Stimulated Brillouin scattering threshold variations due to bend-induced birefringence in a non-polarization-maintaining fiber amplifier

C. Guintrand, J. Edgecumbe, K. Farley, J. Abramczyk and K. Tankala
Nufern, 7 Airport Park Road, East Granby, CT 06026
Author e-mail address: cguintrand@nufern.com

Abstract: We report on the SBS threshold variations due to the coiling-induced birefringence in a non-polarization-maintaining fiber high power amplifier. We demonstrate that a control of the output polarization can permit higher SBS threshold operation.
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1. Introduction

Stimulated Brillouin scattering (SBS) is a major impediment in achieving high output power fiber amplifiers with narrow linewidth operation. Doped LMA fibers are widely used to achieve kW-level amplifiers due to larger effective area and pump coupling capabilities. Even in few-moded LMA fibers, coiling is necessary to suppress higher modes [1] and achieve near diffraction limited beam quality. For many applications controlling the output state of polarization (SOP) is critical. This can be achieved by incorporating all polarization maintaining (PM) fiber in the amplifier or by using strictly non-PM fiber and implementing a feedback loop to control the polarization state output. We report the observation of SBS polarization dependence in a non PM fiber amplifier due to coiling-induced birefringence.

2. Experimental Setup

A multi-stage non PM fiber amplifier where the output SOP is set and controlled by a feedback loop configuration is shown in Figure 1.

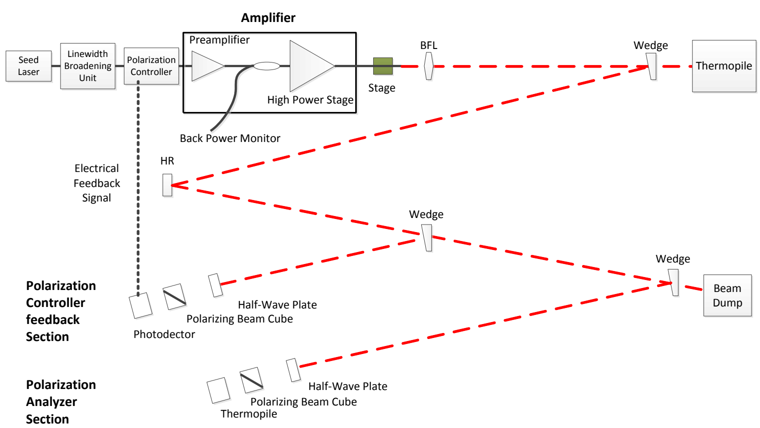

Figure 1: Experimental Setup.

A 1064 nm narrow seed laser (~kHz linewidth) phase modulated by a white noise source [2] to ~15 GHz linewidth was sent into a commercially available polarization controller before being injected in the first stage of the amplifier. The high power stage of the amplifier consists of ~10 m of a double clad 25/400 LMA Ytterbium-doped fiber (non PM) pumped by 976 nm pump diodes. The first 4.5 m of fiber are coiled in a 100 mm diameter coil. A fraction of the output beam was passed through a half-wave plate and a polarizing beam cube to select any output linear polarization. This polarized light is then detected and a feedback signal is generated and sent to the polarization controller to stabilize the SOP. The back-reflected power coming from the high power stage is measured as a function of SOP through a fiber tap.

3. Results

The backward power exhibits 90° periodicity dependence versus linear output polarization angle (Fig. 2). The output linear polarization directions producing the maximum back- reflected power correspond to 0° (in the coiling plane) and 90° while the minimum value is achieved for a 45° angle relative to the coiling plane. It was verified by monitoring the optical backward spectra that the Brillouin Stokes peak power was significantly increased for 0° and 90° compared to the 45° linear polarization. The backward power was recorded at 45° and 90° versus the amplifier output power with the 15 GHz linewidth source. For reference, an un-polarized broadband fiber laser not inducing SBS was also used (Fig. 3).

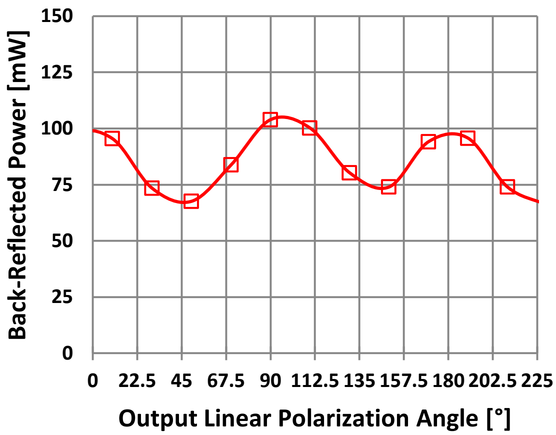

Figure 2: Back-reflected power vs. output linear polarization angle.

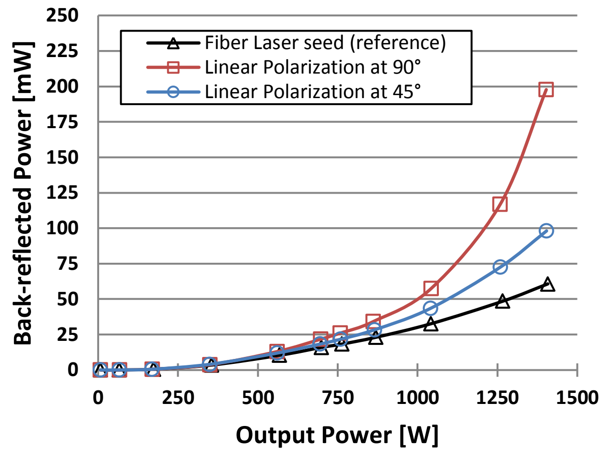

Figure 3: Back-reflected power vs. amplifier output power for 90° and 45° output linear polarization.

We believe that the observed SBS threshold dependence on SOP is due to Bend-induced- Birefringence (BiB) induced by the coiling. It is known that coiling the fiber induces birefringence through stress [3-5]; thus a non PM fiber will exhibit some birefringence properties when coiled tight enough. It is also acknowledged that the SBS gain for a pump launched at 45° relative to the birefringence axes of a PM fiber (high birefringence) is only half the one obtained if the light was maintaining a linear polarization along the fiber [6-8].

For a freely bent fiber (no extra tension applied during coiling) the birefringence (β_b) is given by [5]

$$\beta_b = -0.86\frac{r^2}{\lambda R^2}. \qquad (1)$$

Where λ is the vacuum wavelength, r the fiber outer radius and R the radius of curvature, the fast axis coinciding with the radius of curvature and the slow axis normal to the plane of curvature. Using the experimental values λ=1064 nm, r=200 µm, R=50 mm, the calculated birefringence value is β_b=0.13 rad/cm ($\Delta n=2.2\times10^{-6}$), corresponding to a beat length of 48 cm. Measured data of 45 cm beat length and $\Delta n=2.4\times10^{-6}$ are in good agreement with the expected values. The polarization extinction ratio (PER) for any locked output linear SOP was greater than 17dB.

4. Conclusion

The coiling-induced birefringence observed in the non polarization-maintaining fiber amplifier can be exploited to increase the SBS threshold while maintaining a stable linear output polarization with the use of a polarization tracker [9]. This is an attractive alternative to an all PM fiber amplifier for which the light maintains a linear polarization along the fiber and leads to a lower SBS threshold. Also, it is worth mentioning that achieving a good PER with a PM fiber amplifier can be challenging.

5. References

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