7700%/W second-harmonic generation efficiency in ultrahigh-Q SiC photonic crystal nanocavities

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Second-harmonic generation (SHG), which is one of the most representative nonlinear optical phenomena, has attracted significant interest owing to its wide range of applications such as quantum frequency conversion, visible laser sources, and molecular imaging. Compared to SHG in bulk materials, photonic crystal (PC) nanocavities can greatly enhance the SHG because of their ability to strongly confine light not only spatially but also temporally. Recently, a record SHG efficiency of 1900%/W has been reported in a SiC PC nanocavity with an ultrahigh quality (Q) factor of 6.0×10^5 owing to the large nonlinear optical coefficient and wide transparency range of SiC[1)]. In this work, we report that further enhancement of SHG efficiency is achieved in SiC PC nanocavities by improving the Q factors up to 8.6×10^5. We fabricated 2D PC heterostructure nanocavities in low-loss 4H-SiC slabs. Figure 1 shows an example of the measured fundamental resonant spectra. The resonant wavelength and the line width of the spectrum are 1552 nm and 1.81 pm, respectively. The linewidth corresponds to an ultrahigh Q factor of 8.6×10^5, which is a record value for SiC photonic cavities. As shown in the inset, the measured SHG spectrum shows a peak at 776nm, which is exactly half of the fundamental resonant wavelength. Figure 2 shows the measured SHG power (P_{SHG}) as a function of fundamental resonant power ($P_{fundamental}$) in this nanocavity. From the quadratic relation between them, the normalized SHG efficiency ($P_{SHG}/P_{fundamental}^2$) is estimated to be 7700%/W, which is largest value among the photonic nanocavities. We also measured the SHG efficiencies of the nanocavities with various Q factors. The results are shown in Fig. 3 together with our previous results.[1),2)] As shown in Fig. 3, the experimental SHG efficiencies are largely enhanced by the increase of the Q factors. Also, the experimental results are in good agreement with the theoretical curve (dashed line) calculated by using the coupled-mode theory, which is proportional to Q^2. Details will be presented in the conference.

Ref: 1) B. S. Song, et al., Optica 6, 991 (2019). 2) Kim, et al., The 66th JSAP Spring Meeting, 12a-W631-4 (2019).

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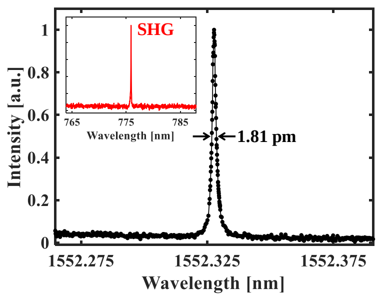

Fig. 1. Fundamental resonant spectrum of a SiC PC nanocavity. The inset shows the experimental SHG spectrum

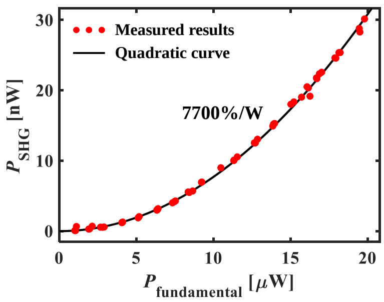

Fig. 2. Measured SHG power as a function of fundamental power in the nanocavity with $Q = 8.6\times10^5$.

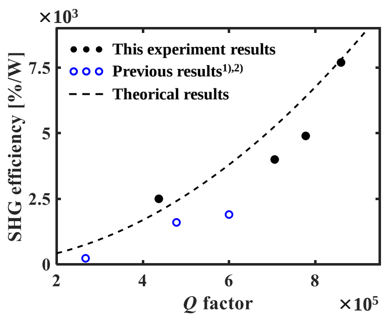

Fig. 3. SHG efficiency (circles) for Q factors including previous results[1),2)]. The dashed line indicates theoretical resuls.