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유도 브릴루앙-파이버 링센서에서 비안정화 현상

Effect of Steady and Relaxation Oscillation in Brillouin-Active Fiber Ring Structural Sensors

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I. Brillouin Fiber-Ring Instability

We have developed a practical Brillouin active fiber ring sensor of length less than 20m, by employing an optical amplifier to compensate for most of the connection losses in the ring. The loss reduction brings the standard Brillouin threshold from 21 down to 0-0.1 through the enhancement of the finesse of the ring. However, in the course of our experiments, some level of temporal instability and chaotic behavior in the backscattered Stokes intensity and also in its spectral line shift were consistently observed. (see Fig.1,2). It is thus essential whether in section of an amplifier will further destabilize the system.

Since our proposed Brillouin fiber ring sensor is based on monitoring the Stokes spectral line shift with temperature and strain, the origin of the temporal chaotic behavior must be understood and its correlation to spectral line shift examined.

It turns out stimulated Brillouin scattering(SBS) is a paradigm in the field of nonlinear dynamics, in which a signal originating from noise evolves into deterministic dynamical behavior through a nonlinear interaction. The question is whether the originating noises have any effect on the evolved dynamics. This is a fundamental question in the field of nonlinear optics, in which many interactions originate from stochastic processes, the sources of which are either thermal fluctuation or quantum noise.

It is shown experimentally that, on increasing the pump signal strength, the noise that initiates this process is dramatically suppressed, giving rise to highly deterministic dynamics, or low dimensional chaos, evolving from quasi-periodicity[1]. The dynamics is found to be noise dominated only for weak pumping near the threshold for SBS. Here, feedback suppresses stochasticity in the amplification process of the Stokes emission, giving rise to deterministic behavior, the forms of which are found to be critically dependent on the strength of the nonlinear refraction. Assuming fiber ring is equivalent to zero feedback, the dynamics is periodic with much higher frequency content (Fig.1. a-c). The dynamics of Stokes emission above threshold was very distinct and reproducible, exhibiting different classifiable forms. Two windows of periodic behavior (Fig.1. d-f; h-j) were observed, separated by a window of quasiperiodic and chaotic motion (Fig.1. h-j).

Within the first window, the dynamics exhibited sustained relaxation oscillations, and on increasing the pump signal, underwent a transition to sinusoidal oscillations, of periods $2T_r$. This is interpreted physically as arising from the interplay of the SBS with the feedback from the external cavity. The amplitudes of these oscillations were quite stable over a time scale of hundreds of the cavity round trip time. In the second of these windows periodic behavior was found to occur with frequencies at various harmonics of the characteristic frequency $1/2Tr$, the relative strength of which changed with the pump strength. On increasing the pump signal (Fig.1. h-j), the dynamics was found to change dramatically with change of its frequency components, occasionally reverting to limit cycles when the frequencies locked. Within this region, loss of stability of the quasiperiodicity led to weak chaotic emission.

Two contributions to nonlinear polarization are considered, namely electrostriction and intensity-dependent refraction. The former causes the nonlinear gain of the Stokes wave and the latter results in self-and cross- phase modulations due to the presence of the light fields.

II. Proposed Control of Chaos

The possibility of converting chaos to periodic motion has recently inspired much theoretical and experimental activities in the area of nonlinear dynamics[2](see Fig.3). The basic idea is the stabilization of unstable periodic orbits embedded within a chaotic attractor. Since these orbits are very dense in such an attractor, a successful control may therefore serve as a generator of rich forms of periodic waves, thus turning the presence of chaos to advantage.

We propose to employ continuous optical feedback for the control in which coherent interference of the chaotic optical signal with itself, when delayed, is used in achieving signal differencing for the feedback.

1. R.G. Harrison, et al, Physica D, **86**, 182, (1995).
2. W. Lu et al, Opt. Comm. **109**, 457, (1994).

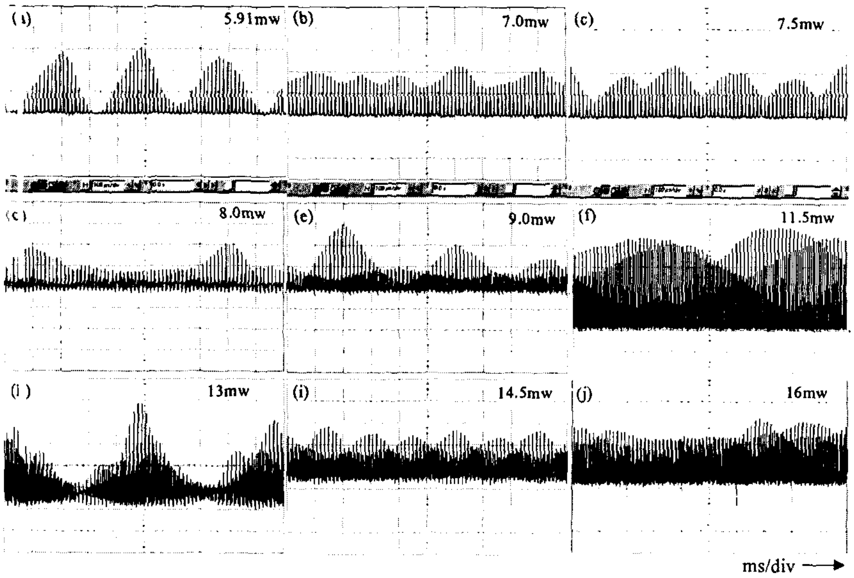

Fig.1. Temporal structure of SBS Instability pulse train in long-time range.

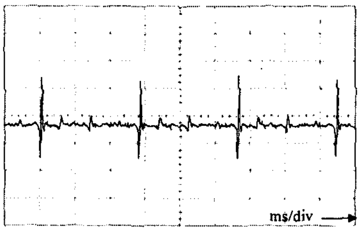

Fig.2. Temporal structure of backward-stimulated Brillouin pulse train in short-time range

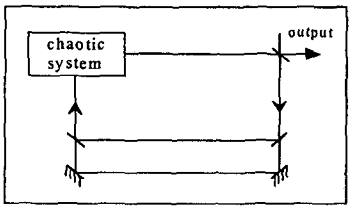

Fig.3. Schematic diagram for controlling chaos in optical system.