5-5 Optical Chaos CDMA

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Ultrafast secure communication systems are proposed based on applications of chaos theory to designing optical pulse code for optical CDMA. Chaotic optical pulse code generator was recently fabricated on a planar lightwave circuit for optical Chaos CDMA. We experimentally demonstrate 10 Gbit/s transmission by using chaotic pulse code generators.

Keywords
Chaos, Analog optical signal processing, CDMA

1 Introduction

Recent remarkable events in telecommunication is that CDMA (code division multiple access) systems were eventually commercialized all over the world although most people did not know CDMA until 1980's. The key to its success can be seen as that the power control problem were solved in radio-wave CDMA systems by the developments in digital signal processing. However, in optical fiber based CDMA communications, we must consider optical and analog signal processing such as how to process Ex.OR for realizing linear feed back register to generate PN sequence for use of CDMA but the power control problem

Recently, several analog chaotic codes had been found to have an ideal correlation characteristic for their use as spectrum spreading sequences for code-division multiple access (CDMA)[4]-[8]. Thus, it is of great interest to consider the issues of physical implementation of such chaotic codes. However, the chip rate of spreading sequence generators of Gold sequence or other spreading sequences has the fundamental physical speed limitation for LSI chip implementation such that their chip rate is less than or equal to several ten giga chip/s for several giga bit/s data transmission. Thus, it is vitally important to consider an all-optical implementation of chaotic spreading generators for their use as high-speed optical fiber communication such as transmission at 10 Gbit/s. The purpose of this paper is to introduce our concept of all-optical chaotic sequence generator and the first experiment about data transmission at 10 Gbit/s utilizing such an optical chaotic sequence generator.

2 All-optical chaos generator.

Ideal chaotic sequence is illustrated by a simple equation such as a logistic function:

$$Xn+1=f(Xn)=4Xn(1-Xn) \quad (1)$$

In this case this mapping f(x) is called as "chaotic map".

Let

$$Xn=\sin^2(\omega). \quad (2)$$

Thus, by Eq. (1), we derive

$$Xn+1=4\sin^2(\omega)(1-\sin^2(\omega))=\sin^2(2\omega). \quad (3)$$

Eq. (3) is nothing but the duplication formula of $\sin^2(\omega)$. If, the phase ω is changed to $\omega+\delta\omega$, the difference $\delta\omega$ will be amplified to $2\delta\omega$. At the second step, the difference will be amplified to $4\delta\omega$.

This exponential change of the difference about the initial conditions is an essential characteristic of chaos. Such duplication formula and more general addition theorem of periodic functions like elliptic functions can be used for constructing more general ideal chaos [1].

We use this simple fact to implement all-optical chaos generators.

Figure 1 shows the basic concept of our all-optical chaotic code generator we proposed in Ref. [2][3]. The sequence generator is composed of N phase-programmable Mach-Zehnder interferometers with N-tapped delay line. Since the output profile of Mach-Zehnder interferometers has a profile of periodic sin functions of the phase that is linearly proportional to phase difference in the interferometers, the measured values can be adjusted to satisfy the simple chaotic map (1).

3 Experimental setup

Experimental setup is shown in Fig.2. In our experiment, we use 10 GHz optical pulse trains as an optical source. 10 GHz mode locked laser diode (MLLD) with 1550 nm

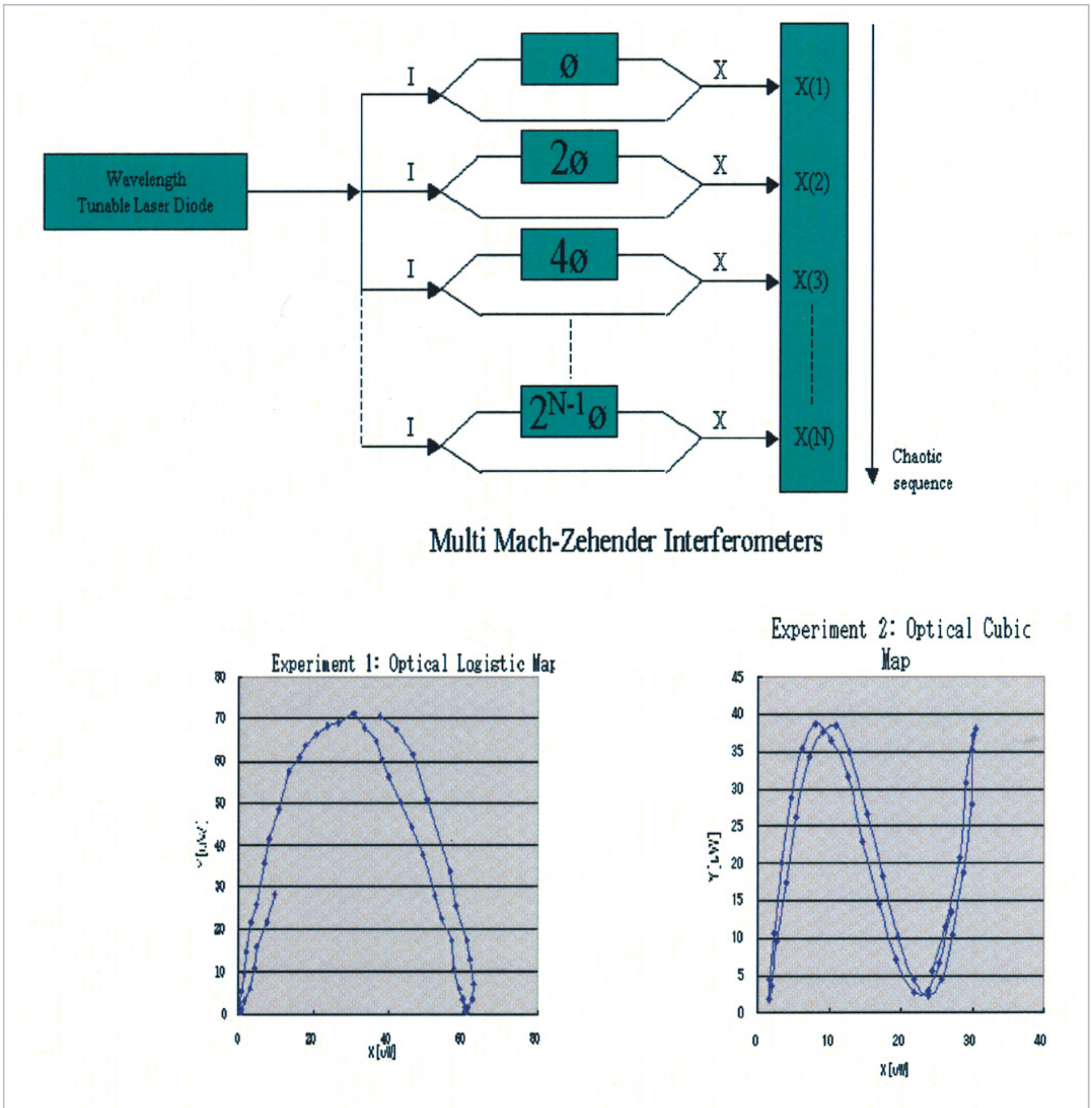

Fig.1 Basic concept of all-optical chaotic code generator. This is composed of N phase-programmable Mach-Zehnder interferometers with N-tapped delay line. If there is no delay, optical output powers satisfy a simple chaotic map.

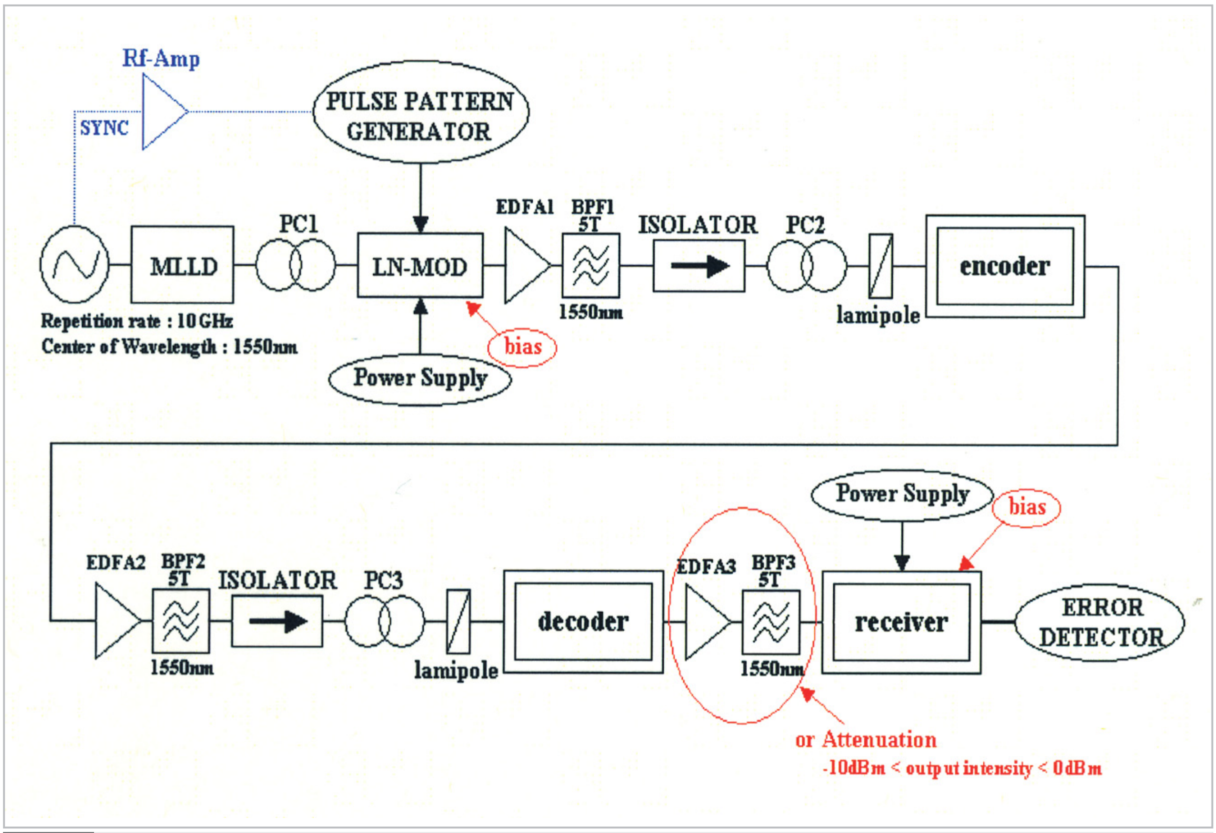

Fig.2 Experimental setup. The encoder and the decoder are composed of 8 phase-programmable Mach-Zehnder interferometers with 8-tapped delay line. The chip rate of encoded signal is 100Gchip/s with period 8. Encoded signal has the chaotic nature specified by a one-dimensional chaotic mapping.

wavelength are utilized here. Encoder and decoder use the same type of optical chaotic sequence generators composed of 8 phase-programmable Mach-Zehnder interferometers with 8-tapped 10 psec delay line. Thus, the chip rate of encoded signals is 100 Gchip/s and such modulated signals have the 8 chip chaotic pattern. Encoded signal is transmitted by a single-mode optical fiber and is received at the 3R receiver. The encoder and decoder were fabricated on PLCs (planar Lightwave Circuits).

4 Experimental Results

Measured eye diagram of 10 Gbit/s is shown in Fig.3. As shown in the eye diagram, we successfully transmit 10 Gbit/s data with optical chaotic modulation. We observed bit-error rate (BER) below 10^{-9} by the error detector.

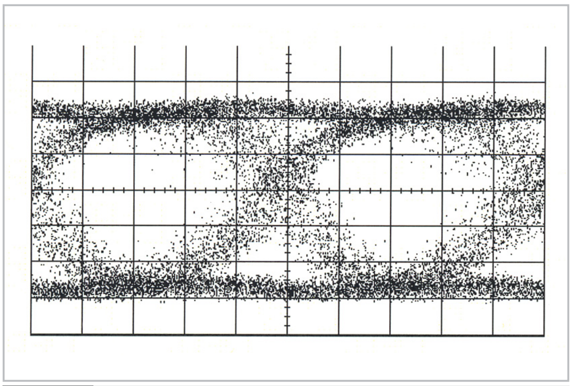

Fig.3 Eye diagram for 10Gbit/s transmission. The horizontal scale is 20 psec/div.

5 Conclusion

We introduce a new concept of all-optical chaos generator for optical chaos-based CDMA.

It has been experimentally demonstrated for the first time that 10 Gbit/s signal transmission with those all-optical chaotic encoders and decoders is done with BER < 10^{-9}.

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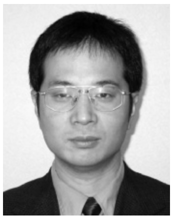

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