Summary of thesis:
Nonequilibrium phenomena and dynamical controls in strongly correlated quantum systems driven by AC and DC electric fields

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In recent years, various interesting nonequilibrium phenomena are observed in solids and gathering great attention. For example, it has been reported that applying strong laser fields induces transient superconductivity above the equilibrium critical temperature. Topological states of matter can also be changed with laser light. This has been theoretically proposed and already experimentally observed. It has been revealed that not only the laser light (AC field), but also the DC-field induces quite interesting phenomena recently. For instance, it has been reported that DC electric field induces a finite current in Mott insulators, giving rise to very strong diamagnetism in the nonequilibrium steady states. Furthermore, based on the study of these nonequilibrium phenomena, the possibility of controlling states of matter with nonequilibrium phenomena has also been investigated. It is expected that some important controls which are impossible or difficult in equilibrium become available in nonequilibrium. In fact, a control using periodic driving with external fields is called "Floquet engineering" and this has been established as one of the useful experimental techniques to realize desired quantum states in the field of cold atomic systems. As shown above, nonequilibrium phenomena and controls with them in condensed matter systems are forming a rapidly growing research field in recent years.

On the other hand, theoretical understanding of these nonequilibrium phenomena still has been a challenging problem. In particular, nonequilibrium phenomena in strongly correlated systems are difficult to treat theoretically and proposing nonequilibrium control in strongly correlated systems is more tough problem because we have to treat the effect of interaction and nonequilibrium dynamics at the same time. However, various interesting and exotic phases of matter (e.g. unconventional superconductivity and quantum spin liquid) mostly appear in strongly correlated materials and thus it is an important task to investigate strongly correlated systems.

Motivated by this situation, we have studied the nonequilibrium phenomena in strongly correlated systems and proposed possible schemes to control the states of matter using nonequilibrium phenomena. In this thesis, we present our recent studies in this direction. Brief summaries of these studies are shown below.

(i) *Laser-induced topological superconductivity in d-wave superconductors*

Topological superconductivity (TSC) has attracted much attention because it can host Majorana fermions that are expected to be applied to quantum computation. However, the experimental realization of TSC has been very limited and highly desired. In this study, we proposed a possible scheme to realize TSC in laser-irradiated *d*-wave superconductors such as cuprate superconductors. Our calculation based on Floquet theory revealed that the laser-induced effective Zeeman-field plays an important role in realizing TSC.

(ii) *Control of Kondo effect and topological phases in heavy fermion systems with AC electric fields*
In heavy fermion systems, interplay between Kondo effect and RKKY interaction plays an important role and realizes various quantum phase transitions. In this study, we investigated how this interplay is affected by the application of laser fields and how we can control the quantum phase transitions. We found that either enhancement or suppression of Kondo effect occurs depending on crystalline structures and systematically studied the effect on the phases of matter including topological phases (e.g. topological Kondo insulators).

(iii) *Control of insulating magnets with DC electric fields or terahertz laser fields*
In this study, we considered the application of DC electric fields or slow AC fields (such as terahertz fields) to insulating magnets and investigated how the exchange interaction is modified with electric fields. We found that the coupling in the direction of electric fields is enhanced and this is very useful to control the anisotropy of magnetic interactions. Based on this idea, we proposed exotic phases of matter induced by electric fields, e.g. electric-field-induced quantum spin liquids and electric-field-induced topological phases.