TRANSPORT IN QUASI-ONE DIMENSIONAL CORRELATED RANDOM MEDIA

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Motivation

Problem

Technologically interesting quasi 1d systems like nanowires and graphene stripes are experimentally hard to access (nm-scale and low temperature).

Solution

→ Use correspondence between electron wave and microwave transport properties.

Advantages

- Mode resolved measurement possible
- Investigation of arbitrary types of disorder

Focus here

- Correlations in disorder on lattices can suppress or enhance transport.
- Transport depends on the Fourier transformation of correlation function $C(n)$ of the disorder:

- Inverse localization length l^{-1} is proportional to $W(2γ)$.
- Correlations are imposed by structural disorder, but can be introduced via compositional disorder or even cross correlations of both.

Experimental Setup

- 2 moveable antennas
- Scatterers here: brass bars
- Absorbers at both ends mimic an infinite system.

Wave propagates as sine wave through channel. Waves are discrete in y-direction. k is given as

$$k = \sqrt{k_{x,n}^2 + \left(\frac{n\pi}{d}\right)^2}$$

Antennas measure at several positions y_1, y_2 :

$$S(y_1, y_2) = \sum_{nm} S_{nm} \sin\left(\frac{m\pi y_1}{d}\right) \sin\left(\frac{n\pi y_2}{d}\right)$$

Via Fourier transform one can extract S_{nm} , i.e., transport from mode m to mode n . Quantity of interest is total transport to mode n :

$$T_n = \left| \sum_m S_{nm} \right|^2$$

Example

First mode starts to propagate at $\lambda = 2d$:

Empty Waveguide

First 8×8 sub matrix of S_{nm} for $\nu = 11$ GHz with 7 open modes. S_{nm} is nearly diagonal. Highest conducting mode always has the strongest contribution to the total transport. Off diagonal elements contribute less than 5%.

Transmission intensity T_n (blue) related to Green's function (red) for 1d channel:

$$T_n \sim |G(k_{x,n})|^2 = \left| \frac{i}{2k_{x,n}} \exp(ik_{x,n}L) \right|^2$$

Example: 4th mode with $\text{Im}(k_{x,n}) = 0.2$.

Regular Lattice

Band structure example for 3rd (blue) and 4th mode (yellow).

- Clear band structure which is the same for all modes.
- Vertical lines indicate band edges.
- Description in terms of an effective bilayer model.
- Use band edges to determine the free parameters (n_a, n_b, α) from the dispersion relation:

$$\cos(\gamma) = \cos(k_x n_a a) \cos(k_x n_b b) - \alpha \cdot \sin(k_x n_a a) \sin(k_x n_b b)$$

- a : spacing between bars, $a = 40$ mm
- b : width of the bars, $b = 8$ mm
- n_a : effective n for spacing between bars
- n_b : effective n for width of bars
- α : effective impedance ratio

Dispersion relation $\cos(\gamma)$ (blue) and allowed bands γ (red). Effective parameters: $\alpha = 1.72$, $n_a = 0.75$ and $n_b = 1.4$.

Disordered Lattice

Band structure of 3rd mode. Transmission for white noise disorder (yellow) and correlated disorder (blue). The dashed red line indicates the region of the Fabry-Perot resonance at $k_x = 280.5 \text{ m}^{-1}$, corresponding to resonances due to the constant brass bar width.

Blue marked range from figure above. The blue dotted lines indicate the expected correlation gaps for the magnified band, at $\gamma/\pi = 0.3$ and $\gamma/\pi = 0.7$.

- Experiment with compositional disorder yields similar results.
- Upcoming experiment: disorder with cross correlation between compositional and structural disorder