Design of a doubly-resonant SiC photonic crystal nanocavity

Kyoto Univ. [1], Sungkyunkwan Univ. [2], °H. Kim[1(Visiting student),2], T. Asano[1], B.-S. Song[1,2], and S. Noda[1]

E-mail: hjoon518@skku.edu, tasano@qoe.kuee.kyoto-u.ac.jp, songwiz@skku.edu

SiC based photonic crystal (PC) nanocavities have great potential for enhancing various nonlinear optical effects because of their small mode volumes, high quality (Q) factors, and transparency from visible to infrared wavelengths. Recently, a large second-harmonic generation (SHG) efficiency of 1900%/W has been experimentally achieved using a single high-Q resonant mode in a SiC PC nanocavity[1]. A doubly resonant SiC nanocavity, which has a high-Q fundamental mode and another mode with twice the frequency of the fundamental mode, has the potential to enhance the SHG efficiency. We propose a design of one such doubly-resonant SiC PC nanocavity based on one-dimensional (1D) PCs.

To obtain a doubly-resonant PC nanocavity for SHG, photonic bandgaps for the fundamental and second harmonic frequencies are required. Therefore, we utilized 1D PCs because the control of photonic bandgaps is easier compared to two- or three-dimensional PCs. Fig. 1 shows a schematic of the nanocavity we investigated, which is formed by modulating the lattice constants in four steps ($a_1 = a$, $a_2 = 1.0046a$, $a_3 = 1.0093a$, $a_4 = 1.0139a$, $a_5 = 1.0185a$), where the base structure is a 1D PC nanobeam with a radius (r) of 0.29a, width (w) of 1.8a, and thickness (t) of 2.8a. Fig. 2 shows the resonant spectra of the nanocavity at a round the fundamental resonant frequency (f_1) and 2f_1. We can see that the fundamental mode exists at f_1 = 0.2395 [c/a] and the higher-order mode exists at f_2 = 0.4728 [c/a], where f_2 is slightly lower than 2f_1. The frequency matching between f_2 and 2f_1 can be obtained by adjusting t, for example, as shown in Fig. 3, because of the different rates of change of f_1 and f_2 with respect to t. At the matching condition ($t \approx 2.72a$), we estimated the SHG efficiency by calculating the Q factors (Q_1, Q_2) and nonlinear field overlap (β) of the two modes. We obtained $Q_1 = 1.2\times10^7$, $Q_2 = 2.1\times10^3$, and β = 7.1 [$J^{-1/2}$]. The SHG efficiency is estimated to be 2.4×10^4 [%/W] from these parameters, which is much higher than the previous result[1]. Details will be presented at the conference.

Ref: 1) H. Kim, et. al, The 80Th JSAP Spring Meeting, 12a-W631-4 (2019).

Acknowledgement: This work was supported by JSPS KAKENHI (19H02629), and the National Research Foundation of Korea (2017R1A2B4003374) grant funded by the Ministry of Science and ICT.

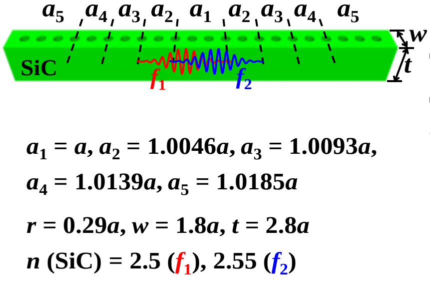

Fig. 1: Schematic of a doubly-resonant SiC nanocavity based on a 1D photonic crystal nanobeam.

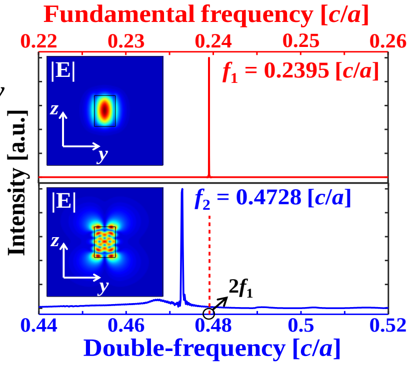

Fig. 2: Resonant spectra of the fundamental mode (f_1, red line) and higher-order (f_2, blue line) mode near 2f_1

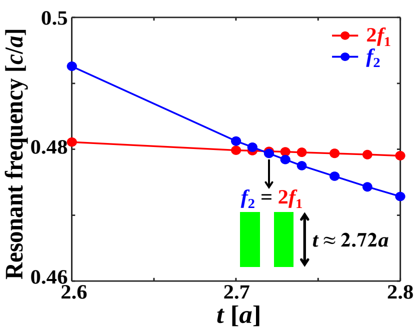

Fig. 3: Dependence of the fundamental (red) and higher-order (blue) frequencies on the nanobeam thickness.