Transport on the surface of a topological insulator

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We evaluate the dc and ac conductivities of a two-dimensional topological insulator including a mass term m_z in its Hamiltonian[1]. Starting with a Kubo formula we derive an expression for the dc Hall conductivity σ_{yx} valid for finite temperatures using the analytically derived eigenfunctions and eigenvalues. At zero temperature this expression gives the dc *half-quantum Hall conductivity*[1], $\sigma_{yx} = (m_z/|m_z|)(e^2/2h)$ *in the absence of a magnetic field*. Corrections due to scattering by impurities are taken into account. The longitudinal component σ_{xx} is evaluated as well. Further, we evaluate these conductivities for finite frequencies ω and show that in addition to a Drude term we have logarithmic, frequency-dependent corrections. We also evaluate the power absorption spectrum $P(\omega)$, pertinent to optical experiments, using the linear-response expression $P(\omega) = (E^2/2) \times \mathrm{Re}\{\sigma_{xx}(\omega) + \sigma_{yy}(\omega) + i\sigma_{yx}(\omega) - i\sigma_{xy}(\omega)\}$ with E the electric field of light. The sum $\sigma_{xx}(\omega) + \sigma_{yy}(\omega) = 2\sigma_{xx}(\omega)$ varies as $(E_F^2 - m_z^2)\tau/[\hbar E_F(1+\omega^2\tau^2)]$ whereas the real part of $i\sigma_{yx}(\omega)$ ($= -i\sigma_{xy}(\omega)$) surges upward at a frequency $\omega = 2|m_z|/\hbar$ and its imaginary part drops drastically, see Fig. 1(a). Accordingly, as shown in Fig. 1(b), $P(\omega)$ increases very sharply at this frequency.

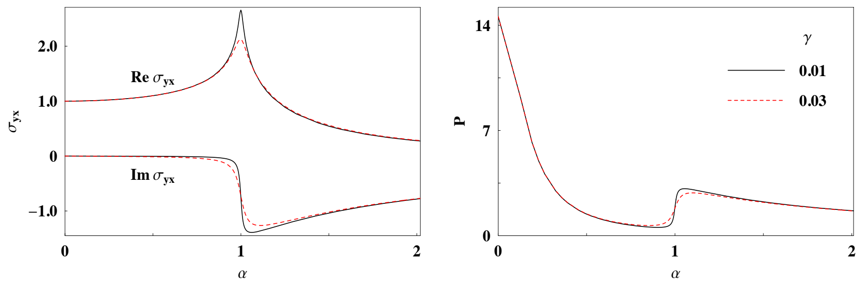

Fig. 1. Left panel. The real (upper) and imaginary (lower) part of $\sigma_{yx}(\omega)$ versus $\alpha = \hbar\omega/2|m_z|$ in units of $e^2/2h$. The solid (dashed) curves are for $\gamma = 0.01$ ($\gamma = 0.03$), $\gamma = \Gamma/2|m_z|$. Notice its dc limit $\sigma_{yx}(0) = e^2/2h$. Right panel. Power spectrum $P(\omega)$ vs α, in units of $E^2 e^2/2h$, for two values of γ with Γ the width of the energy levels, a relaxation time $\tau = 10^{-13}$ s, a Fermi level $E_F = 100$ meV, and $m_z = 0.2E_F$.

1. X.-L. Qi *et al.*, Rev. Mod. Phys. **83**, 1057 (2011).