Stimulated Brillouin Scattering Microwave Photonic Notch Filter in Silicon Nitride

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Abstract: We show the first all silicon nitride microwave photonic notch filter using stimulated Brillouin scattering (SBS). The filter has a rejection of more than 60 dB, a linewidth of 1 GHz, and a tunable center frequency over 1 GHz. © 2022 The Author(s)

1. Introduction

Stimulated Brillouin scattering (SBS) is a coherent optomechanical interaction between optical and acoustic waves. SBS on chip is an emerging field, and has shown promising results in applications including sensing and communications [1]. Unlocking SBS processing in established microwave photonic platforms, such as mulitlayer silicon nitride [2] will lead to improved processing capabilities. We have recently shown that these multilayer silicon nitride waveguides can exhibit SBS [3]. Figure 1 gives a brief overview of these results for the waveguides we use in this work, (a) shows the waveguide geometry, (b) and (c) the simulated optical and acoustic responses respectively, and (d) shows the simulated and measured gain curves.

In this paper we show how active SBS and traditional passive processing techniques, namely ring resonators, can be combined in silicon nitride chips. We use this combination to create a high rejection (60 dB) notch filter.

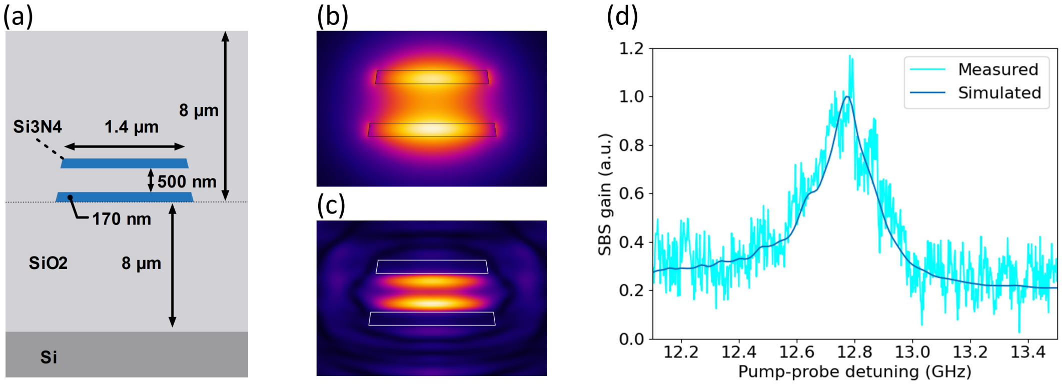

Fig. 1. (a) The geometry of our Brillouin active waveguide, with (b) the electric field of the simulated optical mode, (c) the total displacement of the simulated optical response, and (d) the simulated and measured Brillouin response.

2. Setup

Our setup is based on earlier work which combined a ring resonator and a spiral made from chalcogenide glass (As_2S_3) [4]. The waveguides are based on the symmetric double stripe (SDS) silicon nitride geometry [2]. The SDS geometry is a 1.2 µm wide waveguide consisting of two silicon nitride layers of 170 nm height, separated by a 500 nm silicon oxide layer. For our Brillouin active region we selected a waveguide with the same layer thicknesses, but a width of 1.4 µm, as depicted in Figure 1 (a). Our previous work has shown that widening the SBS waveguide results in a higher Brillouin gain [3]. This experiment used two chips. The first contains a waveguide with 6 ring resonators, all made with the standard SDS geometry. These rings have a free spectral range of 25 GHz, and tunable couplings and phase sections. Only one ring is required for the signal processing, the other five will therefore be tuned to give no response. The second chip contains a 50 cm long spiral of the 1.4 µm wide SDS waveguide, which will be used as the Brillouin gain section.

A schematic overview of our setup can be seen in Figure 2 (c). The signal is modulated onto the carrier laser using an intensity modulator, creating two sidebands of equal amplitude and phase. After modulation our notch filter uses two components to process the signal, as can be seen in Figure 2 (b). The intensity modulated signal first passes an overcoupled ring resonator. This induces a small decrease in amplitude at the center frequency, along with a π phase shift. Next, the signal enters a spiral, where it undergoes gain via SBS. This reverts the amplitude

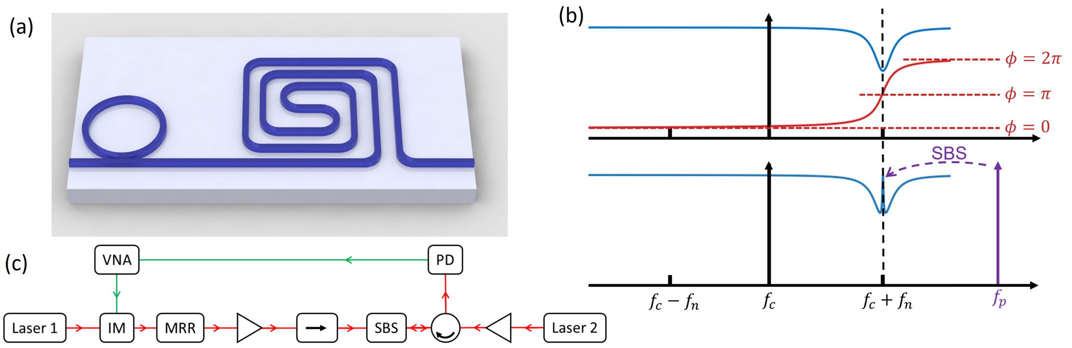

Fig. 2. (a) An artist's impression of our silicon nitride based chip design. (b) Working principle of our notch filter. The top graph shows the signal after the ring resonator, with a notch in the amplitude (blue), and a π phase shift (red). The bottom graph shows the amplitude of the signal (blue) after passing through the SBS gain section. (c) A schematic overview of the measurement setup we used.

loss from the ring, but keeps the phase relation. When the signal then enters a photodiode, the two sidebands destructively interfere only there where the ring and SBS gain have modified the signal, resulting in a deep notch.

Our gain waveguide has a Brillouin gain coefficient of 0.16 $\text{m}^{-1}\text{W}^{-1}$ and an effective length of 29.28 cm. The waveguide is pumped with 2.4 W of power, which is coupled to the chip with a coupling loss of 2.35 dB/facet. The resulting SBS gain is around 0.4 dB, which means that the depth of the notch created by the ring has to be tuned accordingly.

3. Results

Figure 3 (a) shows the notch filter when only processed using the pump (in blue), and when the SBS pump is turned on (in red). The SBS pump increases the rejection by 35 dB, resulting in a total notch rejection of 60 dB, and a 3dB linewidth of 1 GHz. Figure 3 (b) shows the tunability of the filter. The SBS response of the fibers connected to the chip is also visible as a small peak at 2 GHz higher than the notch.

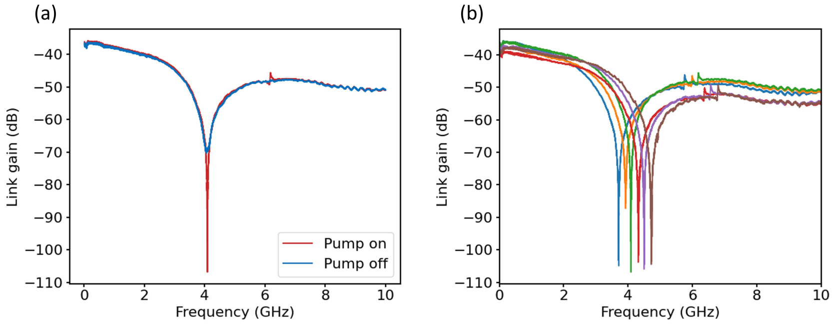

Fig. 3. (a) The SBS notch filter created (red), with overlayed in blue the signal when the SBS pump is turned off. The small peak that appears around 6 GHz when the pump is turned on is caused by the SBS response of the fibers that are used to couple light into the chip. (b) The filter can be tuned in frequency. The fiber SBS response is again visible.

4. Conclusions

We have shown that an SBS notch filter for microwave photonics is feasible. The notch has a rejection of more than 60 dB and can be tuned. The current setup uses two chips, but these are made with the same fabrication process. It is therefore possible to integrate the ring and spiral onto a single chip, as depicted in Figure 2 (a), creating a compact signal processor.

References

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