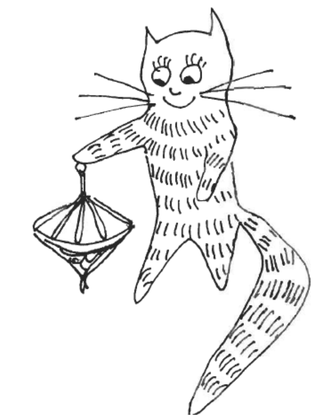

Polariton spin transport in a microcavity channel: A mean-field modeling

M.Yu.Petrov[1] and A.V.Kavokin[1,2]

[1]*Spin Optics Laboratory, Saint Petersburg State University, Russia*
[2]*Physics and Astronomy School, University of Southampton, UK*

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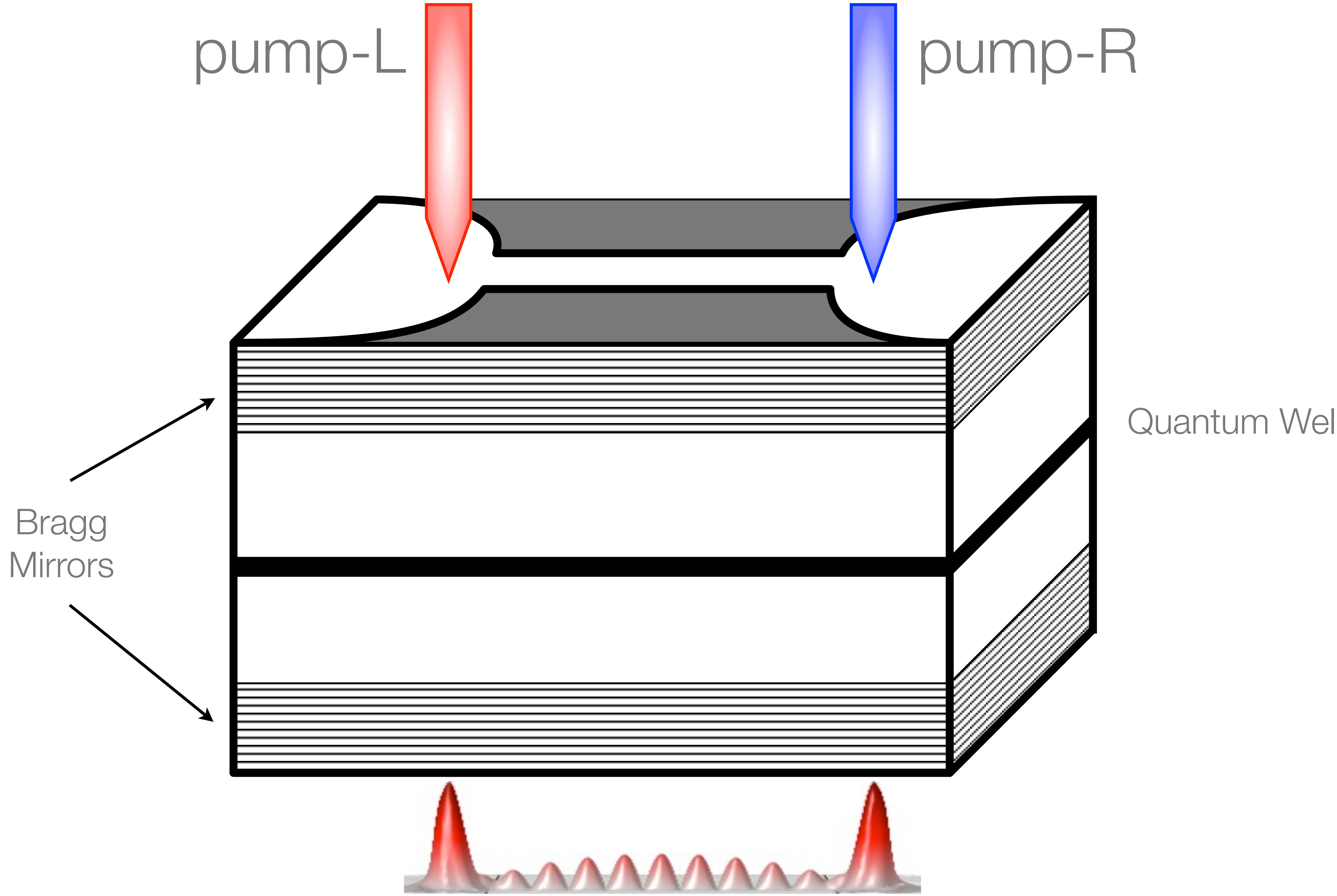
Outline

- Motivation for experimentalists
- Mean-field model and its numerical implementation
- Results of modeling
  - Interference of two flows in a channel
  - Spin-polarized polariton transport in a channel
  - Interpretation in terms of spin conductivity
- Summary and further steps

Motivation for experimentalists



Mean-field model

$$\alpha_2 = -0.1\alpha_1$$

$$\begin{cases} i\hbar\frac{\partial}{\partial t}\psi_+(\mathbf{x},t) = \left(-\frac{\hbar^2}{2m}\nabla^2 + \alpha_1|\psi_+(\mathbf{x},t)|^2 + \alpha_2|\psi_-(\mathbf{x},t)|^2 - \frac{i\hbar}{2\tau}\right)\psi_+(\mathbf{x},t) + p_+(\mathbf{x},t) \\ i\hbar\frac{\partial}{\partial t}\psi_-(\mathbf{x},t) = \left(-\frac{\hbar^2}{2m}\nabla^2 + \alpha_1|\psi_-(\mathbf{x},t)|^2 + \alpha_2|\psi_+(\mathbf{x},t)|^2 - \frac{i\hbar}{2\tau}\right)\psi_-(\mathbf{x},t) + p_-(\mathbf{x},t) \end{cases}$$

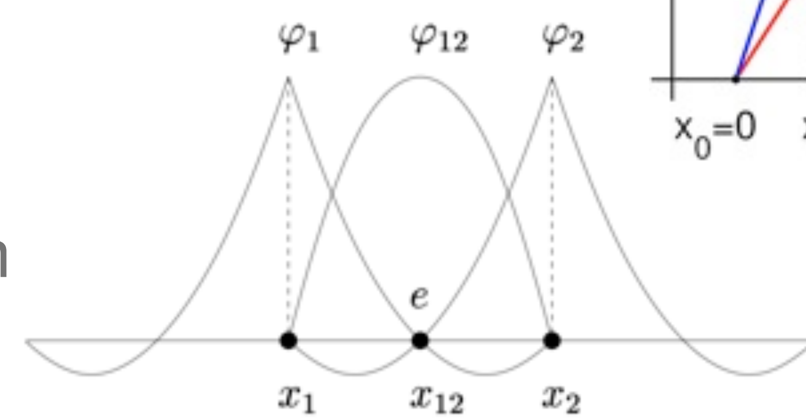
$$\tau \simeq 10\mathrm{ps}$$

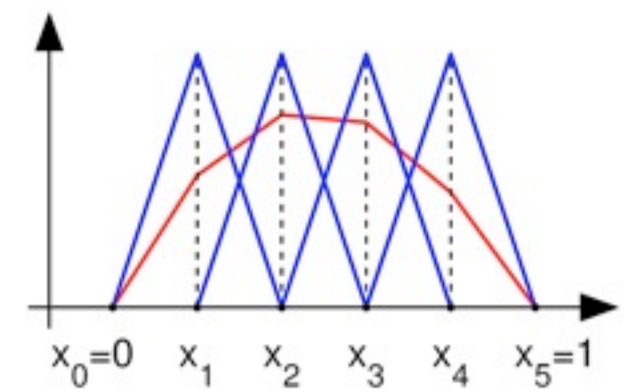
$$m \simeq 3\times 10^{-5} m_0$$

$$p_\pm(\mathbf{x},t) = p_\pm^L e^{-\frac{(\mathbf{x}-\mathbf{x}_L)^2}{\delta x^2}} e^{iw_L t + i\mathbf{k}_L\cdot\mathbf{x}} + p_\pm^R e^{-\frac{(\mathbf{x}-\mathbf{x}_R)^2}{\delta x^2}} e^{iw_R t + i\mathbf{k}_R\cdot\mathbf{x}}$$

Numerical implementation

- Spatial discretization by using **F**inite **E**lement **M**ethod
    - Quadratic elements
    - Grid size: Δx<0.25μm @ L_{ch}~100μm





- Time discretization
    - 5-step **B**ackward **D**ifferentiation **F**ormula
    - Max time step: Δt<100fs @ τ=10ps

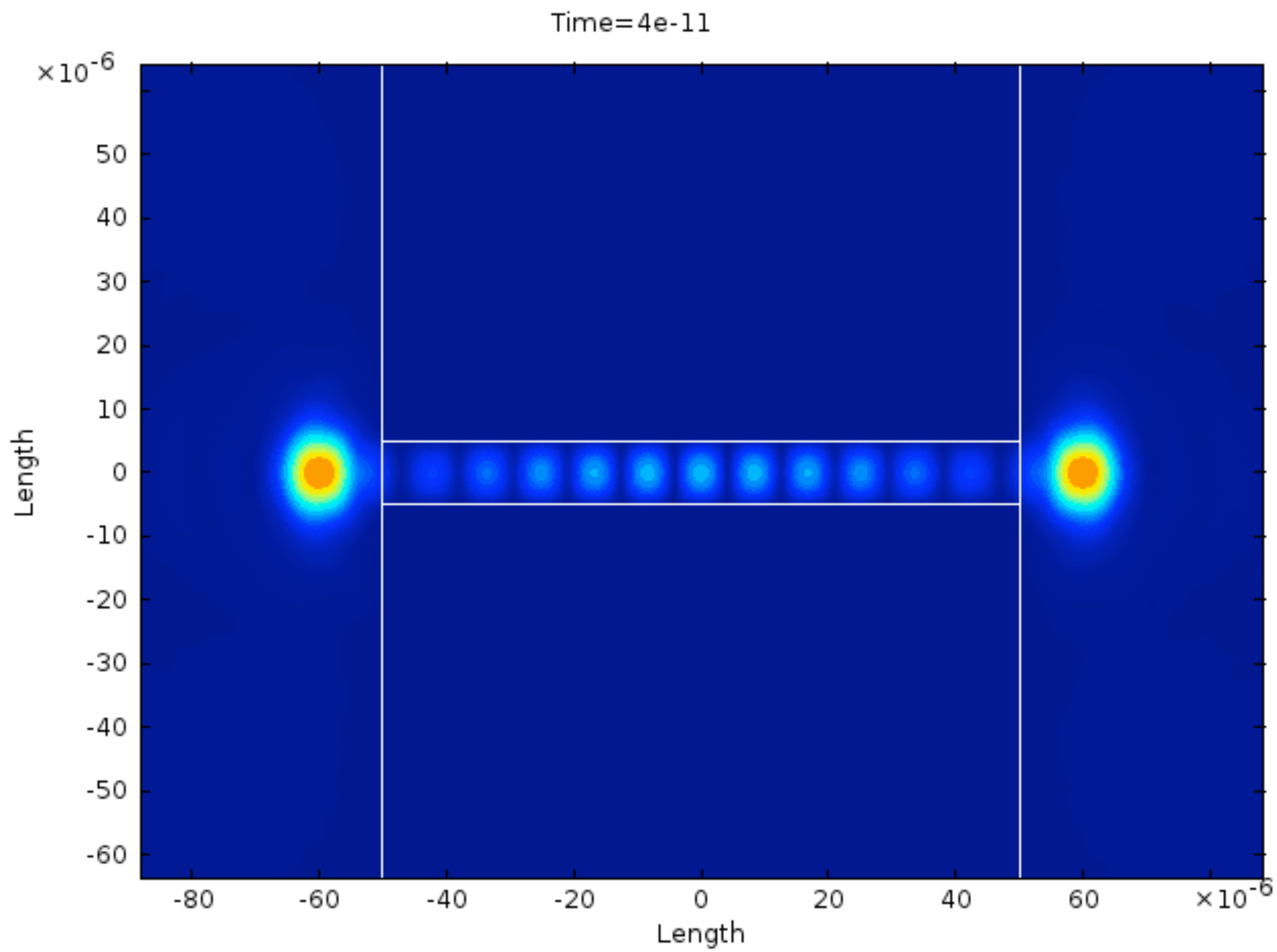
$$u' = f(t, u), \qquad u(t_0) = u_0;$$

$$\sum_{k=1}^{s} a_k u_{n+k} = h\beta f(t_{n+s}, u_{n+s});$$

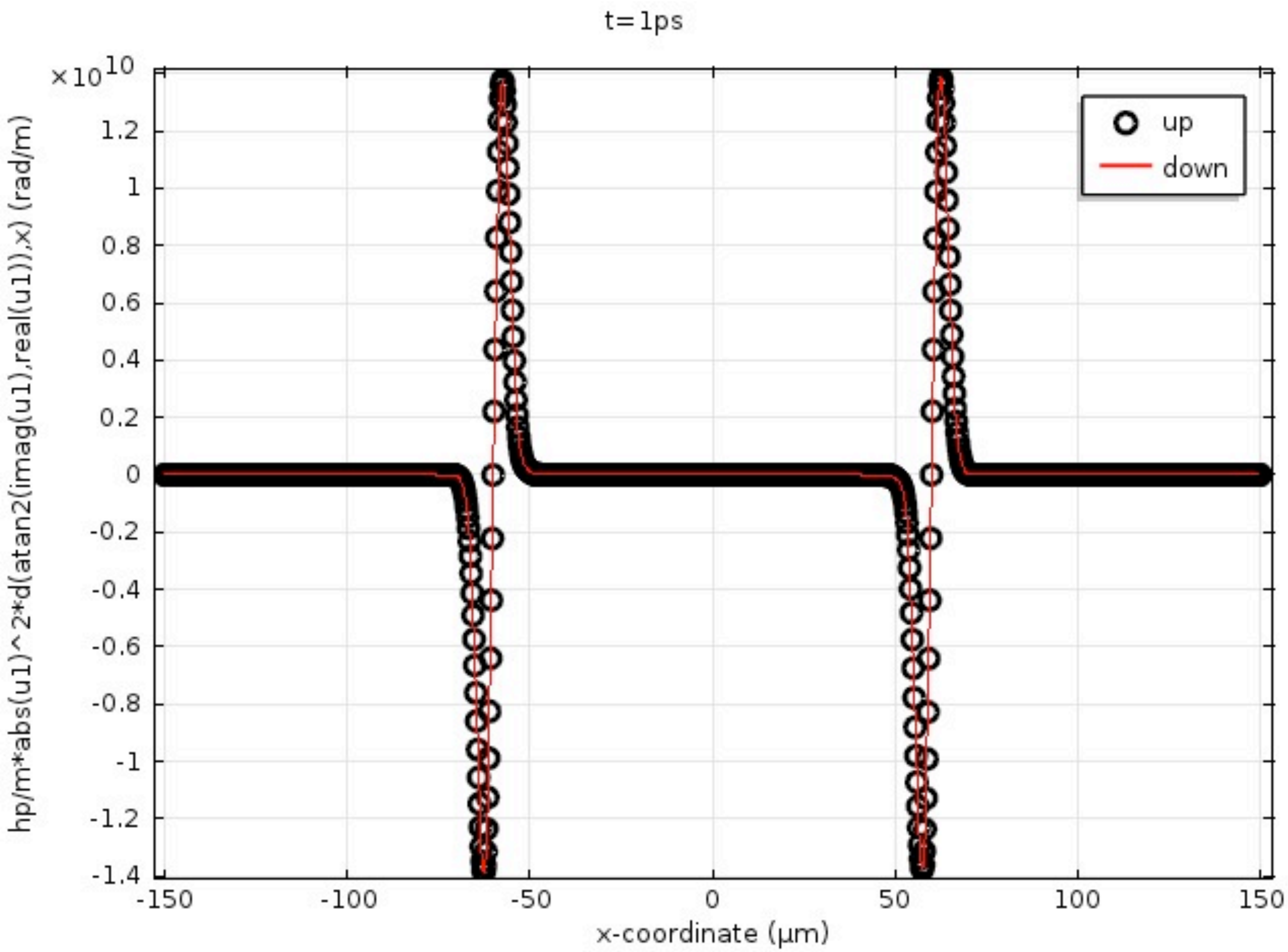
$$t_n = t_0 + nh.$$

- Implementation using Comsol (2D and 1D) and a private software (1D)

Interference of two pump pulses

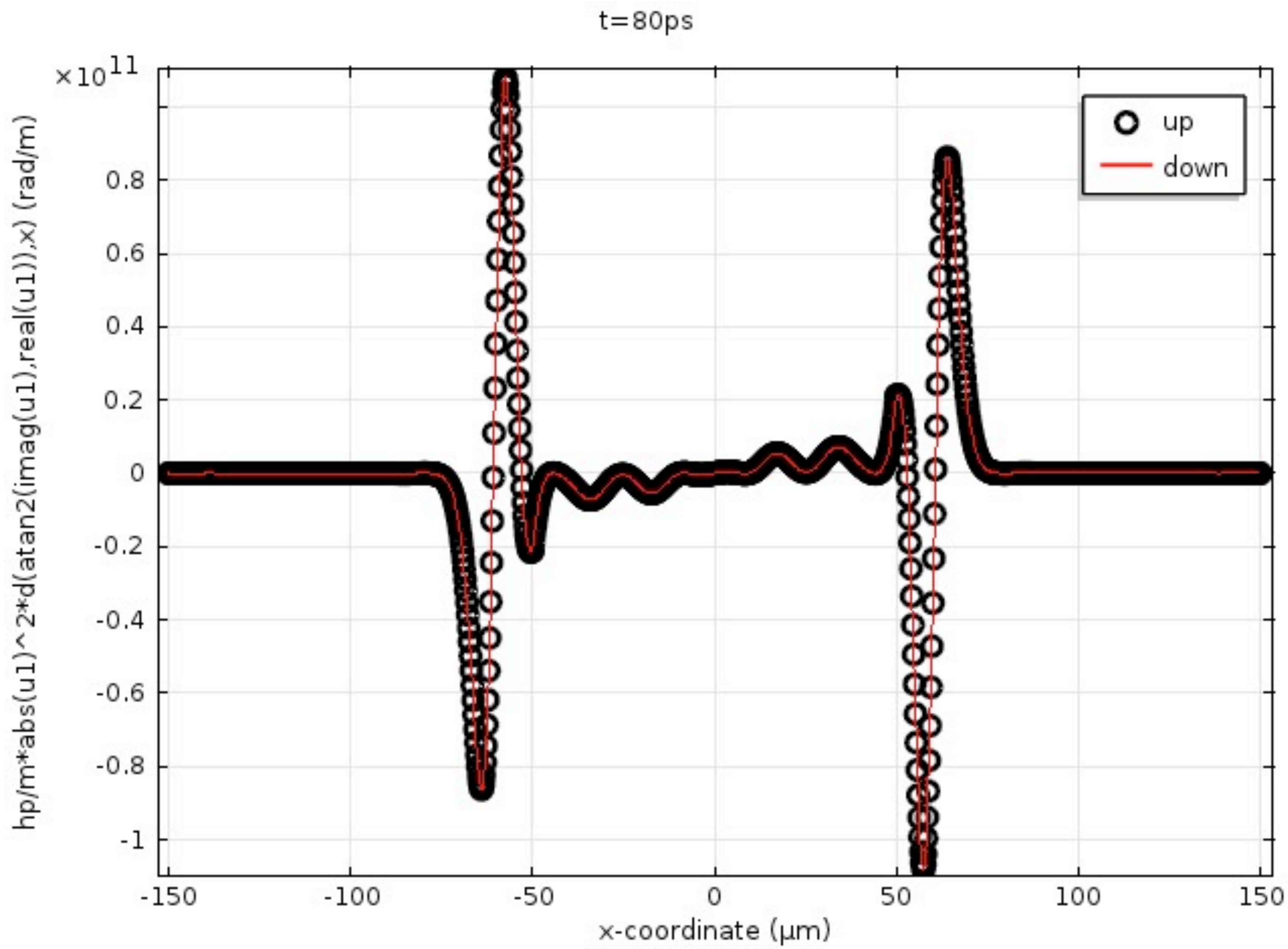


Interference of two pump pulses (2) current density



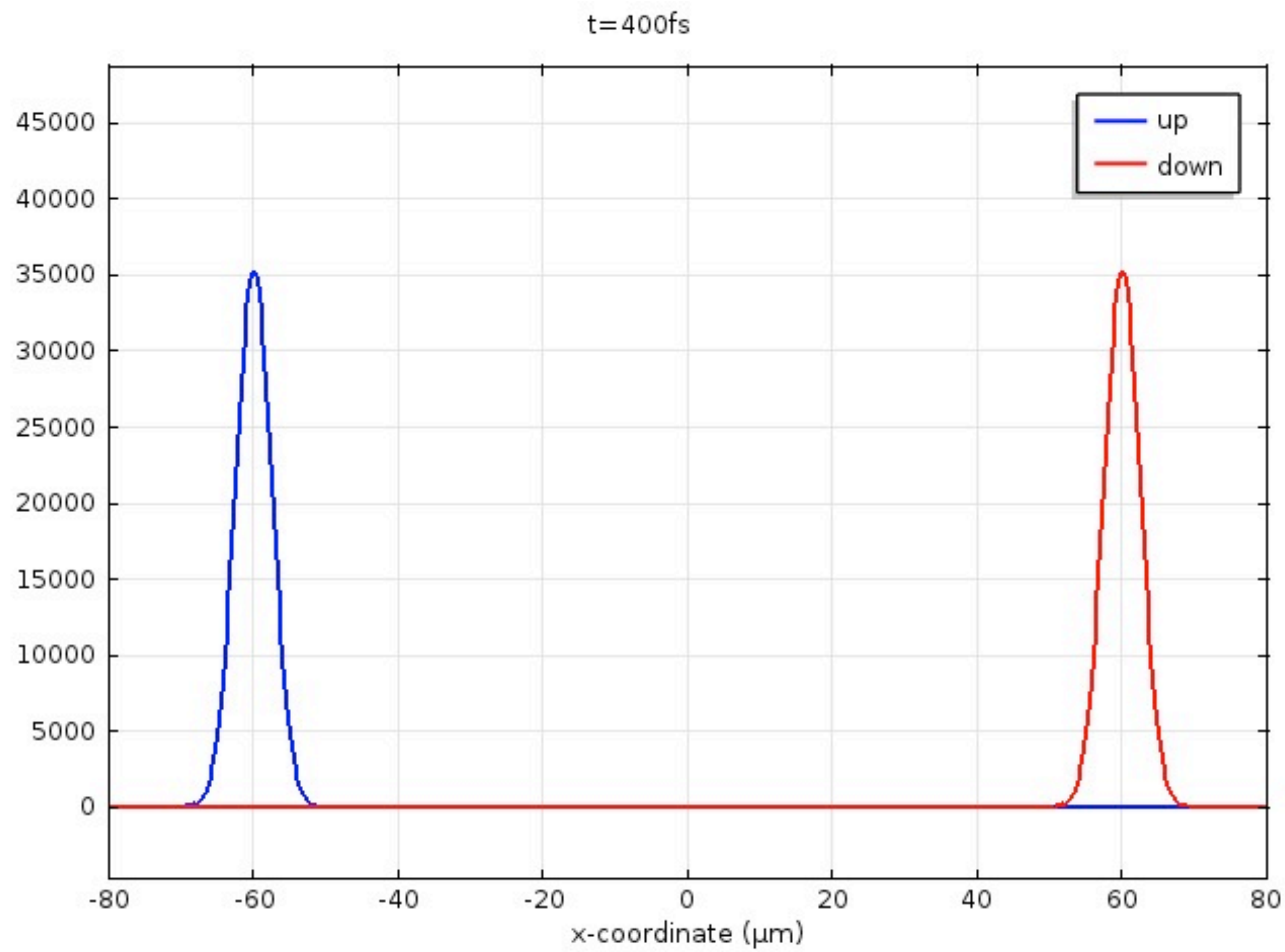
$$\mathbf{j} = -\frac{i\hbar}{2m}(\psi_{\pm}^{*}\nabla\psi_{\pm} - \psi_{\pm}\nabla\psi_{\pm}^{*})$$

Interference of two pump pulses (2) current density

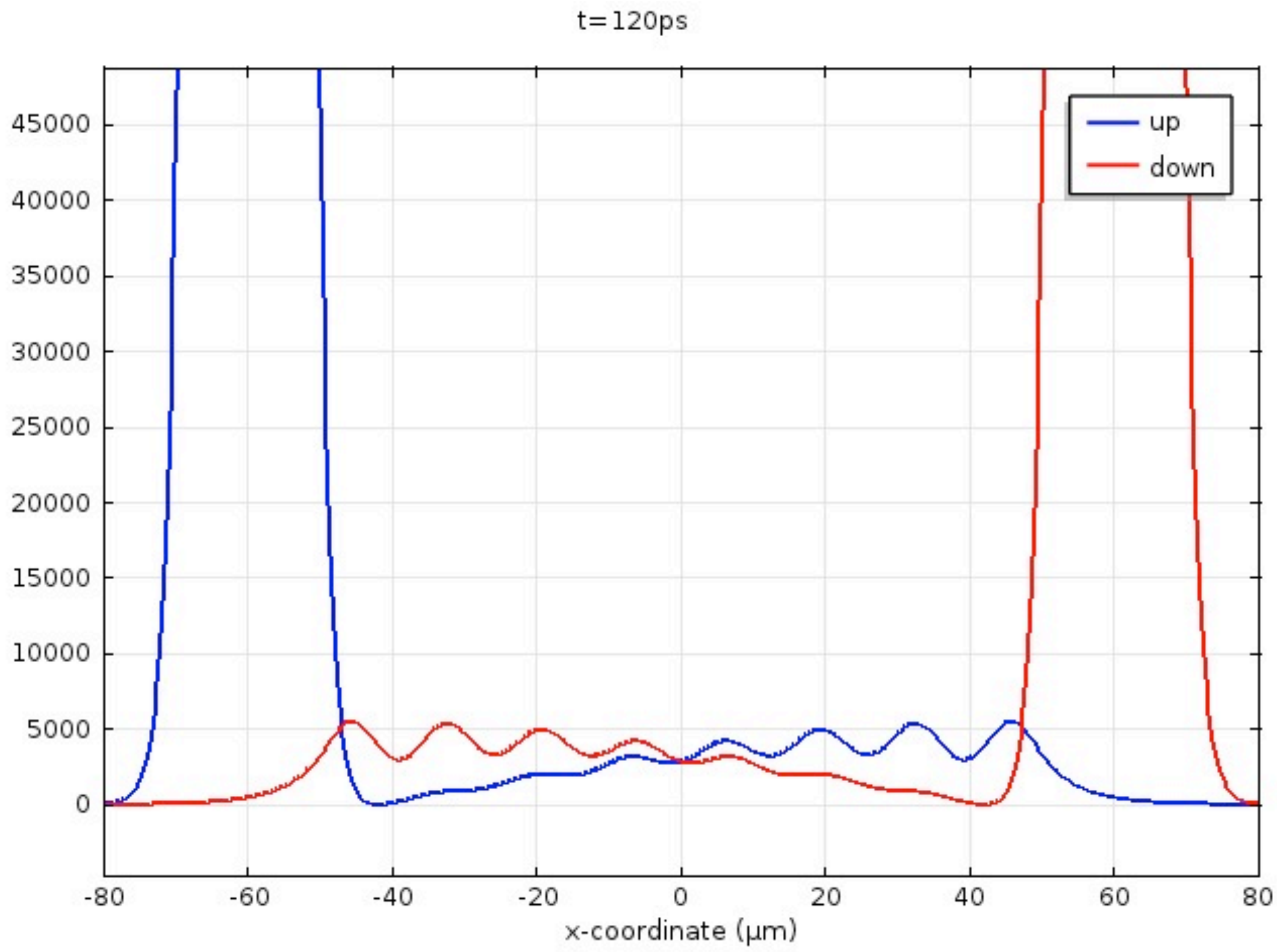


$$\mathbf{j} = -\frac{i\hbar}{2m}(\psi_{\pm}^{*}\nabla\psi_{\pm} - \psi_{\pm}\nabla\psi_{\pm}^{*})$$

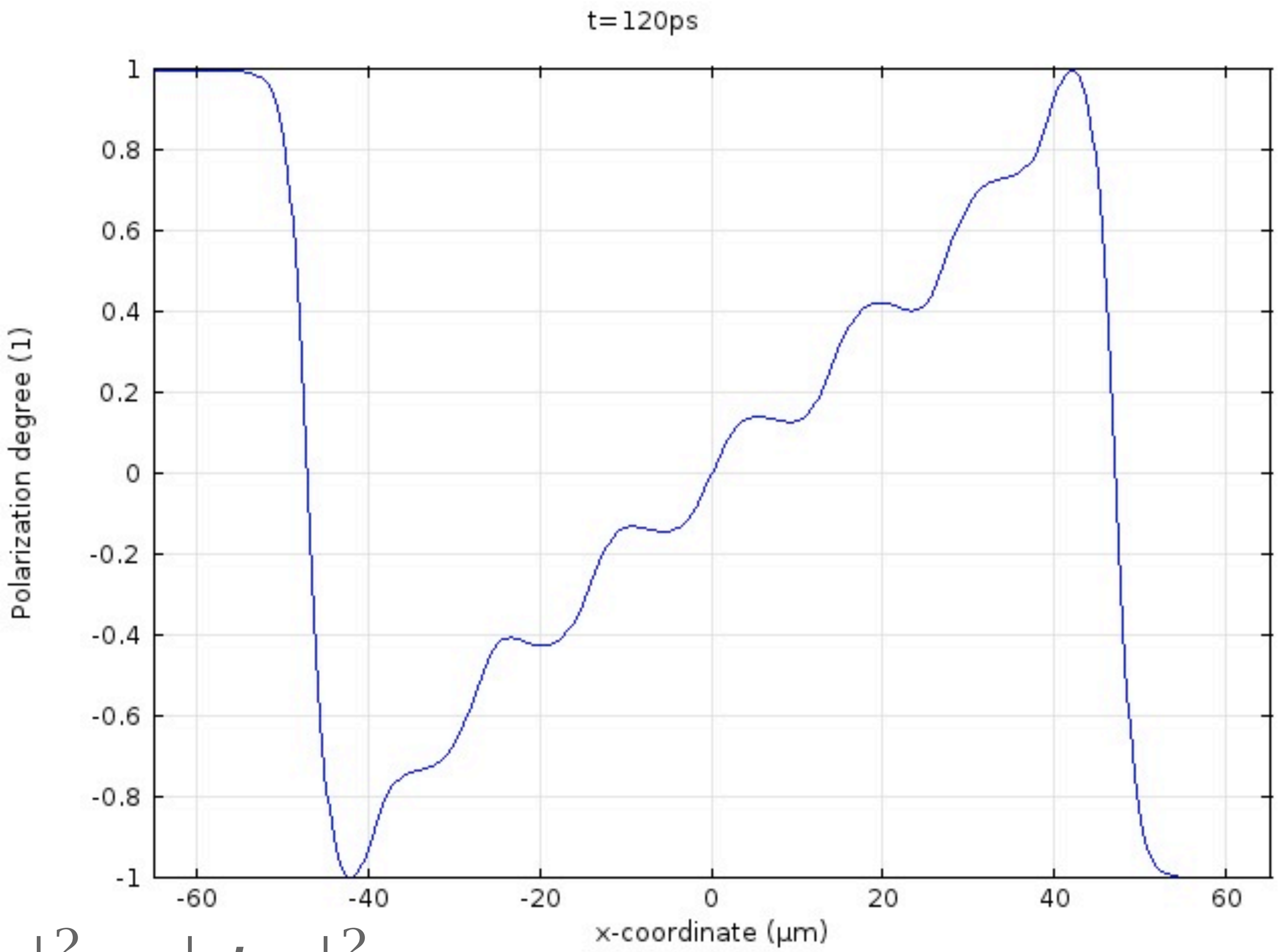
Spin-polarized polariton transport



Spin-polarized polariton transport



Spin-polarized polariton transport



$$\rho_c = \frac{|\psi_+|^2 - |\psi_-|^2}{|\psi_+|^2 + |\psi_-|^2}$$

Conductivity tensor

$$i\hbar\frac{\partial}{\partial t}\psi_\pm = \left(-\frac{\hbar^2}{2m}\nabla^2 + \alpha_1|\psi_\pm|^2 + \alpha_2|\psi_\mp|^2 - \frac{i\hbar}{2\tau}\right)\psi_\pm + P_\pm$$

$$\psi_\pm = \sqrt{n_\pm}e^{i\varphi_\pm}$$

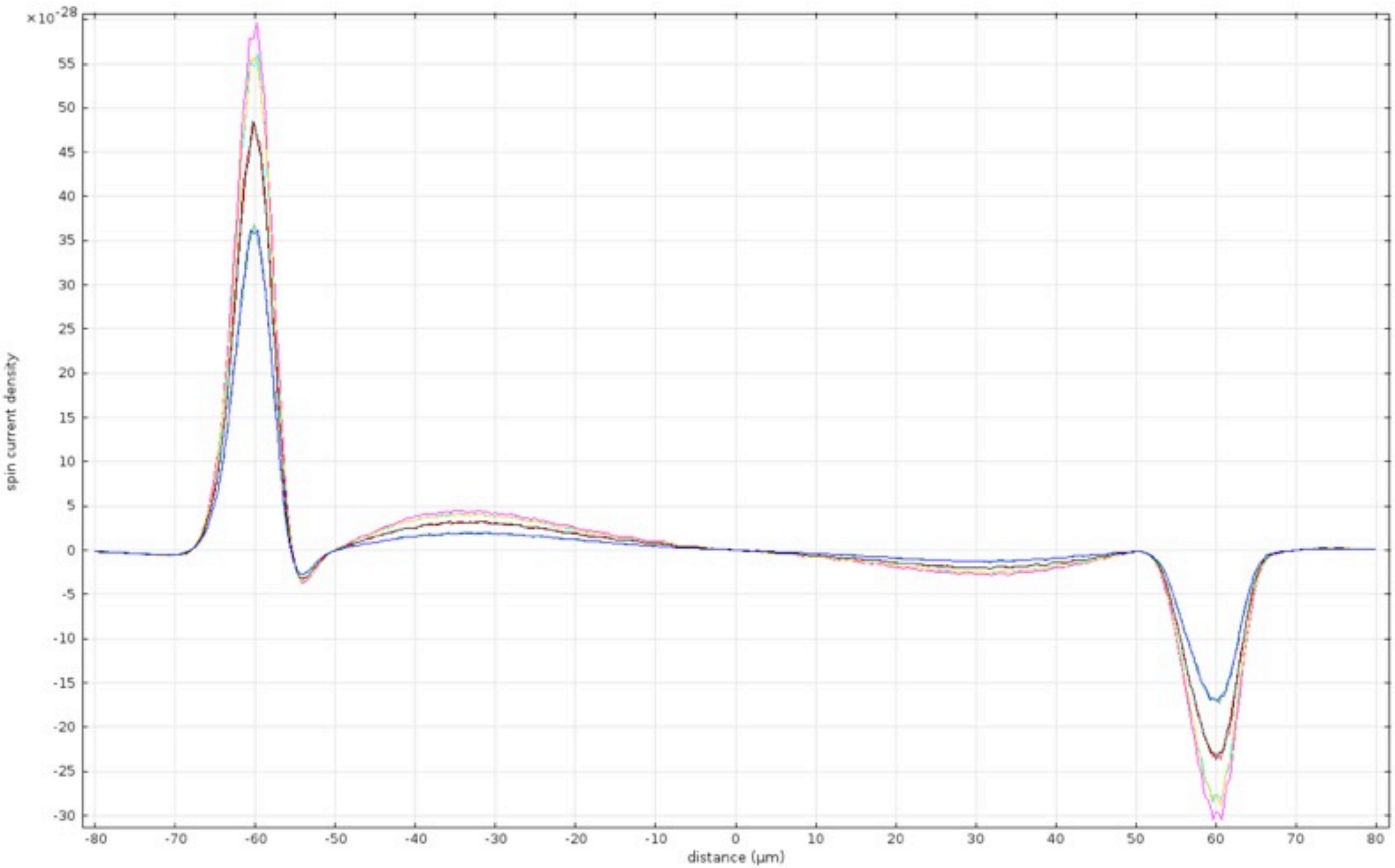
Imaginary part of GP eq. decomposition gives: $$\frac{\partial n_\pm}{\partial t} + \mathrm{div}\,\mathbf{j} = 0$$

$$\mathbf{j} = \frac{\hbar}{m}\begin{bmatrix} n_+\nabla\varphi_+ \\ n_-\nabla\varphi_- \end{bmatrix} = \begin{pmatrix} \sigma_{++} & \sigma_{+-} \\ \sigma_{-+} & \sigma_{--} \end{pmatrix}\begin{bmatrix} \mu_R^+ - \mu_L^+ \\ \mu_R^- - \mu_L^- \end{bmatrix}$$

$$\psi_\pm(\mathbf{x}, t) = \psi_\pm(\mathbf{x})e^{i\mu_\pm t/\hbar} \qquad P_\pm = p_0 e^{-\frac{(\mathbf{x}-\mathbf{x}_0)^2}{\delta^2}} e^{i\omega_\pm t/\hbar + i\mathbf{k}_\pm\cdot\mathbf{x}}$$

$$-\mu_\pm\psi_\pm(\mathbf{x}) = \left(-\frac{\hbar^2}{2m}\nabla^2 + \alpha_1|\psi_\pm|^2 + \alpha_2|\psi_\mp|^2 - \frac{i\hbar}{2\tau}\right)\psi_\pm(\mathbf{x}) + P'_\pm(\mathbf{x})$$

Spin-current density with diferent pump-pulses



$$\mathbf{j} = \frac{\hbar}{m}\begin{bmatrix} n_+ \nabla \varphi_+ \\ n_- \nabla \varphi_- \end{bmatrix} = \begin{pmatrix} \sigma_{++} & \sigma_{+-} \\ \sigma_{-+} & \sigma_{--} \end{pmatrix} \begin{bmatrix} \mu_R^+ - \mu_L^+ \\ \mu_R^- - \mu_L^- \end{bmatrix}$$

Summary and further steps

- A mean-field model describing polariton spin transport based on coupled Gross-Pitaevskii equations is developed
    - Numerical implementation of the model demonstrates interference of two flows stimulated by CW excitation near both boundaries of a channel
    - If pumps are cross-polarized the effect can be emphasized by detection of circular polarization degree
- Further steps
    - Possibility of experimental observation