Abstract

We theoretically investigate how magnetic and electronic states are affected by modulations of lattice and magnetic structures in spin-charge coupled systems on a geometrically-frustrated lattice. We focus on a magnetically ordered phase with a four-sublattice noncoplanar spin configuration, which was recently discovered in the Kondo lattice model on a triangular lattice near 1/4 filling. This state is a topologically-nontrivial Chern insulator showing a quantized anomalous Hall effect and a chiral edge state because of the scalar chiral ordering. We investigate the self-consistent reconstruction of magnetic and electronic states through the spin-charge coupling near the spatial modulations, such as edges, domains, and vortices. In order to perform the space-resolved analysis of the reconstruction, we adopt an efficient numerical method, the Langevin-based simulation. The method enables us to obtain space-resolved information of large size systems, in particular, the reconstruction process of magnetic and electronic states in terms of the fictitious Langevin time. As a result for the system with open edges, we find that the magnetic and electronic states are substantially reconstructed presumably associated with the peculiar chiral edge states in the Chern insulator. We find that ferromagnetic spin correlations are induced and the scalar chirality is suppressed near the edges. In addition, we find that the persistent chiral edge current is substantially enhanced through the reconstruction. As the Hund's coupling is increased, the persistent current increases for small Hund's coupling but slightly decreases for larger Hund's coupling, while the ferromagnetic spin correlations increase monotonically. We estimate the penetration depth of the spatial modulations after the self-consistent reconstruction, and show that it is inversely proportional to the direct gap in the bulk electronic structure. We also calculate the changes of physical quantities by introducing the electron hopping connecting the edges and by varying it from zero to the bulk value. In the analysis of reconstruction near domain walls, we consider two different configurations: a domain wall between the states with positive and negative scalar chirality and a dislocation in the spin configuration for which the both sides have the same scalar chirality. As a result, we find that the changes of spin correlations, scalar chirality, and charge density are qualitatively the same in the two cases. They are also similar to those in the case of the edges. On the other hand, the current density near the dislocation has a peak at the second sites from the dislocation, while that for the domain wall between different chiralities shows a peak at the next sites to the wall. The latter behavior is similar to that in the case of the edges. Finally, we analyze the reconstruction by introducing a $\mathbb{Z}_2$ vortex in the scalar chirality ordered phase. As a result, we find that the reconstruction is considerably slow compared to the cases of edges and domains. We also find that the charge density is enhanced, while the scalar chirality and the Eddy current are suppressed near the vortex core through the reconstruction.