# In-Band SBS Suppression for Optical High Power Transmitter

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**Abstract:** No observable implementation loss is demonstrated with an in-band carrier frequency dithering technique to suppress stimulated Brillouin scattering (SBS) in a 50-W optical BPPM transmitter, contrast to previous demonstration with out-of-band modulation [1].



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## 1. Introduction

Suppression of stimulated Brillouin scattering (SBS) becomes necessary for some applications as recent progress on fiber based optical high power amplifiers (OHPA) makes it possible to transmit power in the multi-kilowatt range [2,3]. Liu recently demonstrated a SBS suppression technique within an OHPA by using non-uniform fibers [4]. However, a long fiber is typically employed after the OHPA to deliver the power to a desired location before its launch into free space, where SBS threshold can be easily reached even when the external power delivery fiber is short.

Directly dithering a DFB source has been suggested in a previous study for analog lightwave CATV systems, where the dithering signal frequency is in the GHz range and is outside the CATV signal bandwidth [1]. This approach is not feasible for use with some high power low chirp DFB lasers, and also not feasible for high data rate applications where the dithering frequency is always in-band.

In many applications, external modulation of a CW DFB laser is used to alleviate the problem of laser chirp associated with direct modulation. Although the overall optical spectrum is broadened due to data modulation, the residual narrowband content, such as carrier or clock frequencies, can still result in SBS and limit the OHPA optical power that can be delivered through a fiber. Other techniques have also been proposed to increase the SBS threshold. For example, using a large mode area fiber can raise the SBS threshold to a few hundred watts [4]. In practice, other components in a typical free space communication system, such as low loss optical switches [5] following the OHPA, may not use large mode area (LMA) fibers and the splicing loss among different kinds of fibers prohibits the use of LMA fibers to reduce SBS.

In this paper, we directly dither the carrier with in-band frequency, yet, the resulting wideband frequency modulation (FM) significantly reduces narrowband components with a corresponding increase in the SBS threshold. Our approach features (1) efficient use of an OHPA, (2) low overall size, weight, and power, (3) no or minimal implementation loss or power penalty to a communication link, (4) no special requirement on the OHPA, that is, a regular commercial-off-the-shelf OHPA can be used, and (5) minimal output power fluctuations in the source laser.

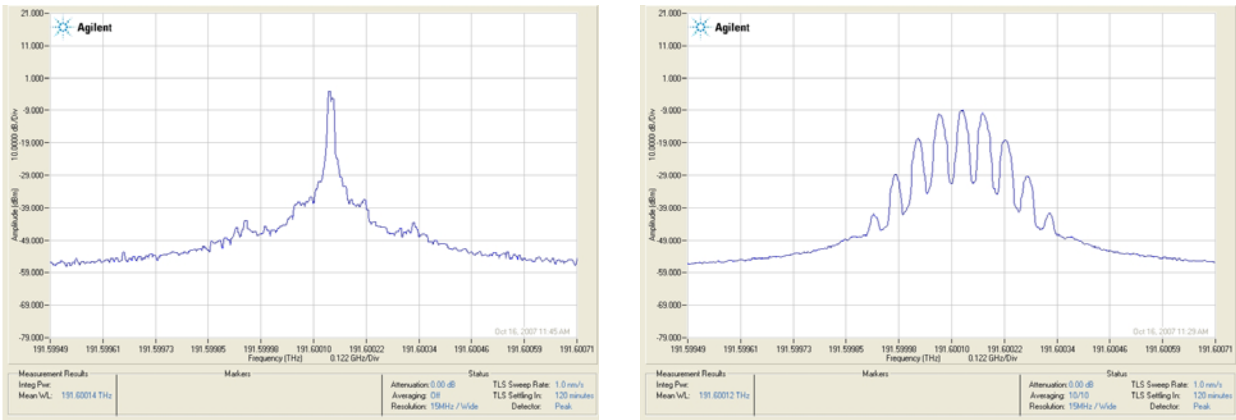
## 2. EXPERIMENT

The concept is demonstrated using a DFB laser, an external $LiNbO_3$ intensity modulator, and a 50 W OHPA. External 8 m SMF-28 fiber is used after the OHPA although additional optical elements could further extend the power delivery fiber length after OHPA.

The DFB laser wavelength is directly frequency modulated with a sine wave on the DFB driving current. The accompanying DFB laser power fluctuations are small with a peak-to-peak (p-p) amplitude modulation index between 1% and 3%. In this experiment, the 10 Gb/s BPPM data is applied to the intensity modulator. A back reflection monitor triggers a protection circuit which shuts down the 50 W OHPA to prevent damage due to SBS. Without dithering the DFB laser, back reflected power caused by SBS triggered our shutdown protection circuitry even when the OHPA output was set to 35 W. It requires a 3 dB increase in the SBS threshold with DFB laser modulation when the OHPA output is 50 W.

## 3. RESULTS AND DISCUSSION

Figure 1 shows the measured DFB laser output spectra without and with dither modulation using an Agilent high resolution spectrometer. The DFB output spectrum is broadened to ~100 MHz and the single frequency tone is suppressed ~5dB, although the p-p amplitude modulation is only 1%. The FM index can be calculated from the DFB output spectra. The measured AM index, calculated FM index, and measured largest tone suppression is shown in Table 1.




(a) (b)

Figure 1: Measured DFB output spectrum -- (a) no modulation; (b) DFB is modulated with 50 MHz sine wave, amplitude modulation index of 1%.

Table 1: Measured AM index, calculated FM index and measured largest tone suppression.

| AM Modulation Index (p-p) | FM Modulation Index | Largest Tone Suppression (dB) |
|---|---|---|
| 1% | 1.3 | -5.2 |
| 2% | 2.6 | -5.0 |
| 3% | 3.9 | -5.8 |

A small portion of the OHPA output is sent to an optical receiver for BER measurement. The 10 Gb/s BER vs. received power curves are shown in Figure 2. There are two sets of curves shown. One set of curves is for lower OHPA power of 30 W such that OHPA is not shut down without dithering the DFB laser. A high sensitivity receiver is used and the sensitivity is -44.2 dBm at $10^{-4}$ BER, which is about 2 dB from theory when the OHPA output is 30 W. It can be seen that there is no power penalty even with 3% amplitude modulation index applied on the DFB laser and 30 W OHPA output. The 0.6 dB power penalty, comparing 50 W OHPA output with 30 W output, is due to self-phase modulation (SPM). At 50 W, there is negligible power penalty when the 1% amplitude modulation is increased to 3%.

Since 1% modulation can provide 5 dB carrier suppression as shown above, 1% modulation is sufficient to suppress SBS for this specific demonstration. Larger modulation index can be used for longer fiber. Although slightly large modulation index can cause a few tens of dB penalty, this penalty can be overcome with wider receiver filter, which is also in alignment with further increase of SPM effect from longer fiber.

## 4. CONCLUSION

We demonstrated that SBS in high power transmitter can be suppressed with an in-band dithering technique and minimum modulation of direct dithered DFB laser. It is shown that 1% modulation index is sufficient to reduce SBS to low level such that 50 W optical power can propagate 8 m SMF-28 fiber without causing problem to the OHPA, and no link penalty is observed due to the dithering approach.

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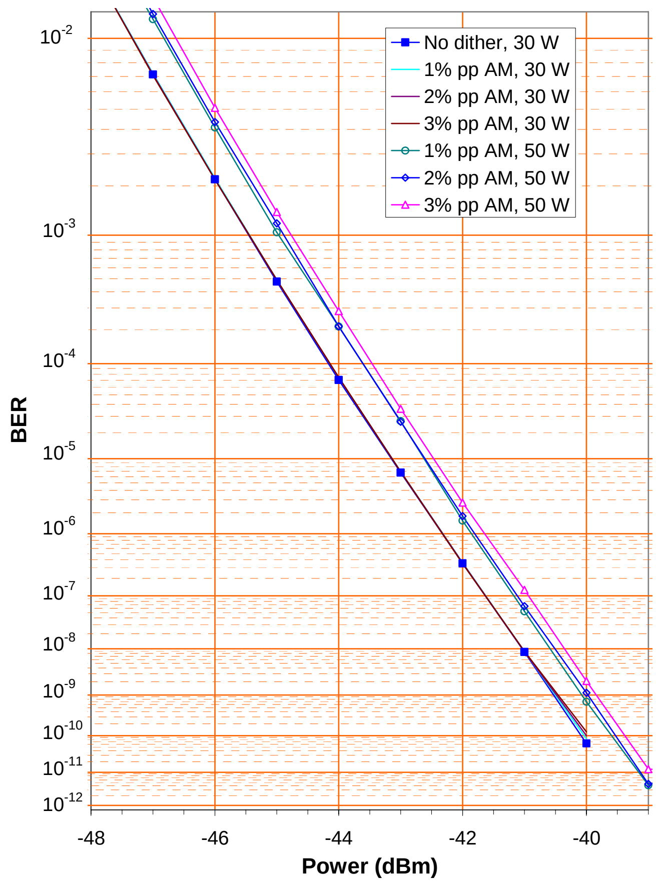


Figure 2: 10 Gb/s BER vs. received power curves.

## 5. ACKNOWLEDGEMENT

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## References

[1] F.W. Willems, W. Muys, and J.S. Leong, "Simultaneous suppression of stimulated Brillouin scattering and interferometric noise in externally modulated lightwave AM-SCM systems," IEEE Photon. Tech. Lett., v.6, p.1476, (1994).

[2] J.E. Rothenberg, "Suppression of stimulated Brillouin scattering in single-frequency multi-kilowatt fiber amplifiers," paper 6873-23, Photonics West, (2008).

[3] B.N. Samson, J.P. Edgecumbe, J. Galipeau, K. Tankala, M.O'connor and D.P. Machewirth, "Power scaling monolithic PM-LMA fiber amplifiers towards 1kWatt," paper 6873-21, Photonics West, (2008).

[4] A. Liu, "Suppressing stimulated Brillouin scattering in fiber amplifiers using nonuniform fiber and temperature gradient," Opt. Exp. 15(3), p.977, (2007).

[5] T. Holcomb, B. Scott, S. Hellman, J. Kondis, and P. Townley-Smith, "Performance of a fiber-optic high power switch," Milcom'2008, San Diego, CA.