Simultaneous opto-acoustic light storage at multiple frequency channels

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***Abstract*—We store optical data in acoustic waves on a planar waveguide based on stimulated Brillouin scattering (SBS) and demonstrate for the first time that this coherent light storage concept allows for the simultaneous storage at different frequency channels, separated by 100 GHz, without observable cross-talk between the individual channels.**

Keywords—Nonlinear optics; stimulated Brillouin scattering; photonic integrated circuits.

I. INTRODUCTION

The advent of photonic integrated circuits requires solutions for optically controlling the speed of optical data that is transmitted through photonic chips. A number of techniques to store light temporarily have been proposed, amongst them, several approaches based on opto-mechanics [1-3]. They usually rely on an opto-mechancial resonator, which limits their operation to the distinct transmission wavelengths of the resonator. Moreover, the phonons can couple to different optical wavelengths, a feature that can be used for frequency conversion [3], which is desired in some cases, such as the transfer of quantum properties into another frequency range. However, this is detrimental when the storage of parallel frequency channels is needed.

Here, we show a technique to store light - based on stimulated Brillouin scattering (SBS) in planar waveguides [4] - that allows for the first time for storage in separate frequency channels simultaneously and for addressing specific frequency channels while no measureable cross-talk to other frequency channels is observed. The data is stored by a specific write and read pulse configuration and does not interfere with data storage on a different frequency channel that is operating 100 GHz apart. The specific phase matching condition of our phonon-based optical memory ensures that no frequency conversion to another channel takes place and that one single frequency channel can be addressed separately.

II. PRINCIPLE

The principle of operation is based on SBS [4,5], an interaction between travelling optical and acoustic waves. The information of a data stream at frequency ω_{data} can be coherently transferred to an acoustic wave with help of a counter propagating write pulse at frequency $\omega_{\text{write/read}}$. The information is stored in an acoustic wave with frequency Ω and can then be read out by depleting the latter with a read pulse, also at frequency $\omega_{\text{write/read}}$. The frequency Ω of the acoustic wave corresponds to the Brillouin frequency shift of the material and fulfills the condition $\Omega = \omega_{\text{data}} - \omega_{\text{write/read}}$. The memory can be operated over a large bandwidth corresponding to the transparency window of the waveguide. As photonic waveguide, a highly nonlinear As_2S_3 rib waveguide [6] is used that is arranged as a 22cm-long spiral on a photonic chip. The novelty of this work is that we are able to store data pulses at two different frequency channels simultaneously, which are separated by 100 GHz. The principle is shown in Fig. 1. On frequency channel 1, a data pulse at $\omega_{\text{data 1}}$ is stored by corresponding write/read pulses $\omega_{\text{write/read 1}}$ into an acoustic wave Ω_1. Simultaneously, another data pulse at $\omega_{\text{data 2}}$ - 100 GHz apart from data 1- is stored into an acoustic wave Ω_2 by respective write/read pulses $\omega_{\text{write/read 2}}$ in channel 2.

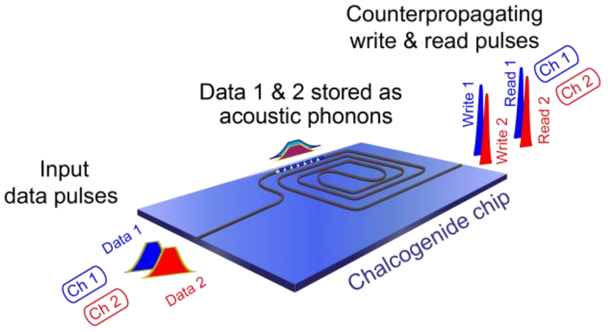

Fig. 1: SBS-based memory principle with two different frequency channels 1 and 2 that are separated by 100 GHz: per channel one data pulse and one counter propagating write pulse enter the photonic chip; via SBS the data pulse gets depleted and one acoustic wave per respective channel is created; per channel, one read pulse enters the waveguide and depletes the respective acoustic wave by the reverse process; the delayed data pulses in the different channels then exit the photonic chip.

III. EXPERIMENTAL RESULTS

The experimental results are shown in Fig. 2 and 3. We study first the simultaneous storage on both channels (both data pulses and write/read pairs enter the chip) with comparison to single-channel operation on channel 1; then we investigate possible crosstalk between both channels.

A. *Simultaneous light storage on both channels*

The original transmitted data pulses 1 and 2 are shown in Fig. 2a and b. They are both directly detected on two different photodiodes after being filtered out with two narrowband filters (bandwidth 3 GHz) that are 100 GHz apart. When sending in the write/read pulses on both channels, the original data pulses get depleted at position 0 ns and are retrieved 5 ns later (Fig. 2c, d), which is defined by the time difference of the write and the read pulse. To confirm that there is no interaction between the two acoustic phonons created in the two channels, we switch off channel 2 and record the memory operation on channel 1 which corresponds to the yellow data in Fig. 2c). We see that the depletion and read-out overlap perfectly which means that the parallel memory operation at channel 2 does not influence the memory at channel 1.

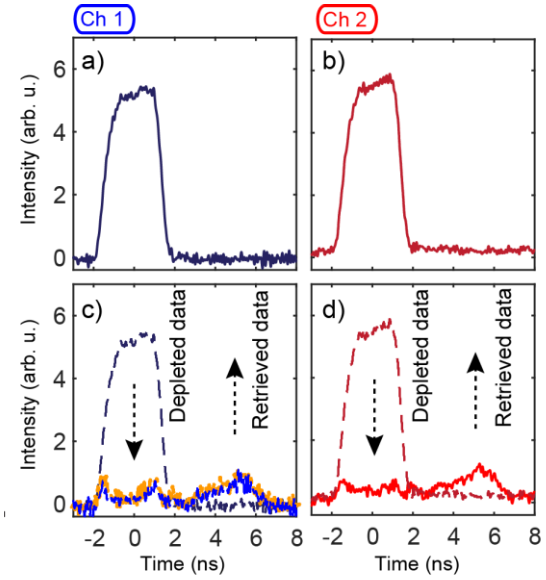

Fig. 2: a) and b) original data pulses on both channels; c) and d) the original data pulses are depleted and retrieved after 5 ns on both channels; the dotted line represents the original data pulse for comparison. The yellow data in c) refers to storage in channel 1 without storage operation on channel 2.

B. *Investigation of crosstalk between the frequency channels*

We further study possible cross-talk by demonstrating that the storage and retrieval processes do not interfere in between the different channels. Therefore, we first consider the case that the memory is operated on channel 1 (data 1 and read/write pulses 1 are switched on) and only data 2 is transmitted through frequency channel 2 without read/write pulses 2. As presented in Fig. 3a and b, the memory is applied on channel 1 while data pulse 2 at channel 2 is unaffected by it (yellow graph). The dotted red graph corresponds to the data pulse 2 when the memory is switched off on channel 1. As a second proof, we study the case that the memory is operated on channel 1 while no data stream is transmitted at channel 2 but the write/read pulses $\omega_{\text{write/read 2}}$ are operating on frequency channel 2. It shows that the write/read pulses $\omega_{\text{write/read 2}}$ do not read out the acoustic wave that has been created at frequency channel 1. Fig. 3c and d show normal memory operation on channel 1, while no read-out is observed at channel 2. All of the measurements have been carried out by simultaneously observing two channels on the oscilloscope and also by inverting channel 1 and 2.

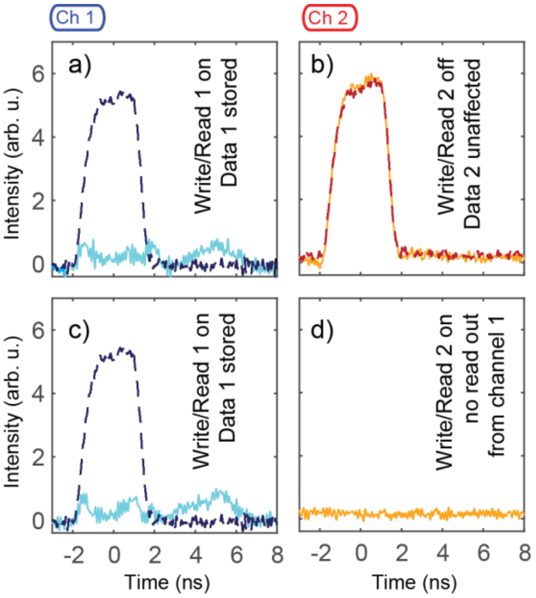

Fig. 3: a) and b) Memory operating at frequency channel 1 while the data pulse 2 on frequency channel 2 is not affected by it; the red dotted line represents the data pulse when no memory is operated on channel 1. c) and d) memory operating at frequency channel 1 and no read-out is observed by the operating write/read pulse 2 on frequency channel 2.

In conclusion, we have shown a photonic-phononic memory that coherently stores optical information in the acoustic domain which is – for the first time - compatible with wavelength division multiplexing. The memory can be operated simultaneously at different frequency channels and no measureable cross-talk between the channels is observed. This offers the possibility to selectively delay data in a specific frequency channel without effect on other frequency channels.

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