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► **To cite this version:**

Anasthase Liméry, François Gustave, Laurent Lombard, Anne Durécu, Julien Le Gouët. Compressive strain gradient for Stimulated Brillouin scattering mitigation in optical fibers. CLEO EUROPE 2023, Jun 2023, Munich, Germany. 10.1109/CLEO/Europe-EQEC57999.2023.10232806 . hal-04278610

**HAL Id: hal-04278610**

**<https://hal.science/hal-04278610>**

Submitted on 10 Nov 2023

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# Compressive strain gradient for Stimulated Brillouin scattering mitigation in optical fibers.

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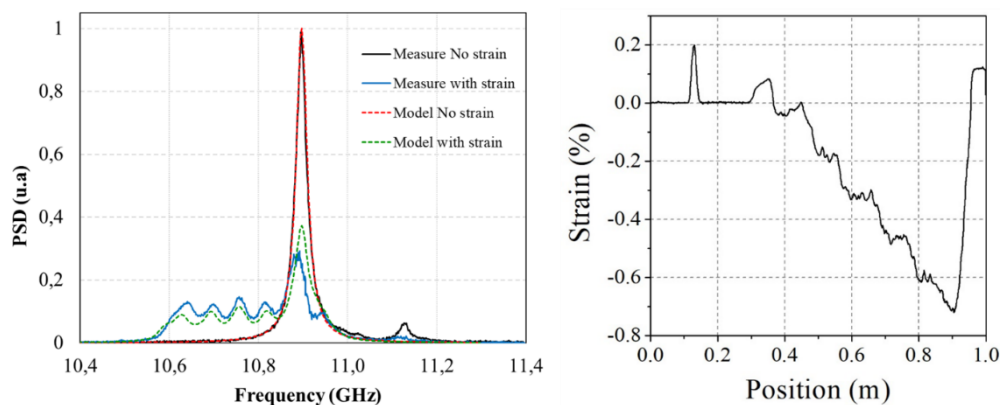
For applications such as mobile and airborne wind profiling Lidar, high-energy all-fiber laser systems with narrow spectral linewidth are required. In these lasers, non-linear effects, in particular Stimulated Brillouin Scattering (SBS), often limit the peak power and thus the Lidar range. In order to mitigate SBS in fiber laser systems, active methods (e.g. spectral broadening of incident light by laser phase control) or passive methods can be implemented. The latter consists in modifying the physical properties of the fiber. This can be achieved by applying a temperature gradient [1] or a stress gradient [2] in order to introduce a broadening of the Brillouin spectrum of a few hundred MHz. While temperature differences of several hundred degrees are required, only ~1% tension or compression can be deployed on the fiber to achieve the necessary broadening. Compared to tension, compression causes less fiber weakening and is therefore a better candidate for maintaining the robustness and lifetime of the laser system.

We have already presented the compression technique applied to a single mode Er:Yb doped fiber [3]. A peak power of 385 W at 1.5  $\mu\text{m}$  was obtained with an optical-optical efficiency of 24% compared to 119 W without compression. We will focus this presentation on our understanding of the strain gradient effect on both the SBS Stokes spectrum and the SBS threshold power for single mode Er:Yb doped fiber and PMF passive fiber.

We are now able to measure with a high-resolution the actual longitudinal strain profile applied to the fiber with an optical frequency domain reflectometer (OBR 4613, Luna Innovations). Combined with the simulated amplified signal profile in the fiber as inputs of our SBS numerical model, we can predict the Brillouin spectral broadening. Fig. 1 shows outputs of this model for a 1 m PM passive fiber with and without compressive strain and prove to be in good agreement with the SBS spectrum measurement. These data allow a good understanding of the strained fiber laser operation and make it possible to design an optimized strain profile adapted to the laser source and the desired Lidar application.

Another characteristic for Lidar application is the polarization extinction ratio (PER), which is given in part by the core birefringence of the PM fibers. Applying a strong longitudinal strain may alters the initial transverse stress of PM fibers and thus the PER. First results show that with compressive strain, active fibers appear to be more prone to PER degradation than passive fibers. This is compatible with the fact that initial birefringence is generally lower in active fibers than in passive fibers. Nevertheless, we can reach a 4-5 dB augmentation of the SBS threshold power while preserving a PER higher than 16 dB (required for coherent lidar systems) in active fibers.

In the meantime, we started to apply our method to strain efficiently a large mode area (LMA) fiber, with a larger clad diameter. The challenge here is twofold. First, the force to apply scales quadratically with the fiber diameter. Second, LMA fibers should be more sensitive to PER degradation since they generally have a lower birefringence than singlemode fibers.



**Fig. 1** Left: Comparison between the results of our model using the measured strain profile and experimental measurements of the SBS spectrum for a passive fiber before and after compression. Right: Reflectometry measurement of the compressive strain profile of the same fiber.

## References

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