Programmable Two-dimension Dispersion Waveshaper for Waveform Shaping

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***Abstract*—This study proposes and experimentally demonstrates a two-dimension (2D) dispersion waveshaper with hyperfine bandwidth management which combines virtually imaged phased array (VIPA) with diffraction grating as 2D disperser. It exhibits excellent waveform shaping and promising performances on optical communication.**

Keywords—waveshaper, 2D dispersion, VIPA, waveform shaping, optical communication

I. Introduction

In recent years, optical transmission network has met the challenge of high-speed growing traffic due to emerging new technologies, such as 5G communication, artificial intelligence (AI) and so on. As a result, this has driven the emergence and development of all-optical networks (AON) with reconfigurable optical add/drop multiplexer (ROADM) [1-3]. The waveform processing plays an important role on optimizing channels management and improving AON performances [4].

Owing to the large angular dispersion, VIPA is considered as a promising wavelength demultiplexer [5]. More importantly, it brings an enhanced spectral resolution based on VIPA-grating architecture [6, 7]. Therefore, we propose here a 2D waveshaper with VIPA-grating disperser to improve performances of waveform processing.

II. Principle and Results

A. *Experimental setup and principle*

VIPA can be treated as a special Fabry-Perot etalon which operates at a tilted angle. The incident broadband optical beam from the input window of VIPA will experience multiple reflections inside VIPA due to the high reflectivity of surfaces. These output beams will interfere with each other and output at different dispersion angles which depend on the wavelengths, as depicted in the inset of Fig. 1. Compared to conventional diffraction gratings, VIPA has a larger angular dispersion. Figure 1 illustrates the operating principle of 2D dispersion waveshaper. Polychromatic beam firstly experiences a vertical fine dispersion via a VIPA, and then is given a horizontal coarse dispersion by a diffraction grating, resulting in a 2D spatial dispersion. The encoded patterns on LCoS (liquid crystal on silicon) via PC can achieve beam steering for different parts of wavelengths, therefore arbitrary spectra can be selected by the 2D dispersion waveshaper, especially some fine structures.

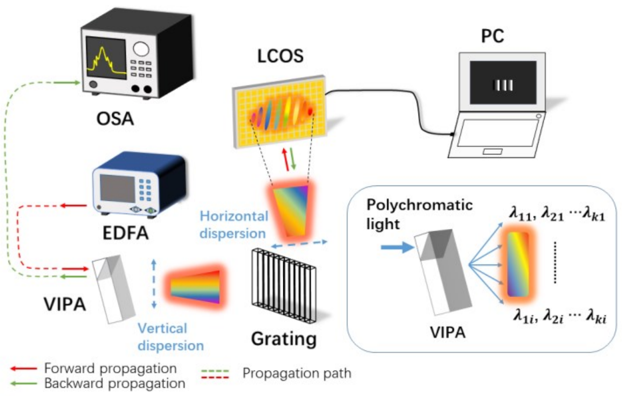

Fig. 1. The schematic of 2D dispersion waveshaper.

B. *Results*

For our experiment, we used a VIPA with 30 GHz free spectral range (FSR) and a 940 lines/mm diffraction grating as a 2D disperser, and employed a LCoS (Holoeye, PLUTO-2.1) as a beam-steering device. The target spectra can be obtained by encoding required blazed grating hologram on LCoS. Figure 2(a) presents some special spectral profiles at the same spectral range by transverse periodic hologram, such as periodic intensity ripples or fixed bandwidth channels. Additionally, intensity modulation can also be achieved via perpendicular periodic hologram, as shown in fig. 2(b). More varied spectral modulation can be realized when we combine these two modulation methods. As illustrated by the bandwidth increment in fig. 2(c), we obtained high resolution bandwidth modulation due to the finer 2D spectral distribution than conventional linearly dispersion design. Owing to the large dispersion angle of VIPA, a single-band dense increment of 1 GHz 10dB-bandwidth or narrower at C band can be achieved by controlling vertical area of hologram, as depicted in fig. 2(d). In the wavelength division multiplexing (WDM) architecture of modern network, this design has the potential to improve communication performances, particularly in AON.

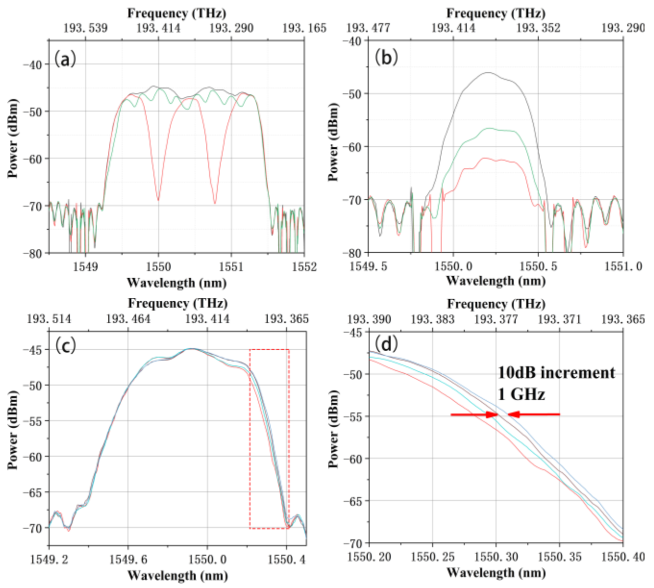

Fig. 2. Output characteristic of 2D waveshaper. (a) Spectral envelope shape modulation; (b) Spectral intensity modulation; (c) Single-band increment and (d) a zoom-in view of (c).

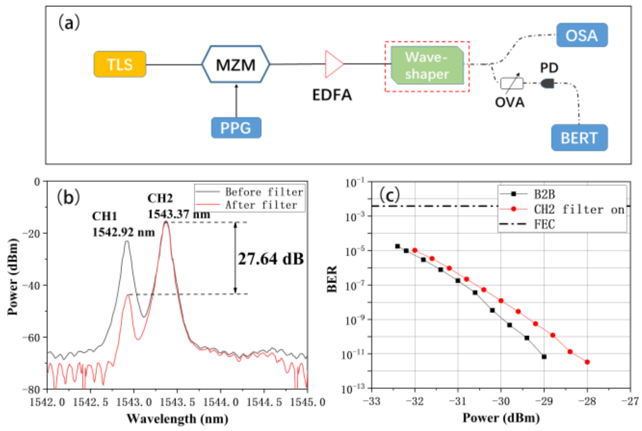

Fig. 3. (a) NRZ-OOK communication testing setup; (b) A two-channels spectrum with 25 GHz interval and (c) BER results with 10 Gb/s data.

Additionally, a non-return-to-zero on-off keying (NRZ-OOK) communication testing was been performed in this system, as displayed in fig. 3. The experimental setup used to test the bit error rate (BER) performance is illustrated in fig. 3 (a). The channels from a tunable laser source (TLS) are loaded with 10 Gb/s NRZ-OOK data via a Mach-Zehnder modulator (MZM). The modulated signals are put into 2D waveshaper system after Erbium doped fiber amplifier (EDFA) to compensate the modulator loss. And then the desired channel arrives optical spectrum analyzer (OSA) or bit error rate tester (BERT) for analysis, whereas the other channels are blocked in the waveshaper. There are a set of data to characterize the performance of the waveshaper in a two-channels signal transmission system at 1542.92 nm and 1543.37 nm with an interval of 25 GHz. The spectral analysis is shown in fig. 3(b). Due to the programmable waveshaper filter, the channel 2 have a signal-to-noise ratio (SNR) of over 27 dB. The BER curves with power changing can be obtained by manipulating the variable optical attenuator (VOA) in front of BERT, as depicted in fig. 3(c). B2B curves represent that the modulated signals are received directly by BERT without passing through the waveshaper. Fig. 3(c) verify that penalty of filter on is 0.62 dB at BER=10^{-9} and the BERs are both below the forward-error correction (FEC) threshold of 3.8E-3. It indicates the error-free transmission can be achieved by means of pre-equalization.

III. Conclusion

To summarize, we proposed and experimentally characterized a 2D waveshaper with high spectral resolution based on VIPA-grating architecture. By encoding patterns for beam steering, some unique waveforms can be generated and the fine spectral increment of below 1GHz has potential to be used in flexible AON. In addition, our experimental results also prove that the waveshaper exhibits expected communication performance.

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