Storing light as sound waves is an intriguing and powerful concept for delaying optical signals, not only because it allows for large fractional delays \[1, 2\] and preserves the coherence of the signal \[2\] but also because it allows advanced functionalities such as uni-directional light storage \[3\]. The non-reciprocity originates from the strict phase-matching condition that allows coupling of the optical to the acoustic wave. This form of non-reciprocity was proposed and implemented in several different optomechanical systems \[4, 5\]. So far non-reciprocal systems based on the interaction between light and mechanical degrees of freedom, however, were limited by the narrow linewidth of the mechanical resonance. To circumvent said limitation it was recently shown that one can achieve non-reciprocal behavior with a large bandwidth via acoustic pumping using inter-digital transducers (IDT) instead of optical pumping \[6\].

Here, we demonstrate non-reciprocal light storage based on stimulated Brillouin scattering. The scheme is implemented utilizing high Brillouin gain planar waveguides. As we are operating in a waveguide instead of a resonator, we are not limited by the mechanical linewidth of the resonator. Without this limitation, the profile of the Brillouin response follows the profile of the optical pump and hence can be extended far beyond the intrinsic narrow acoustic linewidth. We are able to achieve non-reciprocal light-storage over a bandwidth that approaches a GHz which is more than an order of magnitude wider than the intrinsic Brillouin linewidth of around 30 MHz.

The basic principle of uni-directional Brillouin light storage is shown in Fig. 1. The optical data pulses are transferred to the acoustic domain via counter-propagating optical write pulses, offset in frequency to the data pulses by the Brillouin frequency shift of the waveguide. A second optical pulse (read pulse) following the write pulse retrieves the optical data pulse by transferring it back from the acoustic to the optical domain. The underlying phase-matching condition is only fulfilled for counter-propagating optical data and write/read pulses and therefore data pulses traveling in the reverse direction are not affected by the Brillouin light storage process.

The experimental setup is shown in Fig. 2. Two lasers are used to generate data and write/read pulses via a pulse generator and intensity modulators. A multi-wavelength multi-channel switch is used to direct the pulses to the input/reverse input of the chalcogenide chip that acts as the storage medium. After the pulses are being stored in the chip, narrowband filters are used to separate the wavelength channels and the retrieved data pulses are measured with a fast photodiode and oscilloscope.

Figure 3(a) shows the storage of two channels at different wavelengths simultaneously. In Fig. 3(b) the propagation direction of the optical data stream is
FIG. 2. Experimental setup. CW: continuous wave; SSB: single-sideband modulator; IM: intensity modulator; PG: pulse generator; BP1/2: bandpass filter 1/2; PD1/2: photodiode 1/2; CH1/2: wavelength channel 1/2.

FIG. 3. a) and b) shows the simultaneous storage and retrieval of two data pulses at separate wavelengths in a waveguide. c) Reverse propagation direction of data 1 shows the transmission of the data pulse without being stored due to the Brillouin phase matching condition. d) While data pulse 1 is transmitted in the reverse direction data is stored as an acoustic wave and retrieved at wavelength channel 2.

In summary we showed on-chip uni-directional signal processing utilizing interactions between optical and acoustic waves with a bandwidth exceeding the intrinsic acoustic linewidth of around 30 MHz by more than an order of magnitude.

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