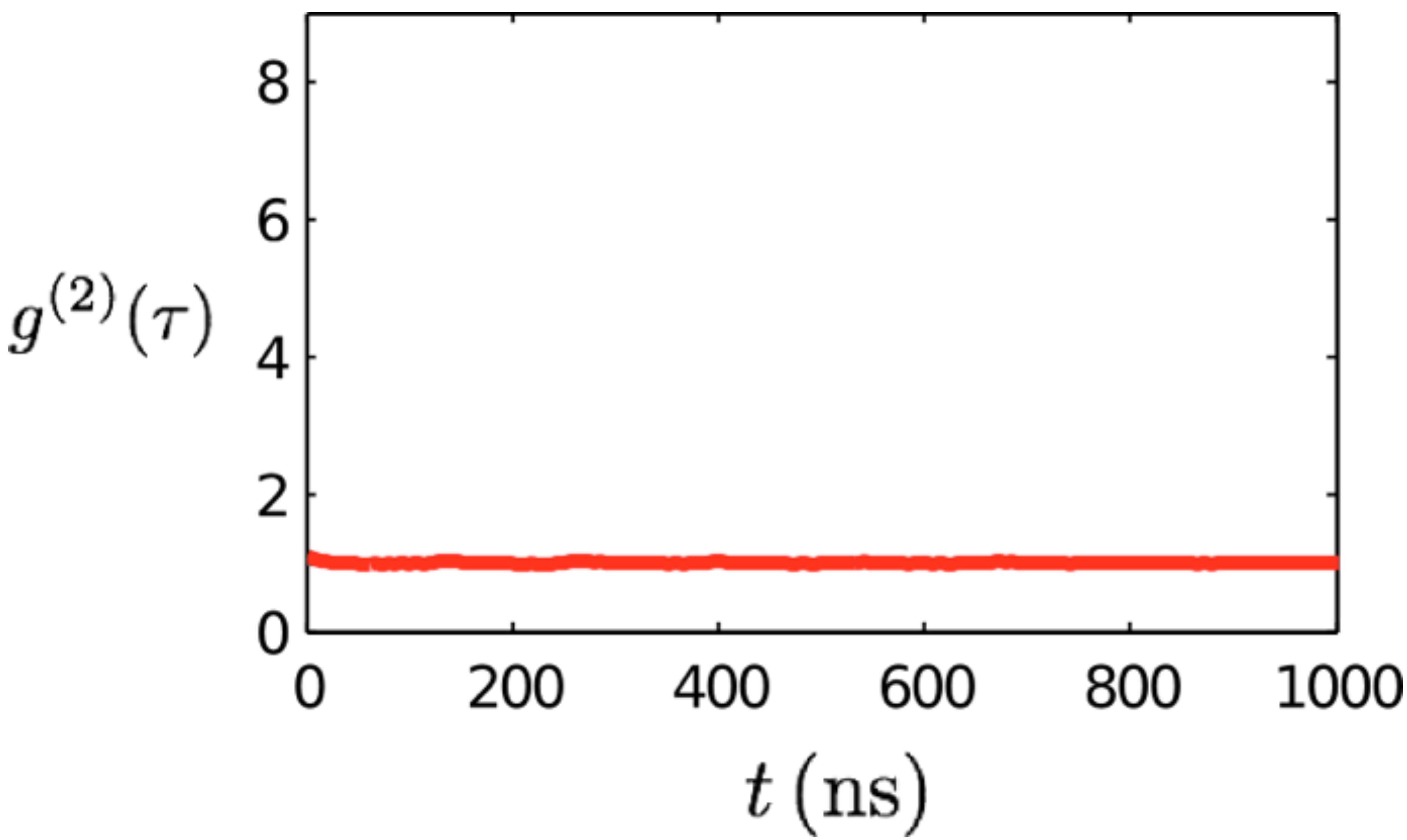
Autocorrelation simulations



Taken from Jonathan Pritchard's Thesis, Durham 2011

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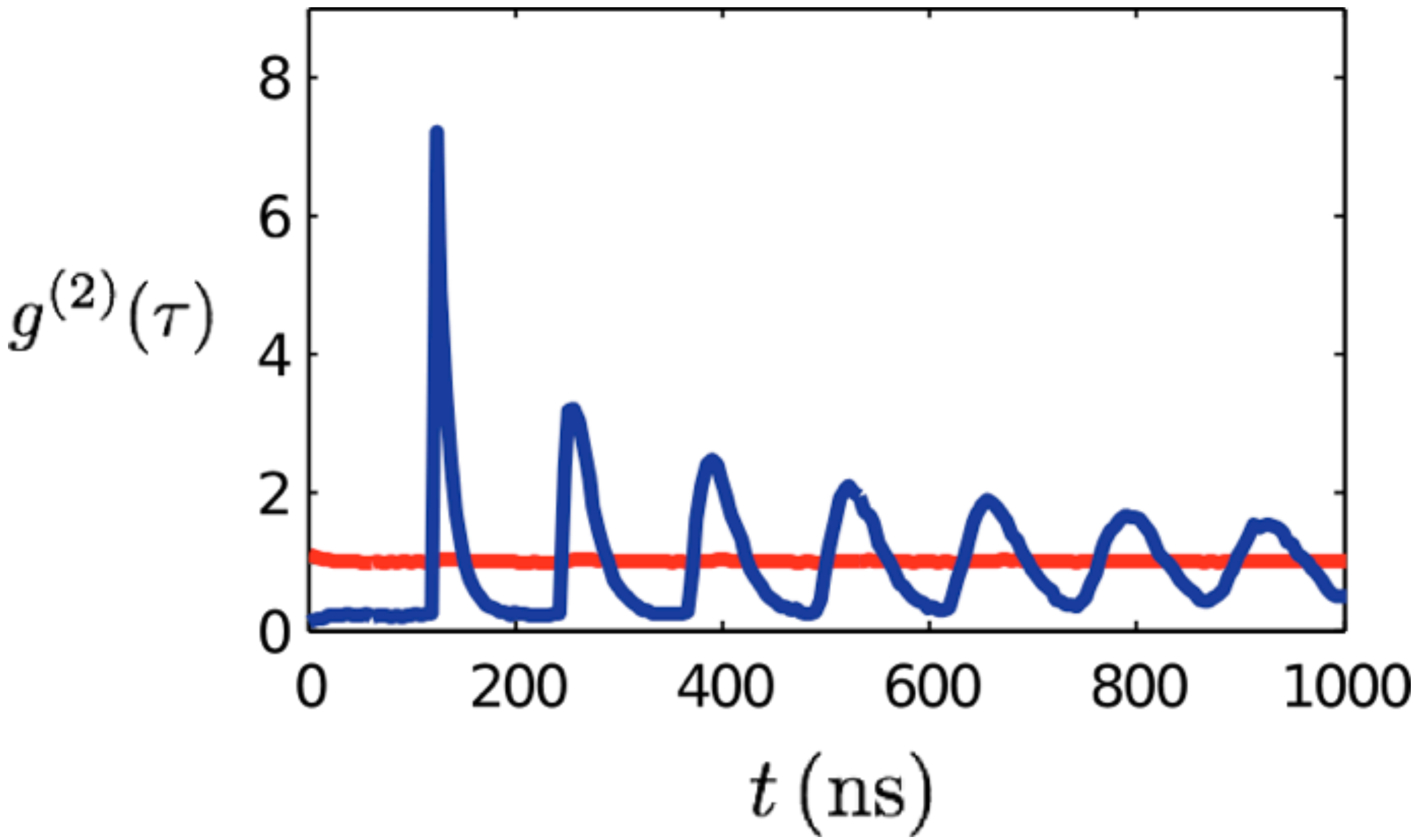
Autocorrelation simulations



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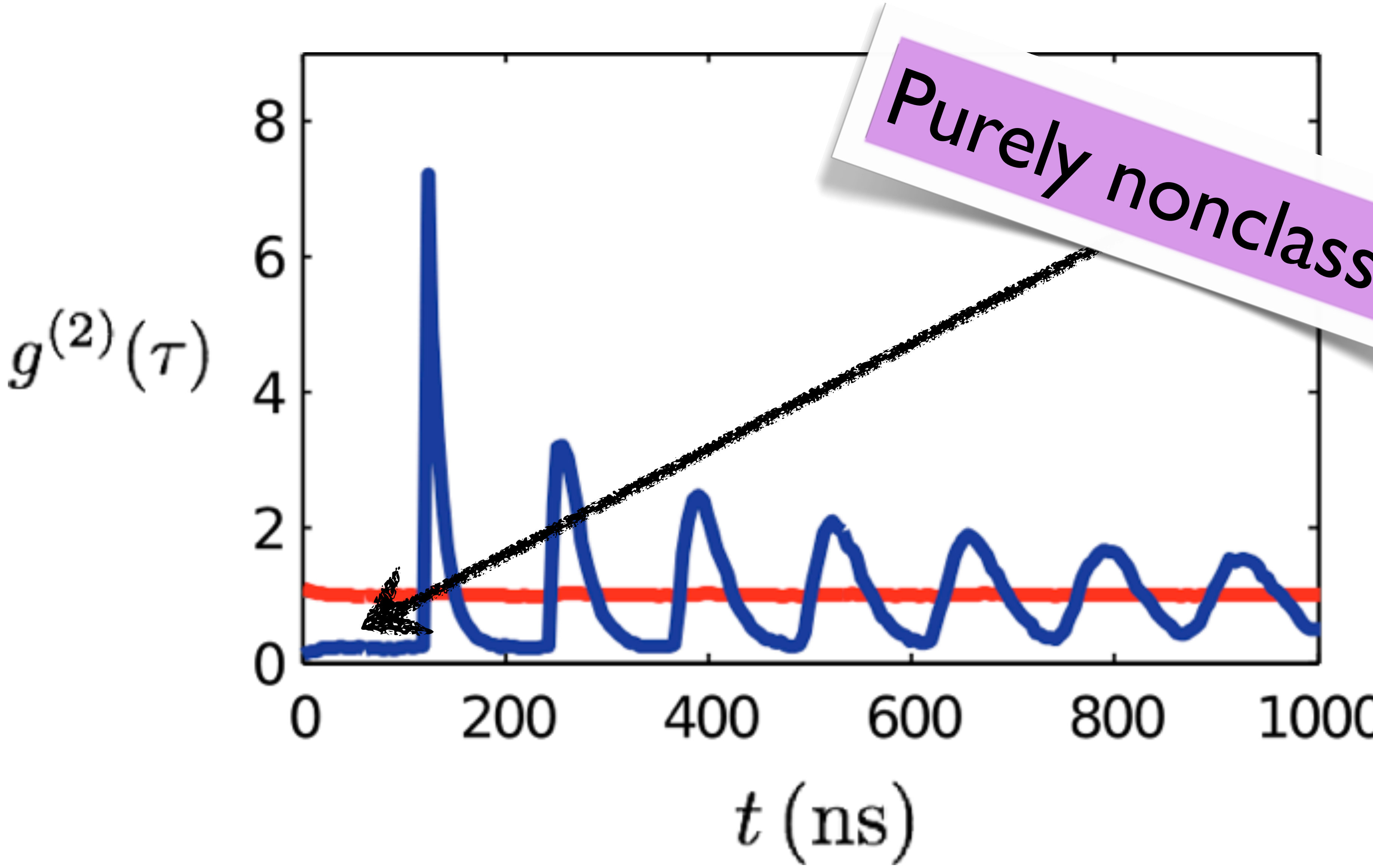
Autocorrelation simulations



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Future

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Future

- Single-photon source (HBT)

Future

- Single-photon source (HBT)
- Quantum phase gate

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Conclusions

- Exploit Rydberg nonlinear interactions
- Use EIT and blockade to generate nonclassical states

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