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Reducing polarization sensitivity for all-optical wavelength conversion of the optical packets based on FWM in the HNL-DSF using co-polarized pump scheme

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Abstract

Polarization insensitivity is a fundamental requirement for wavelength conversion technique in the future all-optical networks. Our experimental results show that a co-polarization pump configuration based on four-wave mixing in high-nonlinear fiber can reduce largely the polarization sensitivity. We have theoretically investigated those experimental phenomena, and the theoretical analyses are in good agreement with experimental results.

Keywords: Frequency conversion; Four-wave mixing; Polarization; Polarization insensitivity; Dynamic wave equation; Optical fiber communications

1. Introduction

The remarkable growth of Internet traffic has spurred the research and development of scalable and high-capacity optical networking technologies. The introduction of wavelength-division multiplexing (WDM) has provided increased capacity beyond 10 Tbit/s over a single strand of fiber [1,2], while the switching capacity of current Internet protocol (IP) routers is not improved impressively and becomes the bottleneck. Optical label switching (OLS) which enables the routing and forwarding of the ultra-high bit rate packets directly in the optical layer is one of the most promising solutions for the next-generation optical networks [3–5]. All-optical wavelength conversion (AOWC) is considered to be an essential technology for future switching architecture [6–17]. Among many different wavelength conversion technologies, AOWC based on four-wave mixing (FWM) is one method that is transparent to the signal bit-rate and modulation format [11–17]. Here, we present a novel AOWC scheme based on FWM in a high-nonlinear dispersion shifted fiber (HNL-DSF) which implements AOWC for optical packets generated by optical carrier suppression and separation (OCSS) technique with unchanged wavelength spacing and spectral non-inversion, and shows slim polarization sensitivity. Based on the theory of the modulation of the beating grating from the dynamic wave equation, we theoretically analyze the spectral configuration and the polarization insensitivity.

The paper is organized as follows. In Section 2, the experimental setup and results of wavelength conversion based on co-polarized pump configuration is described. In Section 3, the spectral configuration and polarization sensitivity of the two different schemes are investigated theoretically based on the modulation of the beating grating from the dynamic wave equation. At last there is a conclusion in Section 4.

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2. Experimental setup and results

Our experimental setup is shown in Fig. 1. Optical packet with 10 Gbit/s payload and 2.5 Gbit/s label is generated by optical carrier suppression and separation technique [4]. The lightwave at 1534.14 nm from distributed feedback laser diode (DFB-LD) is modulated by dual-arm $LiNbO_3$ modulator (LN-MOD) driven by 15 GHz sinusoidal RF signal to generate optical carrier suppression and then separated by an inter-leaver (IL) with 50 GHz channel spacing into two longitudinal modes with a fixed frequency spacing of 30 GHz and a carrier suppression ratio larger than 25 dB traveling to two different output ports. The shorter wavelength mode is modulated by 2.5 Gbit/s NRZ label via single-arm LN-MOD while the longer wavelength mode is modulated by 10 Gbit/s NRZ payload via another single-arm LN-MOD. The payload and the label are combined through an IL before coupled with the co-polarized pumps. The co-polarized pumps are obtained by two tunable lasers with the polarization controllers (PC). The polarization direction of payload and label is parallel and can be adjusted by PC. The pumps and the optical packets are combined with an optical coupler (OC) and then amplified by an Erbium Doped Fiber Amplifier (EDFA) with a total power of 17 dBm. The amplified signals and pumps are injected into 1 km HNL-DSF for wavelength conversion. The HNL-DSF has a non-linear coefficient of 10 W^{-1}/km, a loss of 0.4 dB/km, a zero-dispersion wavelength of 1561 nm, and a dispersion slope of 0.03 ps/nm^2 km. The powers into the HNL-DSF for pump 1, pump 2, optical label and optical payload are 10, 12, 3.4 and 8.4 dBm, respectively. We fixed the wavelengths of the two pumps to be 1538.5 and 1539.5 nm, thus the pump wavelength spacing is 1 nm.

We measure the frequency spectra using an optical spectrum analyzer (OSA) with a resolution of 0.01 nm. A typical measured optical spectrum is shown in Fig. 2. From the spectrum we can see that there are two sidebands with strong powers: the upper and the lower converted payload and label, and that each group has the same frequency spacing and order as that of the originals. The wavelength shift of the convert payload and label is 1 nm, just equal to the wavelength spacing of the two pumps. The measured optical power of the converted payload vs. the polarization direction is shown in Fig. 3. The converted payload shows little sensitivity to the polarization which is favorable to the wavelength conversion.

For comparison we also measured the spectrum of single pump wavelength conversion with the same experimental setup and input payload/label powers as that of co-polarized pumps in Fig. 1 except that the two co-polarized pumps are replaced by the single pump with 15 dBm power at wavelength 1535.7 nm. The converted payload and label have the same frequency spacing as the original ones, but the order of them is inverted according to mirror image. The measured converted payload optical power vs. the polarization direction is also shown in Fig. 3. The converted payload generated by single pump scheme is sensitive to the polarization. According to our measurement above, the co-polarized pump scheme largely reduces the

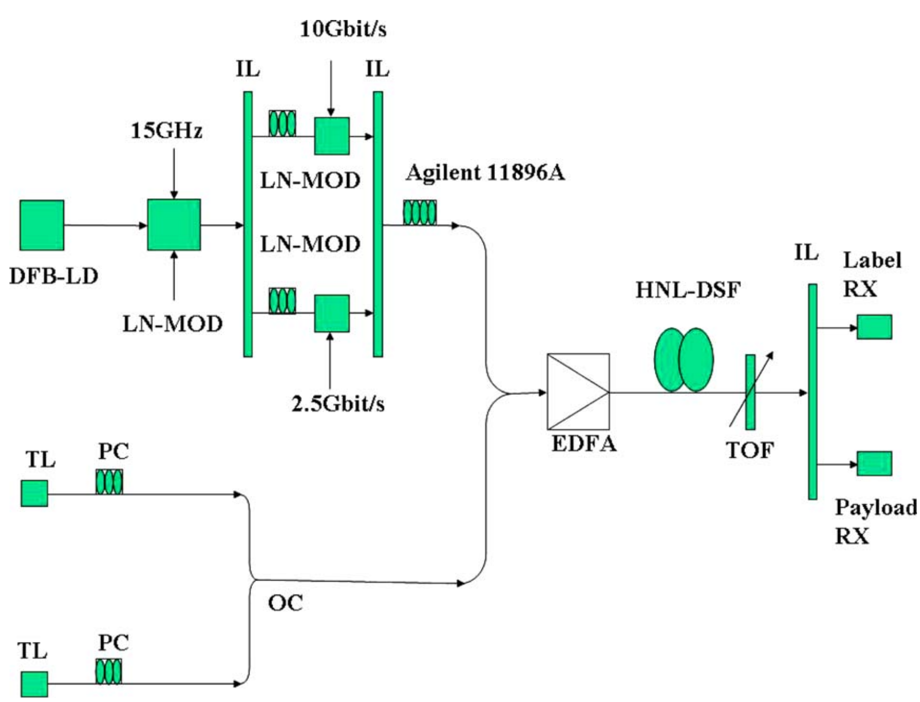

Fig. 1. Experimental setup for wavelength conversion based on FWM. DFB-LD, distributed feedback laser diode; TL, tunable laser; PC, polarization controller; LN-MOD, $LiNbO_3$ modulator; IL, inter-leaver; OC, optical coupler; EDFA, Erbium doped fiber amplifier; HNL-DSF, high-nonlinear dispersion shifted fiber; TOF, tunable optical filter; RX, receiver.