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シリカクラッドを有する シリコンフォトニック結晶導波路における誘導ラマン散乱の観測

Observation of Stimulated Raman Scattering in Silicon Photonic Crystal Waveguides with silica cladding

東大生研, ○蕭 逸華, 岩本 敏, 荒川 泰彦
IIS, Univ. of Tokyo, °Yi-Hua Hsiao, Satoshi Iwamoto, and Yasuhiko Arakawa
E-mail: yihua@iis.u-tokyo.ac.jp

Raman scattering effect has been investigated for realizing silicon-based light sources based on photonic crystal (PhC) structures recently, which are advantage for making the device size small and for improving the efficiency. Ultra compact Raman laser with low threshold power has also been demonstrated using a high-*Q* air-bridge PhC nanocavity [1]. Considering light amplification at multiple wavelengths with high output power, waveguide (WG) structures would be suitable. Enhanced spontaneous and stimulated Raman scattering in silicon air-bridge PhC WGs due to the slow light effect have been observed [2]. On the other hand, there is no study on Raman scattering in silica-cladded PhC WGs, which are also useful structures thanks to their better mechanical and thermal stability. In our previous study, high Raman gain enhancement had been designed by PhC WGs with modified holes [3]. Enhanced spontaneous Raman scattering in a silica-cladded silicon photonic crystal (PhC) waveguide with modified holes due to slow light effect has also been observed [4]. In this report, we further measured the nonlinear increase of the Stokes signal intensity, which indicates the onset of stimulated Raman scattering, was observed as the pump power increases. This is the first demonstration of stimulated Raman scattering in silica-cladded PhC structures.

The device was designed as silica cladded PhC WGs with modified holes [3] with x=0.7, lattice constant (a) =462 nm, WG length (L)=200a=92.4 μm, r/a=0.302 as Fig.1 (a). The thickness of the slab (D) is 210 nm. We redraw outline of PhC WG patterns from SEM images as Fig.1 (b) and calculated the corresponding photonic band structure as Fig. 1(c). Figure 1 (d) shows pump power dependence of Stokes signal at two different pump wavelengths λ_1=1459.87 nm and λ_2=1475.60 nm. Stokes signal in the former case increases superlinearly as the pump power increases, because the sharper peaks with narrower fringe spacing around the Stokes wavelength (as Fig. 1 (e)) for the pump at former case λ_1 indicate the smaller group velocity than that for the latter case. This shows a clear evidence for the onset of stimulated Raman scattering. We also measured Raman singles in a silica-cladded W1 PhC WG (a=435 nm, L=87 μm, r/a=0.3, D=210 nm) and a 2 mm-long silicon wire waveguide in Fig. 1 (d). However, only the linear dependence of Stokes signal on pump power was observed at the same pump powers. This indicates that PhC WGs with modified holes are useful for highly efficient Raman amplifier or lasers.

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References

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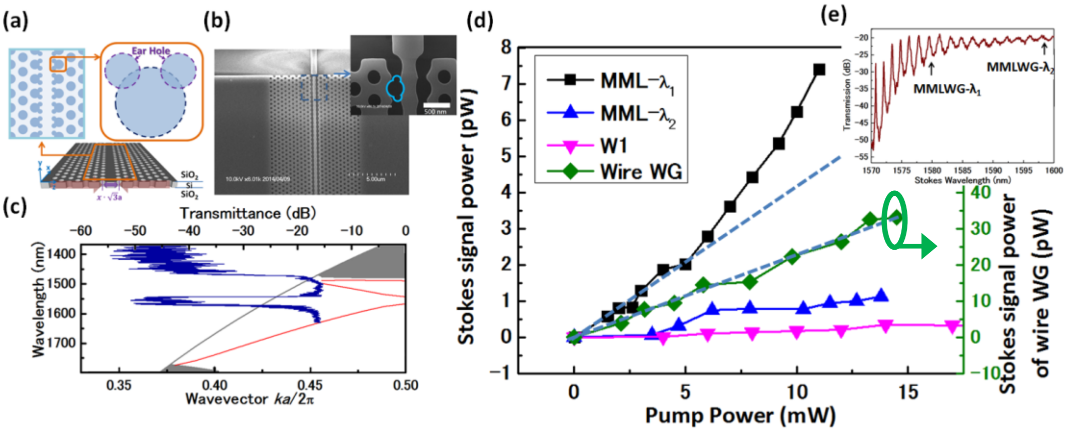

Fig. 1 (a) Illustration of designed silica cladding PhC WG and the modified holes. (b)SEM images of the fabricated MML PhC WG. The images were taken after removing the silica clad. (c) Transmittance spectrum and the corresponding calculated band structure by the parameters from the SEM images. (d) Power dependence of Raman scattering signals of MML PhC WGs which Stokes wavelengths at λ_1=1459.87 nm and λ_2=1475.60 nm, W1 WG ((a=435 nm, L=87 μm, r/a=0.3, D=210 nm)), and 2-mm long wire WG. Broken lines show linear dependence. (e) Transmittance spectrum in the wavelength range of 1570nm~1600nm.