Local and tunable geometric phase of Dirac fermions in a topological junction

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Electrons in graphene and a surface of topological insulators behave as Dirac fermions (DFs). They have the interesting property of spin-momentum locking that their spin rotates following the change of the spatial momentum. Massless DFs acquire the Berry phase of π in the spatial motion along a closed trajectory on a plane, as their spin rotates along a great circle on Bloch sphere. This special value π causes topological phenomena [1, 2, 3] such as the half-integer quantum Hall effect and weak antilocalization.

When DFs become massive, they can have the other possible values of Berry phase of spin 1/2. The continuous values of Berry phase give rise to the modification of the known effects of Berry phase π. They may also result in new interesting effects, together with unusual transport of DFs, and will offer a way of experimentally detecting Berry phase of spin 1/2 in a controlled fashion.

We theoretically show that DFs acquire geometric phase as a scattering phase shift in a *local and nonadiabatic scattering* event of reflection or transmission at a junction with mass gap (See Fig. 1). The geometric phase of spin 1/2 is an electronic analogue of polarized light in optics [4, 5, 6]. The Pancharatnam-Berry phase has new roles in solids. It carries the information of the Chern number of the insulator side of a metal-insulator junction of DFs. This implies a new type of bulk-edge correspondence for a *metal-insulator* junction, which is different from the conventional version of the correspondence with gapless edge states between *two insulators* with different Chern numbers. The Pancharatnam-Berry phase also modifies the quantization rule of DFs. This suggests *geometric-phase devices* with non-trivial charge and spin transport such as a topological wave guide and a topological field effect transistor.

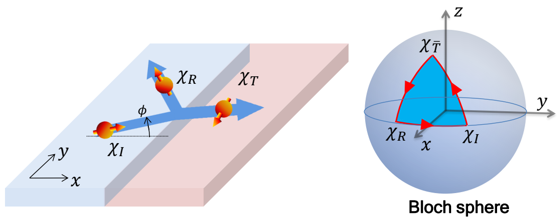

Figure 1: (left) Scattering of DFs at a junction with mass gap. A plane wave with a spin state χ_I incident from the left side is reflected to a wave with a spin state χ_R or transmitted to a wave with a spin state with χ_T. (right) The reflection coefficient of the scattering is shifted by geometric phase which amount is given by $-\Omega_{I\bar{T}R}/2$. $\Omega_{I\bar{T}R}$ is the solid angle of the *geodesic* polygon on the Bloch sphere which sequentially connects the vertices representing spin states χ_I, $\chi_{\bar{T}}$, χ_R, where $\chi_{\bar{T}}$ denotes the spin state orthogonal to χ_T.

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