

Highly efficient slow and fast light generation via Brillouin scattering in As₂Se₃ chalcogenide fiber

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Abstract: Delaying and advancement of optical pulses using stimulated Brillouin scattering in As₂Se₃ fiber is demonstrated. Pulses can be delayed by 37 ns in a 5-m-long fiber with a pump power as low as 60 mW.

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1. Introduction

Future all-optical networks will require optical buffering schemes to avoid packet contention within the routing nodes. Such all-optical buffers allow the control of the group velocity of an optical signal in a nonlinear medium. Among the various physical mechanisms that can be used to exert this control, stimulated Brillouin scattering (SBS) in optical fibers [1, 2], is particularly attractive for optical communication systems, because of the compatibility with fiber-optic systems and operability at an arbitrary wavelength without any temperature constraint. The narrow bandwidth over which Brillouin amplification occurs, causes a large change in the group index within the gain band and introduces a certain group delay in the signal. As the optical group delay is linearly proportional to the logarithm of the net Brillouin gain in the fiber, fibers with large Brillouin gain coefficient are highly desirable to reduce the optical power requirement of the pump wave and also the device length. Indeed, recently, slowing of light has been demonstrated in a 2-m long bismuth-oxide fiber, where pulses were delayed by 46 ns by means of a cw pump of 410 mW [3].

In this paper, we demonstrate slowing and advancement of light in a single mode As₂Se₃ chalcogenide optical fiber with the best efficiency ever reported. This kind of fiber has a Brillouin gain coefficient that is two orders of magnitude larger than in conventional silica fibers. Hence, to achieve the same amount of delay, these fibers allow a reduction of two orders of magnitude in the pump power. Pulse delays as long as 37 ns were obtained in a 5-m-long fiber with a continuous-wave pump of only 60 mW, which shows delay generation with an efficiency of 0.61 ns/mW. This pumping efficiency is the highest demonstrated among all types of optical fibers so far.

2. Experiments and results

The experimental setup used for the observation of delaying and advancement of optical pulses is shown in Fig. 1. As a nonlinear medium we have used a single-mode As₂Se₃ chalcogenide fiber that was found to have a gain coefficient g_B of 6×10^{-9} m/W, two orders of magnitude larger than that of silica fibers [4]. The fiber was 5 m long and had a core diameter of 6 μ m, a NA of 0.18 and a transmission loss of 0.84 dB/m (measured at 1.55 μ m).

Continuous wave laser radiation at 1.56 μ m from an external cavity semiconductor laser was divided into two parts. One part was amplified for use as a cw pump, while the rest was phase-modulated using an RF oscillator at a frequency of about 7968 MHz, equal to the Brillouin shift ν_B of the As₂Se₃ fiber. The output from the phase modulator was then intensity-modulated using a Mach-Zehnder modulator to produce Gaussian probe pulses with about 50 ns width at a 1-MHz-repetition-rate, and launched into the fiber in a direction opposite to that of the pump. The cw pump and the probe pulses were coupled by means of tapered lenses through the AR-coated facets of the As₂Se₃ fiber.

At the fiber output, following Brillouin interaction with the pump, we could select the lower or higher modulation sidebands of the probe pulse by using a narrow band Fabry-Perot filter. This allowed us to observe both delaying or advancement of the probe pulses in the fiber [1].

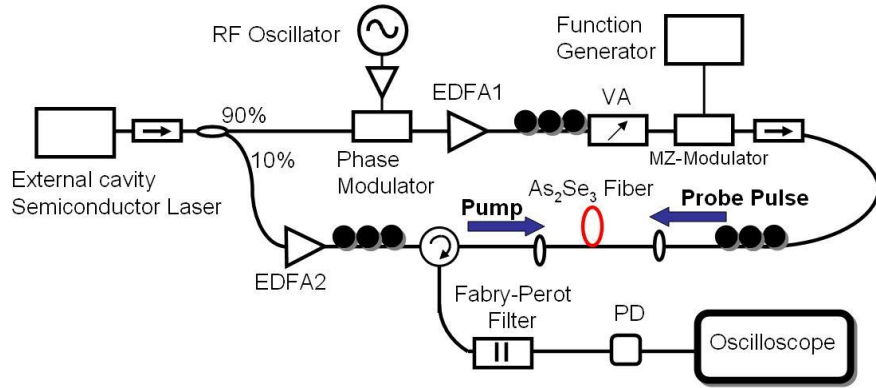


Fig. 1. Experimental setup

3. Results

Fig. 2(a) shows the probe waveforms observed at the fiber output. Using the lower frequency sideband as the probe, the pump power was raised from 0 to 60 mW to obtain a maximum Brillouin gain of 43 dB, corresponding to a delay of 37 ns. By using the higher frequency sideband as the probe we could observe a maximum attenuation of -10 dB, corresponding to an advancement of 7 ns. By tuning the frequency separation between pump and probe, we could clearly determine that the pulse delaying and advancement was caused by SBS in fiber. Figure 2(b) plots the measured delay and gain suffered by the probe for different pump powers. Linear fitting of the curves, in consistence with theory, yields a delaying efficiency of 0.61 ns/mW. This result after normalization by the effective length of 3.2 m yields a value of 0.19 ns/mW/m, which is about 2.8 times larger than that reported in bismuth fiber [3]. For the As_2Se_3 fiber, we could obtain a gain efficiency as high as 0.71 dB/mW, which corresponds to a delay/gain coefficient of 0.86 ns/dB.

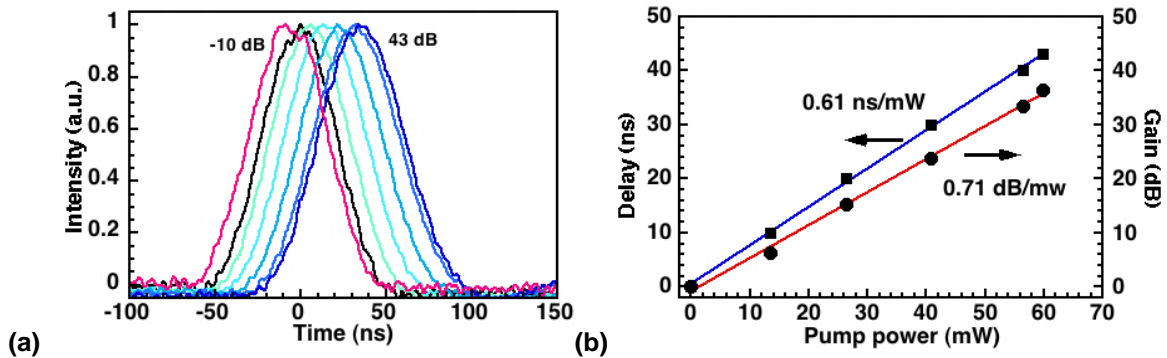


Fig. 2. (a) Waveforms of probe pulses for different amount of Brillouin gain (Stokes) and attenuation (Anti-Stokes) in As_2Se_3 fiber. (b) Delay vs. pump power and gain vs. pump power. Straight lines show linear fitting.

4. Conclusion

In conclusion, we have demonstrated for the first time pulse advancement and delaying achieved using SBS in As_2Se_3 chalcogenide fiber. The As_2Se_3 fiber had a Brillouin gain coefficient two orders of magnitude larger than conventional silica fibers, resulting in a significant reduction of the pump power requirement. A maximum delay of 37 ns was achieved in a 5m-long fiber for a pump power as low as 60 mW, the best power efficiency ever reported in the SBS slow light generation.

4. References

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