Does self-induction matter in quantum transport?

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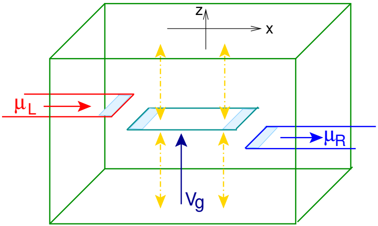
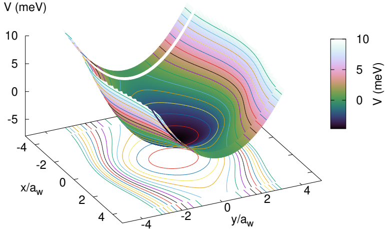
Time-dependent transport

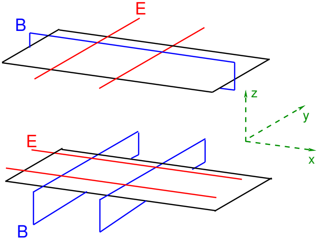




Short quantum GaAs wire ($L_x = 180$ nm) in a 3D photon cavity
Weak coupling $g_0 g^{\mathrm{L,R}} a_w^{3/2} \sim 0.101 \times (\mathrm{state-dependence})$ meV
($a_w \approx 20.75$ nm, $B_{\mathrm{ext}} = 1.0$ T)

Quantized cavity field

$$\mathbf{A}(\mathbf{r}) = \begin{pmatrix} \hat{\mathbf{e}}_x \\ \hat{\mathbf{e}}_y \end{pmatrix} \mathcal{A}\left\{a + a^\dagger\right\} \begin{pmatrix} \cos\left(\frac{\pi y}{b_{\rm c}}\right) \\ \cos\left(\frac{\pi x}{a_{\rm c}}\right) \end{pmatrix} \cos\left(\frac{\pi z}{d_{\rm c}}\right), \qquad \begin{matrix} \mathrm{TE}_{011}, & x\text{-pol.} \\ \mathrm{TE}_{101}, & y\text{-pol.} \end{matrix}$$



y-polarization

x-polarization

$\hbar\omega = 0.98$ meV $\rightarrow L_x/a_c, \quad L_x/b_c = 1/(70.7) = \boldsymbol{\delta \approx 0.014}$

Equation of motion

Liouville-von Neumann $\rightarrow$ projection on central system $\rightarrow$ quantum master equation

$$\partial_t W = \mathcal{L}W, \quad \mathcal{L}W = -\frac{i}{\hbar}[H, W]$$

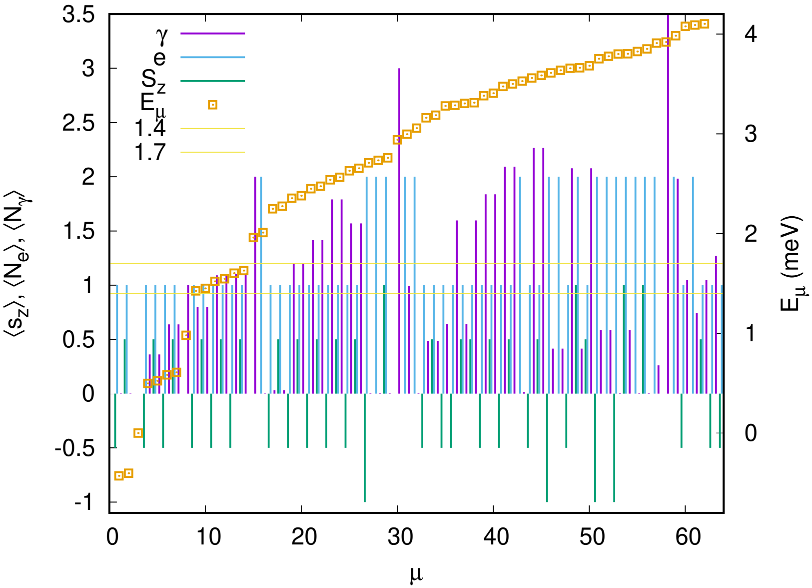
$$H = H_{\mathrm{S}} + H_{\mathrm{LR}} + H_{\mathrm{T}}(t), \quad H_{\mathrm{S}} = H_{\mathrm{e}} + H_{\mathrm{EM}}$$

$$H_{\mathrm{S}} = \int d^2r \psi^\dagger(\mathbf{r}) \left\{ \frac{\pi^2}{2m^*} + V(\mathbf{r}) \right\} \psi(\mathbf{r}) + H_{\mathrm{Coul}} + \hbar\omega a^\dagger a$$
$$+ \frac{1}{c} \int d^2r\, \mathbf{j}(\mathbf{r}) \cdot \mathbf{A}_\gamma + \frac{e^2}{2m^* c^2} \int d^2r\, \rho(\mathbf{r}) A_\gamma^2$$

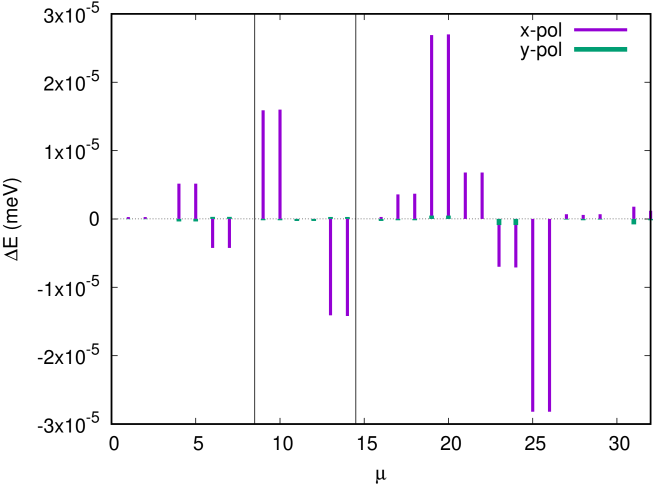
$$\boldsymbol{\pi} = \left(\mathbf{p} + \frac{e}{c}\mathbf{A}_{\mathrm{ext}} \right), \quad \rho = \psi^\dagger \psi, \quad \mathbf{j} = -\frac{e}{2m^*} \left\{ \psi^\dagger \left(\boldsymbol{\pi}\psi \right) + \left(\boldsymbol{\pi}^* \psi^\dagger \right) \psi \right\}$$

Stepwise exact numerical diagonalization, (Fortschritte der Physik 61, 305 (2013))

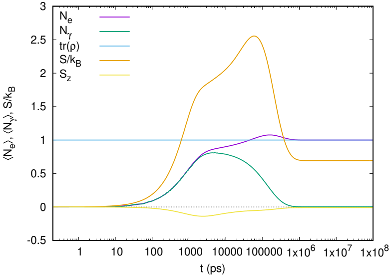
States – energy spectrum – x-polarized field, $\delta \approx 0.014$

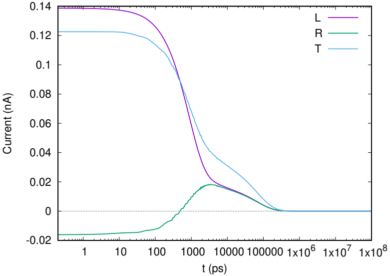


$$\Delta E_\mu = E_\mu^{\delta\approx 0.014} - E_\mu^{\delta\approx 0}$$



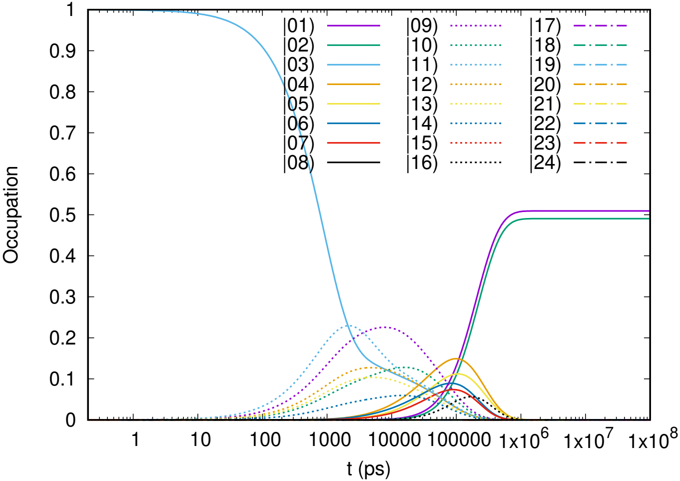
Mean values – $\langle N_e \rangle$, $\langle N_\gamma \rangle$, $\langle I \rangle$, $\delta \approx 0.014$



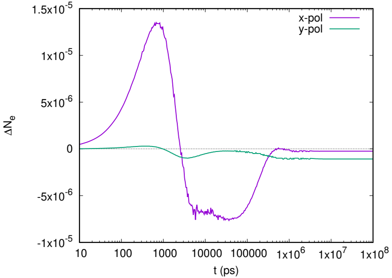


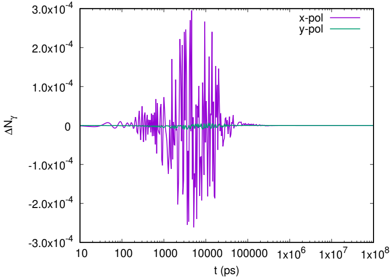
Charging of an empty system

Dynamic occupation of states, $\delta \approx 0.014$

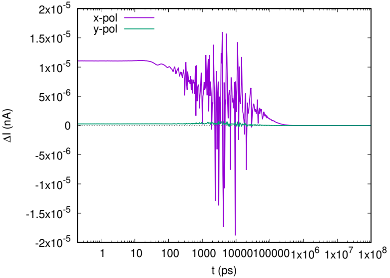


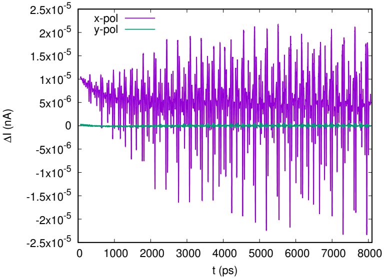
$$\Delta N_e = N_e^{\delta\approx 0.014} - N_e^{\delta\approx 0},\ \Delta N_\gamma = N_\gamma^{\delta\approx 0.014} - N_\gamma^{\delta\approx 0}$$





$$\Delta I = I^{\delta \approx 0.014} - I^{\delta \approx 0}$$





Fourier analysis → Rabi oscillations superimposed (arXiv:2005.10914)

Summary

- Time-dependent many-body approach, all time scales
- Central system: Exact interactions
- Shape – geometry
- Weak coupling to external reservoirs
- **We can see self-inductance**
- Not important with present parameters, **room to enhance**
- Review: *Entropy* **21**, 731 (2019),

  Preprint on induction: *(arXiv:2005.10914)*

- Andrei Manolescu (RU)
- Valeriu Moldoveanu (NIMP)
- Nzar Rauf Abdullah (US, KUST)
- Chi-Shung Tang (NUU)
- Shi-Sheng Goan (NTU)

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