# Coupled collective and Rabi oscillations in electron transport through a photon cavity

Viðar Guðmundsson

Science Institute, University of Iceland

vidar@hi.is

http://hartree.raunvis.hi.is/~vidar/Rann/Fyrirlestrar/Stockholm-05-2015.pdf

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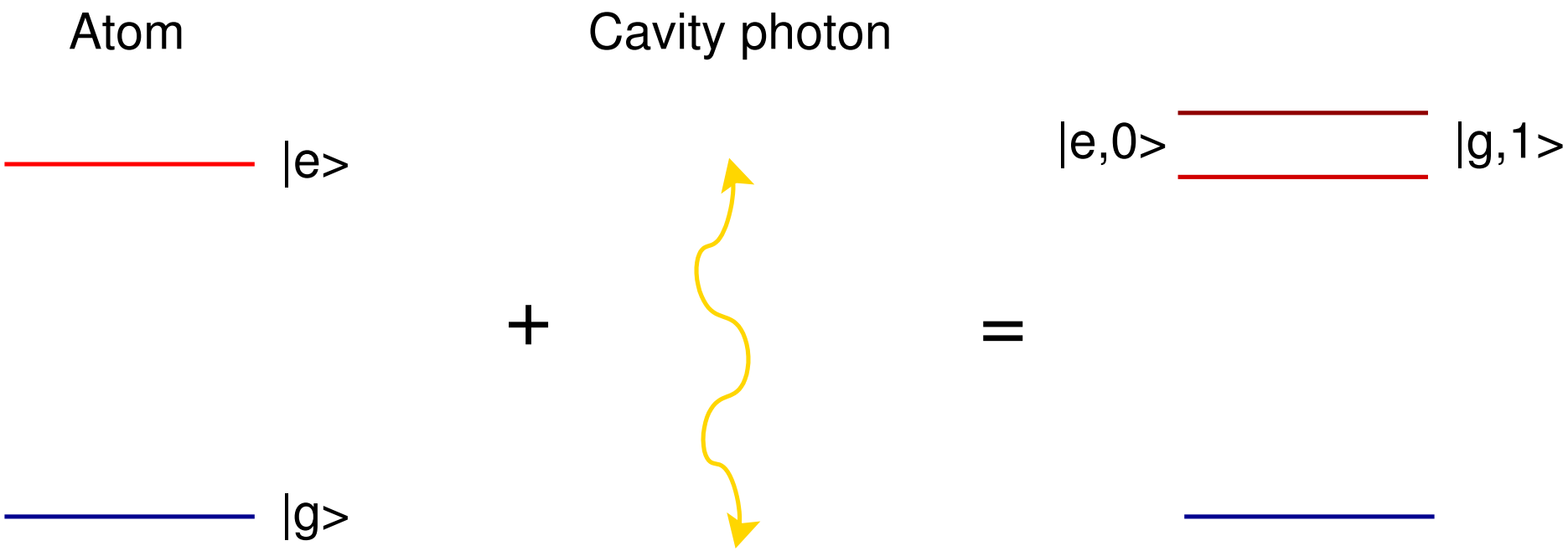
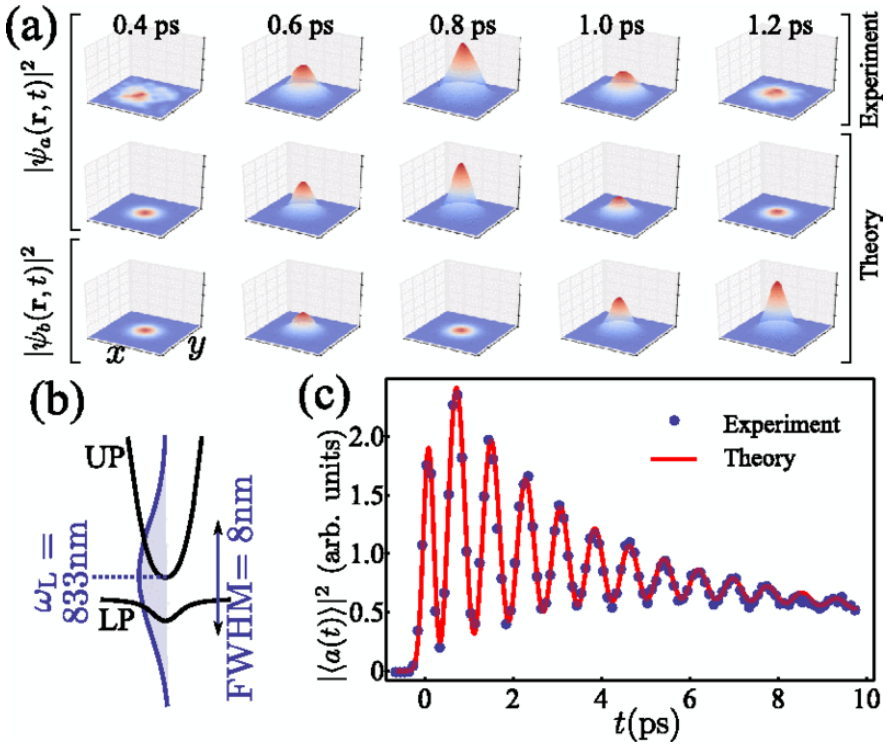
Is it possible to see Rabi-vacuum oscillations in electron transport?

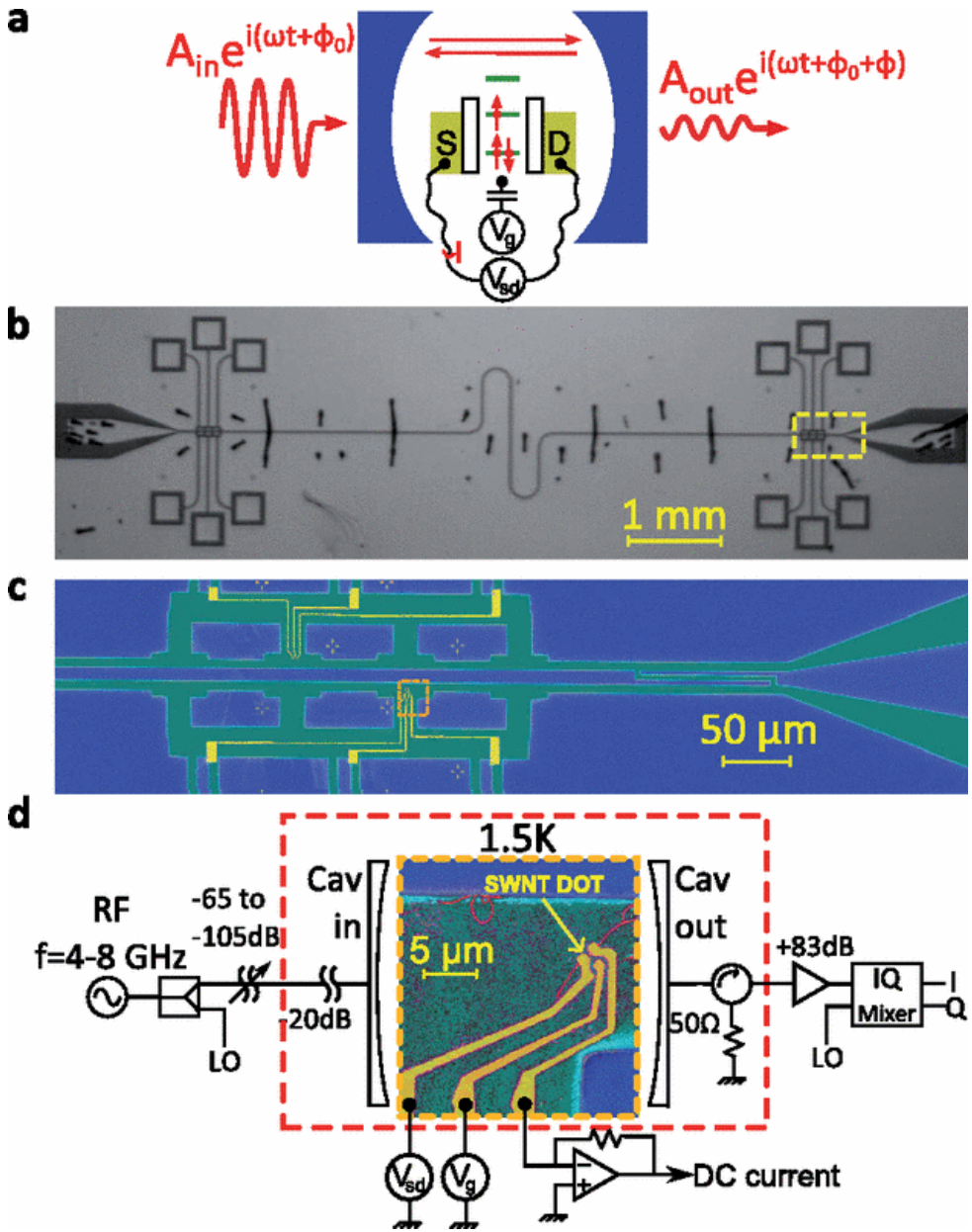



$$\Delta E^{\mathrm{JC}}_{\mathrm{Rabi}} = \sqrt{(\hbar\omega_r)^2 + \delta^2}, \qquad \hbar\omega_r = 2g_{\mathrm{EM}}$$

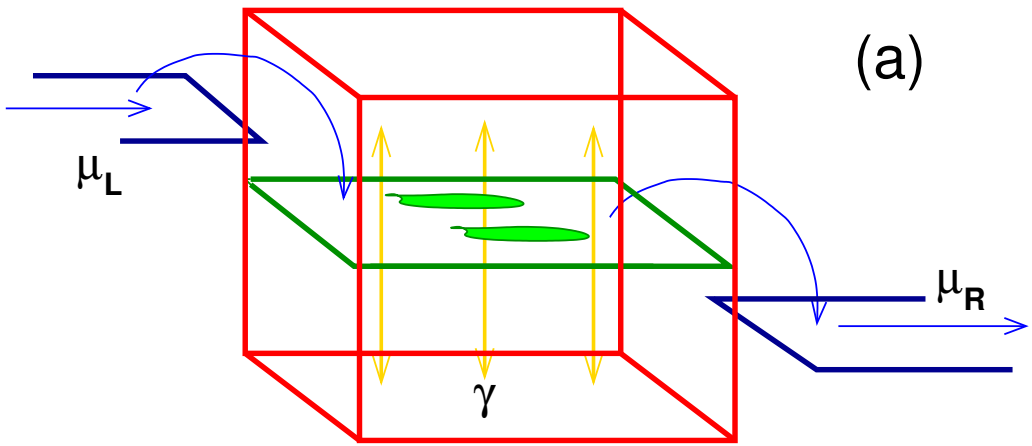
Ultrafast Control and Rabi Oscillations of Polaritons,
L. Dominici et al.,
Phys. Rev. Lett. 113, 226401 (2014)

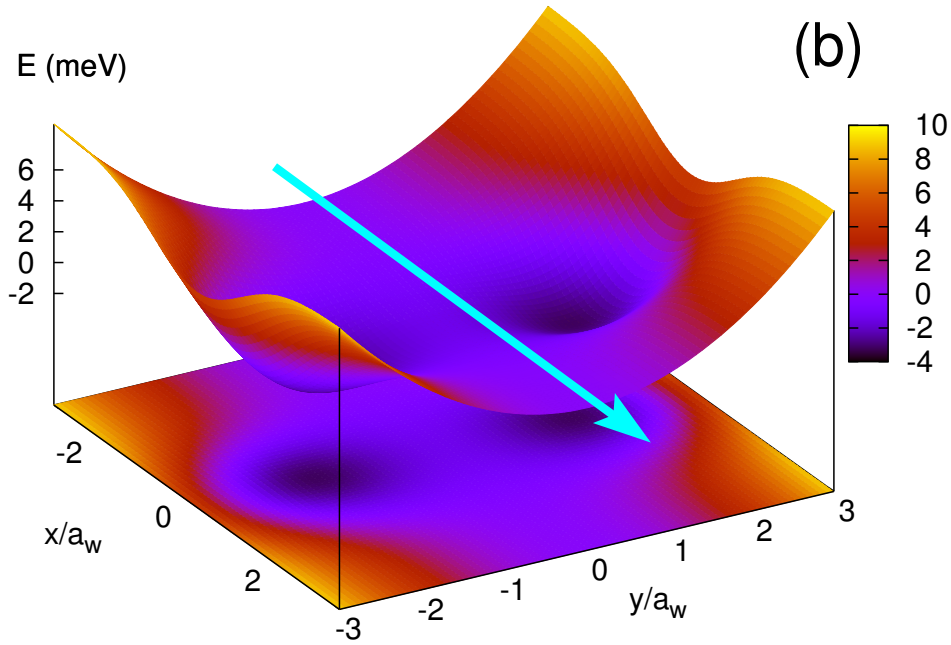


Coupling a Quantum Dot, Fermionic Leads, and a Microwave Cavity on a Chip, M. R. Delbecq et al., Phys. Rev. Lett. 107, 256804 (2011)



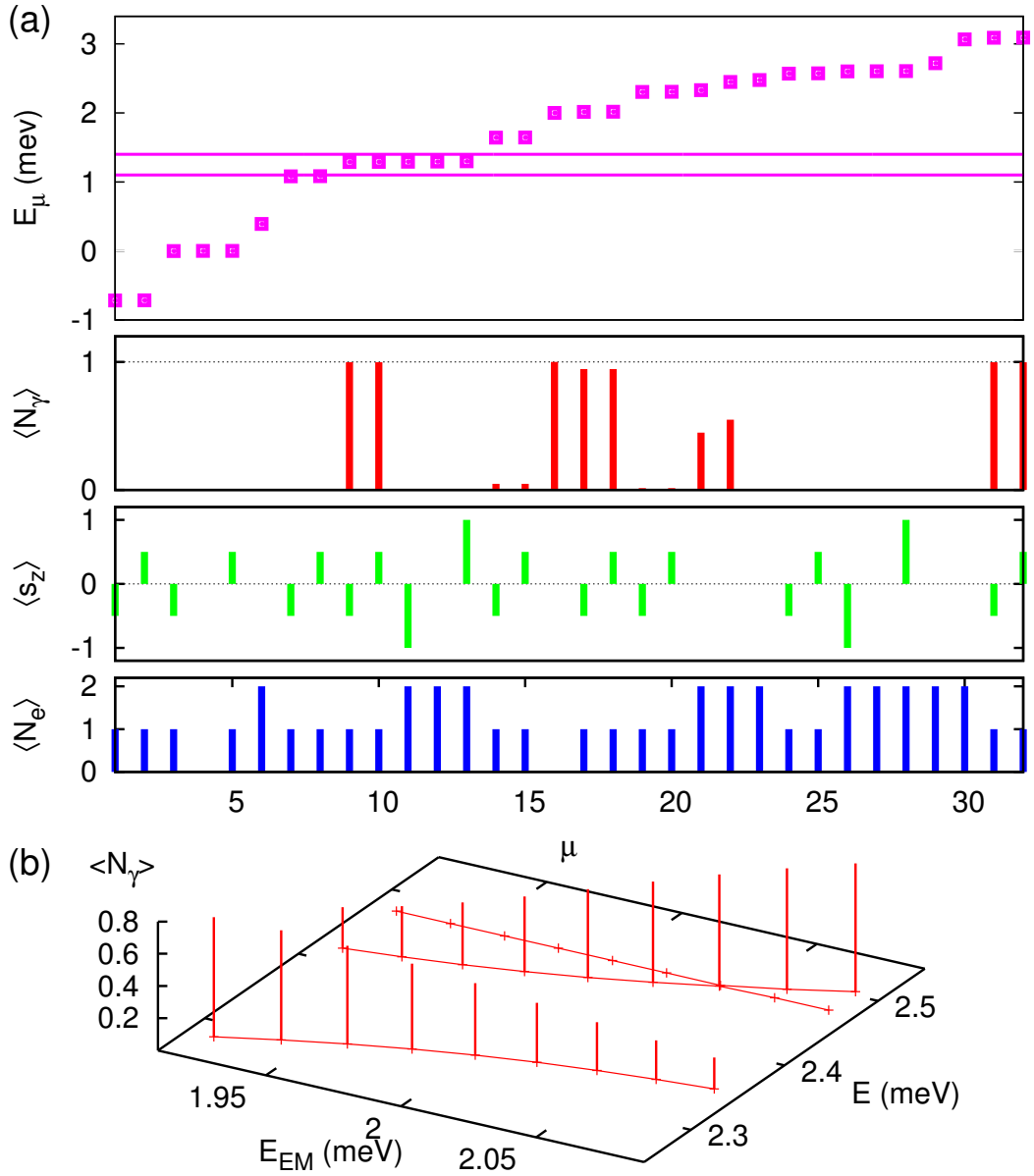
- Two parallel quantum dots
- 0-4 exactly Coulomb interacting electrons
- Para- and diamagnetic electron-photon interaction
- GaAs $\rightarrow$
  $m^* = 0.067 m_e$,
  $\kappa = 12.4 \rightarrow$
  $a_w = 23.8$ nm,
  $(B = 0.1$ T$)$
- Non-Markovian GME for the open system

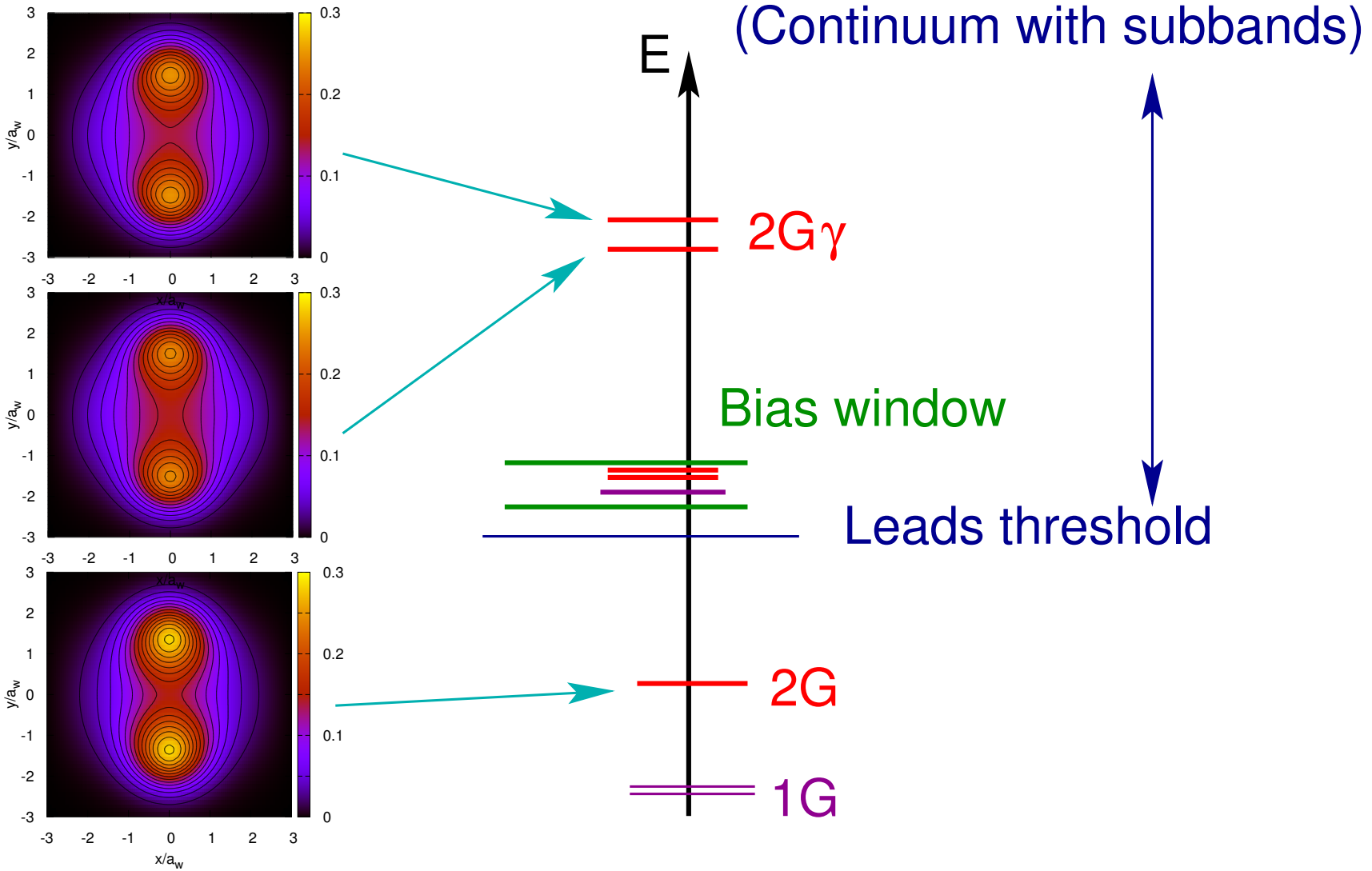


# Properties of the closed static system

- Confinement energy in $y$-direction $\hbar\Omega_0 = 2.0$ meV
- Single photon mode $E_{\mathrm{EM}} \sim 2.0$ meV
- Electron-photon coupling $g_{\mathrm{EM}} = 0.05$ meV
- Rabi pair $|\breve{2}1)$ and $|\breve{2}\breve{2})$




(Continuum with subbands)
E
2Gγ
Bias window
Leads threshold
2G
1G
y/a_w
x/a_w

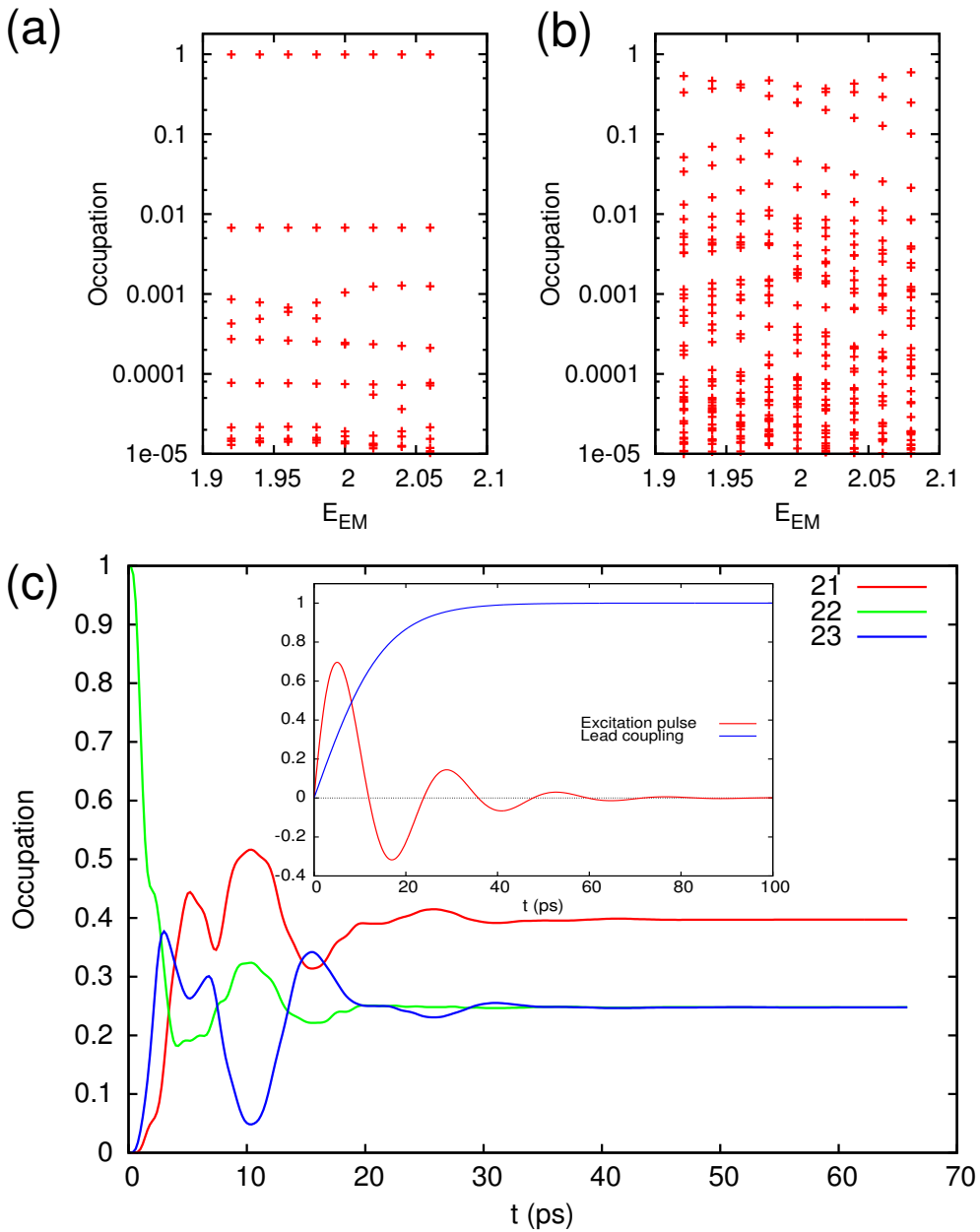
Classical dipole excitation (closed system)

$E_{\mathrm{EM}} = 2.0$ meV

Off-resonance
$x$-polarization photon
$x$-polarization pulse

Resonance
$y$-polarization photon
$y$-polarization pulse

Pulse $\longrightarrow$ entanglement



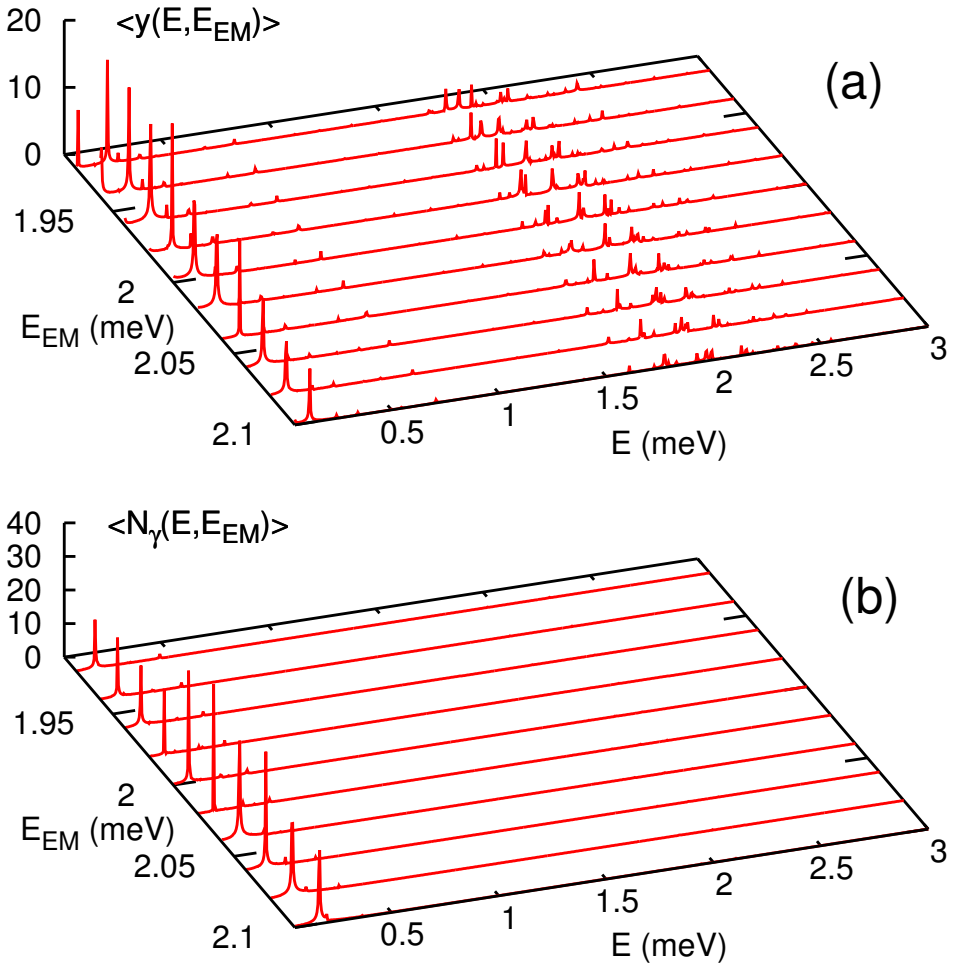
Fourier spectra
(closed system)

$\langle y(t) \rangle$

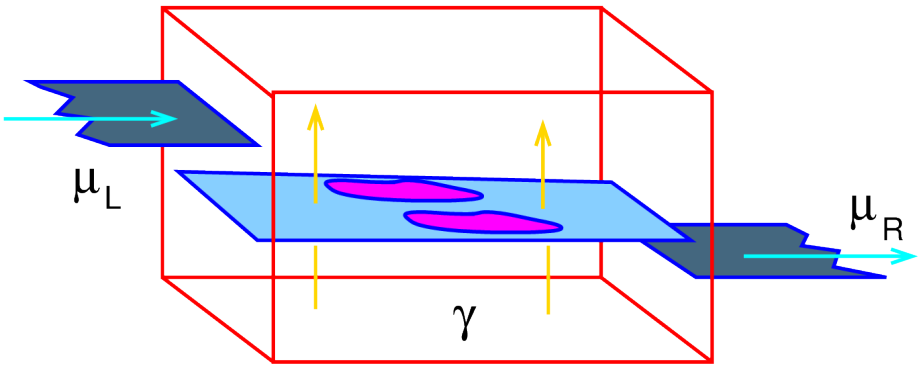
$\langle N_\gamma(t) \rangle$

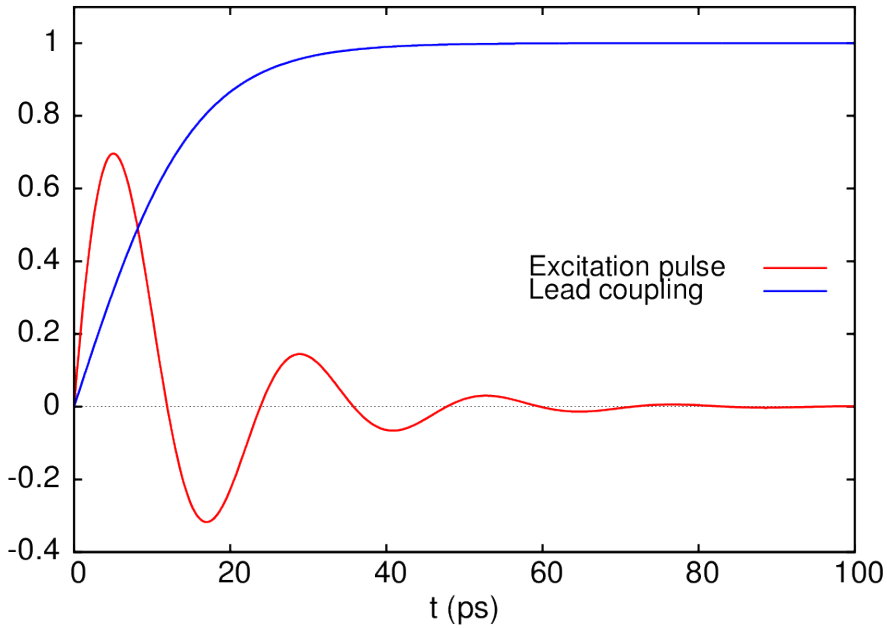
Near resonance
$y$-polarization photon
$y$-polarization pulse
$g_{\mathrm{EM}} = 0.05$ meV

Initial state: Lowest Rabi-split 2-electron state with higher photon content

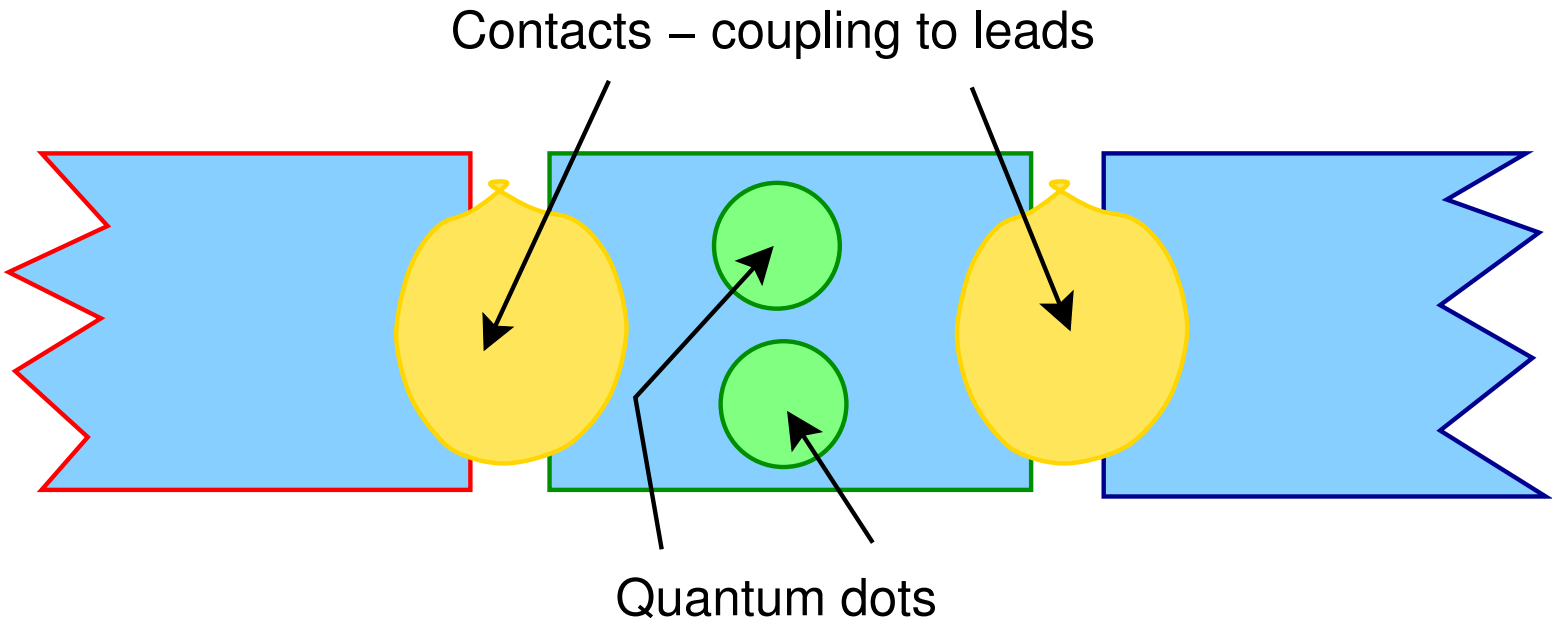


# System opened up for electron transport



Coupling to leads depends on the geometry of wavefunctions

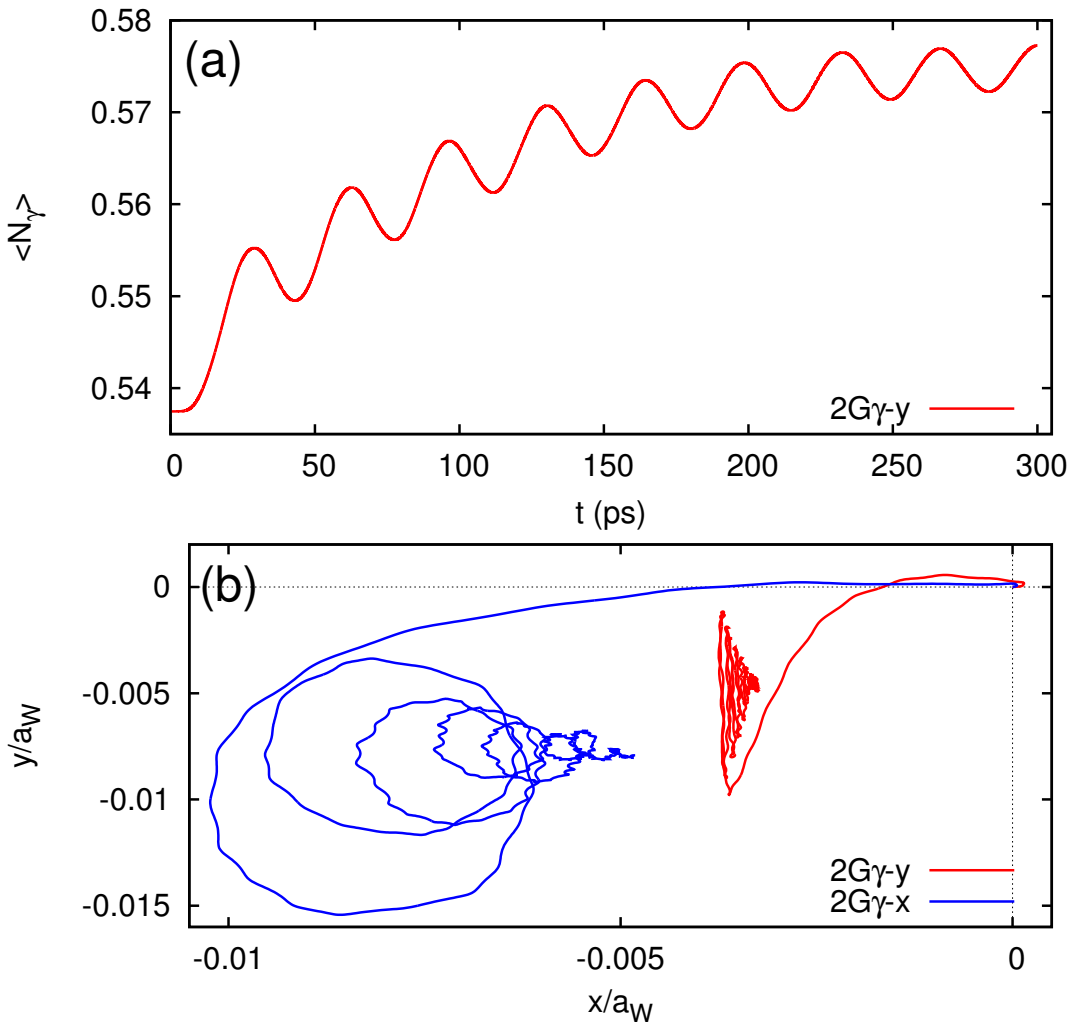


Open system

Initial state: Initial state: Lowest Rabi-split 2-electron state with higher photon content

$g_{\mathrm{EM}} = 0.05$ meV
$E_{\mathrm{EM}} = 2.0$ meV

Transport $\longrightarrow$ collective oscillations

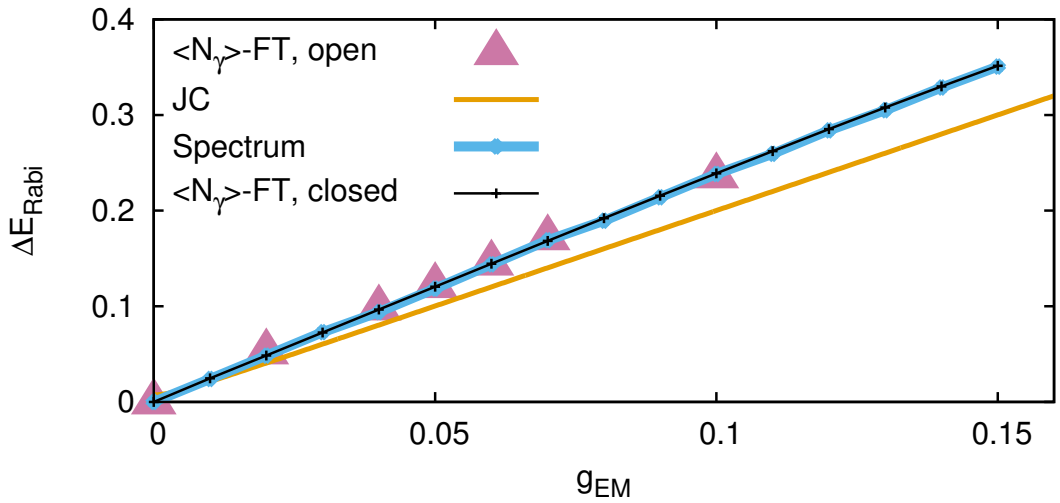


Rabi frequency compared:

2-level Jaynes-Cumming model

Energy spectrum

Fourier analysis of open and closed system

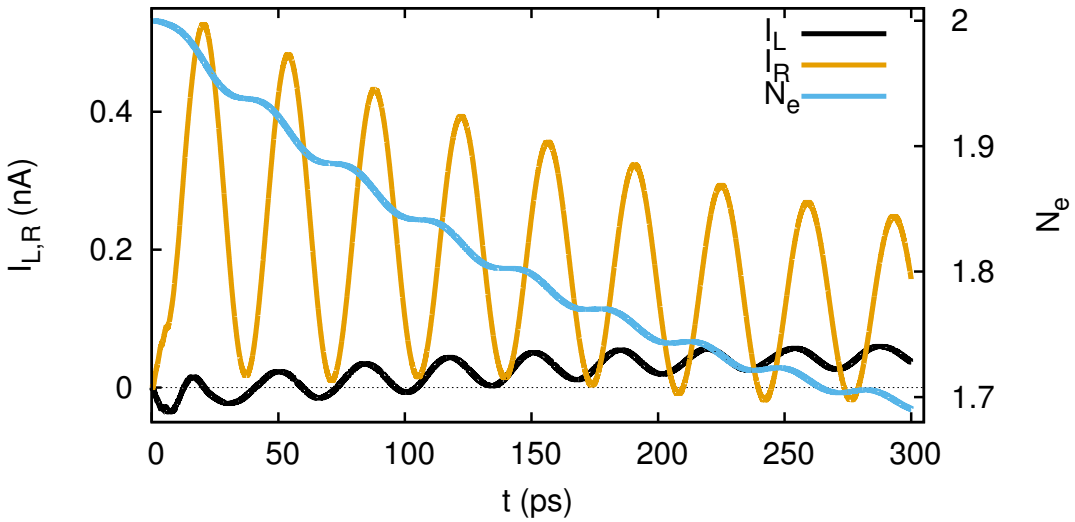


Initial state: entangled
2-electron Rabi-vacuum pair

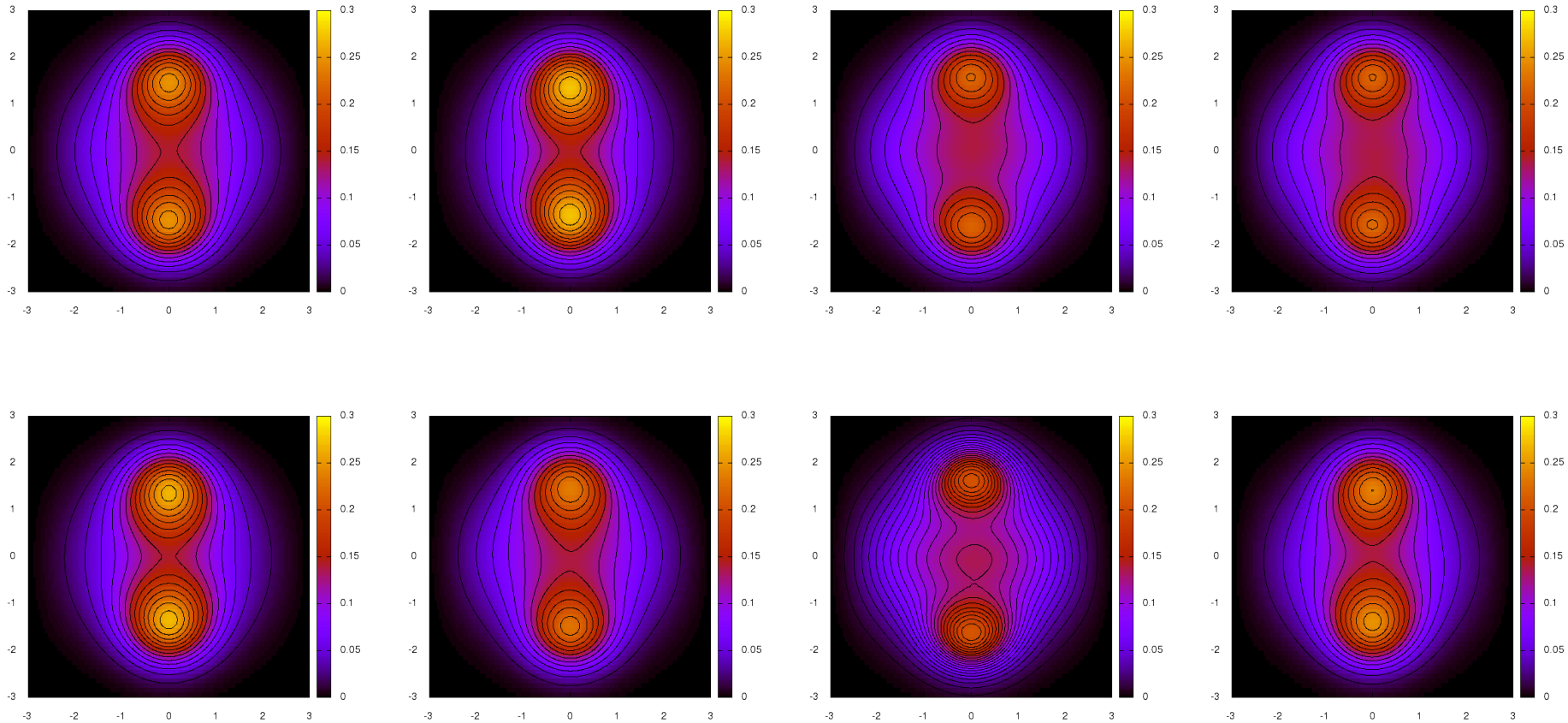
Made by dipole pulse before coupling to leads

Rabi-oscillations in transport current

Decoherence caused by coupling to leads



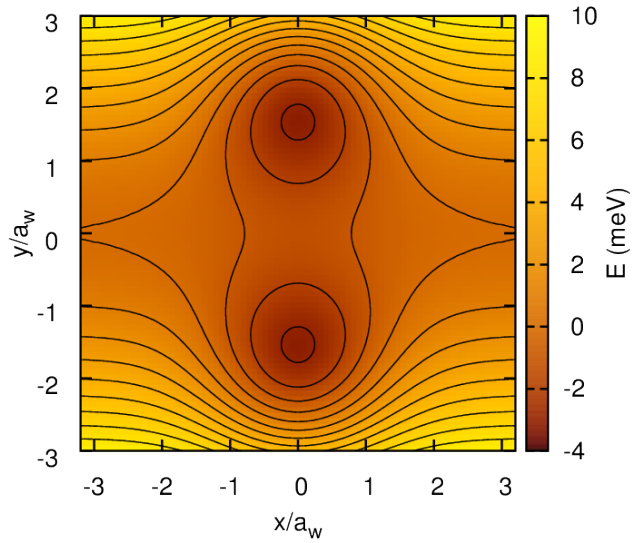
# Quadrupole oscillations, ($t = 0, \cdots, 106$ ps)



Summary

- Transport triggers collective oscillations
- Coupled Rabi-vacuum and collective oscillations
- Geometry + para- and diamagnetic $e$-$\gamma$-interactions
- `http://arxiv.org/abs/1502.06242`

$\cdots$, but why two-electrons and parallel double dots?




Cavity-photon contribution to the effective interaction of electrons in parallel quantum dots

- http://arxiv.org/abs/1505.03181
- Non-resonant 2G, 2G$\gamma$, 2G$\gamma\gamma$, open + closed $\rightarrow$ enhanced repulsion
- Dipole pulse $\rightarrow$ entanglement $\rightarrow$ reduced repulsion

Directly, and indirectly, many contributors. . .