（別紙様式５）

変革を駆動する先端物理・数学プログラム（FoPM）
国外連携機関長期研修　報告書

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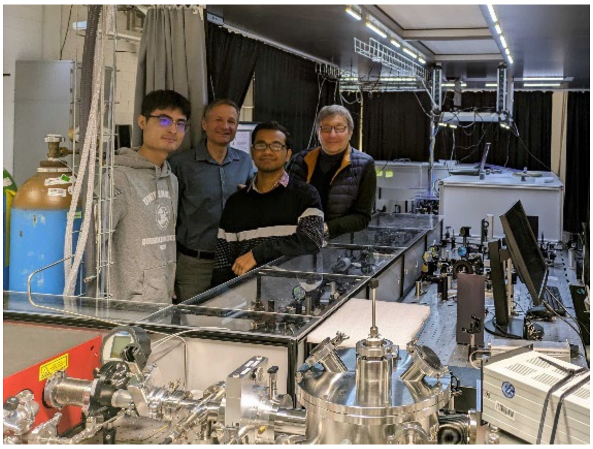
The Duisburg-Essen University, where I stayed for about two months, is one of the youngest universities in Germany, founded in 2003. The campus I visited is located near the center of Duisburg, a city on the west side of Germany. It is a ten-minute train ride to Dusseldorf, one hour to Cologne, and three hours to Amsterdam (Netherlands), making it an attractive place with excellent access to many cities. Taking advantage of its great location along the Rhine and Ruhr Rivers, it has also been developed as the city with the country's largest inland port. The coal mined there historically made Duisburg an important industrial city for a long time. Many foreigners live and work there, for these reasons, making it a very international city.



I joined Prof. Dr. Uwe Bovensiepen's group and participated in the light source development for a table-top soft X-ray laser, a type of light with very high energy or very short wavelength, used for X-ray images and CT in the medical field, for instance. A lot of scientists aim to confine X-rays into a femtosecond (a thousand trillionth of a second) time scale. That is called a soft X-ray pulse laser, and utilizing this light makes it possible to precisely capture the motion of atoms and electrons. This innovative technology has already been realized at an ultra-large facility called an X-ray Free Electron Laser (XEFL), of which only four are worldwide. However, as you can easily imagine, the FEL facilities are pretty expensive, and it is almost unrealistic for every scientist to utilize them. Therefore, more realistically both types of sources will complement each other.

The most significant challenge to soft X-ray pulse lasers at laboratory-scale is the high-power light sources for them. Unlike FEL, which generates X-rays directly from high-energy electrons, soft X-rays from table-top laser sources are generated by shortening the wavelength of infrared light. Interestingly, before soft X-ray generation, it is necessary to stretch the wavelength of infrared to mid-infrared by employing OPCPA, one of the critical techniques for optical amplification and wavelength conversion. Generated mid-infrared will be focused on the noble gas to get the soft X-ray pulse. These complicated wavelength conversion steps lose a lot of power, meaning we require a high-power laser source. Recent advances in laser technology have made it possible to create high-power lasers that meet the requirements for X-ray generation. However, sophisticated knowledge and experience are still needed to handle them. I spent most of my time at the lab tuning such laser sources for X-ray generation. They are quite a unique and complex system, and their adjustments could not be completed during the stay. The laser system has many difficulties at each step of adjustments, which require continuous team discussions to resolve them. Every Friday, the team held a discussion that included the professor and decided on a detailed plan for the next week.

At the very beginning of the high-power laser system, the Ti: sapphire oscillator generates ultrashort pulses of less than ten femtoseconds. We evaluated the pulse duration from the oscillator using the interferometric technique called SPIDER. We found that the spectra expand/shrink depending on the dispersion in the oscillator, and broader spectra provide us with a shorter pulse duration. Next, a stretcher made of special grating stretches the pulses from picosecond to nanosecond. After that, the regenerate amplifier increases pulse intensity. Each optics is sensitive to the alignment, and getting the perfect one takes much longer than expected. Throughout their adjustment, I gained a lot of “experimental knowledge” about the techniques necessary for high-power laser sources. The OPCPA system can be applied to our laboratory equipment at ISSP, the University of Tokyo.

During the stay, I had the precious opportunity to visit and give seminars at Prof. Dr. Ulrich Höfer (Murburg University) and Prof. Dr. Donath (Münster University). Prof. Höfer performs pump-probe experiments using various lights, from terahertz to visible and ultraviolet light. Prof. Donath mainly works on the spin states of electrons. The ideas for experimental techniques and physical phenomena discussed there will enrich my future projects.

Immersing myself in the different cultures was also a valuable experience for me. The lab members come from all over the world, and we enjoyed talking about their countries' cultures, including religion, food, festivals, etc., during coffee breaks. I rented rooms in the hosts’ apartment and lived with them. My hosts made me homemade German and Asian food. Going to restaurants with my hosts and their friends and listening to their stories about the lifestyle in Germany was very helpful in understanding how life in Germany seems to be. At the weekend, I visited many places such as Köln, Aachen, Essen, etc. In their city centers, there are a lot of adorable and colorful buildings along the street paved with rocks. The Gothic churches ring their bells in the mornings and evenings, whose holy sound can be heard everywhere in the town. The restaurants have large terraces, and people enjoy beer and pizza outside. I felt as if I had entered the world of fairy tales.

I could have a great time in Germany thanks to the support of many people, including my lab colleagues, professors, hosts, and their friends. It was a great learning experience for me not only to learn state-of-the-art equipment but also to get used to living abroad. These experiences will enrich my life in Japan.