Diversity of Optical Signal Processing led by Optical Signal Form Conversion

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Abstract: This talk reviews opportunities of optical signal form conversion as typified by time-space conversion in optical signal processing. Several applications of typical ultra-fast optical signal processing using optical signal form conversion are described.

Keywords: ultrafast optical signal processing, time-frequency transform, time-space conversion, optical signal form conversion

1. Introduction

Optical technology is expected to play an important role in the current and next generation industrial or scientific challenges. To make a full use of the ability of optical technology in the new stage, it is necessary to promote a fundamental review of the nature of light with taking advantage of the features offered by current existing technology. Here, let me remember our original purpose and consider the meaning of time-space conversion again. Basically, a light wave can be represented by spatiotemporal parameters based on a wave-equation and we can use its spatiotemporal parameters for optical signal processing. In addition, the current manner of encoding like intensity modulation used in electrical technology is not always suitable for processing with optical technology. In this sense, it could be said that the true necessity is not optical replacement to find a breakthrough for current electrical technology. One promising approach appears to be employing an appropriate interface for optical signal-form conversion among various physical parameters of optical signals to select an appropriate physical parameter for optical signal processing.

In this talk, we review opportunities of optical signal processing assisted by optical signal form conversion for the next generation of photonics.[2-5]

2. Typical example of optical signal processing assited by optical signal form conversion

Here, optical A/D conversion is introduced as a typical example of optical signal processing assisted by optical signal form conversion.[6,7] Optical A/D conversion is strongly expected to solve the limitations of sampling rate and resolution due to electrical technology. Figure 1 and 2 show a schematic diagram of the proposed photonic A/D convertor and its experimental results of output digital codes. The proposed system realizes optical quantization and optical coding after the optical sampling.

In optical quantization, the power of the input analogue signal is converted into the extent of the center-wavelength shift by use of self-frequency shifting in a fiber. Using the difference of the center wavelength, we can achieve optical quantization of an input analogue signal. Here we use intensity-wavelength conversion for quantization. In optical coding, we use a pulse-shaping technique assisted by simple time-space conversion. We can synthesize an arbitrary shaped pulse by filtering the spectra of the quantized signal in the frequency domain.

This system enables us to output arbitrary digitized signals depending on the intensity of the input analogue signals. Since it is not easy to directly discriminate the intensity of an optical signal, it is necessary to convert it to another physical parameter suitable for discrimination. Wavelength is one of the suitable signal formats because it can be easily discriminated by passive dispersion devices.

Thus, we can achieve optical A/D conversion using intensity-wavelength-space-time conversions.

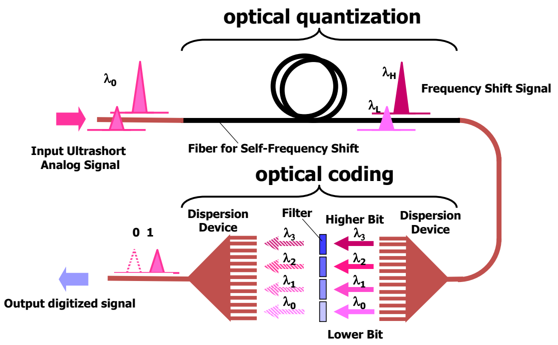

Fig.1. Schematic diagram of optical A/D conversion

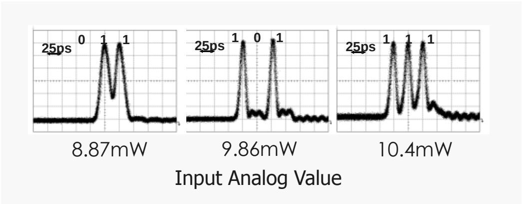

Fig.2. Experimental results of output digital codes

3. Diversity of optical signal processing led by optical signal form conversion

From the above mentioned example, an appropriate interface for optical signal-form conversion could be very effective for exploring new optical signal processing. Here, we consider the meaning of time-space conversion again. Figure 3 shows relationships among physical parameters in time-space conversion. From the phenomenalistic viewpoint, wavelength is the shortest length which can be represented by a light wave and it is at most sub micrometers. In spatial domain, nanotechnology enables us to easily fabricate various dimensional structures in the range from several nanometers to several micrometers. Since this range includes a sub wavelength dimension, it enables us to design artificial materials such as a photonic crystal and control a light wave more leeway. This suggests that spatial dimensions of an ultrashort pulse and an optical device come to be overlapped and ultrafast photonics and nanotechnology could go well together there. In addition, wave equations for temporal and spatial domains are given by 1 and 2 dimensional forms, respectively. This suggests 2 dimensional time-space conversion would be to maximize the use of conventional optical technology.

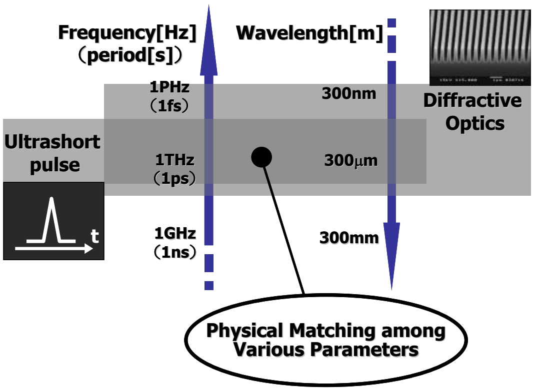

Fig.3. Relationships among physical parameters in time-space conversion.

Here we focus on our works based on 2 dimensional time-to-space conversions. Optical distortion equalizer is a representative example which indicates difference from conventional time-space conversion technique.[26,27] From the viewpoint of time-frequency domain processing, all distortions are distilled to the variation in arrival times of each multiplexed spectral component in a pulse and it is equivalent to a time-frequency map. A distortion can be characterized by both values of a frequency and a relative temporal position from the base time of each spectral component in a distorted pulse. Therefore, once each spectral component in a distorted pulse is converted to the corresponding spatial channel, we can simply achieve adjustment by setting a built-in optical phase shifter for each spatial channel so that each fixed time difference can be cancelled. Since signals after adjustment in a time-frequency domain are still spatially separated, they must finally be returned to the corresponding pulse form by combining all optical delay lines into one. Fig. 4 shows a schematic diagram of the functions of the optical distortion equalizer.

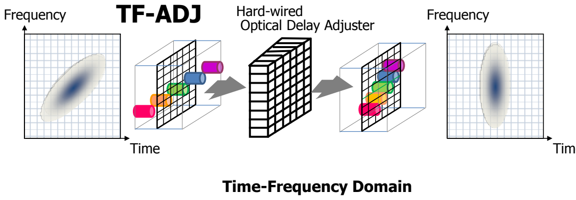

Fig.4. Schematic diagram of optical distortion equalizer.

We performed preliminary experiments to verify the operation of the proposed optical distortion equalizer against two types of distortions: a chromatic dispersion and a timing jitter. Figures 5 show experimental results for distortion equalization of a double pulse with different center frequencies which is a representative example of a distorted multiplexed signal.

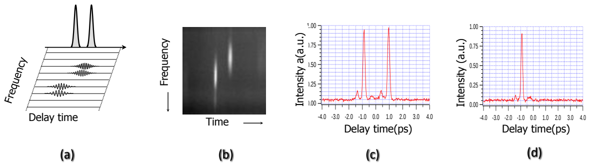

Fig.5. Experimental results of optical distortion equalizer; (a) an illustrative diagram, (b) a 2D-spatial distribution before equalizing, (c) a temporal profile before equalizing and (d) a temporal profile after equalizing of a double pulse with different center frequencies, respectively.

4. Conclusions

This paper reviewed opportunities of optical signal form conversion as typified by time-space conversion in optical signal processing for the current and next generation of photonics. There is now much research proceeding in this field. For example, we have proposed new approach for optical measurement[9,10], optical pulse synthesizer[11,12], optical label recognition[13,14], and digital-to-analog (D/A)[15] conversions, and optical limiter[16].

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