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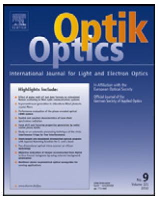

Pulse compression effect based on stimulated Brillouin scattering light storage in an optical fiber

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ABSTRACT

The pulse compression effect in SBS light storage is numerically investigated. We demonstrate theoretically that the compressed width of retrieved data-pulses is not only related with temporal profile of data-pulse, but also spectrum and temple profile of control-pulse. The data-pulses with steep rising edge can be compressed after they are retrieved. The optimum compression effect takes place when a 2-ns-long exponential data-pulse interacts with a 1.5-ns-long chirped Gaussian control-pulse, where the data-pulse width is compressed to 1.73-ns-long and the readout efficiency is the biggest. A 2-ns-long rectangular data-pulse is also compressed to 1.73-ns-long when it encounters to a 1.5-ns-long rectangular control-pulse, but the readout efficiency isn't maximum value. The results are significant for increasing storage capacity and variable bits all-optical buffering.

1. Introduction

The lack of feasible an all-optical memory operating within the whole communication wavelength and with a possibility to control storage time is a well-known bottleneck of all-optical communication network. To realize the all-optical memory, one needs to control the group velocity of light. Various slow light technology have been widely studied both experimentally and theoretically [1,2]. Stimulated Brillouin scattering (SBS) slow light have attracted considerable interest because its room temperature operation, low threshold, working at any wavelength, and compatibility with existing optical communication systems [3–6].

A storage method was recently described and experimentally demonstrated based on (SBS) [7–9]. The basic principle of SBS light store in optical fiber can be depicted as follows: Two light beams are simultaneously injected into a single mode fiber (SMF) from its two ends. One beam is a strong pulse laser as the control light (Including write-pulse and read-pulse) and the other one is a weak pulse laser acting as the data-pulse. The data-pulse that represents bits of information pass through the fiber while, simultaneously, a write pulse passes through the fiber in the opposite direction. Through the process of SBS, essentially all the data-pulse energy is depleted and a coherent acoustic excitation is left behind in the fiber, which contains the information content of the data-pulse. The frequency of the acoustic wave is equal to the frequency difference between the data-pulse and control-pulse. Only a small fraction of the data-pulse energy is converted to the acoustic excitation; most of it is transferred to the write-pulse. After a controllable storage time, a read-pulse passes through the fiber in the same direction as the write-pulse. It depletes the acoustic excitation, and the data-pulse is released from the fiber, propagating in the same direction as the original data-pulse. Energy from the read-pulse is transferred to the released data-pulse in this process. Storage time between data-pulse and retrieved data-pulse is controlled within the phonon lifetime of the fiber material.

In general, stimulated Brillouin scattering is a third-order nonlinear optical process, involved the Brillouin amplification and absorption resonance. Since the Brillouin gain and loss spectrum leads to a spectral narrowing of the pulse, (i.e. frequencies away from the pulse line center are subjected to lower amplification than the frequencies around the center) the pulse will be broadened. But, spectral narrowing is not the only reason for pulse distortion, the other one is the group velocity dispersion (GVD), so it is impossible to provide equal amplification and absorption of all pulse spectral components by nonlinear SBS according to the initial profile. Retrieved data-pulse based on above-mentioned SBS light storage is inevitable in the existence of a pulse broadening, which has been proved [7], which is fatal to the butter capacity and system performance.

In this article, the original two different the rising and falling edges data-pulses with same 2 ns FWHM duration, i.e. exponential and rectangular are stored, the retrieved data-pulse is not broadened but is compressed, and the compressed pulse width is not changed with storage time. This result makes us excited, because

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with the data-pulse profile width is narrowed, buffering capacity is increased. The compressed data-pulse can be achieved by a tailoring of the control-pulse (i.e. write-pulse and read-pulse) and data-pulse temporal distribution profile makes them suitable for each other and by tailoring the gain and loss spectrum profile of control-pulse.

2. Theoretical modeling

The SBS process is described by the three-wave coupled wave equations in [7]. Besides the gain spectrum of the signal pulse $g(\omega)$ is given below [10–12]

$$g(\omega) = g_i(\omega) \otimes I(\omega)$$

where $I(\omega)$ is the power spectrum of the signal pulse, $g_i(\omega)$ is the intrinsic gain spectrum of the SBS process, whose width is approximately 13.2 MHz in the As_2Se_3 optical fibers. For the broadband signal (i.e. GHz bandwidth), the bandwidth of $g_i(\omega)$ can be neglected. Therefore, $g_i(\omega)$ can be approximated by $g_0 \cdot \delta(\omega + \Omega_B)$, where g_0 is the peak absorption coefficient and $\delta(\omega)$ is the unit impulse function. With this approximation, for the broadband signal, $g(\omega)$ can be calculated as $g(\omega) \approx g_0 \cdot I(\omega)$, therefore the gain spectrum has the same shape and width as the spectrum of the signal pulse. From above discussion, we know that gain and absorb spectral width can be modified by properly shaping pulse envelope in the SBS store process. When the spectrum of the control pulse can fully overlap or greater than the gain spectrum of the data-pulse, the energy of the data-pulse can be adequately depleted in the “write” process and read out in the “read” process, the read-out efficiency can be greatly improved, the aberration of pulse can effectively be reduced.

We numerical solve the three-wave coupled wave equations in considering the control-pulse with wider spectrum, and when we compare ours results with the experimental results in [7], the theoretical results correspond to the experimental results. Let us introduce the parameters we used for our simulations. To reduce the required control pulse energy and maximize the storage time, we select As_2Se_3 fiber with high Brillouin gain coefficient and long acoustic lifetime as the material of store light. In calculation we refer to the parameters of As_2Se_3 fiber in [9]. We defined three different data-pulse intensity profiles with an identical FWHM duration of 2-ns-long, showing successively Gaussian, exponential, and rectangular temporal distributions profile. We also defined three different control-pulses intensity profile with an identical FWHM duration of 1.5-ns-long, showing successively Gaussian, rectangular and chirped Gaussian temporal distributions profile and theirs spectrum were numerically obtained through a Fourier transform of the pulse waveforms, where the spectrum of chirped Gaussian control-pulse is the widest enough to fully encompass the three data-pulses spectrum. In calculation, if not special mentioned, data-pulses have a FWHM of 2-ns-long and a peak power of ~10 mW, control-pulse have a FWHM of 1.5-ns-long and a peak power of ~100 W.

3. Numerical results and discussion

3.1. The relationship between the data-pulse compression effect and the temporal profile of data-pulse

We use rectangular control-pulse to simulate three different temporal profile data-pulses (i.e. Gaussian, exponential and rectangular shaped) are stored and retrieved process, respectively. The simulations results of stored data-pulse waveform for different storage time are shown in Fig. 1. It was seen from Fig. 1 that the retrieved Gaussian data-pulse is broadened, but the retrieved exponential and rectangular data-pulses are compressed, and the compressed pulse width is not changed with storage time. The compressed rectangular data-pulse width is narrower than the exponential reach to 1.73 ns. Comparison of three data-pulses temporal distributions profile, we find that all of those compressed data-pulses have steep rising edge. Besides this results, we should know that the impact of the control-pulse in the data-pulse compression process.

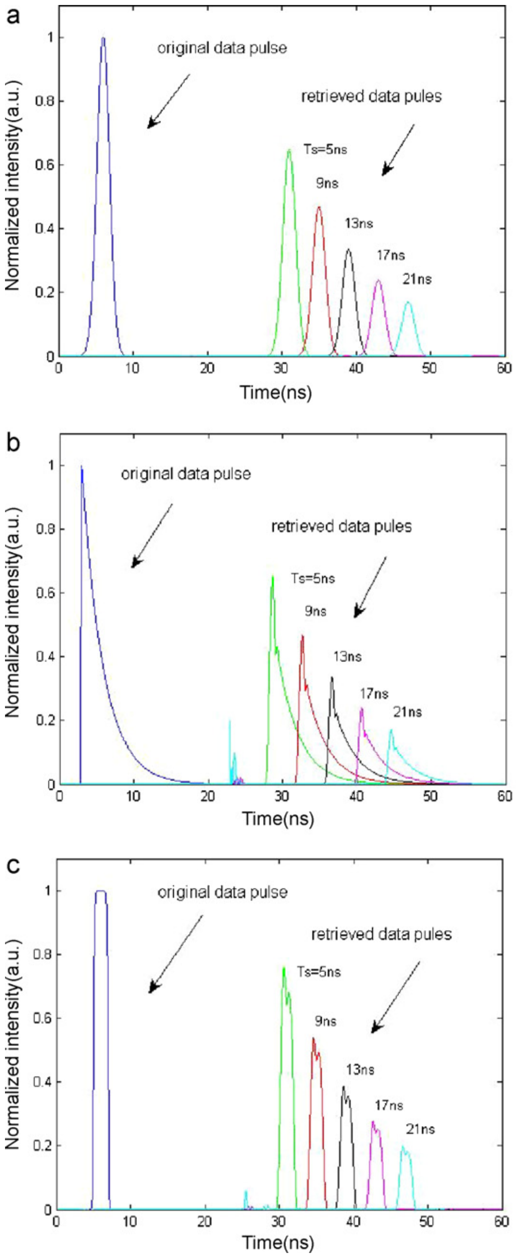

Fig. 1. Observation simulations of the different data-pulses storage for rectangular control-pulse. (a) Shows a 2-ns-long Gaussian data-pulse; (b) shows a 2-ns-long exponential data-pulse and (c) shows a 2-ns-long rectangular data-pulse.

3.2. The influence of spectrum and temporal profile of different control-pulses on the data-pulse compression effect

Firstly, we investigate the influence of spectrum and temporal profile of different control-pulses on the data-pulse compression effect when the data-pulse is exponential.