Integrated Optical Analog Signal Processing

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1. Introduction
All-optical implementations of signal processing have attracted a great deal of attention due to the unique potential of this approach to overcome the bandwidth and speed bottleneck of electronic devices. Many all-optical signal processing techniques, offering processing bandwidths up to several THz, have been proposed and successfully employed in a wide range of areas, such as ultrafast telecommunications, optical computing, microwave photonics and bio-photonics etc.

To build up an all-optical signal-processing and computing platform with complex functionality, a promising solution is to emulate the developments in the electronic domain using photonic technologies. For this purpose, photonics counterparts of fundamental components that form basic building blocks in electronic circuits need to be designed and realized. This is a key step toward the practical realization of all-optical information processing and computing circuits. Recently, some fundamental signal operators, such as all-optical temporal differentiators and integrators, and real-time Fourier and Hilbert transformers, have been experimentally demonstrated by employing fiber- and integrated-optic platforms. Based on the state of art electronics technology, the achievable bandwidth of electronics operators is limited to about 1 GHz. However, the photonics-based signal operators can easily realize an operation bandwidth larger than 200 GHz [1]. In particular, an optical differentiator with a record bandwidth up to 25 THz has been recently reported based on a wavelength-selective directional coupler [2]. Therefore, the key advantage of a photonics-assisted signal operator is that the achievable operation bandwidth can be largely increased.

Very recently, we report and experimentally demonstrate a fully reconfigurable photonic integrated signal processor based on an InP-InGaAsP material system. The proposed photonic signal processor is capable of performing reconfigurable signal processing functions including temporal integration, temporal differentiation and Hilbert transformation. The reconfigurability is achieved by controlling the injection currents to the active components of the signal processor. Our demonstration suggests great potential for chip-scale fully programmable all-optical signal processing. [3-5]

In addition, we propose and experimentally demonstrate an analog optical signal processor based on a phase-shifted DFB-SOA, to perform two functions including ordinary differential equation (ODE) solving and temporal intensity differentiation. When the phase-shifted DFB-SOA is operating below lasing threshold, it could act as a first-order ODE solver with a tunable constant coefficient by tuning the injection current. While the phase-shifted DFB-SOA is operating above the threshold and is operating jointly with an optical filter, it could behave as a temporal intensity differentiator. The proposed signal processor is experimentally evaluated. The experimental results show that the output waveforms are in a good agreement with those from an ideal ODE solver and a temporal differentiator. In addition, the processing errors of our proposed optical signal processor are also analyzed. To the best of our knowledge, it is the first time that a signal processor that is reconfigurable to operate as a temporal intensity differentiator and an ODE solver based on a phase-shifted DFB-SOA.[6]

In this talk, very recent progresses on integrated all-optical analog signal processing will be introduced and reviewed. These works represent an important step towards the realization of efficient optical signal-processing circuits capable of overcoming the limitation in integration time window, bandwidth and power consumption imposed by electronics.

2. References: