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Nonreciprocal Electronic Devices for Matter Waves

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Abstract

We propose non-reciprocal interferometers for matter waves. These interferometers may be implemented as asymmetric quantum rings with broken time-inversion symmetry. Our preliminary analyses lead us to predict that these devices will feature asymmetric transport properties for particles such as electrons, for which the interferometers' ground states act as directional filters [1].

1. Introduction

The discovery of superconductivity enabled the transport of electric charge without dissipation. Sustained, constructive work to develop sophisticated superconducting materials has led to enormous advances in the performance of superconductors and in raising their critical temperature. Interestingly, dissipation-free charge flow exists also in non-superconducting systems. Atoms, molecules, atomic clusters and mesoscopic conducting rings may, for example, carry such currents.

Here, we report on our search for further possibilities to realize loss-free charge flow in non-superconducting devices or wires, and propose nonreciprocal filters for electrons as candidates [1].

2. Device Concept

Nonreciprocal devices, *i.e.*, devices that let waves pass differently in one direction than in the other, are widely used in radar technology [2]. They have also been implemented, for example, as devices based on plasmons, magnons, electromagnons, and sound waves (see, e.g., [3-7]). Nonreciprocal devices for de Broglie waves can be realized [1] by using Rashba quantum rings [8,9] or asymmetric Aharonov-Bohm rings [10]. Nonreciprocal superconductors are a topic of much current interest [11].

We seek devices wherein electrons would be transmitted from left to the right with a higher probability than electrons passing the device from right to left. This also applies to electrons driven by thermal excitation. To break the time-reversal symmetry we focus on devices subject to a magnetic field, considering effects such as the Rashba-effect [8] caused by the magnetic field that break the parity of the device in current-flow direction.

If driven by currents or biased by voltages the proposed devices show asymmetric transport, thereby reminding of diodes. The devices are homopolar, however, and function by interference of de-Broglie waves. They do not feature a built-in voltage and indeed lack any energy scale beyond kT. In forward direction they may operate virtually free of losses.

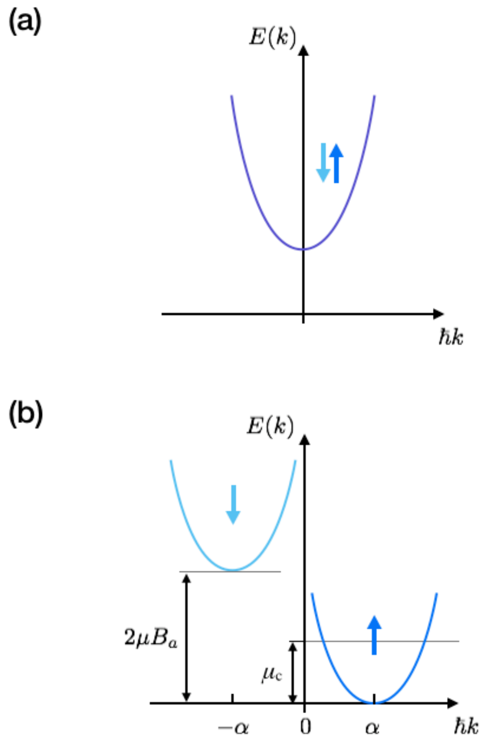

Fig. 1 Illustration of a possible shaping of the band-structure induced by combing the Zeeman-effect and the Rashba effect. The parabolic, spin-degenerate band shown as example in (a) may become spin-split in energy by the Zeeman effect and split in k space by the Rashba momentum α, as shown in (b). As a result, states at the chemical potential may show k values that are nonsymmetric to k=0.

3. Possible Applications

These devices may be useful for many applications, in analog and digital electronics as well as in quantum computation and quantum communication. An especially exciting possible application field is nonreciprocal transport of matter, such as the sought-after loss-free, non-superconducting flow of sizable electric currents at very high temperatures.

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