p-i-n ダイオード構造を有する シリコンフォトニック結晶導波路におけるラマン散乱の観測

Observation of Raman Scattering in a silicon photonics crystal waveguide with *p-i-n* diode structure

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Raman scattering effect enables bulk silicon to generate coherent light. Photonics crystal (PhC) is one of promising structures to enhance Raman scattering and reduce the device size. Ultra-compact Raman laser with low threshold power has been demonstrated using a PhC nanocavity[1]. PhC waveguide is also attractive for Raman amplification using the slow light effect. Stimulated Raman scattering in PhC waveguides has been also observed [2,3]. However, at high pump powers, free carrier absorption (FCA) associated with two photon absorption (TPA) is a crucial obstacle for achieving the amplification. Adding a reverse bias through a *p-i-n* junction is known as an effective way to suppress the FCA effect [4]. Nevertheless, to date there is no report on Raman scattering in a silicon PhC WG with *p-i-n* diode structure. Here, we report the observation of Raman Stokes signal in silica-cladded Si PhC WGs with *p-i-n* structure.

An SEM image of the PhC WG used here shown in Fig. 1(a). A *p-i-n* junction was formed across the waveguide. Electrodes (not shown) were deposited to provide reverse bias through the junction. Figure 1 (b) shows the transmission spectra for both TE- and TM- polarizations of a sample with the *i*-region width of 0 μm. We utilized the band edge of the TE-like waveguide mode for pump and the fundamental index-guided TM-like mode for Stokes wave. Calculated field distributions of the TE- and TM-like modes are shown in Fig. 1 (c) and (d), respectively. *I-V* curves with various input pump powers (Fig. 2(a)) indicate that photo-excited carriers, which cause the FCA loss, are swept away from the waveguide region. Figure 2(b) shows the Stokes signal power as a function of pump power for various configurations. Compared to the Stokes signal in open-circuit condition, Stokes signals are improved in short-circuit and reverse-biased (-4V) conditions. Details will be discussed in the presentation.

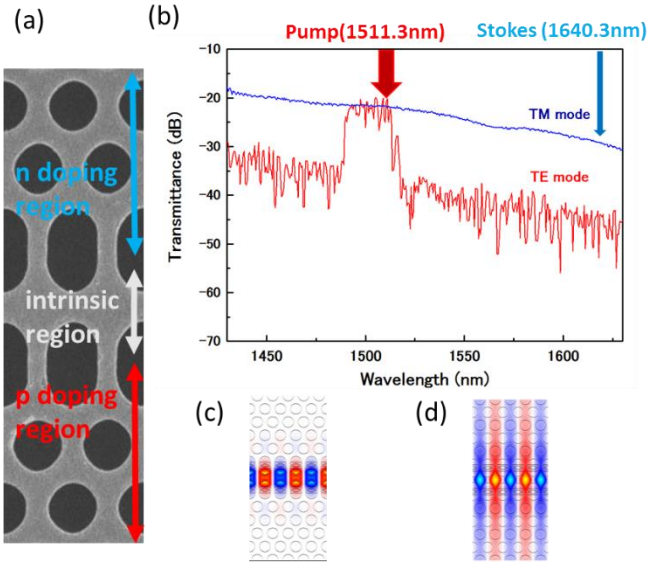

Fig. 1: (a) SEM image of silicon PhC WG with pin diode structure. (b) Transmission spectra. (c), (d) calculated field distributions of pump and Stokes modes, respectively.

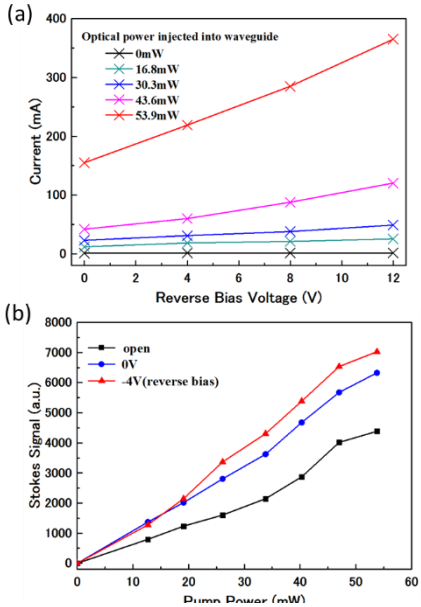

Fig. 2: (a) *I-V* characteristics at several input pump power. (b) Stokes signal power as a function of pump power in open-circuit, short-circuit, and reverse-biased conditions.

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Reference: [1] Y. Takahashi *et al.*, Nature **498**, 470 (2013). [2] Y. H. Hsiao *et al.*, Jpn. J. Appl. Phys. 54, 04DG02(2015). [3] X. Checoury *et al.*, Phys. Rev. B **82**, 041308 (2010). [4] H. Rong *et al.*, Nature **433**, 725-728 (2005)