

MERIT Long-term Overseas Dispatch Report

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Materials composed of individual constituents that consume energy and thus operate far from equilibrium, such as collective swimming bacteria, pedestrian flows, and traffic flows, are referred to as active matter. In active matter systems, a wide range of phenomena—such as ordering and pattern formation arising from the nonequilibrium nature of the constituents—have been reported, and active research has been conducted mainly in the fields of nonequilibrium statistical mechanics, soft matter physics, and biophysics. In recent years, attempts have also been made to control the ordered states of active matter by modulating the surrounding environment. If the effects of the environment on collective motion can be clarified, it is expected that guidelines for controlling them can be obtained. In this training program, I studied control techniques for active colloidal systems and investigated the responses of both the individual particle motion and collective motion to temporally modulated environments.

Research Activities and Outcomes

This training was carried out through a research stay in the laboratory of Professor Wei Wang, who conducts research on active colloidal systems using a variety of driving and control mechanisms. During the stay, I intensively learned driving methods and control techniques for active colloidal systems. In the first few weeks, I studied representative driving mechanisms for active colloids, including ICEP Janus systems, Quincke roller systems, H₂O₂-driven systems, and photo-activated systems. In parallel, I acquired experimental techniques for controlling particle motility, direction of motion, and interactions using magnetic fields, optical patterns, and ultrasound. Subsequently, I conducted research activities based on the experimental techniques acquired during this period.

In the following days, I carried out experiments to explore the environmental response of active colloidal systems using magnetic fields. The host laboratory was equipped with a magnetic field generation system in which three orthogonal coils could be controlled independently; however, there was no existing system that allowed simultaneous acquisition and integration of the applied magnetic field conditions and microscope camera images. To address this issue, I investigated a method in which LEDs were activated based on the coil current information, thereby visualizing the magnetic field information within the camera's field of view, and constructed an experimental system capable of simultaneously acquiring both types of information. Although the construction of the experimental setup did not proceed as smoothly as initially expected and required considerable trial and error, it ultimately became possible to extract both collective motion information and oscillating magnetic field information from the same image data.

Using this experimental system, magnetic fields were applied to active colloids, and the responses of individual particles and collective behavior to external fields were observed. For the active colloidal system used in this study, several hypotheses regarding the mechanism of magnetic-field response have been proposed in previous studies. To examine these hypotheses, I conducted observations of individual particle motion using dilute suspensions. I then investigated collective motion using concentrated suspensions. As a result, I found that the spatiotemporal structures of the collective motion changed depending on the conditions of the applied magnetic field. Analysis of the data obtained is ongoing, with the aim of compiling the results into a scientific paper.

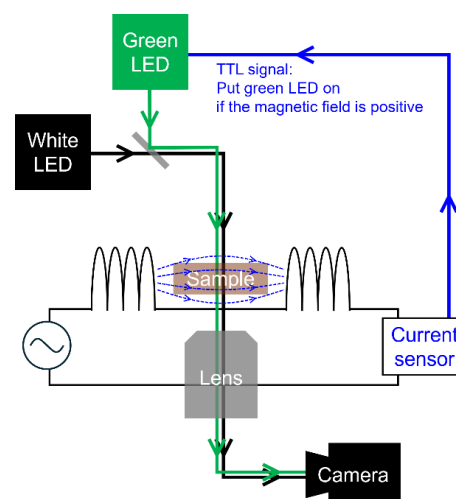


Figure 1: Experimental setup constructed for this study to monitor the applied magnetic field using an LED.

Life and experiences during the stay

Regarding daily life during the stay, although international circumstances were often reported as tense, the members of the host laboratory treated me kindly throughout my stay, providing an environment in which I could concentrate on research. The area around the university was safe, and I was able to walk outside at night without concern. Dining options were abundant, with relatively low-cost and high-quality meals, so I mainly ate out. I frequently shared meals with laboratory members at the university cafeteria and nearby shopping areas, which provided regular opportunities for informal interactions (Figure 2). During my stay, I also had the opportunity to discuss active colloidal systems. Every week, I discussed the experimental results with Professor Wei Wang. In addition, I discussed the mechanism of the phenomenon we observed in our experiments, the significance of our study, and related topics with the laboratory members. For daily necessities and experimental components, the convenience of online payment services and e-commerce platforms in China was extremely high, and these were actively used for both daily life and research activities. For example, electronic components were available in a wide variety at low-cost, which was highly beneficial for constructing experimental setups. On some weekends, I also had the opportunity to go out with laboratory members and enjoy the environment around the institute. Toward the end of my stay, we visited Shantou City. There, we enjoyed coastal scenery and seafood, as well as karaoke, movie nights, and home-style cooking using ingredients purchased at local markets. These experiences provided opportunities to see different aspects of the laboratory members beyond the research setting. Through both research activities and daily life experiences, this training program provided many valuable insights and experiences, and overall, it was a highly meaningful and productive stay.



Figure 2: Meals I ate with the members of laboratory during the stay

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