Numerical Characterization of a Harper-Hofstadter Topological Laser

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Harper-Hofstadter Topological Laser

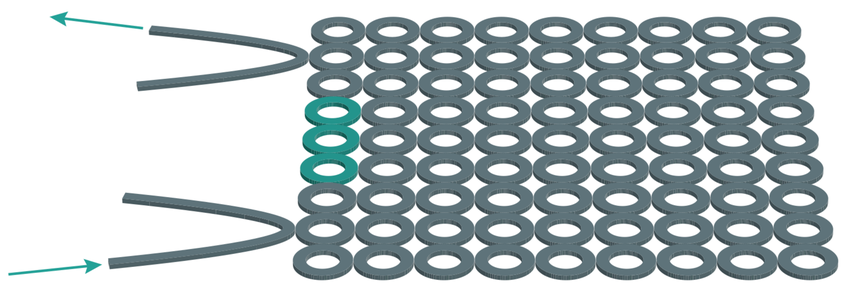
• Harper-Hofstadter Hamiltonian (ϑ = 1/4):

$$H = \sum_{m,n} \left\{ \omega_0 a^\dagger_{m,n} a_{m,n} - J\left(a^\dagger_{m,n} a_{m+1,n} + e^{-i2\pi\vartheta m} a^\dagger_{m,n} a_{m,n+1} + \text{h.c.} \right) \right\}$$

• Add losses and saturable pumping

• Write semiclassical equations for the fields:

$$\dot{a}_{m,n} = i\left[H, a_{m,n}\right] - \gamma a_{m,n} + \frac{P_{m,n}}{1+\beta|a_{m,n}|^2} a_{m,n}$$



• Array of ring resonators with complex hoppings, coupled to input/output waveguides.

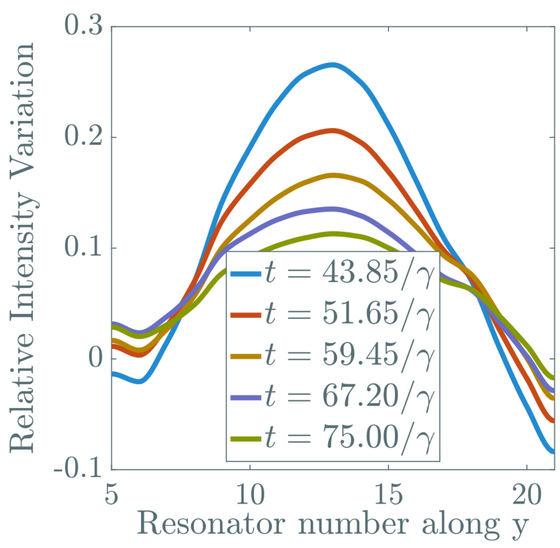
• Selection of topologically protected edge modes by placing the amplification along the border.

Full Border Lasing Mode

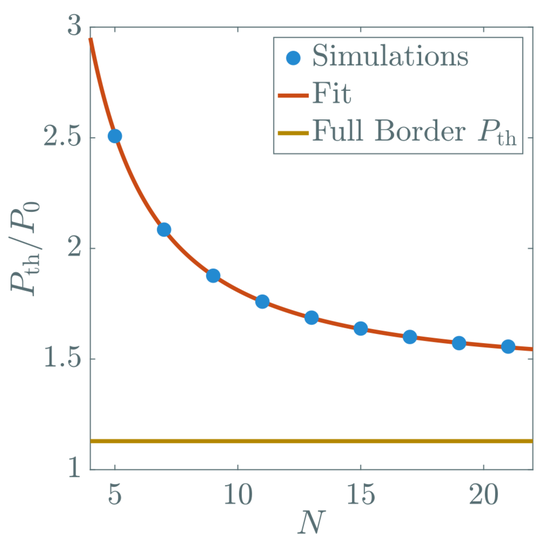
• More efficient in terms of lasing threshold.

• Plagued by intensity oscillations and different SS frequencies at each realization.

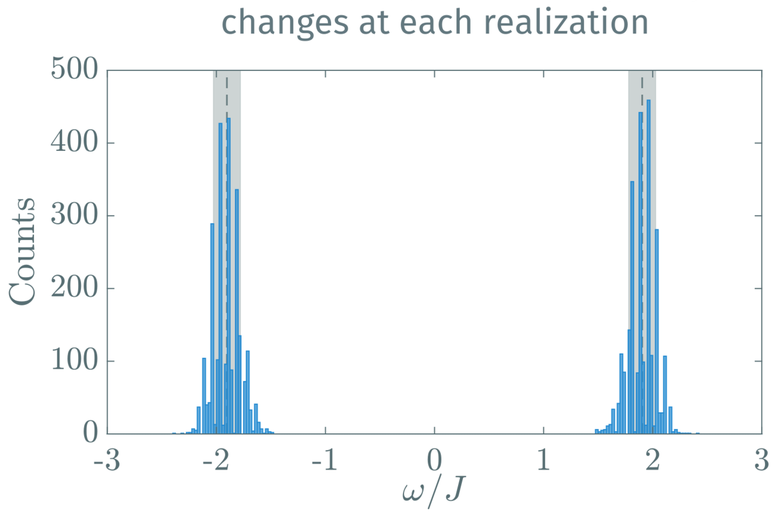
Long damping time of intensity oscillations

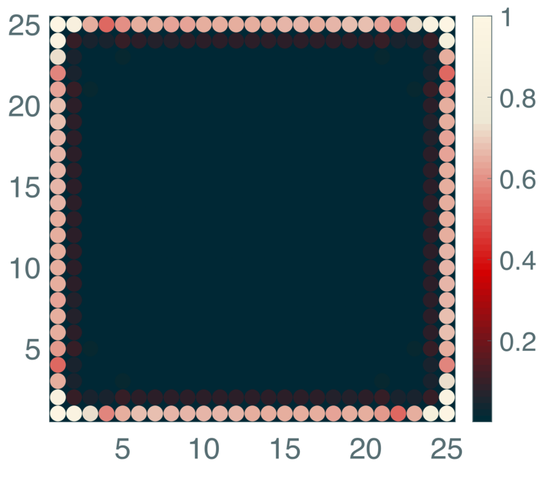


Lower threshold compared to the 1×N strips case



Monochromatic, but the frequency changes at each realization



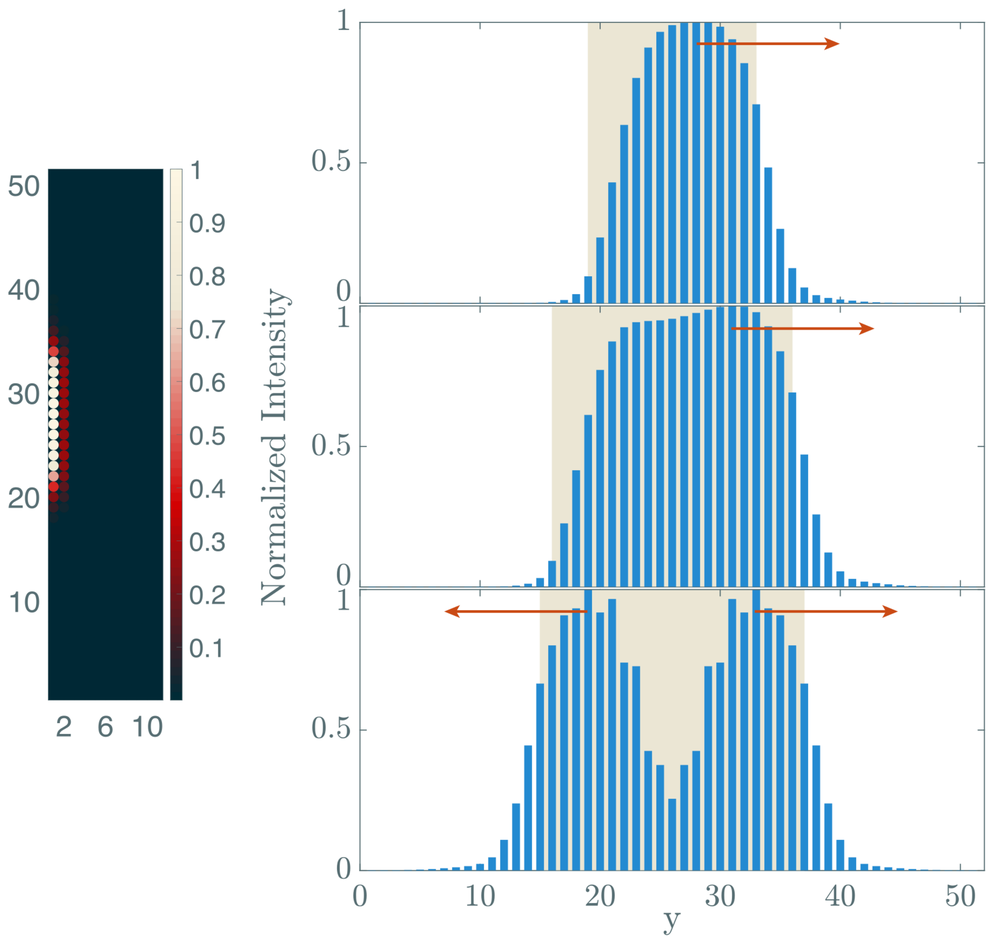


Chiral Modes Competition

• We amplify 1×N strips along the left border.

• The intensity profile is a lobe travelling with a single chirality for small enough N.

• After a critical N, the intensity profile breaks into two lobes travelling with opposite chiralities.

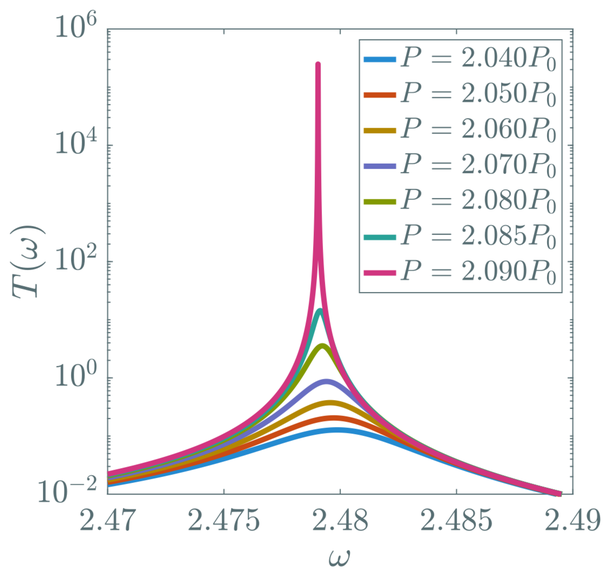


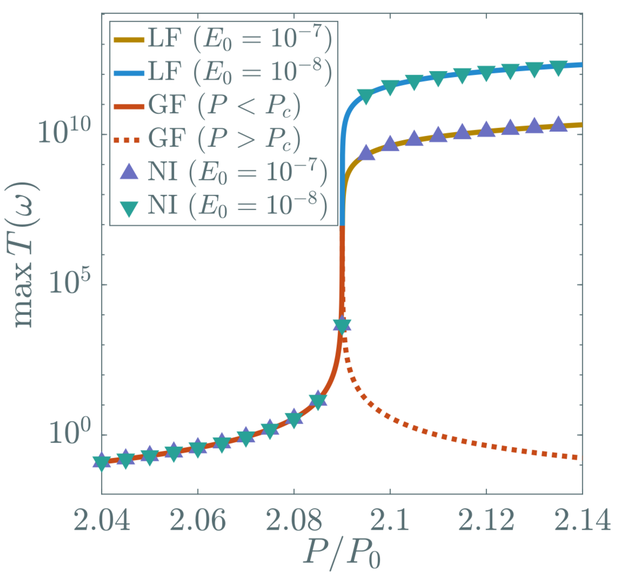
→ Competition between the two available chiralities.

→ High sensitivity to the initial conditions.

Transmission Coefficient & Lasing

• Calculation of the transmission coefficient near P_{th}, both via the Green's function and the numerical integration.





→ The Green's function predicts a divergence of the transmission at $P_c = P_{th}$ around the lasing frequency.

• Transmission coefficient obtained from the Green's function (in the linear amplification regime):

$$T(\omega) = \nu_{\text{in}}\nu_{\text{out}} \left| \mathcal{G}_{\text{out}\sigma,\text{in}\sigma}(\omega) \right|^2$$

• Transmission coefficient obtained from the numerical integration:

$$T(\omega) = \nu_{\text{out}} \left| \frac{a_{\text{out}}(\omega)}{E_0} \right|^2$$

References

[1] M. Seclì, *Edge State Lasing in a 2D Topological Photonic System*, MSc Thesis, University of Trento, Trento (2017).

[2] M. Seclì and I. Carusotto, *in preparation* (2018).