INTRODUCTION

1. Stimulated Brillouin Scattering

The stimulated Brillouin scattering originated from constructive reinforcement of the acoustic and Stokes waves in the spontaneous Brillouin scattering [1]. As the incident and scattered light fields beat together, the density and pressure in the media vary as a result of electrostriction. Such density variations give rise of refractive index variation, which will further be scattered off by the incident laser field. The scattered light, at the Stokes frequency, will add constructively with the Stokes radiation that produced the acoustic disturbance. The two waves grow to larger amplitudes in this way, seen as the stimulated Brillouin scattering.

Tunable stimulated Brillouin scattering (SBS) gives the chance to modulate signal frequency, thus can be utilized in silicon photonics, microelectromechanical systems and signal processing technologies [2][3].

Here we presented an attempt to calculate, measure and compare the SBS gains in different optical waveguides, including the highly nonlinear fiber and silicon waveguides.

We proposed to design long silicon suspended membrane waveguides [5] for enhancing on-chip stimulated Brillouin scattering and verify the designs by FDTD simulation tools.

Since that slow light in photonic crystal waveguides show possibility to enhance nonlinear effects [6][7], we also proposed to use photonic crystal structure to enhance on-chip SBS.

Figure 1. (a) Silicon suspended membrane waveguide (b) Computed SBS contributions from electrostriction (ES) and radiation pressure (RP) with relation to the silicon suspended membrane waveguide dimension a (for both ES)[8]

The current goal is narrowed down to design and fabricate a proper photonic crystal (PhC) nano-cavity with acceptable Q-factor and strong resonance in SBS peaks at telecommunication frequency.

EXPERIMENTS AND SIMULATIONS

1. Stimulated Brillouin Scattering in Highly Nonlinear Optical Fibers (HNLF)

While we examined the SBS in HNLF with the lowest input power of about 25–37 mW, which is comparable to the theoretical calculation of 240 mW for such optical fiber. Direct dependency of the SBS beating signal intensity on input pump power is shown by experiments of SBS in HNLF. However, the power level of the beating signal is much lower than expected, resulting from the instability of the system and noise. Giant Reduction of reflections and other methods were used to minimize the noise. To further improve the results, we suggested adding optical isolators, filters or feedback stabilization systems.

2. Design of Silicon Photonic Crystal Lattices

We optimized the design of Silicon PhC lattice with lattice constant a = 0.42 um, radius r = 0.12 um. The thickness of the slab is 2um.

2. Design and Simulation of PhC Nanocavities

The horizontal PhC nanocavity has a Q-factor of about 2020, two peaks at 1284 nm and 1809 nm. The tilted one with Q-factor of about 1340, two peaks at 1263 nm and 1791 nm. The separation of the resonance wavelengths may not be small enough for enhancing SBS frequencies inside the cavity.

2. Silicon Wire Waveguides, Photonic Crystal Waveguides and Nanocavities

Recently it has been theoretically found that giant enhancement of SBS exists in silicon waveguides [4]. The contrast in propagation of both optical waves and acoustic phonons between air and silicon contributes to both the electrostriction and radiation pressure, giving an SBS gain of possibly times greater in silicon wire waveguides than in conventional silicon fibers.

REFERENCES


DISCUSSIONS

1. Limitations for the SBS Measurement Set-up

We examined the SBS in HNLF with the lowest input power of about 25–37 mW, which is comparable to the theoretical calculation of 240 mW for such optical fiber. Direct dependency of the SBS beating signal intensity on input pump power is shown by experiments of SBS in HNLF. However, the power level of the beating signal is much lower than expected, resulting from the instability of the system and noise. Giant Reduction of reflections and other methods were used to minimize the noise. To further improve the results, we suggested adding optical isolators, filters or feedback stabilization systems.

2. Design of Silicon Photonic Crystal Lattices

We optimized the design of Silicon PhC lattice with lattice constant a = 0.42 um, radius r = 0.12 um. The thickness of the slab is 2um.

2. Design and Simulation of PhC Nanocavities

The horizontal PhC nanocavity has a Q-factor of about 2020, two peaks at 1284 nm and 1809 nm. The tilted one with Q-factor of about 1340, two peaks at 1263 nm and 1791 nm. The separation of the resonance wavelengths may not be small enough for enhancing SBS frequencies inside the cavity.

CONCLUSION

Despite the promising applications with enhanced on-chip SBS in nanoscale silicon devices, it remains hard to design and fabricate such devices. The device typically has to be long while maintaining ultra-low loss, which is hard to fabricate. We would continue to explore possibilities with silicon suspended membrane waveguides and PhC nanocavities.