Electronic properties of the boundary between hexagonal and Lieb lattices

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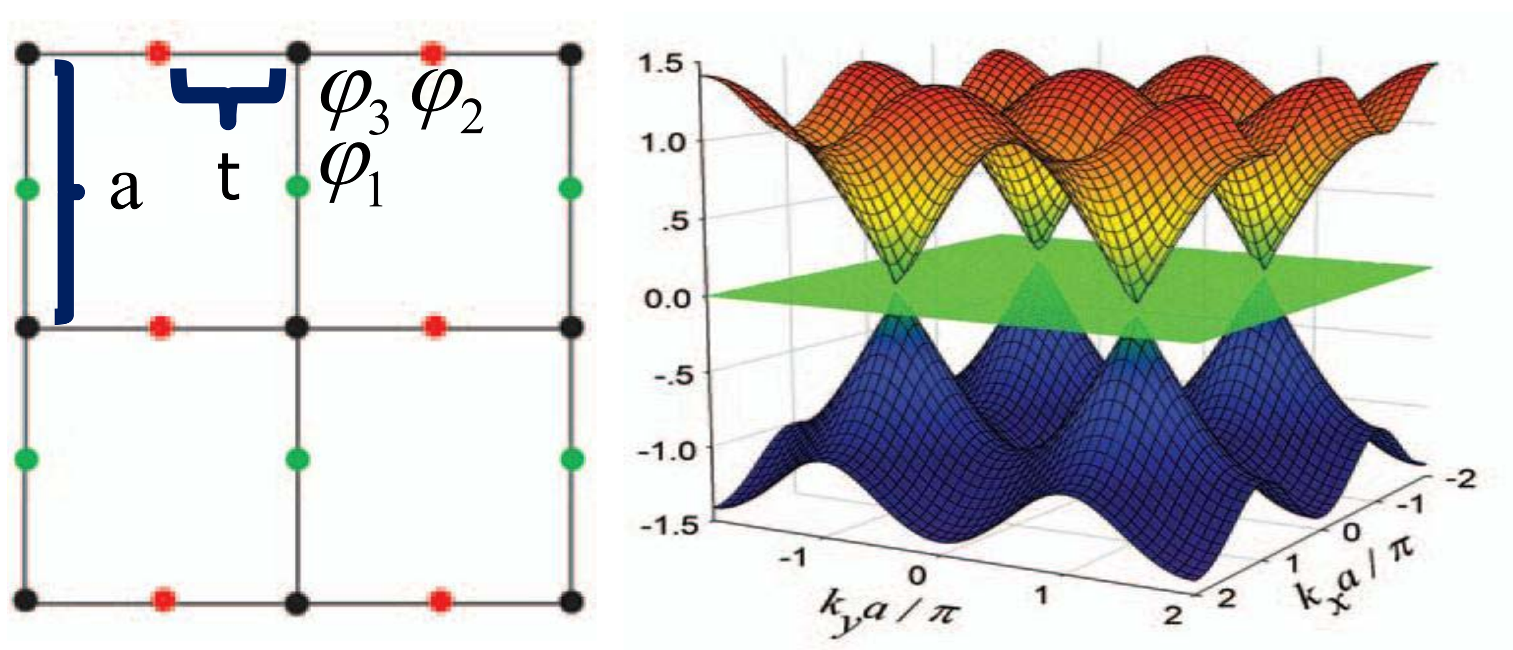
A boundary of two media with different topological order can be characterized by series of properties, the existence of which the existence of which is associated with the difference in the nature of the two materials. The well-known example is the surface conductivity of topological insulators. In the present study, the boundary between a conventional Dirac conductor and a conductor with Dirac cone without Berry phase in the electron energy spectrum is considered. A similar system can be implemented on the boundary between hexagonal and Lieb lattices [1]. The geometry of the problem was chosen based on considerations of maximum similarity of the classical electron energy spectrum of both conductors. As was shown earlier and first presented at the previous conference, in such system specific edge states appear that implement a continuous transition between two types of topological conductors. Despite a number of interesting theoretical properties, this system cannot be considered simple for experimental research. Thus, it is of interest to search for and calculate characteristics that are most convenient for observation, which is the goal of the presented study.



a. b.

Fig.1 Lieb lattice (a) and its electron energy spectrum (b).

Problem formulation.

Let us consider the contact between the Lieb lattice and a graphene-like lattice, as shown in Fig. 2. within the standard nearest neighbor approximation for the electronic energy spectrum

$$E = \sum_{i,j} t_{i,j}\bar{\phi}_i\phi_j, \tag{1}$$

where $t_{i,j} = t_L$ for Lieb lattice, $t_{i,j} = t_G$ for the graphene-like lattice, and $t_{i,j} = t_M$ between atoms of two types, the summation is carried out over all pairs of neighboring atoms, ϕ_i -- amplitude of the probability of finding an electron near a site i. The energy of edge states is considered positive and small enough so that deviations from the linearity of the energy spectrum can be neglected,

$$0 < E << t_{G,L,M}\,. \tag{2}$$

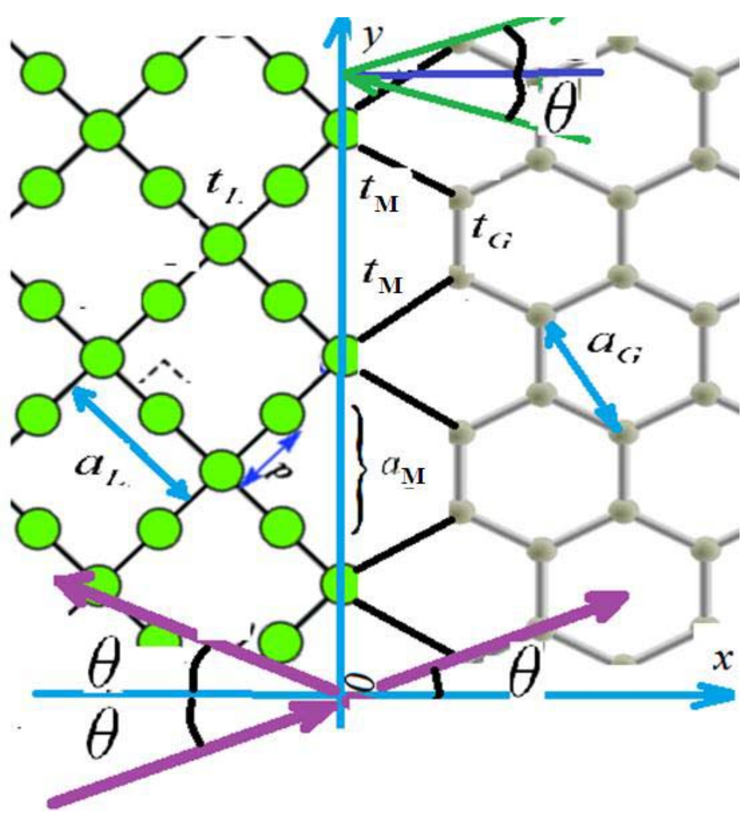


Fig.2 The boundary of two lattices and some of their parameters.

Results: The contribution to magnetization appearing from the orbital magnetism of edge states is obtained. The dependences of the local density of states $\rho(\mathbf{r},E)$ and current density $\mathbf{j}(\mathbf{r},E)$ were calculated numerically. The first is similar to the value considered by the authors in the work [2] for systems of a different nature. The numerical calculation recurrently uses the previously obtained analogue of the area quantization rule and quasi-classical wave functions. These dependencies can be useful in studying edge states using STM. The longitudinal and Hall conductivity also attracted attention. The existence of the latter is guaranteed by an additional twofold degeneracy of the Landau levels in the hexagonal lattice, which is absent in the Lieb lattice and can be considered a natural manifestation of the theorem [3] on the even number of cones in usual Dirac conductors.

The edge contribution to conductivity along the boundary σ_{yy} is shown in Fig.3 for the condition $\Omega\tau >> 1$, where τ is the relaxation time, Ω is cyclotron frequency. The density of states is also shown in the figure, obtained by us earlier, and which determines features of the conductivity.

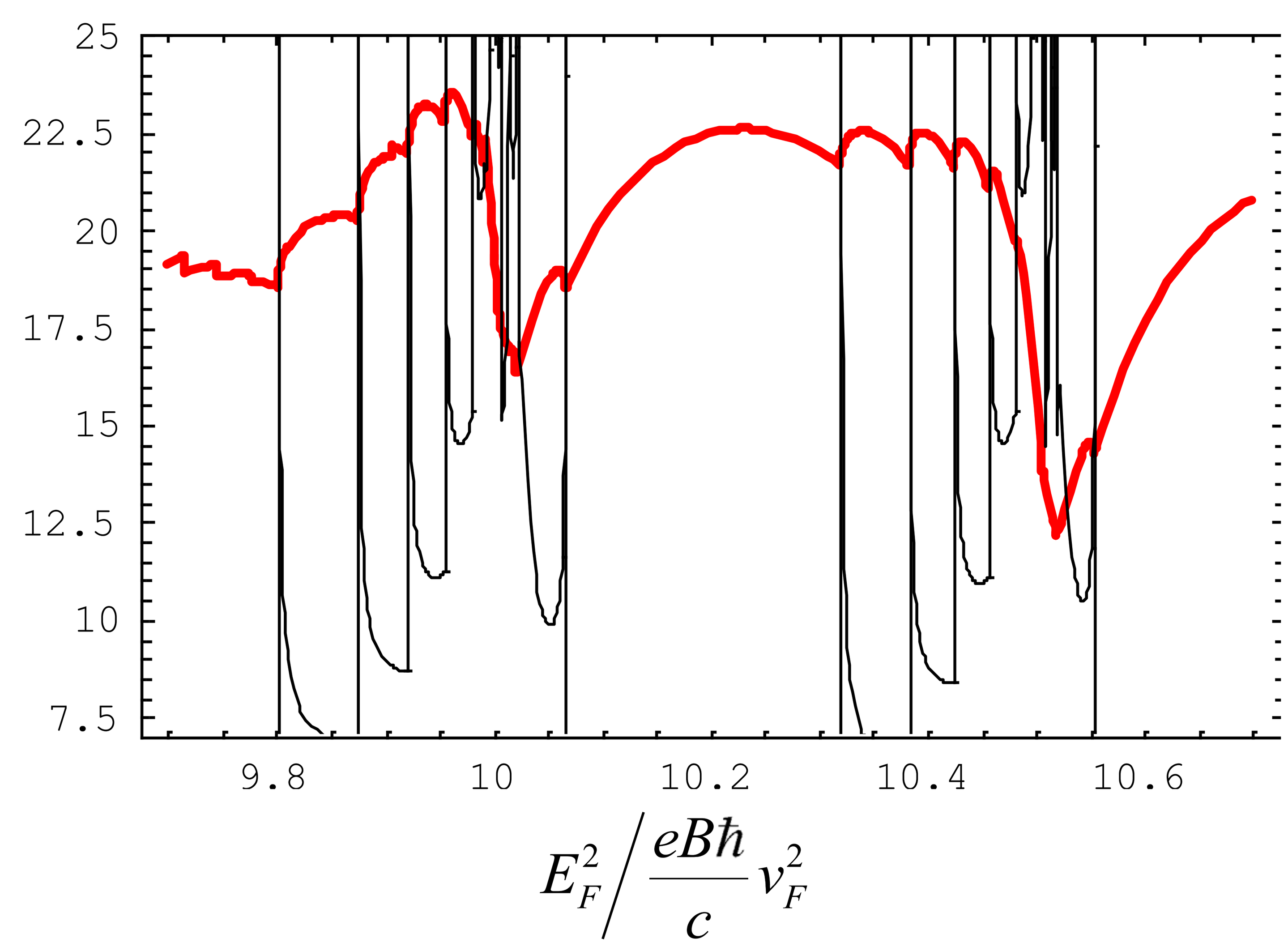


Fig.3 The conductivity along the edge σ_{yy}/σ_0 (red) and the density of states $\nu(E)\times\hbar v_F$.(black)

Oscillating part $\tilde{M}$ of the magnetization appearing from the orbital magnetism of edge states is shown in Fig.4.

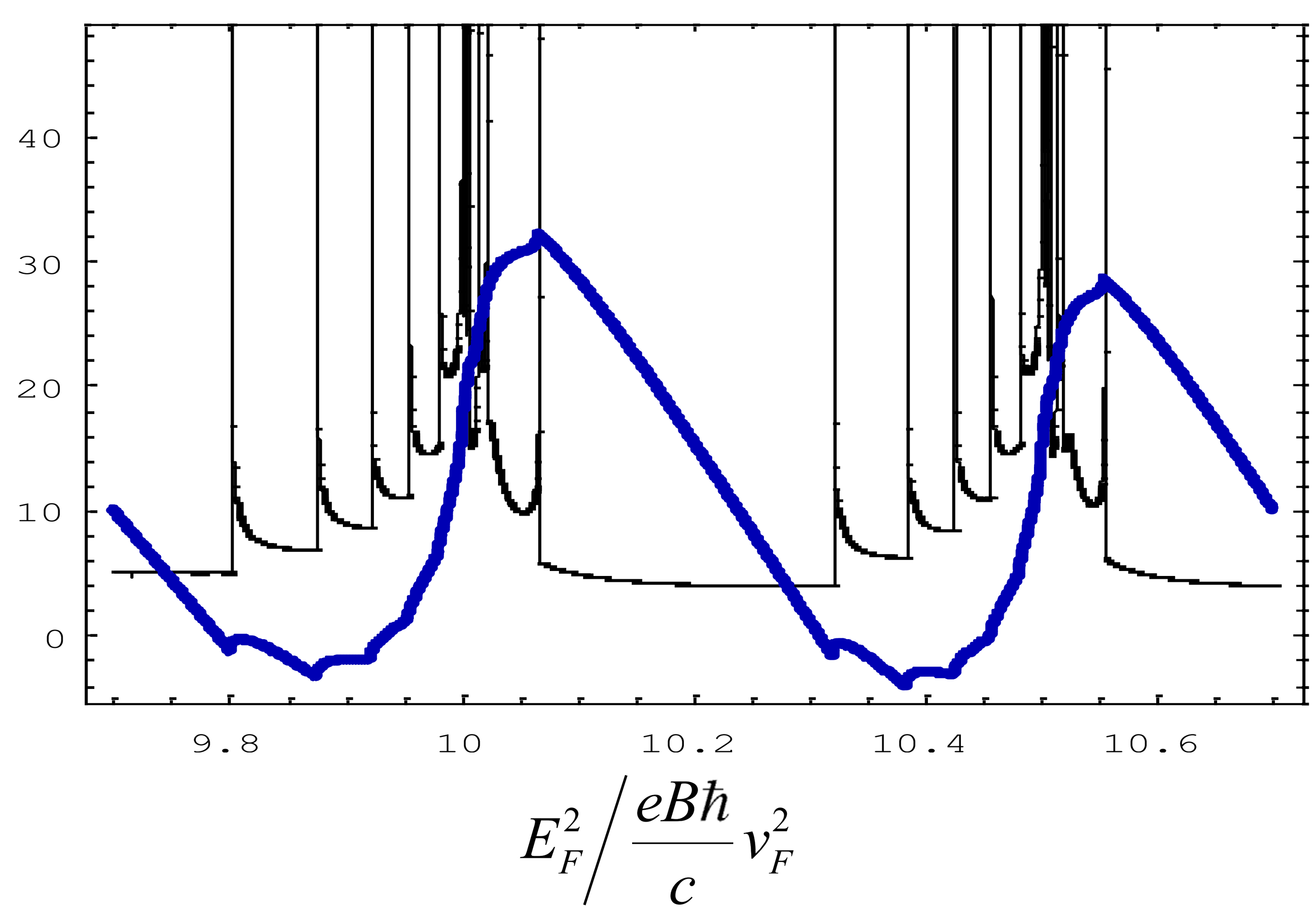


Fig.4 Oscillating part $\tilde{M}$ of the magnetization (blue) with the density of states.(black)

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