브릴루앙 산란에서 유발되는 비선형적인 불안정 현상에 대한 제어연구

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Study of Transient Control of Nonlinear Dynamically Induced Instabilities in Brillouin-Active Fiber

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Abstract – In this present the transient control of SBS chaos induced instability in Brillouin-active fiber systems is described. The inherent optical feedback by the backscattered Stokes wave in optical fiber systems leads to instabilities in the form of optical chaos. At weak power, the nature of the Brillouin instability can occur at before threshold. At strong power, the temporal evolution above threshold is periodic and at higher intensity can become chaotic. Multistable periodic states, makes transition to logic *'on'* or *'off'*. It can make theoretically potential large memory capacity.

1. INTRODUCTION

Nonlinear effects in optical fibers, specifically stimulated Brillouin scattering (SBS), has emerged as a versatile approach to the construction of active optical devices for all-optic in-line switching, channel selection, amplifiers and oscillators in optical sensing, and optical communications[1-4]. The backward scattering nature of Brillouin scattering, which is the light reflection by laser induced acoustic wave in the fiber, has long been viewed as an ultimate intrinsic loss mechanism in long haul fibers, since Brillouin threshold decreases with increasing effective fiber length [5-6]. The very backscattering nature of this nonlinear process and the existence of a threshold provide potential optical device functions, such as optical switching, sensing, arithmetic and neural functions in networks.

The inherent optical feedback provided by the backscattered Stokes wave (SBS) in an optical fiber also leads to instabilities in the form of optical chaos [7-8]. This paradigm of optical chaos in optical fiber serves as a natural model for studying chaos for possible suppression and exploitation in fiber optic sensing and communications. A possible suppression, controlling chaos induced instability, is the stabilization of unstable periodic pulse-wave embedded within a chaotic attractor [9-10].

If these periodic pulses 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.

In this paper controlling of chaotic effect, Brillouin induced instability in optical fiber systems, is experimentally proposed. Transiently controlling of temporal instability has been explained in its SBS spectral line shift.

2. BRILLOUIN INDUCED CHOAS AND INSTABILITY

Brillouin scattering has the lowest threshold among nonlinear optics phenomena and hence has attracted the greatest interest in small core, low loss single mode fibers for next-generation network and systems. It turns out that Brillouin scattering is a paradigm in the field of nonlinear dynamics in any systems, in which a signal originating from noise evolves into deterministically dynamic behavior through a nonlinear interaction [5-6].

If the optical power launched into the fiber exceeds some critical threshold level, then Brillouin effect can occur. The Brillouin effect causes a significant proportion of the optical power traveling through the fiber transmission line to be converted into a reflected lightwave, shifted in frequency, traveling backward direction. The Brillouin effect can occur in a single pass through long fibers of low loss single mode fiber with launched power levels only a few milliwatt, which is within the envisaged operating range of optical systems. This effect can be detrimental to an optical transmission system in a number of ways: severe additional signal attenuation, by causing multiple frequency shifts in some cases, and high intensity backward coupling in the transmission optics.

An active device in optical systems generally requires the employment of nonlinearity, and possible feedback for increased efficiency in device function. The presence of this nonlinearity with intrinsic delayed feedback has been also repeatedly demonstrated to lead to instabilities and chaos in optical fiber transmission lines. The combination of nonlinearity and optical feedback in optical transmission lines, is a prescription for inherent deterministic instabilities that may ultimately lead to optical chaos in optical fiber [7]. Instabilities are unavoidable in Brillouin scattering due to its intrinsic nonlinearity and feedback. We have designed a setup

for analyzing Brillouin instabilities in a fiber sensor configuration. The experimental setup for analyzing chaos in Brillouin-active fiber-ring is shown in Figure1.
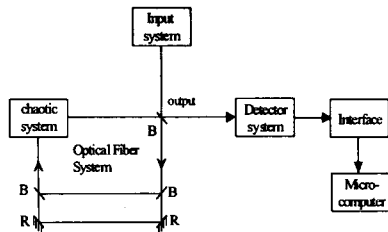

Fig. 1. Experimental schemes for measuring chaos induced instabilities in optical fiber system. R is the mirror reflectivity and B is beam split.

When the pump power reaches a threshold value, a temporal structure arises in the backward signal, consisting of a periodic train of Brillouin-wave pulses.

3. CONTROLLING OF SBS CHAOTIC INSTABILITY

Converting of SBS chaos induced instability to periodic effect has inspired theoretically in the area of nonlinear dynamics. The basic idea is the stabilization of unstable periodic orbits embedded within a chaotic attractor [9]. 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. The experimental setup for controlling SBS chaotic instability is shown in Figure 2.

The temporal repetition rate of which corresponds to a pulse round-trip time in the fiber-ring taken to be less than 10 nsec. The Brillouin pulse train amplitudes remain unstable, particularly just below pump threshold. When the observation is made using a long time scale, the Brillouin output exhibits randomly distributed trains of periodic pulses.
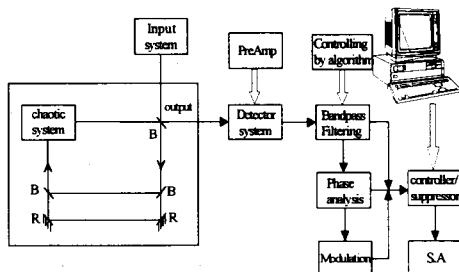

Fig.2. Schematic diagram for controlling chaos induced instability in Brillouin-active fiber system. The optical implementation included chaotic system is configured with fiber ring. R is the mirror reflectivity and B is beam split.

Partial stabilization of amplitude fluctuations is achieved as laser pump power approaching maximum value. These experimental features are shown in time domain in Figure 3 (a) through (b).
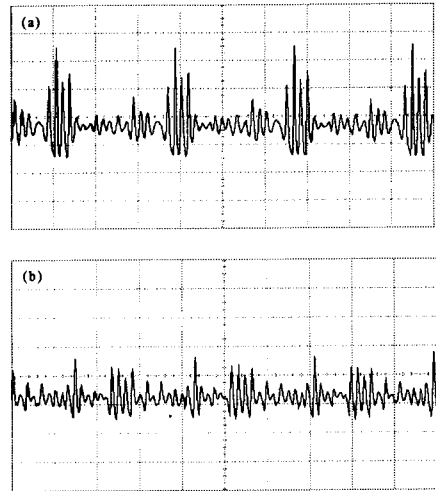

Fig.3 Brillouin induced instabilities in function of time (μsec/div) at threshold (a) and high above threshold (b)

At lower power, the Brillouin instability can occur at before threshold. This required power is much lower than normal Brillouin process intensity involving single pump power. The temporal evolution immediately above threshold is periodic and at lower intensities can become chaotic [11]. We here also proposed 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. If fiber suppressing by attractor proves to control cha os then, fiber suppressing under natural chaos can be exploited as a means for sensing structural chaos. Mu ltistable periodic states, as shown in Figure 4 (a) and (b), makes transition to logic '0' or '1'.
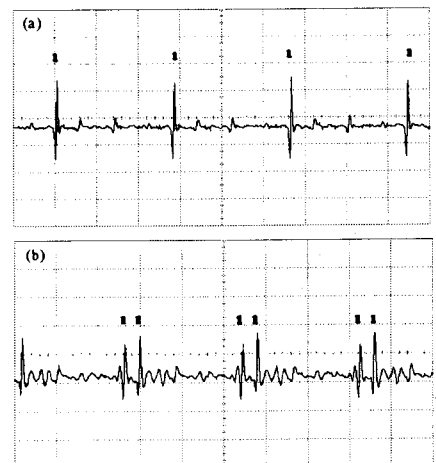

Fig. 4. Transiently controlled SBS chaos induced instabilities (μsec/div) at threshold (a) and high above threshold (b). The examples of sequence of suppression are assigned by '0' and '1' symbol.

It can make theoretically potential large memory capacity as like input bit streams in TDM network sy stems. Its implementation still requires much engineeri ng improvements, such as arriving at a spatial resolut ion that is comparable to the references or speckle, an d suppression of its potential to chaos.

4.CONCLUSION

Our work has demonstrated the controlling of the Brillouin induced instabilities as a highly sensitive and versatile sensor in principle. Its implementation still requires much engineering improvement, such as arriving at a spatial resolution and suppression of its potential to chaos. Actual filed application requires also integration into multiplexing schemes, sensor sifting strategy, etc. Transiently Control of chaotic induced instability in optical systems makes transition to logic *'on'* or *'off'* following with multistable periodic states. It is theoretically possible to apply the multi-stability regimes as an optical memory device for encoding/decoding messages and complex data transmission in optical communications systems. It can make also theoretically potential large memory capacity.

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