4×2.5-Gbit/s all-optical frequency upconversion using nonlinear polarization rotation in highly nonlinear fiber for radio over fiber

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Abstract. We experimentally demonstrate 4×2.5-Gbit/s all-optical frequency upconversion at 20 GHz, based on nonlinear polarization rotation in a highly nonlinear fiber. The demodulated signals are analyzed. © *2007 Society of Photo-Optical Instrumentation Engineers.*
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1 Introduction

Radio over fiber (ROF) systems have been proposed as a possible next-generation broadband wireless access technology for picocellular and indoor wireless LAN applications, etc.[1] The millimeter-wave band (16 to 19, 28, 38, 58, and 62 to 66 GHz) is considered to be a promising solution owing to its large bandwidth, spectrum availability, and the compact size of radio frequency (rf) devices.[2] As the key technique in an ROF system, all-optical frequency upconversion has become a hot research area. Recently, several new schemes[3,4] for realizing this function have been reported.

In this letter, we demonstrate experimentally a scheme for upconversion by nonlinear polarization rotation (NPR) in a highly nonlinear fiber at the 20-Gbit/s optical pulse clock frequency. The four channels of wavelength division multiplexing (WDM) signals are carried by 20-GHz optical pulses after upconversion. In our scheme, just a low-speed modulator with bandwidth 10 GHz and a passive highly nonlinear fiber are required.

2 Principle of Upconversion

In Fig. 1(a) the pump and WDM signals are linearly polarized at 45 deg to each other at the input end, as shown in Fig. 1(b). At the output end, the polarizer blocks WDM signal transmission in the absence of the pump beam. When the pump is turned on, the refractive indices for the parallel and perpendicular components of the WDM signals become different because of pump-induced birefringence. The phase difference between the two polarization components

at the fiber output induces a change of polarization state for the WDM signals. If the change equals 90 deg, the WDM signals will output through the polarizer. The change depends on the pump intensity and can be controlled. As a result, the pump will modulate the WDM signals at a switching speed of 20 GHz to realize frequency upconversion.

3 Experiment and Results

The experimental setup is showed in Fig. 2. A 1-km highly nonlinear dispersion-shifted fiber (HNLDSF) with a nonlinearity coefficient of 10 W^{-1} km^{-1}, and a loss of 0.4 dB/km is used for NPR. Four WDM signals, shown in Fig. 3(a), are modulated by a 2.5-GHz $2^{11}-1$-bit pseudorandom binary sequence through a LiNbO$_3$ Mach-Zehnder modulator. Their wavelengths are 1535.64, 1537.03, 1538.54, and 1540.25 nm. To generate a 20-GHz optical local oscillator (LO) signal, the pump laser is modulated by driving a LiNbO$_3$ Mach-Zehnder modulator biased at ν_π with an electrically amplified 10-GHz sinusoid waveform. The 20-GHz optical LO is shown in Fig. 3(b). Its wavelength is 1544 nm.

Both the optical LO signal and the WDM signals were amplified by erbium-doped fiber amplifiers, and their polarization directions were adjusted by the polarization controller (PC) before they were launched into the HNLDSF. The signal power is 5 dBm/channel, and the pump power is 16 dBm. To get enough polarization rotation, the length of the HNLDSF is 1 km. A tunable bandpass filter was used to reject the LO signal and extract the desired channel signal. The filter's 3-dB bandwidth is 0.8 nm. Through the other PC and polarization beamsplitter (PBS), the best output polarization direction can be chosen. The extracted channel was then converted from optical to electrical by a *pin* diode with a 3-dB bandwidth of 50 GHz. The converted electrical signals were input to the rf port of the mixer. An electrical LO signal at 20 GHz was generated by using a frequency multiplier from 10 to 20 GHz and then amplified by a wideband electrical amplifier (EA) with a bandwidth of 25 GHz centered at 30 GHz. The LO signal is connected to the LO port of the mixer to downconvert the electrical millimeter-wave signal. The downconverted 2.5-Gbit/s signal filtered by a 2.5-GHz lowpass filter was amplified by
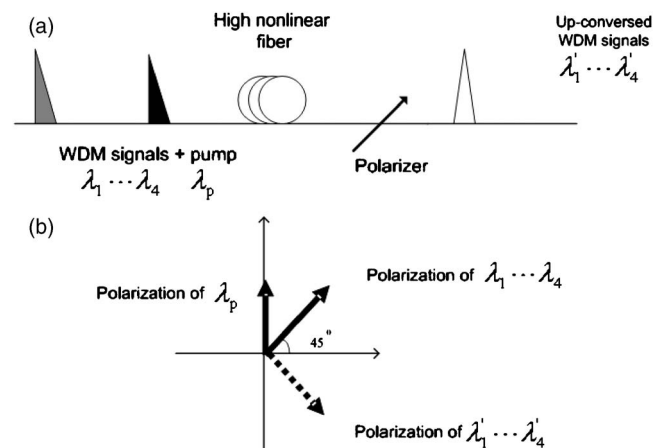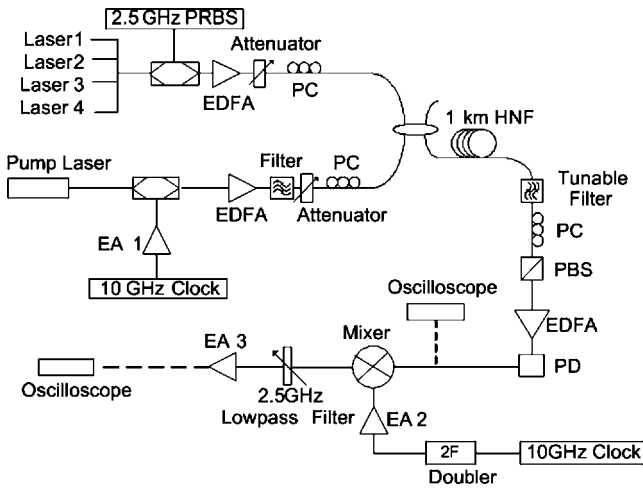

Fig. 1 The upconversion scheme.

Fig. 2 The experimental setup.

the electrical amplifier. Eye diagrams were recorded by a high-speed oscilloscope. Figure 4 shows the output waveforms from the PBS and the eye diagrams of the downconversion signals from the mixer.

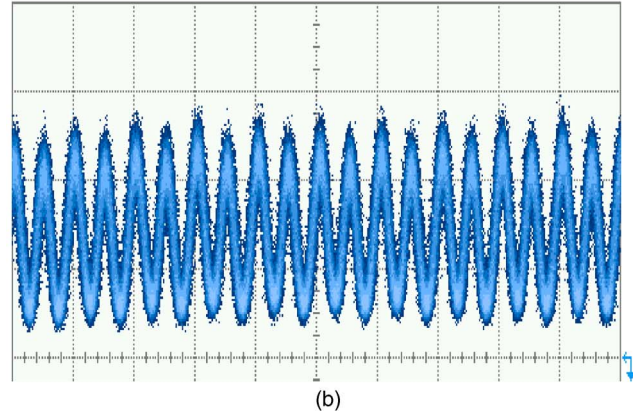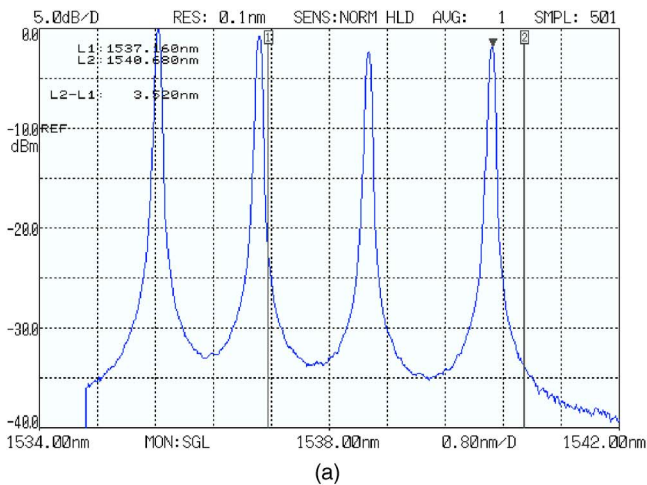Figure 4 shows that the measured optical signal-to-noise ratio (OSNR), defined at a noise bandwidth of 0.1 nm, of

Fig. 3 (a) The spectrum of four WDM signals (0.8 nm/div). (b) the waveform of the 20-Gbit/s optical pulse (100 ps/div).
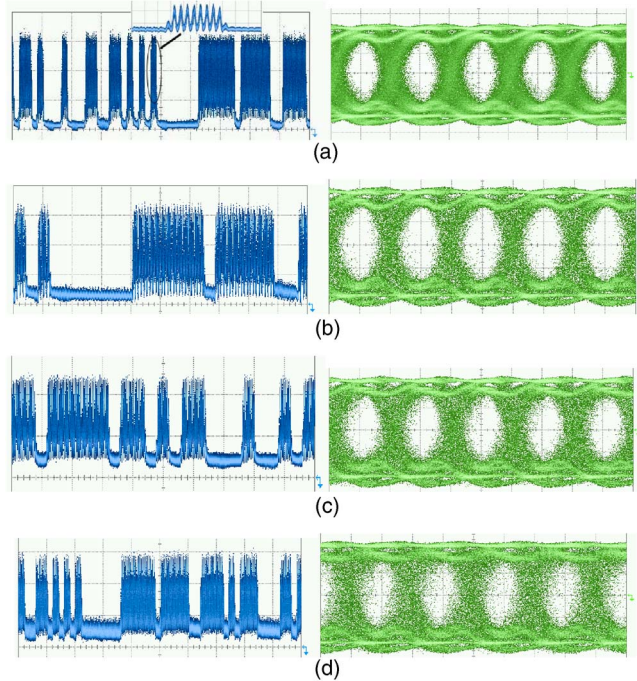

Fig. 4 The waveform of the upconverted WDM signals and the eye diagrams of the downconverted WDM signals: (a) for 1540.25 nm (2 ns/div), (b) for 1538.54 nm (1 ns/div), (c) for 1537.03 nm (1 ns/div), (d) for 1535.64 nm (2 ns/div). All eye diagrams are at 200 ps/div.

each channel after upconversion is larger than 20 dB, and clear downconverted eye diagrams are attained, which indicates that simultaneous upconversion of 4×2.5-Gbit/s WDM to 20-GHz optical carrier has been performed successfully.

4 Conclusion

Based on nonlinear polarization rotation, we have successfully demonstrated 4×2.5-Gbit/s WDM frequency upconversion at 20 GHz in a highly nonlinear optical fiber, which indicates that the NPR effect is a good solution for future upconversion application in radio-over-fiber systems.

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