Non-Hermitian Focusing Deep Inside Strongly Disordered Scattering Media

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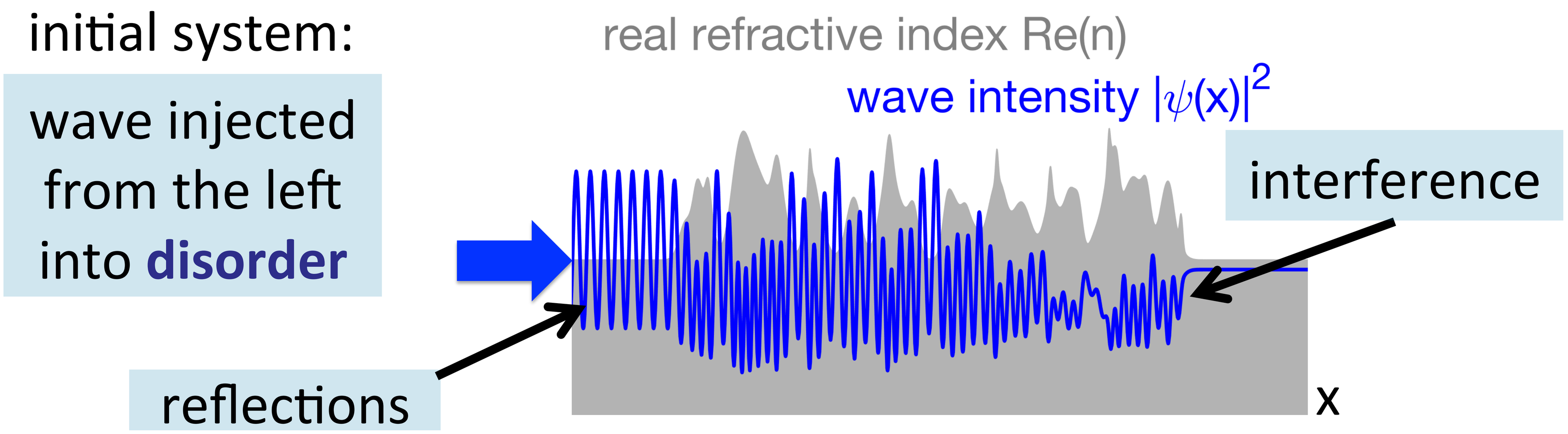
Motivation & Scope

- motivation: create scattering states with **predetermined intensity pattern** by introducing local absorption (**loss**) and amplification (**gain**)
- investigated systems: **non-Hermitian** stationary scattering systems described by Helmholtz equation
- scattered waves obey linear **wave equations** e.g.: Schrödinger equation for **matter waves**, Helmholtz equation for **electromagnetic waves**, **acoustic wave** equation, etc...
- initial system:



Research Goals

goal 1: suppress intensity variations in entire scattering region by adding **gain** and **loss** → **constant-intensity waves**[1,2]

goal 2: create intensity peak inside scattering region by adding **gain** and **loss** → **focusing waves**[3]

Constant-Intensity Waves

wave ansatz:

$$\psi(x) = e^{ik\int W(x')dx'}$$

constant intensity: $|\psi(x)|^2 = 1$

arbitrary real-valued generating function

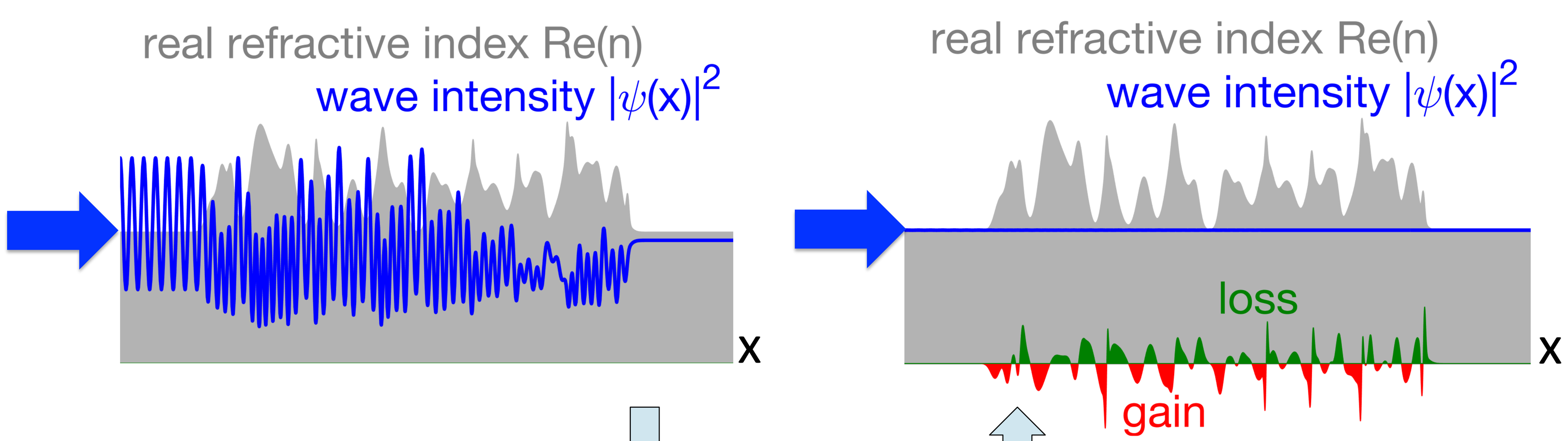
Helmholtz eq.:

$$\left[\frac{\partial^2}{\partial x^2} + k^2 n^2(x)\right]\psi(x) = 0$$

$$n^2(x) = W^2(x) - i\frac{dW(x)}{dx}\frac{1}{k}$$

relation between **real** and **imaginary** part

gain & **loss** required



add corresponding **gain** & **loss** distribution

- **intensity variations**
- **back reflections**

→

- **constant intensity**
- **perfect transmission**

Focusing Waves

same concept as constant-intensity waves but with **complex generating function** $W(x)$ allows for **arbitrary intensity patterns**

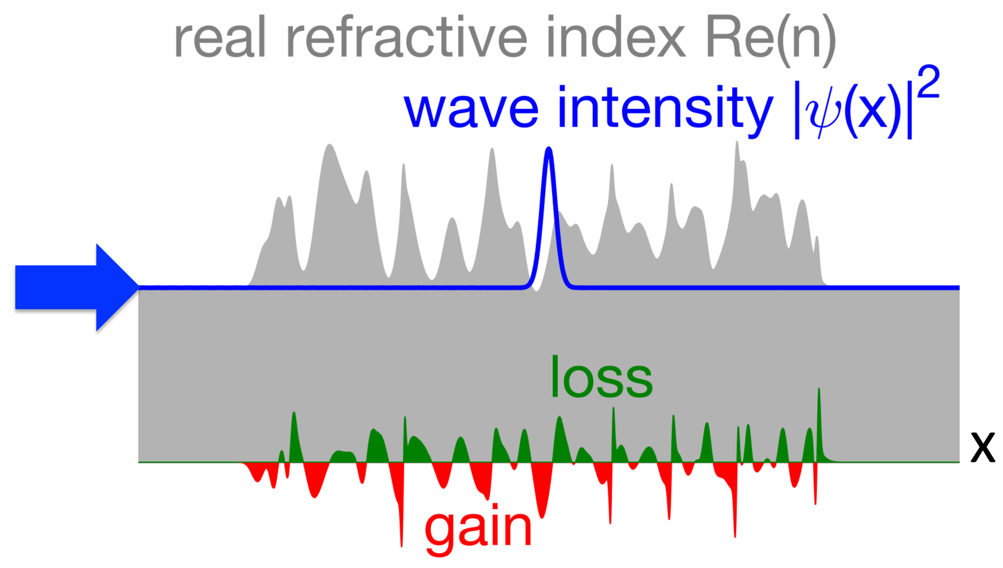
modified wave ansatz:

$$\psi(x) = e^{ik\int[W_R(x')+iW_I(x')]dx'}$$

$$|\psi(x)|^2 = e^{-2k\int W_I(x')dx'}$$

intensity distribution determined by imaginary part of $W(x)$

choose $W_I(x)$ such that intensity is peaked at a certain position:



- **intensity peak**
- **perfect transmission**

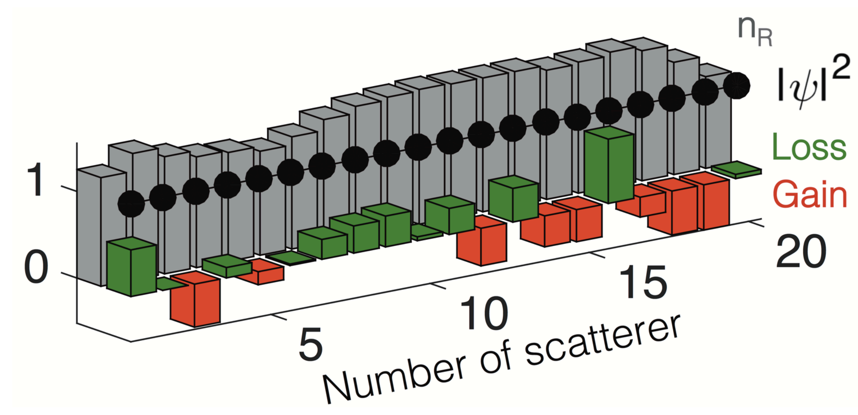
method works for **arbitrary intensity patterns**

Envisioned Experimental Realizations

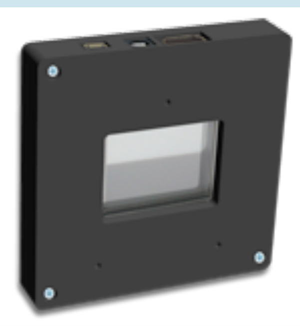
optics: **Rhodamine (6G) dye** as gain material

spatially modulated pump[4] beam controls gain and loss components in active medium

possible realization in **discrete system**[2]: elements (cavities) with gain or loss and a specific real refractive index



spatial light modulator (SLM) to shape pump beam



Summary

- suppress backscattering and intensity variations by adding a **suitable gain and loss distribution**
- method even applicable in **strongly disordered systems**[2]
- procedure can be extended to design **arbitrary intensity patterns**, e.g., an intensity maximum (**focus**) inside a scattering region
- **experimental realization** within reach

References

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