Diversity of optical signal processing  
led by optical signal form conversion

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Abstract. This paper reviews opportunities of optical signal form conversion as typified by  
time-space conversion in optical signal processing. Several examples of typical ultra-fast optical  
signal processing using optical signal form conversion are described and their applications are  
introduced in respect to photonic networks, ultra-fast measurement, and so on.

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. From the theoretical viewpoint,  
a wave equation can be modified into its simplified versions in time and space domains.[1] They  
are respectively given by,

\[
\begin{align*}
\left( \frac{\partial}{\partial z} - \frac{ik}{2} \frac{\partial^2}{\partial t^2} \right) \varphi &= 0 \\
\left( \frac{\partial}{\partial z} + \frac{i}{2k_0} \Delta \right) \varphi &= 0
\end{align*}
\]

As you can see from these two equations, temporal and spatial behaviors of light have some  
similarities each other. It suggests that there is a possibility of exchange between temporal and  
spatial phenomena.

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. Thus,  
physical advancements in optical technologies encourage various kinds of physical parameters to  
have close interactions between them.
In this paper, we review opportunities of optical signal processing assisted by optical signal form conversion for the next generation of photonics.[2-5]

2. Diversity of optical signal processing led by optical signal form conversion
From the viewpoint of optical signal processing, the manner of encoding based on intensity modulation is not always suitable for processing with optical technology. In this sense, it can be said that the true necessity is not optical replacement. 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. Here, we show you representative example concerning optical A/D conversion.[6] The proposed system realizes optical quantization and optical coding after the optical sampling. In optical quantization, the power of the input analog 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 analog signal. Thus, we can achieve photonic A/D conversion using amplitude-wavelength-space-time conversions.

On the other hand, current progress in ultrafast photonics and nanotechnology suggests that they could go well together. In addition, a wave equation can be simplified to these two equations in spatial and time domain as shown in Equations (1) and (2). This suggests the spatio-temporal analogy and exchangeability between them and the derivatives in equations are 2 dimensional ones. There is now much research proceeding in this field. For example, we have proposed new approach for ultrafast optical time-resolved spectroscopy[7,8], 2-D pulse shaping[9,10], optical distortion equalizer[11].

3. Conclusion
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 label recognition[12,13], and digital-to-analog (D/A)[14] conversions, and optical limiter[15].

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