Theoretical On-Demand Adiabatic Transfer of Light Between Adjacent Optical Cavities

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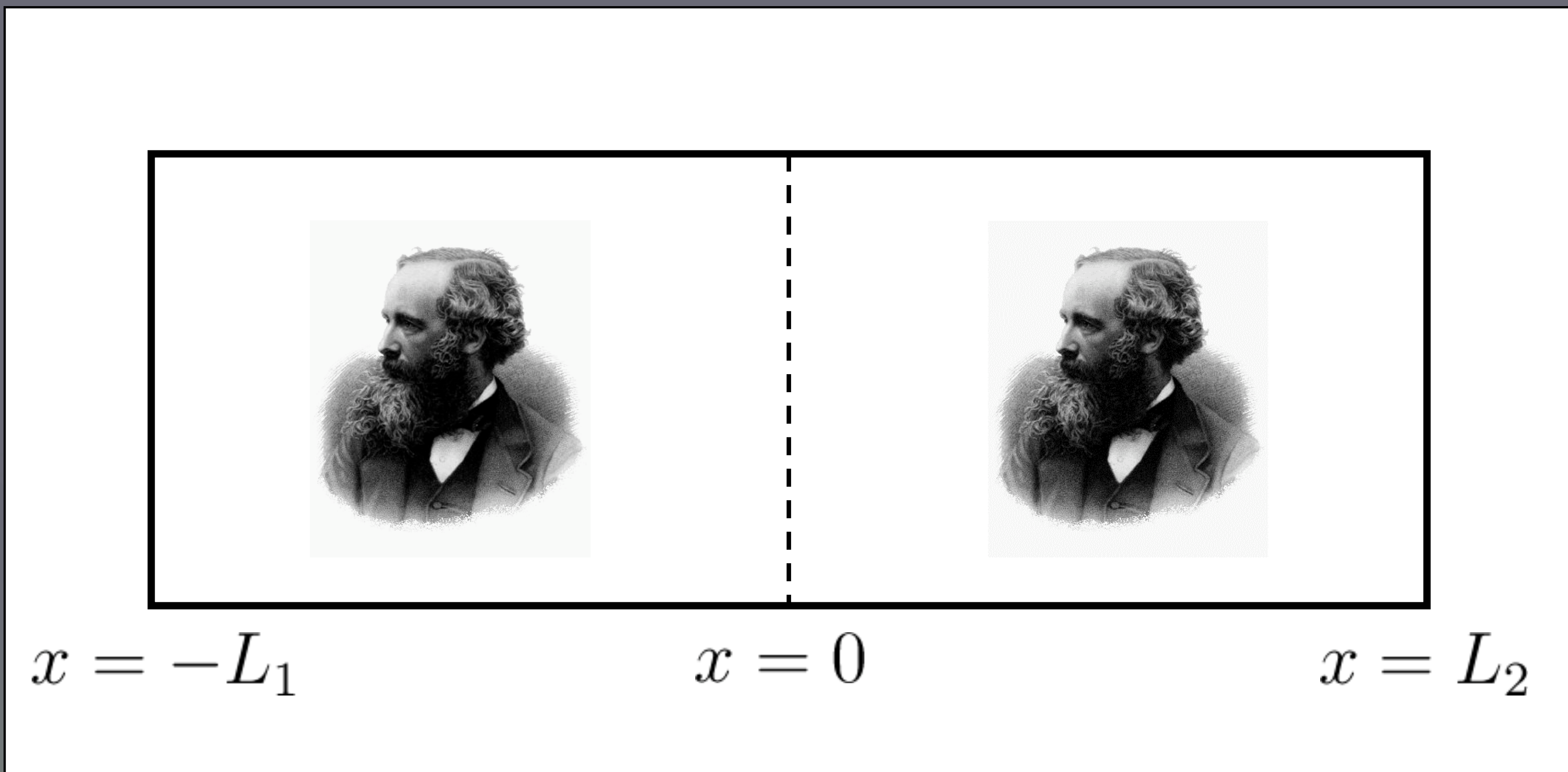
The Setup

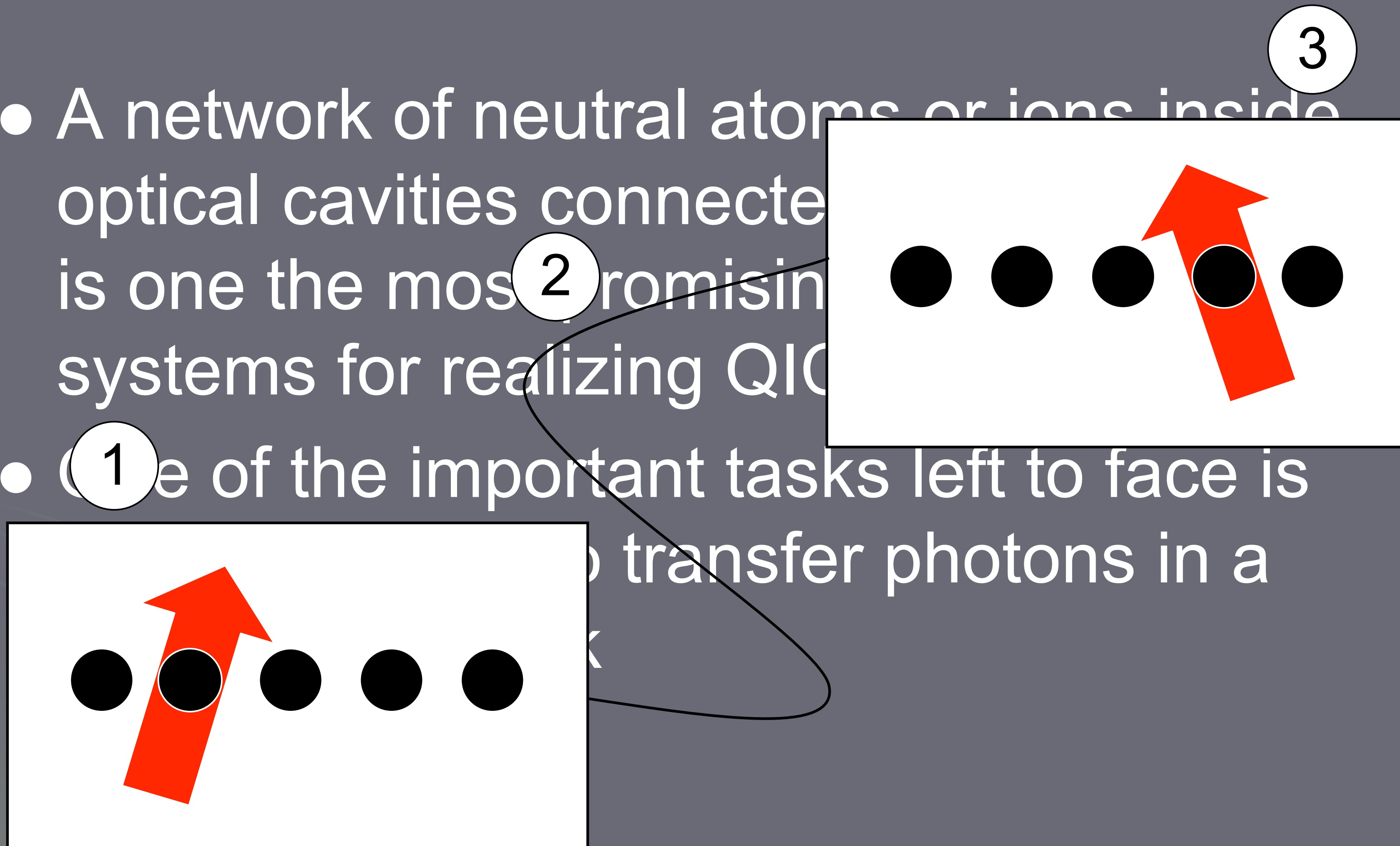


Goal

- Coherently transfer light between two adjacent optical cavities connected by a slightly transmissive mirror

…why bother?

- A network of neutral atoms or ions inside optical cavities connecte… is one the mos… romisin… systems for realizing QIC…
- O…e of the important tasks left to face is … transfer photons in a … k



Approach

- Examine the modes of the double-cavity model with static boundary conditions for a classical light field
- Look at the energy distribution for these modes
- Adiabatically change the position of the transmissive central mirror in order to transfer light coherently from one cavity to the next

Modes of Static Cavity

- We first solve Maxwell's equations, which in our case reduce to:

$$\frac{\partial^2 E(x,t)}{\partial x^2} - \mu_0\epsilon_0(1+\alpha\delta(x))\frac{\partial^2 E(x,t)}{\partial t^2} = 0$$

- The solutions are separable and we write them as: $E_n(x,t) = E_n(x)e^{-i\omega_n t}$
- Using the continuity boundary condition:

$$E_n(x) = \begin{cases} A_n \sin(k_n(x+L_1)) & -L_1 \leq x \leq 0 \\ B_n \sin(k_n(x-L_2)) & 0 < x \leq L_2 \end{cases}$$

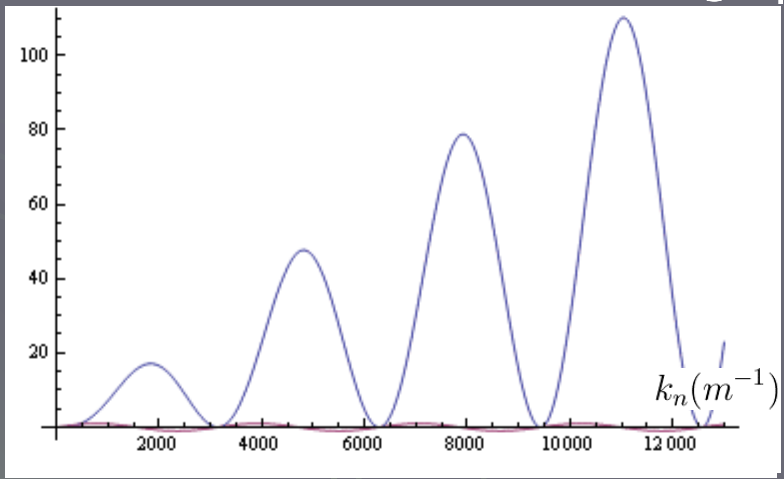
$$\frac{A_n}{B_n} = -\frac{\sin(k_nL_2)}{\sin(k_nL_1)}$$

Modes of Static Cavity

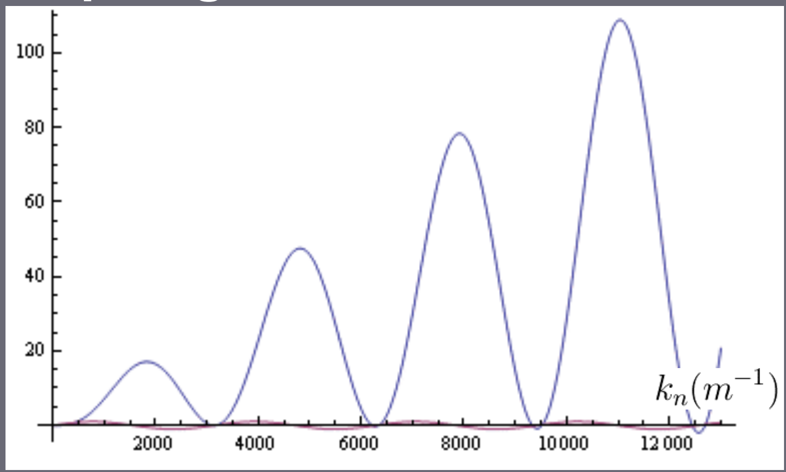
- Applying the boundary condition for the first derivative of the solution, we find:

$$\alpha k \sin(k_n L_1) \sin(k_n L_2) = \sin(k_n L)$$

Finding k_n By Graphing



Solving for k_n with $L_1 = L_2 = 10^{-3}$ m, and $\alpha = 10^{-2}$ m



Solving for k_n with $L_1 = 0.99 \times 10^{-3}$ m $L_2 = 1.01 \times 10^{-3}$ m, and $\alpha = 10^{-2}$ m

Modes of Static Cavity

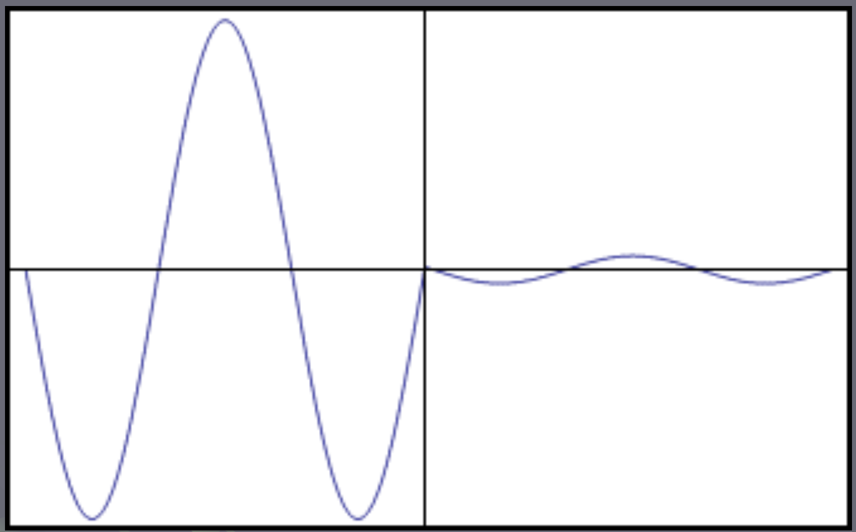
- Rearranging, and using the normalization condition, we find:

$$A_n^2 = \frac{1 - B_n^2[\frac{L_2}{2} - \frac{\sin(2k_n L_2)}{4k_n} + \alpha \sin^2(k_n L_2)]}{\frac{L_1}{2} - \frac{\sin(2k_n L_1)}{4k_n}}$$

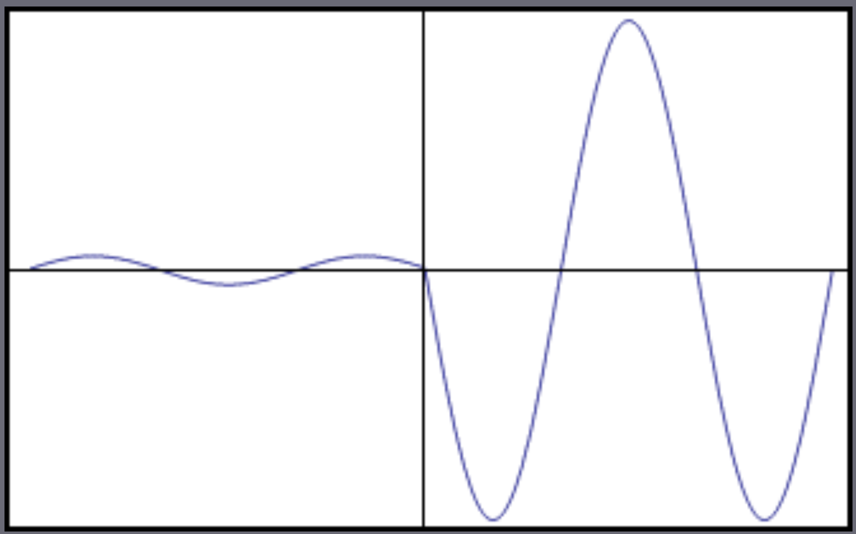
$$B_n^2 = \frac{1}{\frac{\sin^2(k_n L_2)}{\sin^2(k_n L_1)}[\frac{L_1}{2} - \frac{\sin(2k_n L_1)}{4k_n}] + [\frac{L_2}{2} - \frac{\sin(2k_n L_2)}{4k_n} + \alpha \sin^2(k_n L_2)]}$$

Modes of Static Cavity

Double-Cavity Modes for α = 10^{-2} m



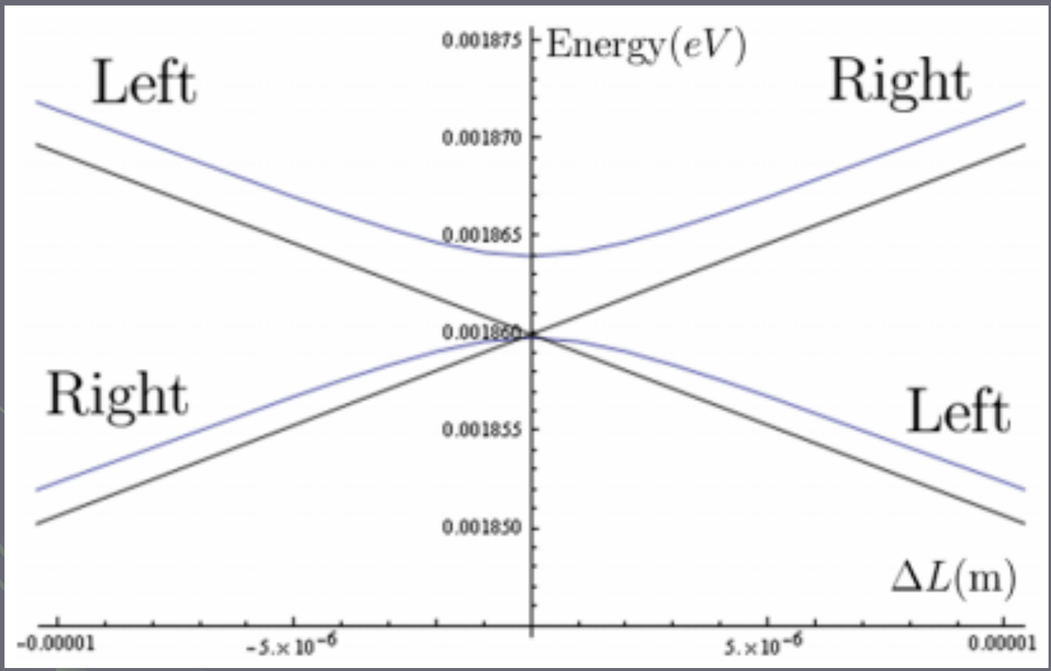
Double-cavity mode for k_n = 9531.15 m^{-1},
L_1 = 0.99 x 10^{-4} m, L_2 = 1.01 x 10^{-3} m



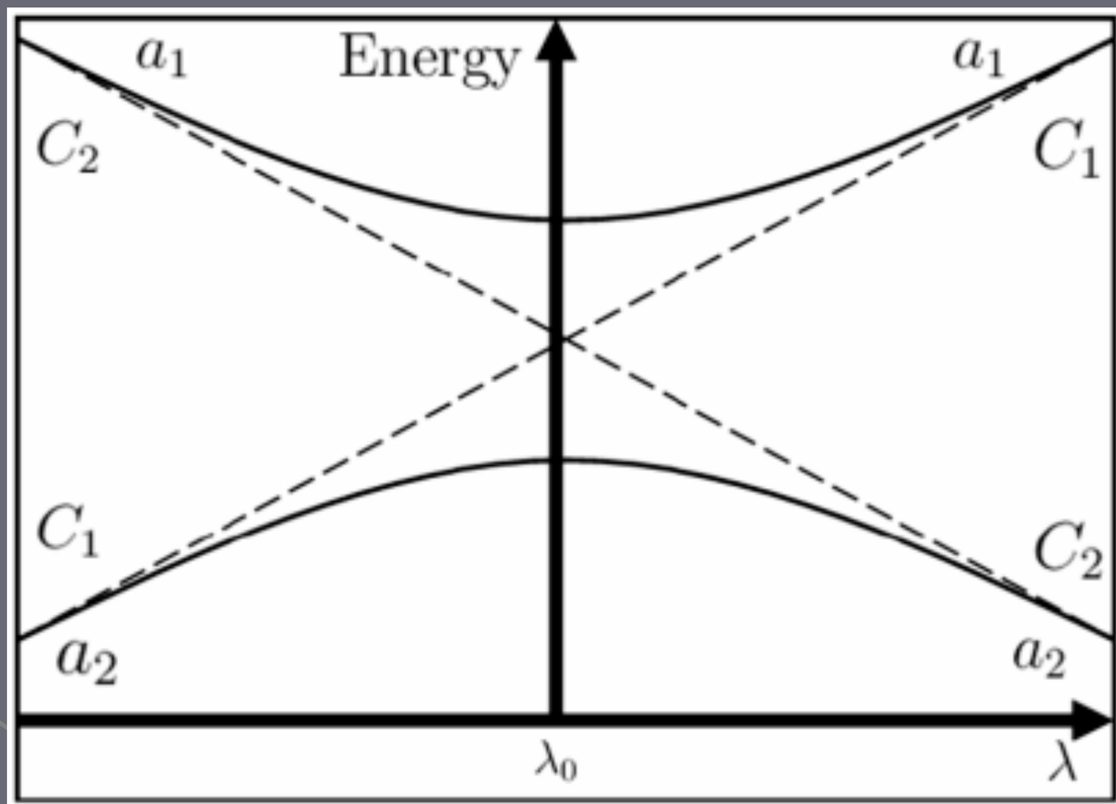
Double-cavity mode for k_n = 9341.46 m^{-1},
L_1 = 0.99 x 10^{-4} m, L_2 = 1.01 x 10^{-3} m

Energy Distribution

- Choosing one energy "rung", we fill each mode with one photon and calculate the corresponding energy

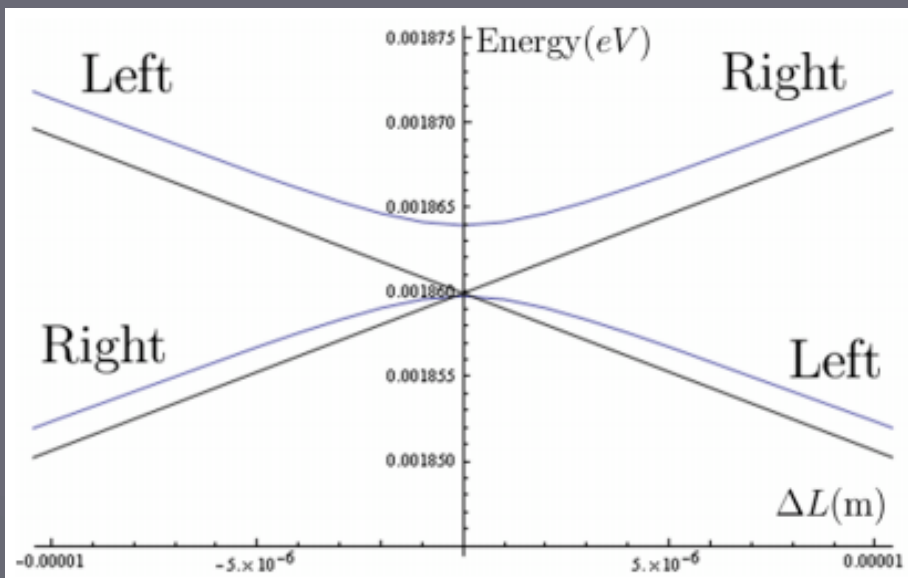


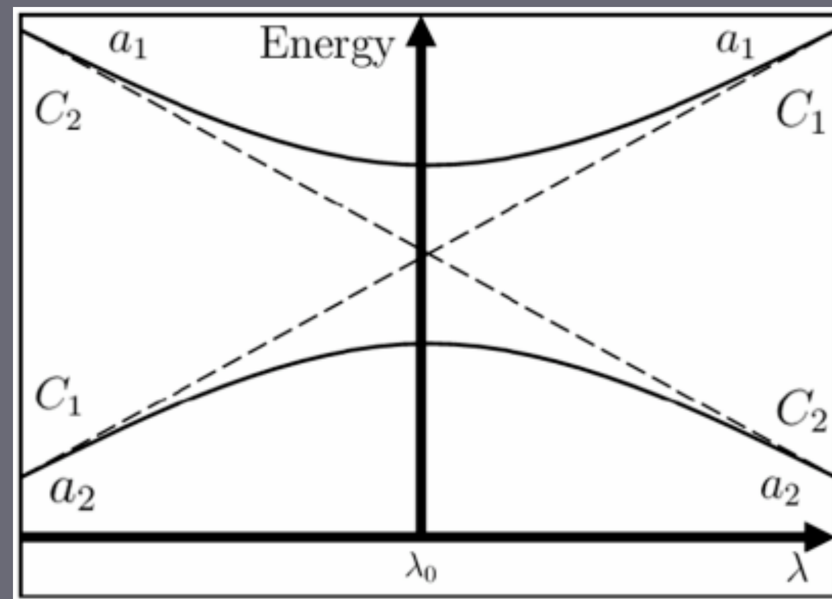
Landau-Zener Problem



- Changing the parameter λ adiabatically, the adiabatic state changes which bare state it is associated with

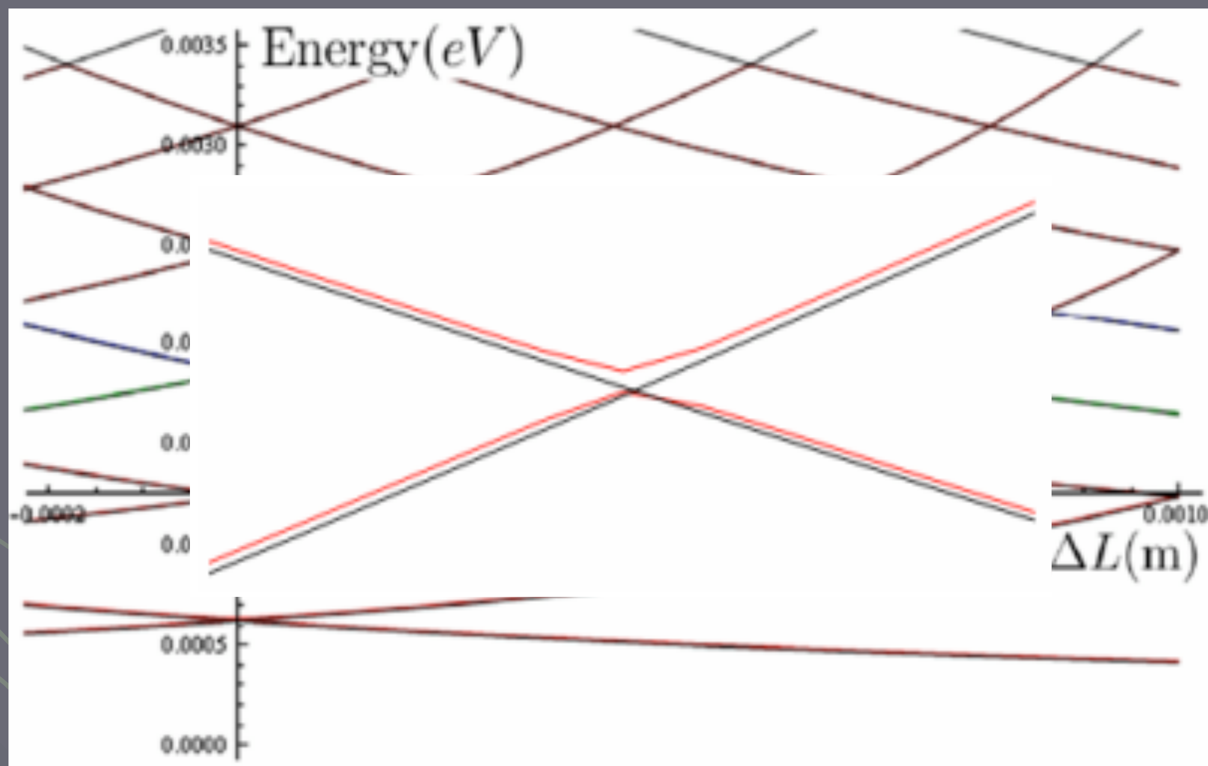
Light Field Transfer



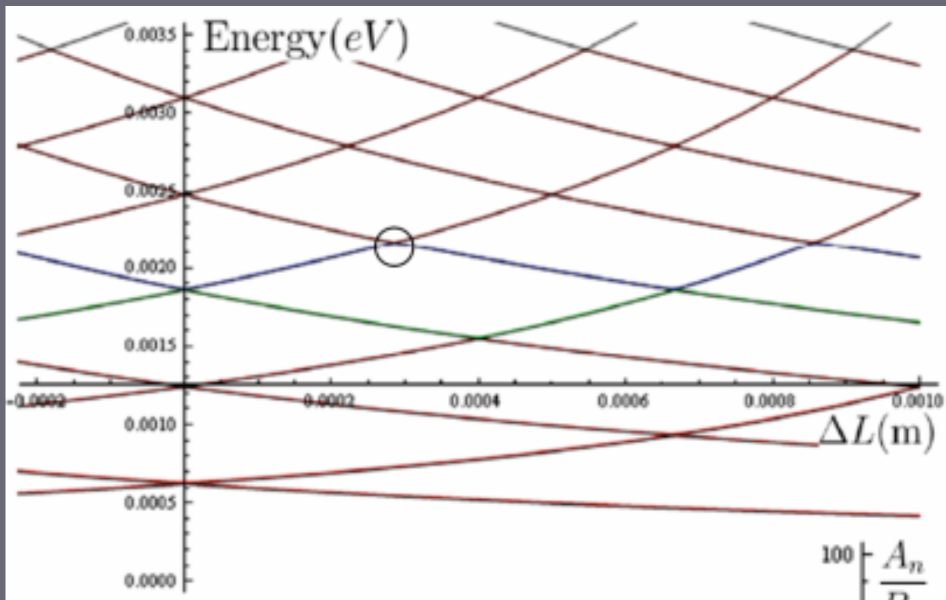


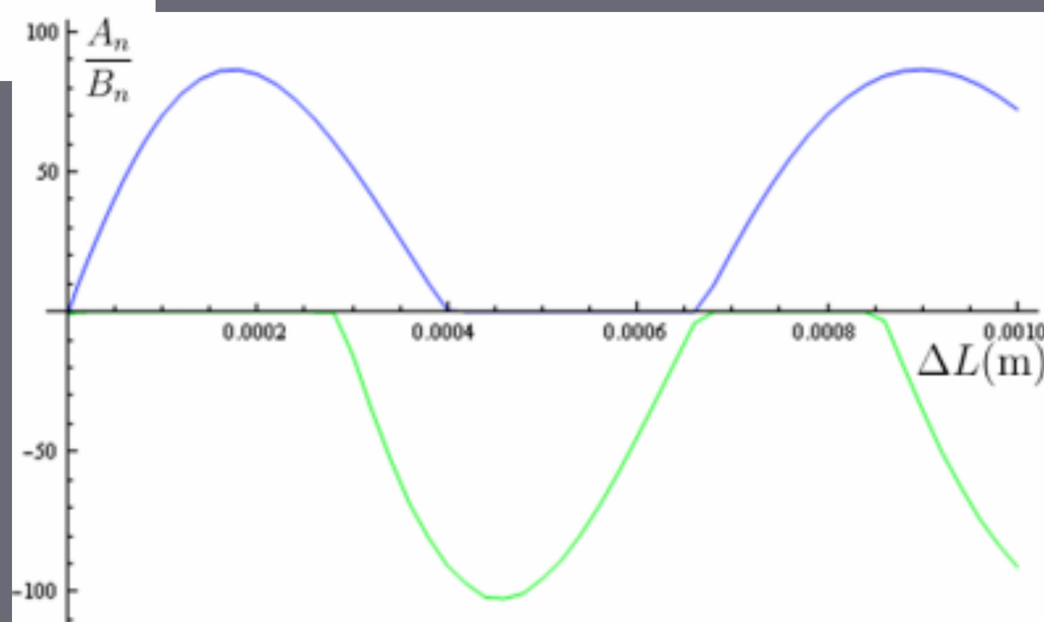
- Transfer the light field from one cavity to the next by adiabatically changing the position of the central mirror

…and for other displacements?



…what about the amplitudes?





Conclusions

- By taking $x \neq 0$ for the shared mirror, we can localize the light modes into different cavities
- We have identified level crossings that can be used to adiabatically transfer light from one cavity to the next

Future Direction

- Apply Landau-Zener formalism
- Apply more realistic values to our system
- Optimize the localization of the light modes
- Extend the double-cavity model to two optical cavities connected by an optical fibre
- Collaboration with the group of Ed Hinds?

References

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[2] R. Lang, M.O. Scully, and W.E. Lamb, “Why is the Laser Line So Narrow? A Theory of Single-Quasimode Laser Operation,” Phys. Rev. A 7, 1788 (1973)

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