Supplemental Material: Manipulation of Majorana bound states in proximity to a quantum ring with Rashba coupling

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Quasiparticle spectra, Charge and Spin Currents For $N = 5, 6$.

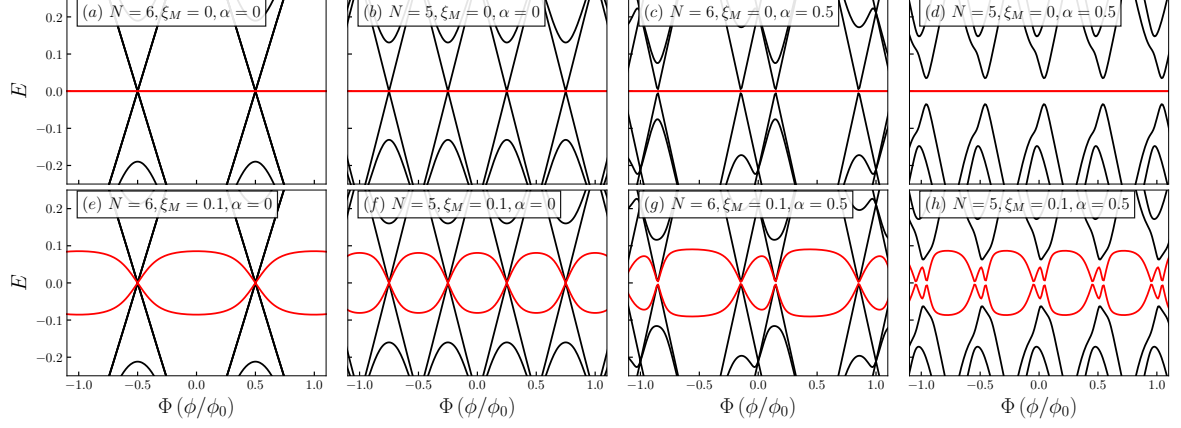The spectra and currents for $N = 5, 6$ are presented.

Figure 1: Quasiparticle spectra for $\lambda_1 = 0.1$ and $\lambda_2 = 0$. The number of sites, N, the coupling between MZMs, ξ_M, and the Rashba spin-orbit coupling, α, are indicated in the figure. Black curves represent the states in the quantum ring and the red curves correspond to the Majorana modes.
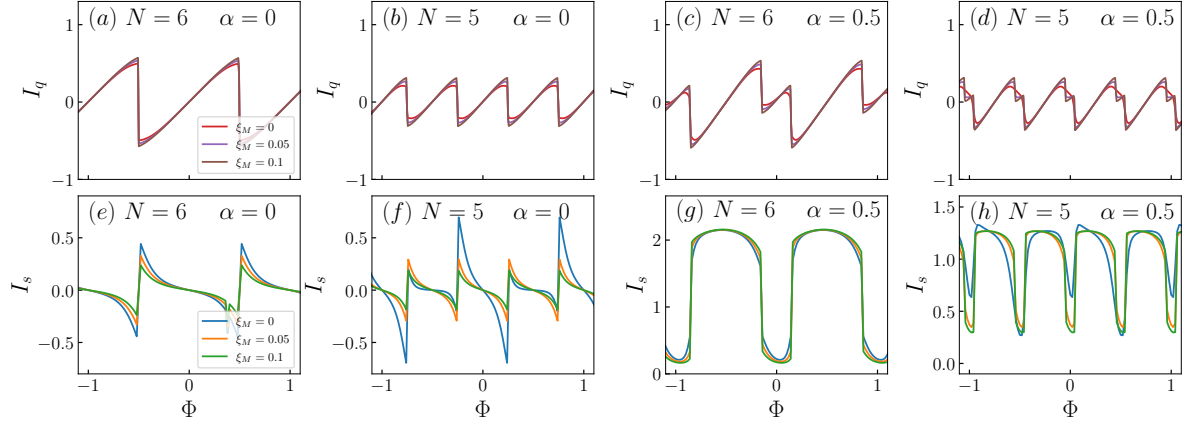

Figure 2: Charge and spin persistent currents, I_q and I_s respectively, for $\lambda_1 = 0.1, \lambda_2 = 0$. The number of sites, N, and the Rashba spin-orbit coupling, α, are indicated in the figures. The coupling between MZMs, ξ_M, is indicated by coloured lines, shown in the leftmost panels.
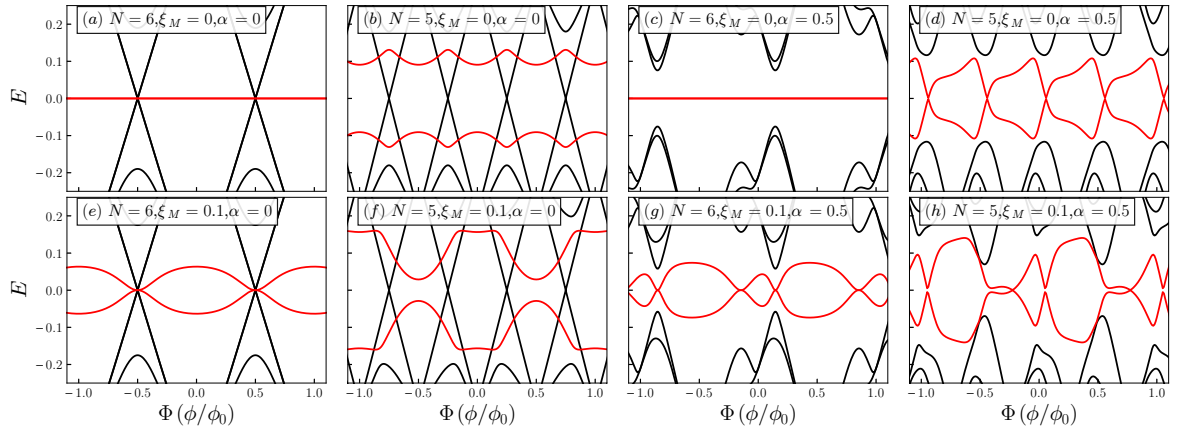
Figure 3: Quasiparticle spectra for $\lambda_1 = 0.1$ and $\lambda_2 = 0.15$. The number of sites, N, the coupling between MZMs, ξ_M, and the Rashba spin-orbit coupling, α, are indicated in the figure. Black curves represent the states in the quantum ring and the red curves correspond to the Majorana modes.
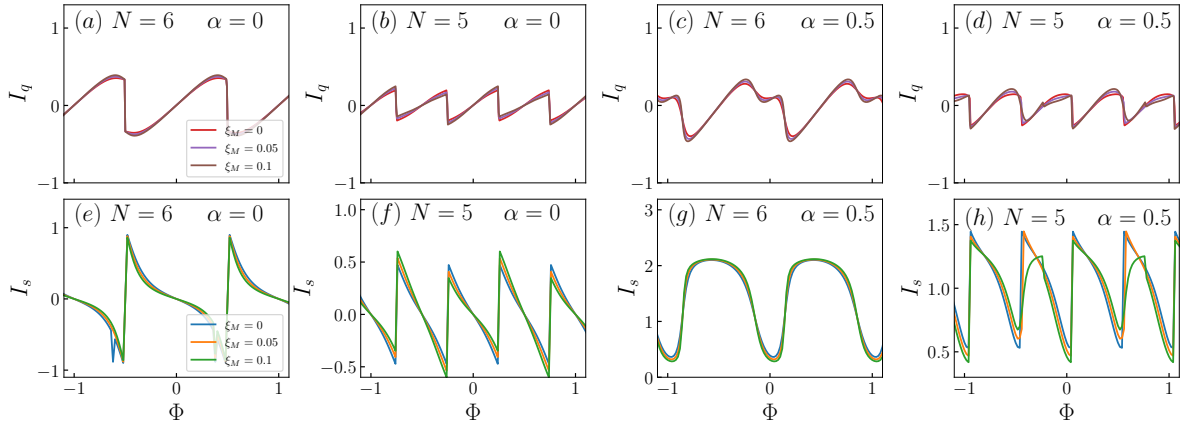

Figure 4: Charge and spin persistent currents, I_q and I_s respectively, for $\lambda_1 = 0.1, \lambda_2 = 0.15$. The number of sites, N, and the Rashba spin-orbit coupling, α, are indicated in the figures. The coupling between MZMs, ξ_M, is indicated by coloured lines, shown in the leftmost panels.

The spectra obtained for $N = 5$ show avoiding crossings between Majorana modes in panel (b) and (f) from Figure 3. In the spectra for $N = 3$ Majorana modes display zero energy crossing around 0.5 and -0.5, as we mention before, this does not happen for $N > 5$ as can be observed in panel (f) from Figure 6.
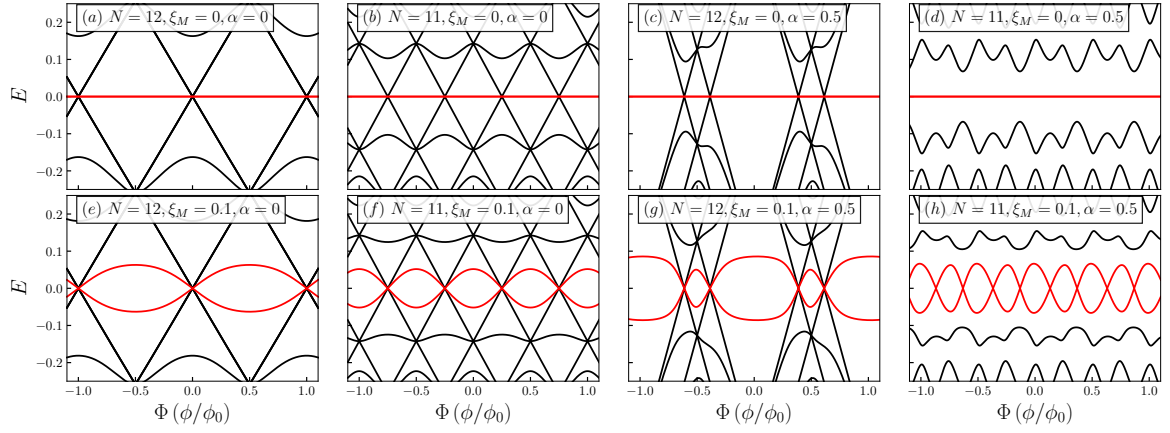
Quasiparticle Spectra for $N = 11, 12$.

Figure 5: Quasiparticle spectra for $\lambda_1 = 0.1$ and $\lambda_2 = 0$. The number of sites, N, the coupling between MZMs, ξ_M, and the Rashba spin-orbit coupling, α, are indicated in the figure. Black curves represent the states in the quantum ring and the red curves correspond to the Majorana modes.
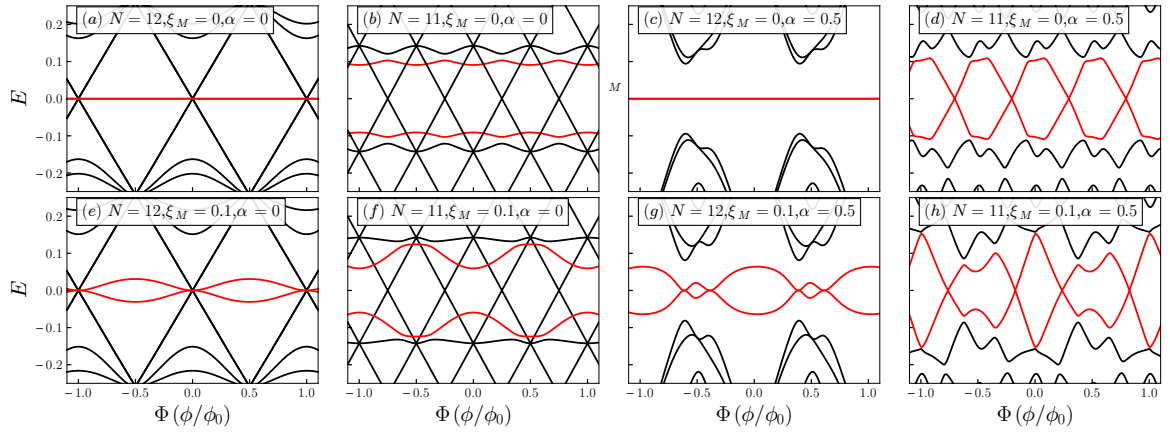

Figure 6: Quasiparticle spectra for $\lambda_1 = 0.1$ and $\lambda_2 = 0.15$. The number of sites, N, the coupling between MZMs, ξ_M, and the Rashba spin-orbit coupling, α, are indicated in the figure. Black curves represent the states in the quantum ring and the red curves correspond to the Majorana modes.