Report on MERIT long-term overseas dispatch

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Abstract

I stayed at the University of Twente in Enschede, the Netherlands, from 5th January to 15th March 2016, and studied as a group member of the Complex Photonic Systems (COPS) chair under the direction of Prof. Willem L. Vos.

Previous work at the laboratory I visited

Three-dimensional photonic crystals (3D PCs), which have a three-dimensional periodicity in their reflective index, have energy gaps for photons. The energy gap is called photonic band gap (PBG). Photons with any polarization and wave vector are prohibited to propagate in the PBG, thus, 3D PCs function as insulators for photons within wavelength ranges of their PBGs. Crystal defects in 3D PCs can make new photonic states, which are strongly localized around the defects, and enable to integrate photonic circuit components, such as photonic waveguides or cavities in 3D PC structures. However, large scale integration of optical components in 3D PCs has not been realized at optical communication wavelength due to technological difficulties. In the laboratory I visited, 3D PCs with PBGs at optical communication wavelengths had been successfully fabricated on Si wafers by using a deep etching technique. Periodically arranged deep pores of 10 μm depths are etched from both top and side surfaces of a Si wafer sequentially by using this technique. Although the two periodic patterns on the top and the side need to be carefully aligned in this method, they have recently been developing a new technique in which etch masks for the two patterns are formed simultaneously, thus the alignment for the two patterns are no longer needed. Also, how to introduce cavities inside the 3D PC has been investigated using this technique.

Researches and results during my stay

The research objective for my stay is to optically characterize 3D PC cavities fabricated by the new technique where the alignment of the two patterns on the top and the side of a Si wafer is not needed. An optical set up, which had already been built before my visit, was used and the 3D PC cavities were characterized on the basis of reflection spectra measured using the optical set up. Theoretically, reflectivities for the 3D PC are expected to be high within its PBG due to an optical property as a photonic insulator, and the cavities in the 3D PC would be observed as dips in the high reflectivity range due to resonance effects of the cavities. However, while an increase in the reflectivity was actually measured from a 3D PC sample only within the wavelengths range of its PBG which was

estimated by a calculation, the increased reflectivity is low and comparable to that for just a Si bulk. Also, noises in the reflectivity spectra were also an obstacle to recognize the dips originating in the cavity resonances, thus how to suppress the noise would be another problem to be solved for showing the existence of cavity resonances.

I firstly worked to solve the above-mentioned problems with Ms. Grishina and Mr. Hofste, who are 2nd year Ph.D. and 2nd year Master students respectively, under the direction of Prof. Vos. We found the noise can be improved by modifying the optical set up, following the advices by Dr. Emre. However, the reflectivity measured from the 3D PCs still remained low. The reason could be considered in the sample itself. For getting a clear conclusion, I plan to fabricate reference samples in the University of Tokyo and ask them to measure the samples.

For characterizing the 3D PC cavities, we tried to measure polarization dependences of the reflection spectra. If there is no degeneracy, a cavity mode usually has a linear polarization, while a PBG of a 3D PC will show no polarization dependence because a 3D PC has a PBG with no photonic states. Actually, we observed some dips which have polarization dependences in their PBG ranges. I will discuss the result further with Prof. Vos and the students in COPS group.

Daily life in the Netherlands

The University of Twente is located in the small city “Enschede” which is near the border between the Netherlands and Germany. The place is a country side, so the campus has a very large area and we can rent our houses on campus at a relatively low price. Also, many stores which we will need in our daily lives such as supermarkets or barbershops also exist inside the campus. Bicycles are used by many people for traveling around the city there, so I also rent my bicycle soon after the arrival, which was recommended by Prof. Vos.

My study was basically going on the basis of discussions and experiments with Ms. Grishina. We have a meeting every week where all the COPS members attend, and we briefly presented and discussed our research progresses and our research plans. I also have a personal appointment every two weeks with Prof. Vos where we discussed experimental data and the research progresses in more detail than what I did in the COPS meetings. For modifying or repairing the experimental set up, Dr. Emre, Mr. Harteveld, Mr. Hofste or other members were willing to help me. Also, COPS members gathered and spent coffee times in every morning and every early evening and also lunch time around noon. I could ask everything there, namely questions on my daily life and on my research. For my daily life, the secretaries in the COPS group, in particular Ms. Timmer, helped me very well. People in the Netherlands speak English very fluently. So, it was not an easy task for me to understand what they were saying. It often happened that I couldn’t understand what they discussed at meetings, but they were so kind that they told me again in understandable ways whenever it happened, which has helped me to get used to discussions in English. Compared to Japan, I felt like

we can have more chances of communicating with each other, which works very well to share problems in researches and stimulates discussions between lab members.

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