Report on MERIT Long-term Overseas Dispatch

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1. Abstract

I visited Prof. Dr. Martin Eckstein's group in Max Planck Institute for the Structure and Dynamics of Matter (MPSD) during my stay in Hamburg, Germany from January 13th to March 3rd. I report the background of the research, the research contents and life during this dispatch as described below.

2. Research Background

Realizing a superconductivity at room temperature is one of dreams in condensed matter physics. To date, the highest superconducting critical temperature T_c at ambient pressure has been recorded in copper oxide superconductors around 130K. Despite tremendous experimental efforts, however, it has essentially remained unchanged for decades. Recently, superconducting properties such as gap formations above room temperatures have been reported in copper oxides by selectively exciting vibrational phonon modes by light. These studies have shed a new light on the realization of room-temperature superconductivity by utilizing nonequilibrium.

Recently, we numerically show an alternative possibility of enhancement of superconductivity by irradiating strong laser to correlated electron systems which are not restricted to the details of phonon modes. To achieve this study, we use the time-dependent variational Monte Carlo method for strongly correlated electron systems which has been recently developed. This method enables us to treat quantum and spatial correlations at zero temperature accurately and efficiently, it is still an open problem to treat nonequilibrium dynamics at finite temperature. Thus, although our calculations showed that superconductivity can be enhanced at zero temperature, we do not show whether the critical temperature becomes higher directly.

3. Research contents

Prof. Dr. Eckstein is an expert of nonequilibrium dynamics in correlated electron systems and numerical methods for such systems such as dynamical mean field theory (DMFT). Although it is an open problem to include spatial correlation accurately in DMFT, this method is a powerful numerical method by which we can treat nonequilibrium

dynamics in correlated systems at finite temperature.

During the dispatch, I studied the algorithms of nonequlibrium DMFT and its extensions. After that, since the spatial correlation plays an important role to emerge superconductivity in two-dimensional correlated electron systems, I implemented the code of dynamical cluster approximation (DCA) which is one of the extended methods of DMFT to include spatial correlations. I succeeded in developing the DCA code for normal states based on weak coupling expansion technique. Now I'm trying to extend my code to treat superconducting state.

4. Life during my stay

Hamburg, which is located in the north part of Germany, is a harbor city which has the second largest population in Germany. In every Sunday's morning, the fish market is held at the harbor and we can buy not only fishes but also cheese, fruits and so on at a discount. Hamburg also has several famous sightseeing spots such as Speicherstadt (Red brick warehouse) with more than a 100 year history which is classified as a World Heritage Site.

MPSD where I stayed is located away from the central area in Hamburg. Since there are few restaurants near MPSD, I needed to buy some foods in a supermarket and make dinner by myself. I note that some store clerks cannot speak English. So I felt that it is important to study words for dairy life in local language to communicate with local people.

MPSD is one of the most famous research centers on nonequilibrium dynamics in correlated electron systems both experimentally and theoretically in the world. Thus, several famous professors and researchers from across the world visit there and present seminars. Under such circumstance, I had many opportunities to discuss my research with several people such as professors, researchers and students at University of Hamburg.

5. Acknowledgements

I would like to deeply appreciate Prof. Dr. Martin Eckstein and his group members giving not only their academic advices but also their kind support for my stay in Hamburg. I would also like to thank my supervisor, Prof. Masatoshi Imada, for his cooperation to determine the host and his advice to the research. Finally, I would like to express my sincere gratitude to MERIT and my vice supervisor, Prof. Kaoru Kimura, for the supports of this dispatch.