Light localization in a disordered multimode optical fiber

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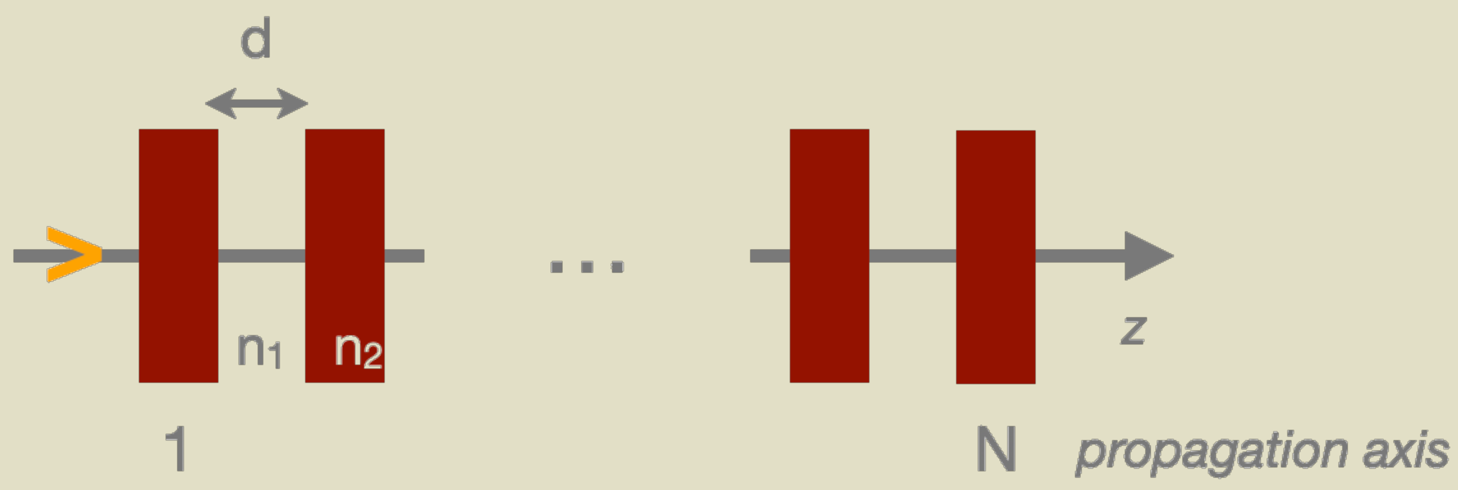
ABSTRACT

Anderson Localization of light has not been observed unambiguously in disordered 3D mediums because its signature is difficult to separate from other optical contributions (absorption, fluorescence, etc.). It has been proposed that time-reversal symmetry breaking using the magneto-optical Faraday effect [3] will provide an accurate probe of localization. With the aim of advancing knowledge about Anderson Localization of light, we study it in a quasi one dimension (Q1D) system.

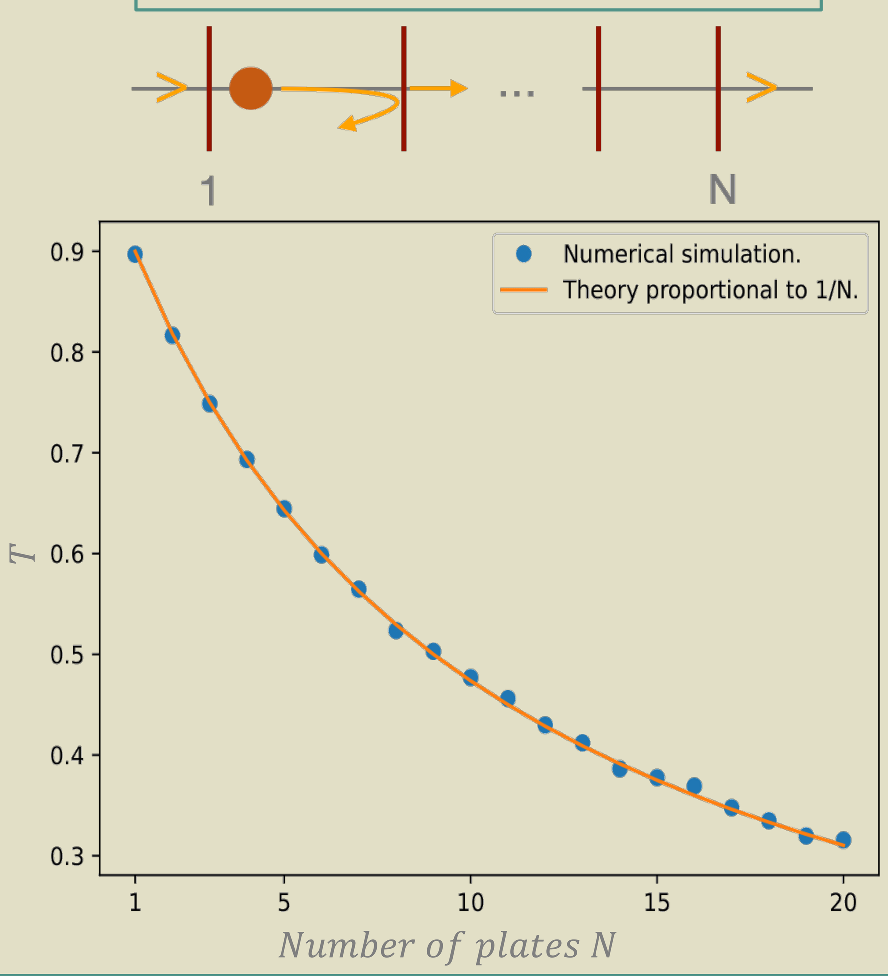
We study the propagation of light in this system using the formalism of transfer matrices and developed a code that allows us to observe the length of localization as a function of the number of modes of a Q1D system.

ANDERSON LOCALIZATION IN A 1D SYSTEM [1]

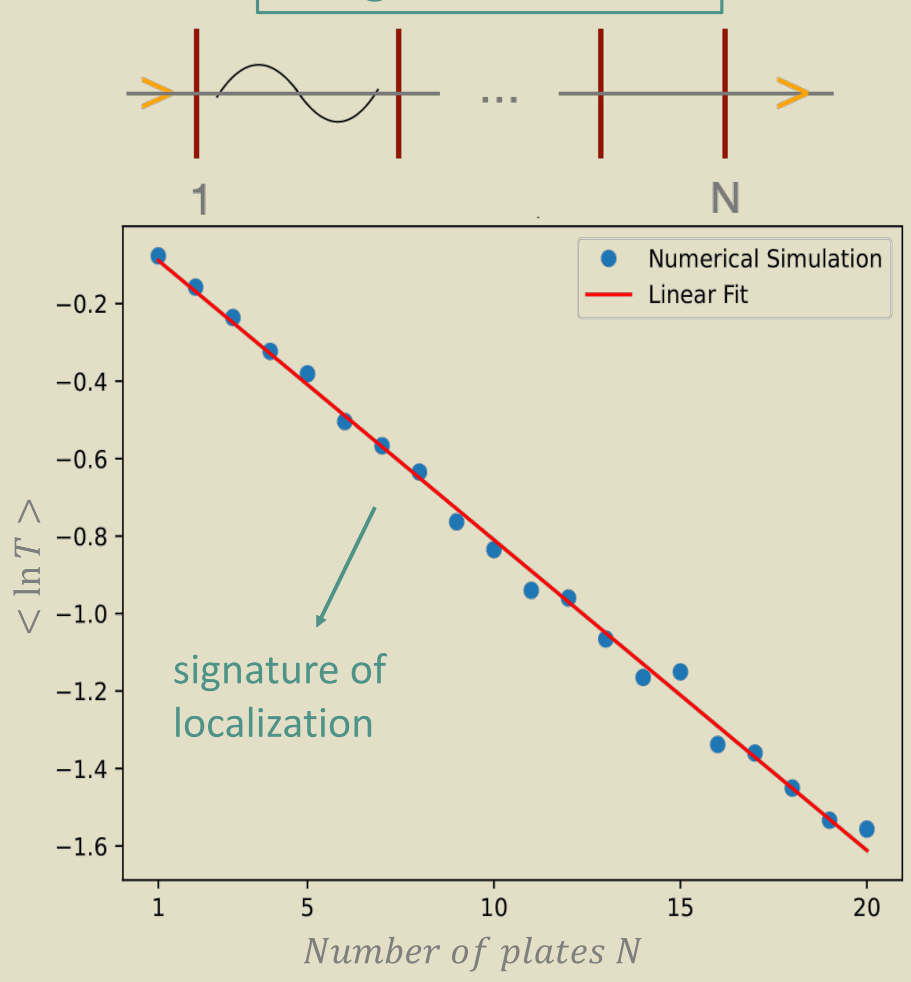


- Glass plates are separated by a distance $d \in [1;10]$ µm with an air layer
- n_1, n_2: refractive indexes of both mediums
- Light propagates towards z axis

Light without interferences

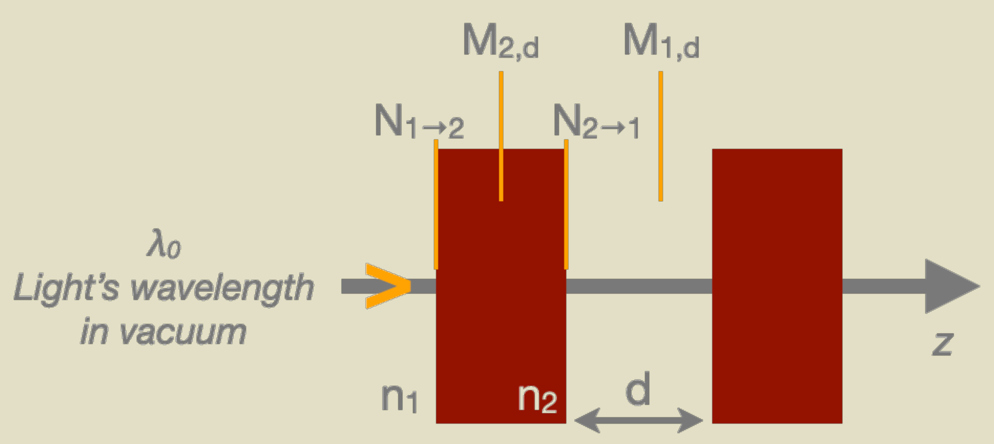


Light as waves



FROM 1D TO Q1D: TRANSFER MATRICES FORMALISM

Transfer matrix of glass plates stack (1D) [1]



$$T_{total} = N_{1\to 2} \cdot M_{d,1} \cdot N_{2\to 1} \cdot M_{d,2} \cdot \ldots \cdot M_{d,N}$$

Fresnel formulae:

$$N_{n_1\to n_2} = \frac{1}{2n_2}\begin{pmatrix} n_2+n_1 & n_2-n_1 \\ n_2-n_1 & n_2+n_1 \end{pmatrix} \quad M_d = \begin{pmatrix} \exp -\frac{2i\pi n d}{\lambda_0} & 0 \\ 0 & \exp \frac{2i\pi n d}{\lambda_0} \end{pmatrix}$$

Q1D Transfer matrix [2]

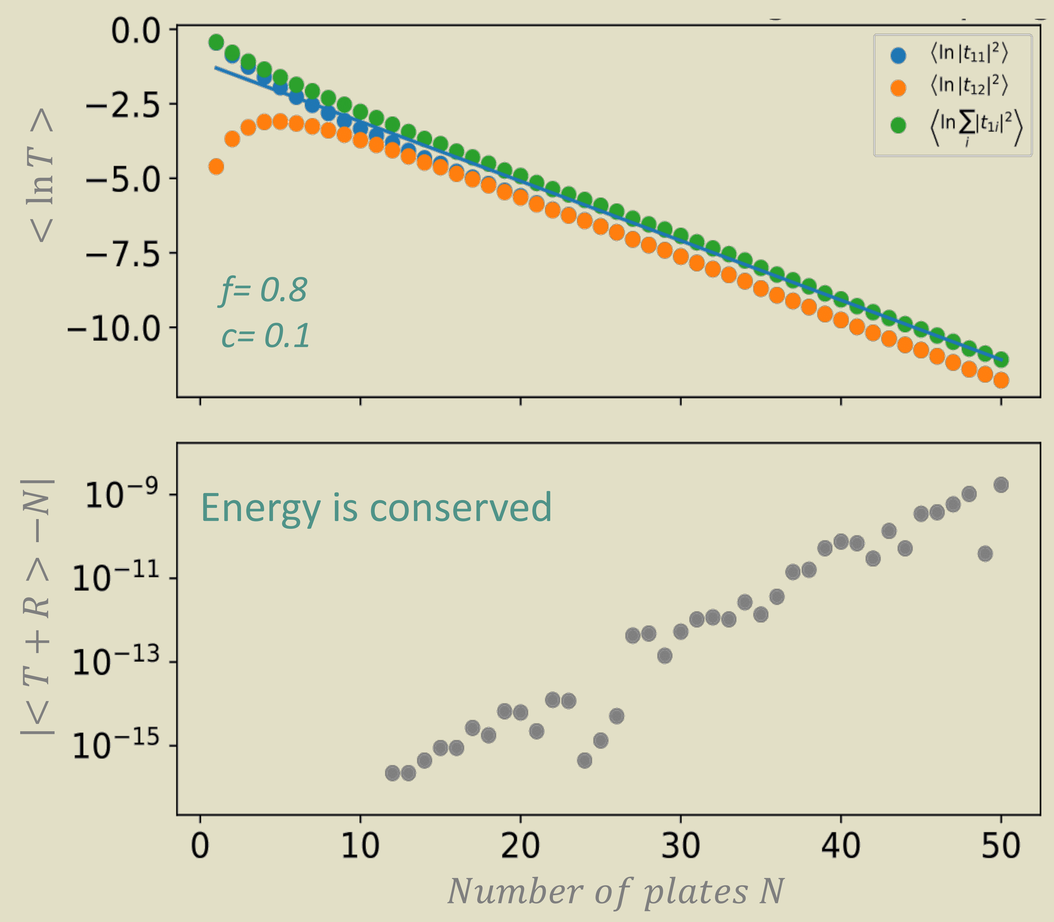
$$\begin{pmatrix} C \\ D \end{pmatrix} = T \begin{pmatrix} A \\ B \end{pmatrix}$$

Modified from [2]

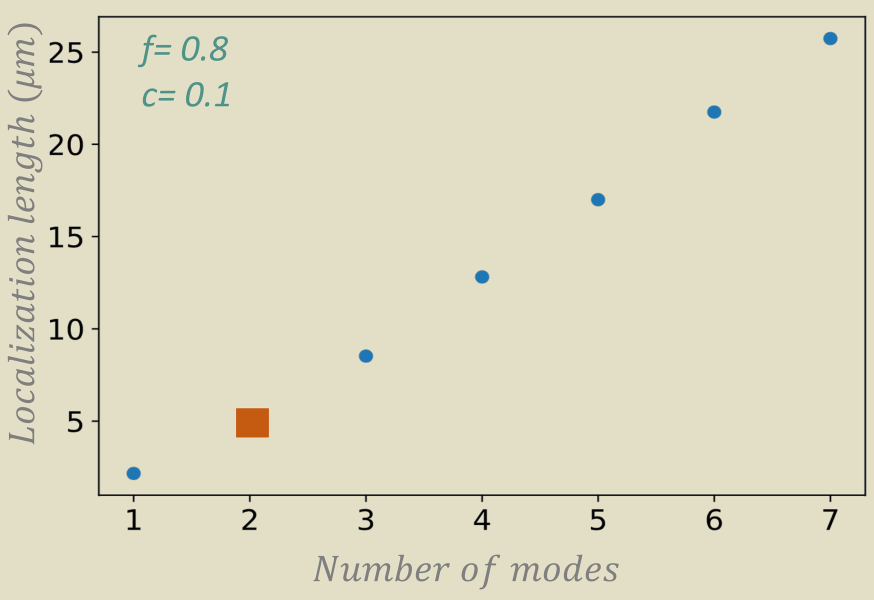
$$\begin{pmatrix} C_1 \\ C_2 \\ D_1 \\ D_2 \end{pmatrix} = T \begin{pmatrix} A_1 \\ A_2 \\ B_1 \\ B_2 \end{pmatrix} \quad \text{with} \quad T = \begin{pmatrix} t^+ - r^-(t^-)^{-1}r^+ & r^-(t^-)^{-1} \\ -(t^-)^{-1}r^+ & (t^-)^{-1} \end{pmatrix} \quad t^+ = \begin{pmatrix} f & c \\ c & f \end{pmatrix}$$

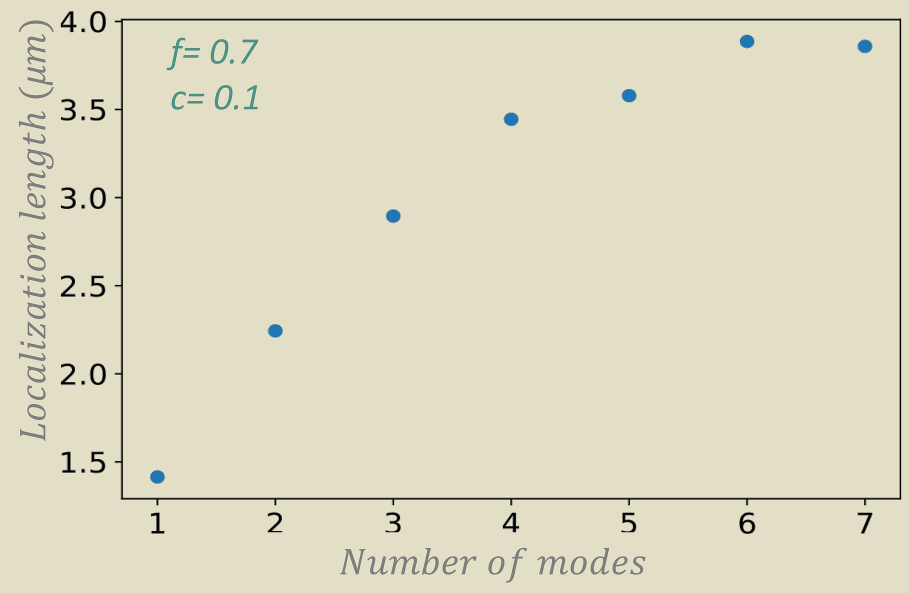
c: coupling coefficient f: forward scattering coefficient

Q1D system with N=2 modes



LOCALIZATION LENGTH VS NUMBER OF MODES



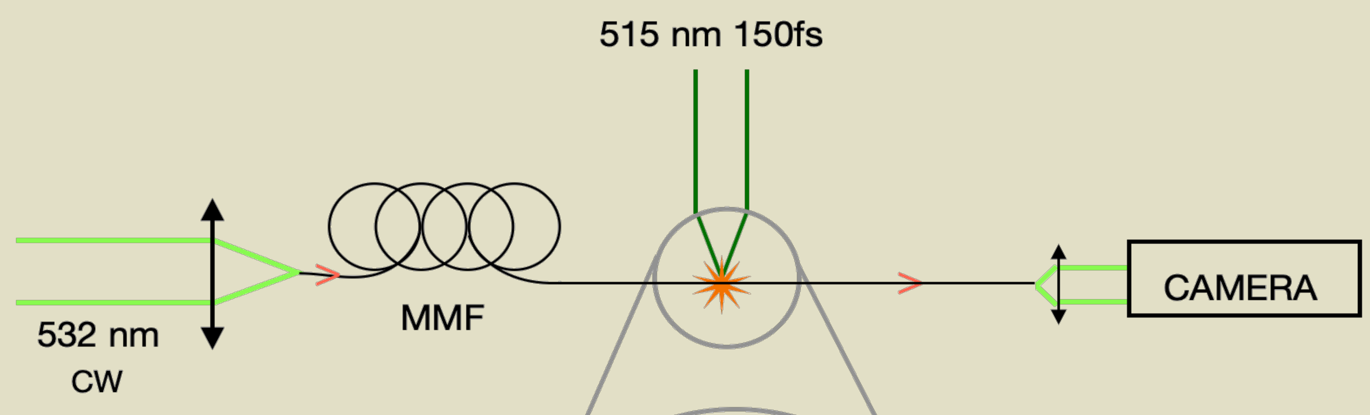


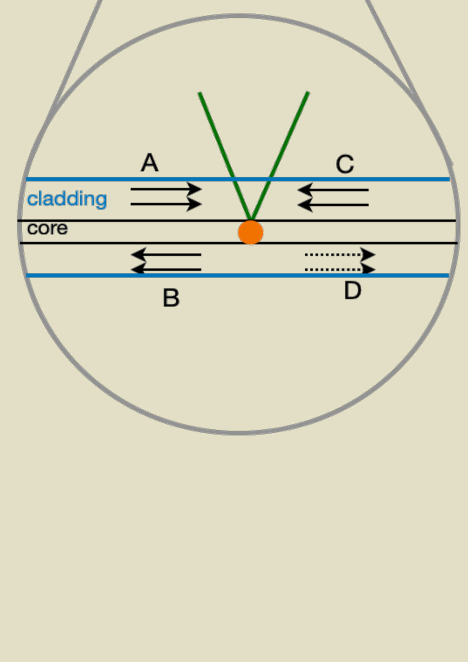
- The localization length increases with the number of modes
- Light still localizes
- Coupling disadvantages localization
- The larger f, the longer the localization length

Perspectives:

- Deeper analysis of the different parameters (N, f, c)
- Introduce the Faraday effect to induce time reversal symmetry breaking [3]

OBSERVING LIVE-COUPLING WITH MULTIMODE FIBER





We inject a continuous laser at 532 nm inside a multimode optical fiber and locally induce a scatterer by modifying the refractive index with a pulsed laser at 515 nm focused in the core of the fiber

The camera at the end of the device allows us to see the intensity distribution variation before and after the scatterer

REFERENCES

[1] Berry, M. & Klein, S, *Transparent mirrors: rays, waves and localization*, Eur J Phys. **18**, 222 (1997)
[2] Markös, P, *Numerical analysis of the anderson localization*, Acta Phys. Slovaca **56**, 561 (2006)
[3] Schertel, L. *et al*, *Magnetic-field effects on 1D Anderson localization of light*, Phys. Rev. A **100**, 043818 (2019)

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