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Reflection Characteristics of Coupled Defect Waveguides in Photonic Crystals

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1. Introduction

The past few years have witnessed growing interest in the use of photonic crystals as a new artificial material that can be used to control light waves [1]. In photonic crystals, defect states play a central role in managing the propagation of the light waves. By using such defects, we can construct a coupled defect waveguide (CDW), where light can be transmitted along a series of defects due to an overlap of the field between the nearest-neighbor defects [2-4]. The CDWs show unique features; small group velocity, controllable large dispersion and sharp bend of light propagation. Thus, CDWs are potentially applied to various optical devices.

In particular, we have been studying group-velocity and dispersion relations of CDWs from the viewpoint of the application to dispersion compensators used for optical communication systems [4]. Here, we report experimental and calculated results of the reflection characteristics of CDW in comparing its transmission characteristics.

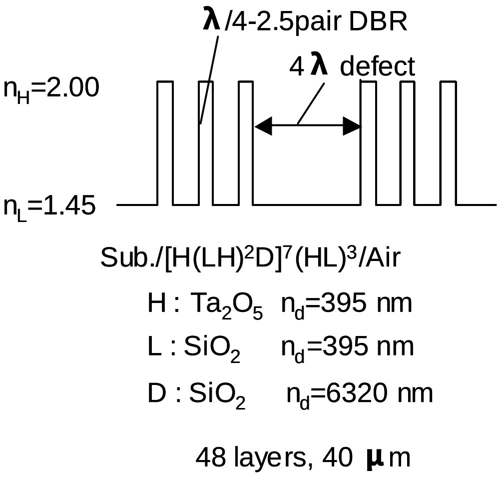

Fig.1 Photonic crystal structure.

2. Sample structure and experimental procedure

The photonic crystal used in the experiment is shown in Fig. 1. Thus, it is basically an one-dimensional structure. The Ta_2O_5/SiO_2 pairs form a $\lambda/4$-DBR (Distributed Bragg Reflector) mirror and 4λ SiO_2 defects are inserted in them at the distance of 2.5 pair of Ta_2O_5/SiO_2. Seven defects are formed and total number of the layers is 48. Light reflection characteristics are measured with the sample shown in Fig. 2. A gold mirror is simply attached on the surface of the stacked film layers. The light beam is inserted from the transparent substrate side and the reflected light is collected from the same side. The delay time of the reflected light is measured by the phase shift method [5] with a 3-GHz intensity modulation.

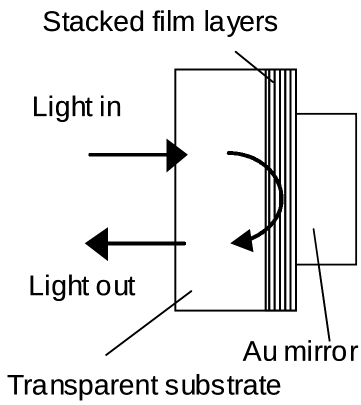

Fig.2 Measured sample structure.

3. Results and discussion

At first, we measured the light reflectance spectrum of the above sample, as shown in Fig. 3. We also show, for comparison, the light transmission spectrum of the same sample after removing an attached Au mirror. The transmission spectrum clearly shows steep peaks corresponding to discrete defect states. Seven peaks are obtained corresponding to 7 defects. However, the light transmittance is considerably low in the wavelength region between the peaks because of the lack of the existing states.

In contrast, we obtained high reflectance over the wide wavelength region using the sample with an Au mirror. This means that the incident light retains its intensity even after reflection. This is due to the fact that the incident light is finally reflected by the Au mirror with high reflectance and inevitably goes back to the incident side.

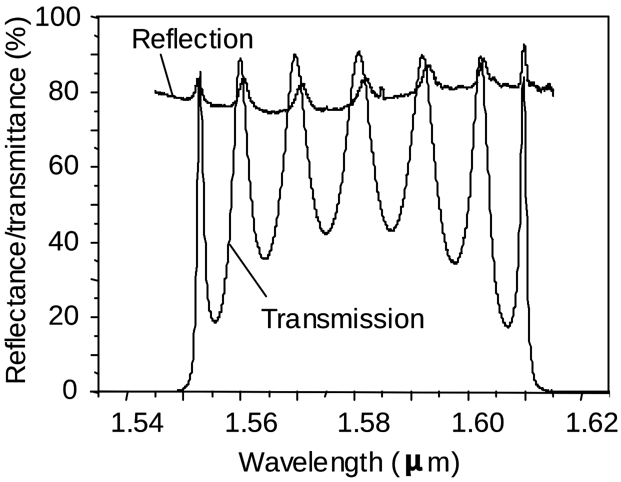

Fig. 3 Measured reflectance and transmittance spectra of the coupled defect waveguide.

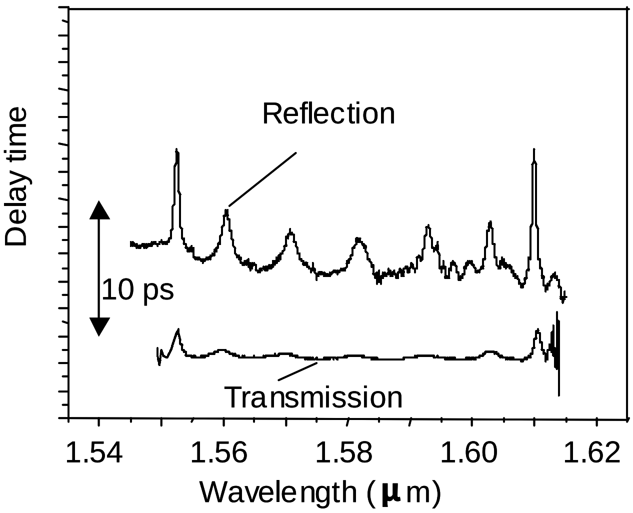

Fig. 4 Measured delay time spectra of the coupled defect waveguide.

The delay time of the reflected light is shown in Fig. 4, together with the result of the light transmitted along the sample without an Au mirror. Seven peaks of the delay time are again obtained corresponding to 7 defects. It should be noted that the delay of each peak in the reflected light is considerably larger than the corresponding delay in the transmitted light. The difference is more than 4 times even though the physical path length of the reflected light is only twice as large as the one of the transmitted light. This experimental result is supported by the calculation based on the transfer matrix method, as shown in Fig. 5. In the calculation, the same behavior as the experiment on the delay time is obtained.

This unexpected large delay time of the reflected light can be interpreted as follows. The time delay of the traveling light along the sequence of the defects depends on the distance of the neighboring defects or, in other words, the coupling of the fields of the light existing in the defects. In the reflection measurement, the distance between the last defect where the light transmit before reflection and first defect after reflection substantially becomes twice as large as the distance of the defects within the crystal itself. This leads to the decrease of the field coupling. Therefore, this configuration has an effect to enhance the delay time of each peak in the spectrum. Thus, the large delay time is resulted from the coherent coupling of the two photonic crystals through the mirror reflection.

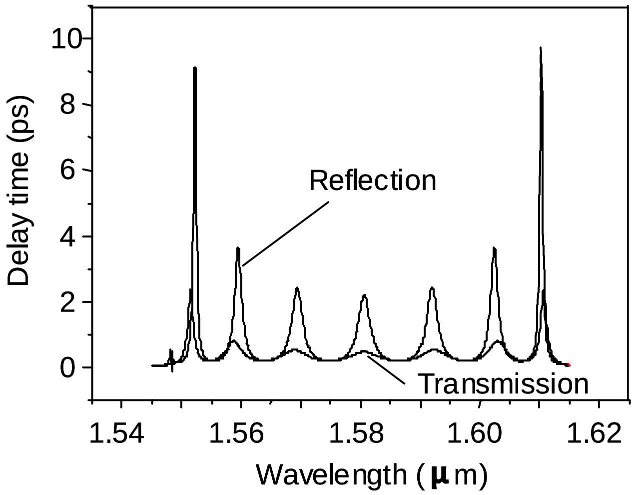

Fig. 5 Calculated delay time spectra of the coupled defect waveguide.

4. Summary

In the reflection measurement, a coupled defect waveguide (CDW) with an Au mirror has a high reflectance over a wide wavelength region. Unexpected large delay time is obtained due to the reduction of the field coupling through mirror reflection. These characteristics are advantageous in the device application of the CDW photonic crystal.

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References

[1] E. Yablonovitch, Phys. Rev. Lett. 58, 2059 (1987)

[2] A. Yariv, Y. Xu, R. K. Lee and A. Schere, Opt. Lett. 24, 711 (1999)

[3] M. Bayindir, B. Temelkuran and E. Ozbay, Phys. Rev. Lett. 84, 2140 (2000)

[4] K. Hosomi and T. Katsuyama, IEEE J. Quantum Electron. 38, 825 (2002)

[5] S. Ryu, Y. Horiuchi and K. Mochizuki, J. Lightwave Technol. 7, 1177 (1989)