Robust Majorana modes in one-dimensional disordered binary alloy

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INTRODUCTION

- The one-dimensional (1D) Aubry-Andre-Harper (AAH) model shows some unique electronic and topological features.
- Recently it has been shown that 1D off-diagonal AAH Hamiltonian with commensurate cosine modulation with the underlying periodic lattice shows remarkable signatures of topologically protected edge states.
- These edge states have been identified as the Majorana modes. For a lattice with even number of sites these modes appear at zero energy as a degenerate pair.
- Also, it had been pointed out that this degeneracy can be lifted by considering the generalized AAH model along with the inclusion of next-nearest neighbor hopping.
- we show that it is possible to lift the degeneracy of the Majorana modes simply by implementing the off-diagonal AAH model in a one-dimensional binary alloy.
- The advantage of this approach is that apart from the off-diagonal part of AAH model it only requires two different site energies ε_a and ε_b.

MODEL

The Hamiltonian of our system is given by,

$$H=\sum_{n}\varepsilon_n c_n^{+}c_n+\sum_{n=1}^{N}t[1+\lambda\cos(2\pi bn+\phi_\lambda)]c_{n+1}^{+}c_n+h.c.$$

- N is the number of lattice sites.
- λ is the modulation strength.
- 1/b is the periodicity of the modulation.
- φ_λ is the phase factor while n = 1 and n = N are the two edge sites.
- The onsite energies ε_n can have only two values ε_a and ε_b.
- c_n and $c_n^{\dagger}$ are the fermionic destruction and creation operators respectively.

Here we are giving conditions for binary alloy without the loss of generality i.e.,

$$\varepsilon_a + \varepsilon_b = 0 \;\text{ and }\; \varepsilon_a - \varepsilon_b = \Delta$$

The above binary lattice can be created with any arbitrary concentration of ε_a or ε_b. But for our case we have taken $\varepsilon_a = 0.25$ and $\varepsilon_b = -0.25$.

RESULTS AND DISCUSSIONS

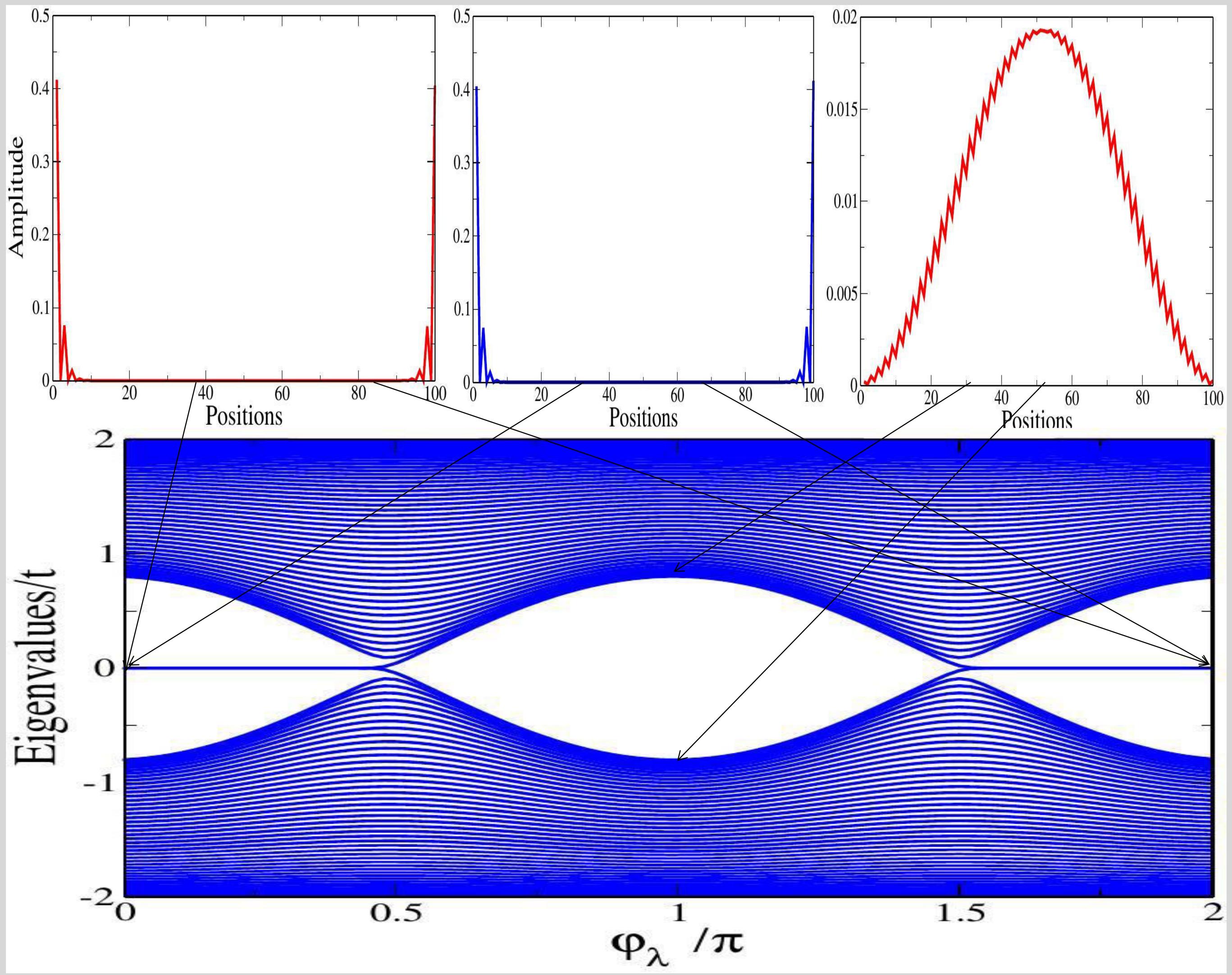
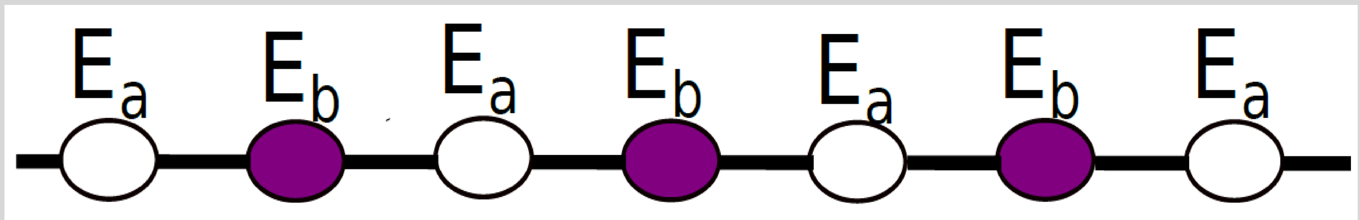


Fig.1. Wavefunctions (top) and edge states (bottom) in off-diagonal AAH model in an uniform lattice. Here, N=100, t=1, λ=0.4, b=1/2, ε_a= 0 and ε_b= 0.



Above figure shows uniform distribution of onsite energies ε_a and ε_b.

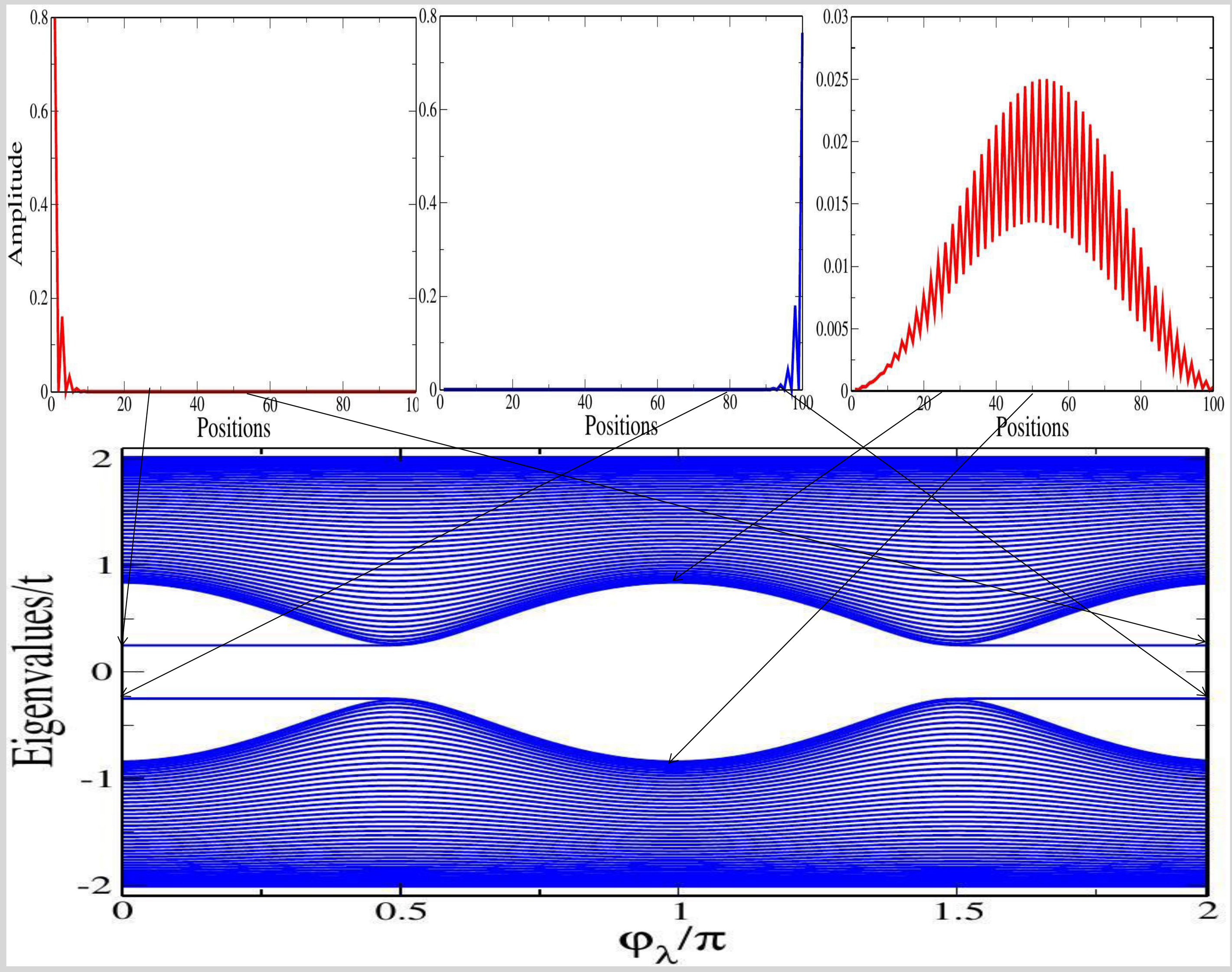
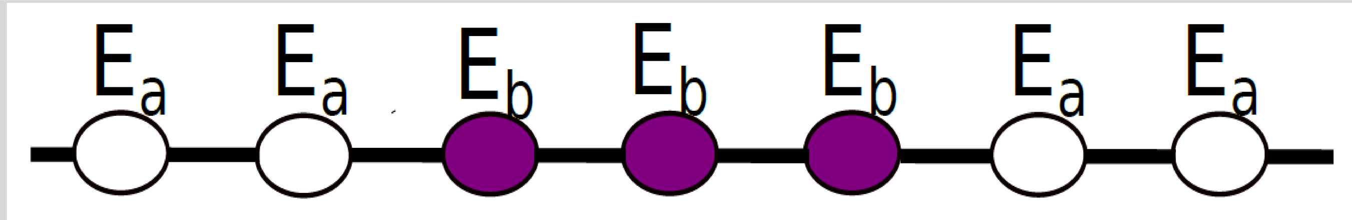


Fig.2. Wavefunctions (top) and edge states (bottom) in off-diagonal AAH model with ordered binary alloy. Here, N=100, t=1, λ=0.4, b=1/2 ,ε_a= 0.25 and ε_b=-0.25.



Above figure shows non-uniform distribution of onsite energies ε_a and ε_b.

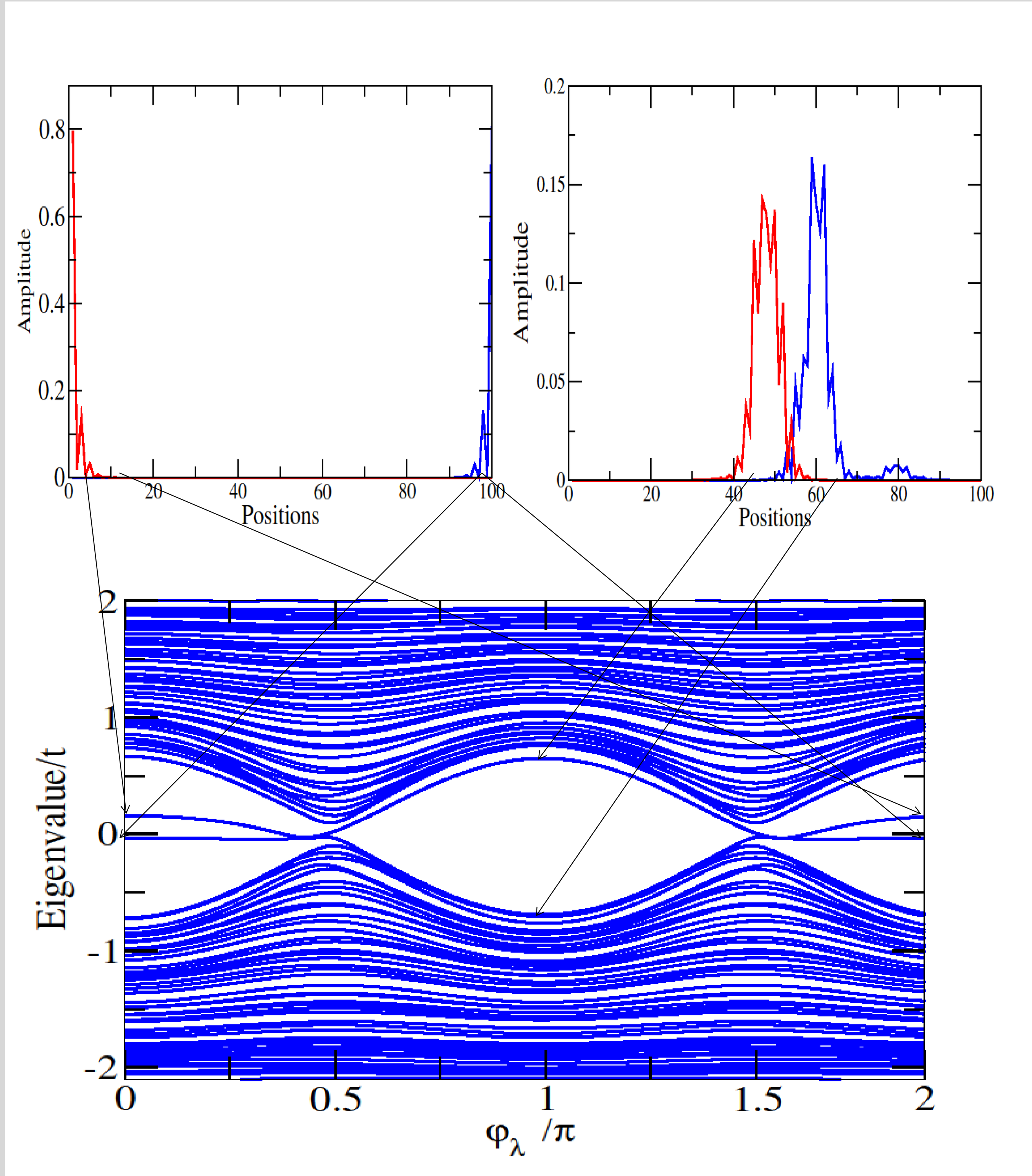


Fig.3. Wavefunctions (top) and edge states (bottom) in off-diagonal AAH model with disordered binary alloy. Here, N=100, t=1, λ=0.4, b=1/2 ,ε_a= 0.25 and ε_b=-0.25.

CONCLUSIONS

- This approach only requires implementing the off-diagonal AAH model on a binary alloy in 1D instead of introducing more parameters in the form of diagonal cosine modulation and next-nearest-neighbour hopping.
- Also, we can conclude that Majorana modes remain intact even in the presence of disordered background.

REFERENCES

[1]. Y. Lahini, R. Pugatch, F. Pozzi, M. Sorel, R. Morandotti, N. Davidson, and Y. Silberberg, Phys. Rev. Lett. 103, 013901 (2009).
[2]. Y. E. Kraus et al., Phys. Rev. Lett. 109, 106402 (2012).
[3]. P. W. Anderson, Phys. Rev. 109, 1492 (1958).
[4]. S. Ganshan et al., Phys. Rev. Lett. 110, 180403 (2013).