CONTROLLING CHAOTIC INSTABILITIES IN BRILLOUIN FIBER SENSOR BASED ON NEURAL NETWORKS

Tae- Su Jnag[1], Kwan-Woong Kim[2] and Yong K. Kim[1]
[1]School of Electrical Information Communication Engineering, WonKwang University, 570-749, Iksan, Korea
[2]Korea Atomic Energy Research Institute, 305-353, Deajeon, Korea

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Abstract: In this paper the neuron operation based on neural network in optical fibre system has described. The inherent feedback wave in optical fibre leads to instabilities in the form of optical chaos. Below threshold value temporal evolution has periodic and can become chaotic condition. Controlling of chaotic induced transient instability in Brillouin fibre sensor has been implemented with Kerr nonlinearity with 13*GHz* backward shift, IR detector with 20*ps* impulse response, and ~10ns round trip time in optical network. The detected sensor has up-shifted in frequency by about ~20*MHz* from sensing target. The Controlling chaotic instabilities can lead to stable and periodical states; create optical logic data streams. It can lead to large optical memory capacity in neural networks.

1 INTRODUCTION

It is well known that optical fibers have potential usage in applied engineering technology other than optical communications, such as expanding research in versatile fiber optic sensors and networks (Cotter, 1983). Our research has also focused on integrating fiber optic sensors with neural networks to create a system that is capable of sensing, and controlling shape or orientation of the medium with respect to its environment, as a first step in creating a smart sensor structure (Yong, 2003). Specifically, we have focused on configuring and developing a fiber sensing system that behaves as a neural network, capable of learning by network experience, predicting future reactions to environmental changes, and executions as prescribed.

Such a smart sensor system based neural networks can potentially implement a massively parallel computational architecture with its attendant reduction in processing time while managing the complexity of the system, i.e. the sensing grid (Lyons and Lewis, 2000). Our fiber sensor network would learn the correct algorithms by example during training and have the ability to generalize to untrained inputs after training is completed under sensor networks (King and Lyons, 2003).

In general, an artificial neuron in neural networks can be thought of as a device with multiple inputs and a single or multiple outputs (Tariq, 1998). Actually, in equivalent networks, the inputs to a neuron are weighted signals in neural systems. The neuron adds the weighted signals, compares the result with a preset value, and activates if the sum exceeds threshold. The networks can be explained as a sensor inputs weighted signals. In the nonlinear optical phenomenon of stokes wave the system combined weighted signals produces an output if the weighted sum is greater than the threshold (Kovalev and Harrison, 2006).

Optical turbulence in the system and instability and periodic oscillation are easily seen with hybrid optically bistable device, which indicated fiber network configuration, with a delay in the feedback (Wang et al., 2008). The stability analysis of steady states is different from the usual criteria applied to differential equations (Agrawal, 2001). The instabilities to arise in steady state has implemented with time dynamics as chaotic (Kuo et al., 2010). A practical implementation for theoretical scheme has discussed for neural networks.

In this paper, the implementation for controlling Chaotic Instabilities in optical fiber has been studied with neuron operation based on neural network.

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2 NEURON OPERATION BASED OPTICAL SENSOR NETWORK

Nonlinear effects in optical fiber has emerged as a versatile tool for the design of active optical devices for all-optic in-line switching, channel selection, amplification and oscillation, as well as in optical sensing, optical communications, optical logic elements in optical computation and sensing, and a host of other applications (Lyons and Lewis, 2000). The paper attempts to present a survey and some of our own research findings on the nature of optical fiber scattering in single mode optical fibres and its device applications (Kuo and More, 2010). In theory, the backscattering nature of the phenomenon enables its application as channel selectors and switches and filters in optical transmission and communications (Agrawal, 2001). We have been engaged in the design and implementation of fiber configurations, such as rings and loop mirrors, with the purpose of lowering the threshold. We report on experimental schemes involving fiber ring with amplifier. These successful devices are being studied for application as optical logic and neuron elements for optical switching, and highly versatile sensors (King and Lyons, 2003).

The backscattering nature of nonlinear process in optical fiber sensor network and the existence of a threshold provide potential optical device functions, such as optical switching, arithmetic, and neural net functions in neural networks (Traq and Habib, 1998). The inputs to the network are the fibre optic sensor signal outputs, and the network outputs are the control signals for actuation controls. The true advantage of this system for application to sensor structures lays both in its capability to analyze complex sensor signal patterns. The experimental feature based on neural networks in hardware implementation is shown in real time in Figure1.

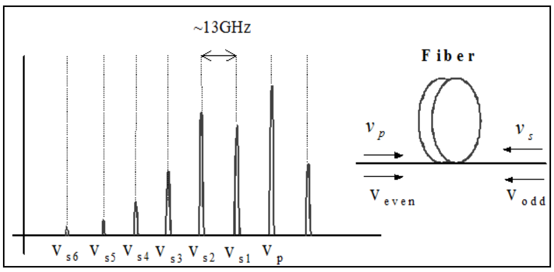

Figure 1: Optical fibre generates multiple Stokes waves for optical logic networks.

An artificial neuron can be thought of as a device with multiple inputs and single or multiple outputs. The neuron adds the weighted signals, compares the result with a preset value, and activates if the sum exceeds threshold values (W.B. Lyons and Lewis, 2000). In the nonlinear optical phenomenon, the combined weighted signals also produce an output if the weighted sum is greater than the threshold. Our research has also focused on a simplified multi-layered ward neural network; the processing node between interconnects in sensor networks, where weighted sums are fed to a threshold decision processing elements. The implemented frequencies scale have $v_p > v_s > v_n$.

3 CONROLLING OF CHAOTIC INSTABILITY

Conversion of optical fibre chaos induced instability to periodic effect is inspired by theory in nonlinear dynamics. The basic idea lies in the stabilization of unstable periodic orbits embedded within an optically chaotic attractor (Kovalev and Harrison, 2006).

The bit stream orbits are very dense; a successful control may therefore serve as a generator of rich forms of periodic waves, thus turning the presence of chaos to advantage (Wang et al., 2008). The experimental setup for controlling chaotic instability based on optical fibre network has shown in Figure 2.

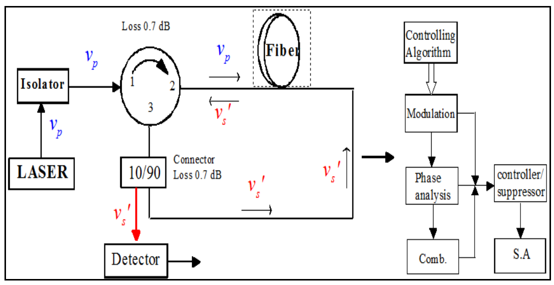

Figure 2: Schematic diagram for controlling chaos induced instability.

There are two fiber ring operations, one passive and one backwards active. In the passive ring, the laser beam circulates the ring, with the output characteristics governed by the finesse of the ring. The neuron active ring is governed by the finesse and the nonlinear scattering phenomenon in the fiber. Through acousto-optic coupling, a laser pump induces an acoustic wave in the fiber, which scatters part of the laser beam backwards as a Stokes wave. As configured, this Stokes wave is circulated in the ring, and continues to be amplified by the laser (pump). The ring is a network resonator or oscillator and amplifier. The enhanced sensor has clearly demonstrated in Fig.1 in the form of line narrowing. The sensor signal will act as a stokes wave for the v_p and as a pump wave for the v_n when v_p - v_n =Δ v_p, and v_s - v_n = Δ v_p. It is to be noted, since neuron is a backscattering process, threshold $g = g_0P_0L/A = 21$ for a straight fiber, has lowered in a fiber ring to approximately 0.1. On increasing the pump strength in the vicinity of the threshold $g \cong 4$, a stoke signal emerges from stochastic high-frequency noise to exhibit randomly amplitude-modulated periodic oscillations at the fundamental periods $2T_r$.

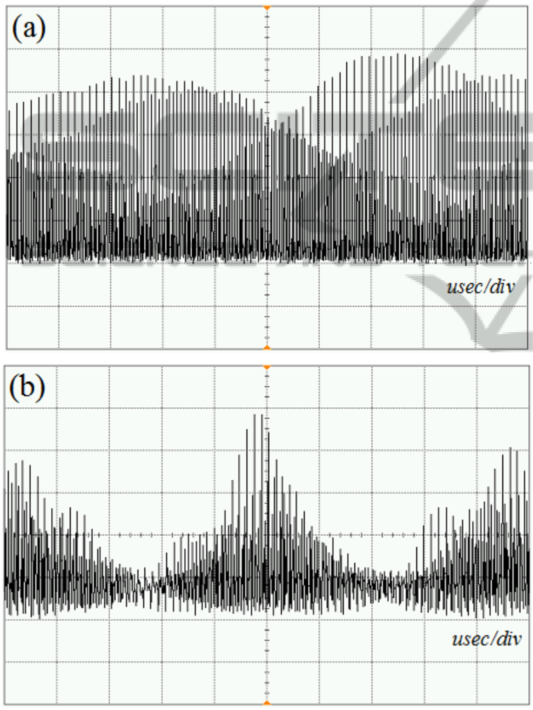

Figure 3: Optical pulse induced instabilities in function of time (μsec/div) at threshold (a), high above threshold (b).

A stabilized proves laser has yielding ~12.1*GHz* backward scattering shift, 25*GHz IR* Photo-detector (20*ps* impulse response) connected to a optical analyzer. The temporal repetition rate of which corresponds to a pulse round-trip time in the fibre-ring taken to be less than ~10*nsec*. The *R* is the mirror reflectivity and *B* is beam splitter. The narrow gain spectrum and relatively small frequency shift of the sensor process will allow the use of the same oscillator format for signals under identical fibres. The sensor signal is up-shifted in frequency by about 10*MHz* from the sensing signal in an amplifier format. It's has been implemented based on neural network to sensed it. The optical sensor pulse train amplitudes remain unstable, particularly just below pump threshold. When the observation is made using a long time scale (~100*usec/div*), the target pulse output exhibits randomly distributed trains of periodic pulses. Partial stabilization of amplitude fluctuations has achieved as laser pump power approaches maximum value with ~nm source pump. These experimental features are shown in real time in Figure 3 (a) and (b). It's shown that the optical pulse induced on instabilities as function of time. In the immediately above threshold, chaotic instabilities have occurred towards turbulence. In high above threshold, chaotic instability has periodically turbulence. The discrete lines have widths of less than 1*MHz*, with a resolution of 90/58 = 1.55*MHz*. We propose to employ continuous optical feedback for control in which coherent interference of the chaotic optical signal itself in achieve signal differences.

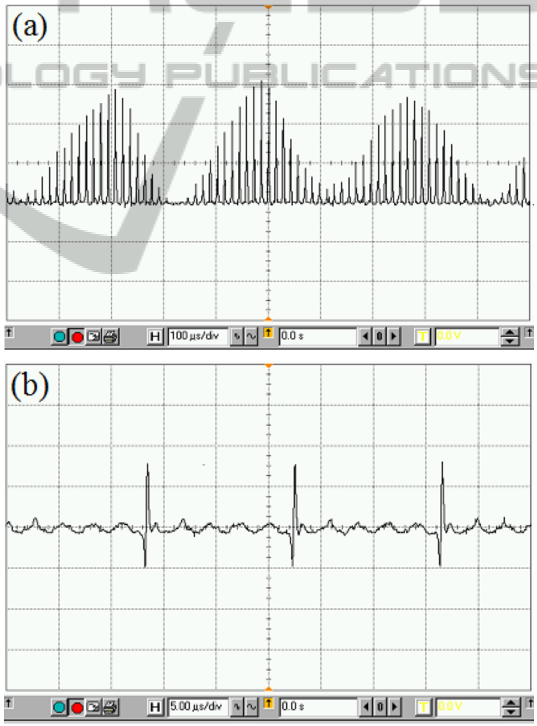

Figure 4: Transiently controlled instabilities at threshold (a) and high above threshold (b). The examples of sequence of suppression are assigned by '1'.

If suppressing by attractor proves to control chaos then, suppressing under natural chaos can be exploited as a means of sensing structural chaos in systems. The examples of sequence of suppression are assigned by 'low level' and 'high level' states since previous results. These states has implemented with TDM phase analysis and modulation. multi-stable periodic states, as shown in Figure 4 (a) and (b), can lead to logic 'low level' or 'high level' and can in principle create large memory capacity as input data bit streams in digital network systems. Its implementation also still requires much engineering improvements, such as arriving target at a spatial resolution speckle, and suppression of its tendency to chaos. We will focus on a more realistic case of *N* weighted pumps, i.e., one v_p, one v_s and v_{n1}, v_{n2}, $v_{n3} \ldots v_{nn}$. The optical sensor based neural networks is typically configured into an array for the sensor networks in optical fiber. This sensor concept can be used to form either adaptive sensor arrays which are similar to our researched neural network system, or used simply as an embedded sensor inside structures or materials.

4 CONCLUSIONS

Controlling of chaotic instabilities in optical fiber sensor networks has been implemented under chaos-induced transient instability in optical systems. Controlling also leads to the possible logic theory with 'low level' or 'high level', as logic '0' and '1' with stable and periodic states. It's used for neural networks as a neural net. It is theoretically possible to apply the multi-stability data regimes as an optical large memory device for multi encoding-decoding messages. It can be also applied for complex data transmission in TDM networks and other optical communications. It can be possible to create large optical memory capacity.

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