Transient stimulated Brillouin scattering dynamics in polarization-maintaining optical fiber

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Stimulated Brillouin Scattering

$\Omega_B = \omega_1 - \omega_2$

Amplification: $I_2(z) = I_2(L)e^{gI_1(L-z)}$

Generation: $P_{th} = \frac{G_{th} \lambda}{2g}$

Short optical pulses have a higher power threshold.
SBS Generation From Noise

- Coupled Wave Equations for SBS.

\[ \frac{\partial A_1}{\partial z} + \frac{n}{c} \frac{\partial A_1}{\partial t} = i\kappa \rho A_2 \]
\[ - \frac{\partial A_2}{\partial z} + \frac{n}{c} \frac{\partial A_2}{\partial t} = i\kappa^{\ast} A_1 \]
\[ \frac{\partial \rho}{\partial t} + \frac{\Gamma_B}{2} \rho = i\alpha A_1 A_2^{\ast} + f \]

\[ \kappa = \frac{\omega_1 \gamma_e}{2nc\rho_0} \]
\[ \alpha = \frac{\gamma_e q^2}{8\pi \Omega_B} \]

- Langevin noise source initiates SBS\(^1\).

\[ \langle f(z, t) \rangle = 0 \]
\[ \langle f(z, t) f^{\ast}(z', t') \rangle = Q \delta(z - z') \delta(t - t') \]

\[ Q = \frac{2kT \rho_0 \Gamma_B}{v^2 A} \]

- We solved these equations numerically near the threshold for SBS.

Experimental Setup

Pulse-Shaping System → Regenerative Amplifier

1. 70 m PM fiber
2. Faraday Rotator
3. λ/2 plate
4. PBS

PM fiber structure

- Inner Cladding
- Outer Cladding
- Core Diameter: 7.2 μm (3M FS-PM-5121)

Advantages of PM fiber:
- Experimentally ideal
- Avoid optical damage
Transmitted Pulse

Theory:

Input Pulse

Experiment:

Pulse is effectively narrowed.
Theoretically Modeled SBS Pulse

SBS Energy = 2.3 μJ

SBS Energy = 2.0 μJ

SBS Energy = 321 nJ

SBS Energy = 174 nJ
Experimental SBS Pulse
Conclusions

- Polarization-maintaining fiber is useful in studying transient SBS in fibers since there is no decrease in the threshold power from depolarization effects.

- In a long fiber, SBS is generated throughout the length of the fiber.

- A Langavin noise source model accurately explains the reflected SBS signal.

- The pump pulse is narrowed on transmission through the fiber as a result of pump depletion.

- Well above the threshold power for SBS, the reflected pulse is narrower than the input pulse (SBS pulse compression).