Suppressing SBS Through Chaotic Phase Modulation

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Introduction

Stimulated Brillouin scattering (SBS) is a nonlinear interaction between optical and acoustical waves that can severely limit the power transmitted through fiber optic systems. SBS begins to grow rapidly after a threshold input power shown below[1]:

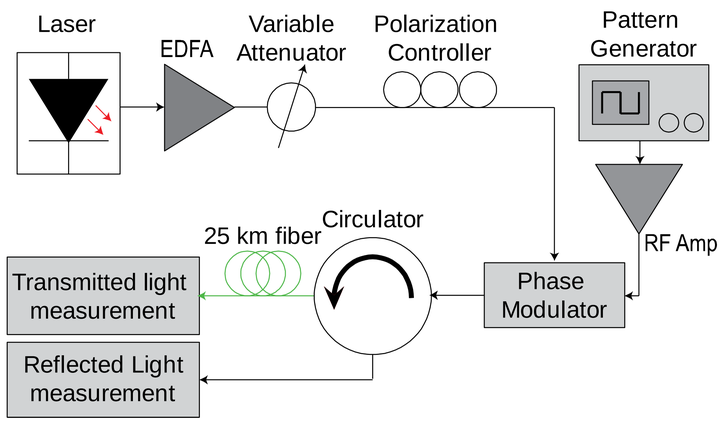
$$P_{th} = \frac{21(b)(A_{eff})}{g_B(L_{eff})}(1 + \frac{\Delta v_L}{\Delta v_B})$$

An existing method of suppressing SBS is through phase modulation, which increases the laser linewidth Δv_L above.

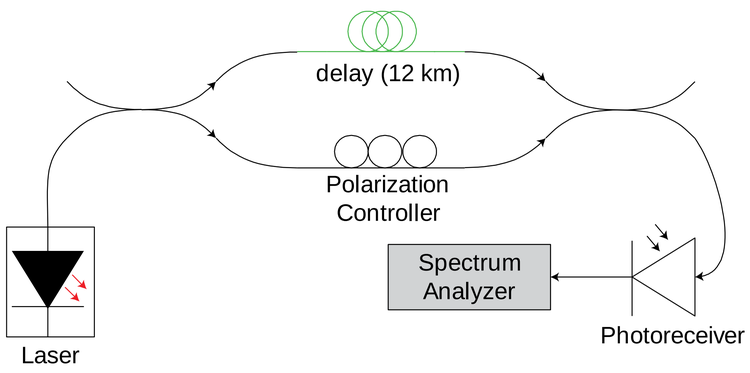
We explore the following:

- Suppression of SBS through chaotic phase modulation
- A comparison between chaotic and conventional non-chaotic modulation
- A theoretical model to simulate the output of a fiber optic system in the presence of phase modulation
- Ways to exploit chaotic synchronization to recover the un-modulated carrier at the receiver

Experimental Methods



Experimental setup used to measure output power.



Delayed self-homodyne experimental setup used to measure laser linewidth.

Simulation Methods

The SBS can be represented by the following three complex coupled partial differential equations[2]:

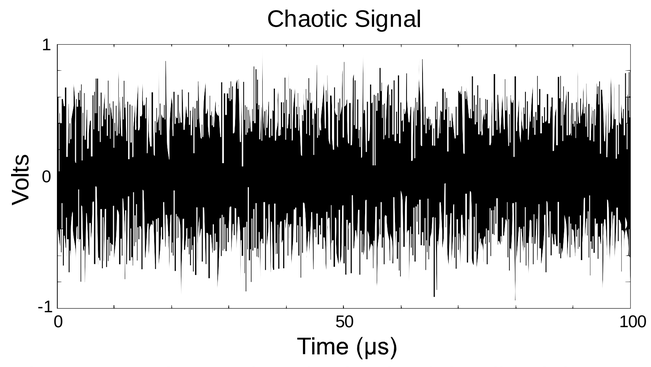
$$\frac{\partial E_L}{\partial z} + \frac{n}{c}\frac{\partial E_L}{\partial t} = -\frac{\alpha}{2}E_L + i\kappa E_S \rho \quad (1)$$

$$\frac{\partial E_S}{\partial z} - \frac{n}{c}\frac{\partial E_S}{\partial t} = \frac{\alpha}{2}E_S - i\kappa E_L \rho^* \quad (2)$$

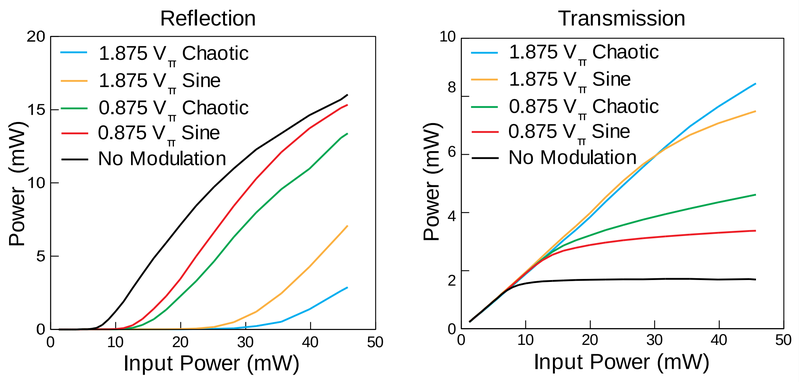
$$\frac{\partial \rho}{\partial t} + \pi\Delta\nu_B\rho = i\Lambda E_L E_S^* + f \quad (3)$$

The simulation of these equations was implemented through a Finite-Difference Time Domain (FDTD) method.

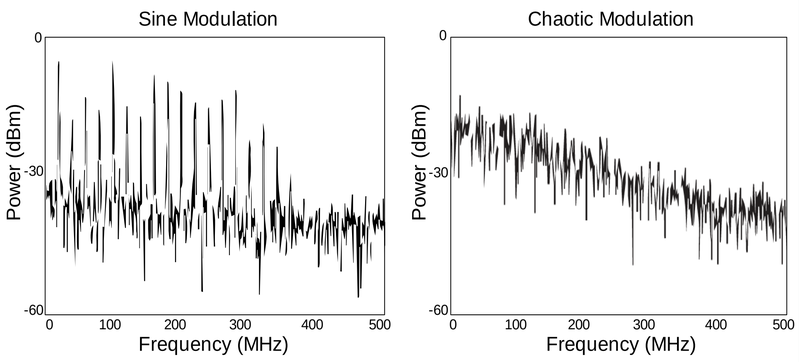
Experimental Results



The output of a Mach-Zehnder (MZ) feedback loop as demonstrated in [3].

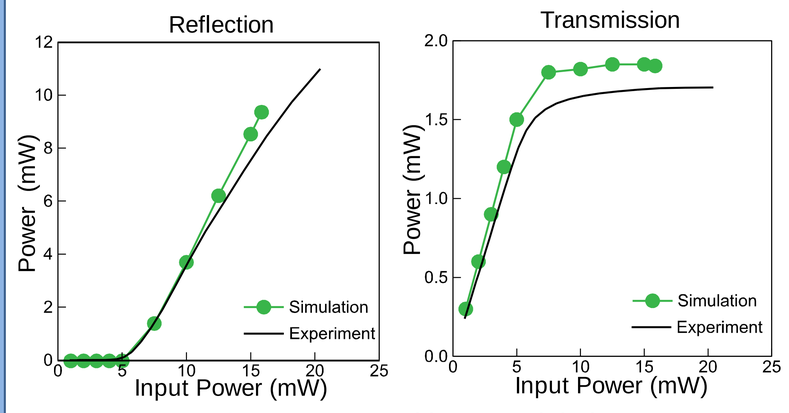


Output power due to phase modulation by 20MHz signals.

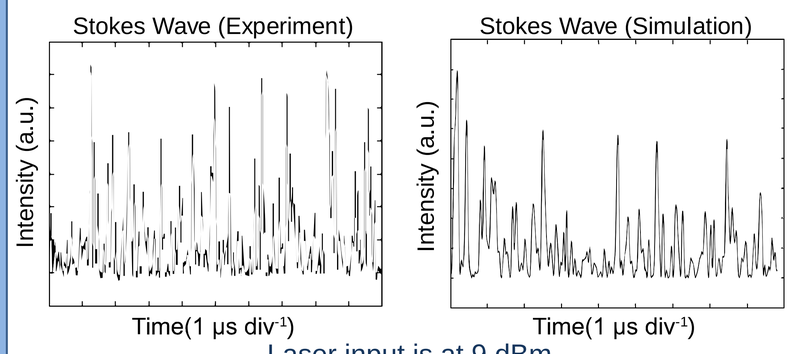


Transmitted laser frequency power spectrum due to modulation by 20MHz signals at 1.875 V_π.

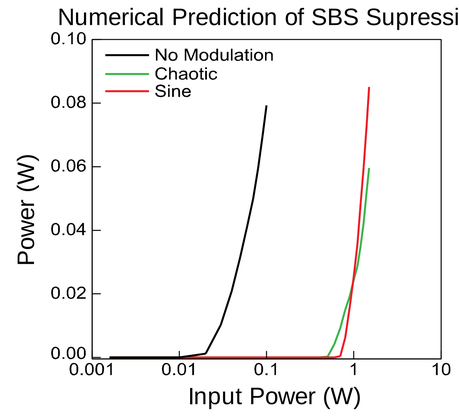
Simulation Results



Output power with no modulation.

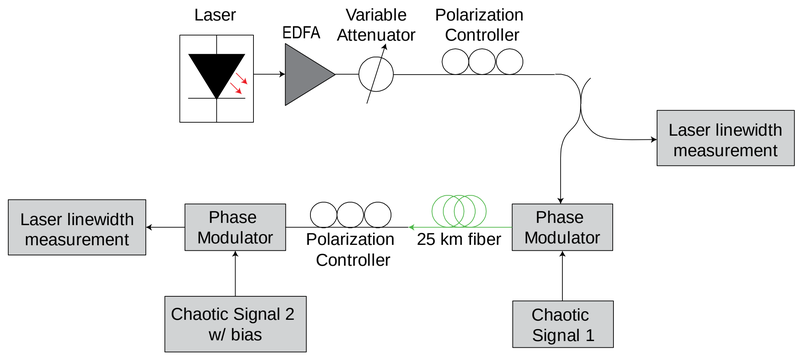


Laser input is at 9 dBm.



Output Stokes power for 5km fiber. Modulating signals are 20MHz at 2.5 V_π.

Future Work



Potential experimental setup to undo modulation and recover a coherent narrow-linewidth laser.

Demodulation Process

1. Measure original laser linewidth
2. Phase modulate the laser with a chaotic signal
3. Apply an equal and opposite phase modulation at fiber exit
4. The two chaotic signals can be self-synchronized
5. Measure output laser linewidth

Conclusions

Experiment

- Chaotic phase modulation is effective in SBS suppression.
- We implemented a method to characterize laser linewidth.

Simulation

- Developed simulation that accurately predicts SBS threshold.
- Chaotic modulation at higher voltages is predicted to be comparable to sine modulation.

References

[1] T. Shimizu *et al.*, "Evaluation methods and requirements for the stimulated Brillouin scattering threshold in a single-mode fiber," *Opt.Fiber Technol.,* vol. 14, no. 1, pp. 10-15, Jan. 2008.

[2] R. Boyd, K. Rzazewski, and P. Narum, "Noise initiation of stimulated Brillouin scattering," *Physical Review a,* vol. 42, no. 9, pp. 5514-5521, Nov. 1 1990.

[3] T. Murphy *et al.*, "Complex dynamics and synchronization of delayed-feedback nonlinear oscillators," *Phil. Trans. R. Soc. A,* vol. 368, no. 1911, pp. 343-366, Jan. 28 2010.

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