Aalto University

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Superconductivity in lattice models

Title of the dissertation	Superconductivity in geometrically and topologically nontrivial lattice models Suprajohtavuus geometrisesti ja topologisesti epätriviaaleissa hilamalleissa
Contents of the dissertation	Superconductivity describes the phenomenon in which the transport of electric current becomes dissipationless when the material is cooled below the critical transition temperature. A great challenge therefore is how superconductivity could be realized at room temperature. To achieve such a goal, the thorough understanding of the physical phenomena behind the superconductivity is required. In this thesis, superconductivity was theoretically studied in two-dimensional Hubbard lattice models. While real condensed matter systems are too complicated to tackle with theoretical tools, the Hubbard model is one of the simplest quantum many-body models to feature a wide spectrum of physically relevant phenomena, from superconductivity to magnetism and topological order. Hubbard models are also interesting as they can be experimentally realized by utilizing ultracold atomic or molecular gases. In the thesis, results concerning for example lattice models featuring so-called flat Bloch bands are presented. In such flat band systems the density of states is high which enhances the formation of superconducting phases. Superconductivity of flat bands, however, is partially a counterintuitive phenomenon as the effective mass of the electrons can be infinite. Thus, it is not entirely clear whether a finite electric current can exist. In the thesis, it is shown that superconductivity of flat band systems follows from the geometric properties of the Bloch quantum states. Furthermore, it is also shown that exotic Fulde-Ferrell (FF) superfluid states can be stabilized with spin-orbit coupling and that topological FF states can be found at finite temperature. The results of the thesis provide new insight related to the understanding of superconductivity in general and may be relevant at developing high-temperature superconductors.
Field of the dissertation	Engineering physics, Quantum physics
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