Experimental comparison between optimized fiber Bragg grating and delay-line interferometer for DPSK signal demodulation

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Abstract *10Gb/s DPSK demodulation effectiveness of a suitably-designed FBG structure is compared with the performance achieved by a compact integrated-optic MZDI. BER measures versus operation stability are reported*

Introduction

For next-generation systems, differential phase-shift keying (DPSK) has attracted renewed interest for its potentially increased tolerance to chromatic dispersion and fiber nonlinearities [1,2]. DPSK signal, which carries information via the phase difference between adjacent bits, is typically demodulated by a Mach-Zehnder delay-line interferometer (MZDI) [3]. As any interferometric structures, it suffers from temperature sensitivity and thus requires active stabilization to maintain the correct operating point. Moreover laser frequency stability represents an issue as it affects the achieved demodulation [4]. MZDI's can be implemented as integrated-optic components using planar waveguide technology. In particular high index contrast technology allows for minimum device dimensions with negligible losses [5]. For low-cost applications, where balanced detection and active stabilization cannot be exploited, alternative and simpler demodulation schemes, based on narrow filters, have been proposed [6]. At the state-of-the-art, the best FBG-based alternative to MZDI is represented by uniform Gaussian-apodized gratings, whose full-width-at-half-maximum (FWHM) bandwidth corresponds to 2/3 of the data rate; however this kind of filter poorly reproduces the spectral response of a MZDI [7].

In this contribution we assess the performance of a 10-Gb/s DPSK demodulator based on an optimized multiple FBG [8] suitably-designed to precisely replicate in reflection the spectral response of a MZDI. In particular comparison with DPSK demodulation obtained with a compact integrated-optic MZDI [5] clarifies the potentialities of this FBG design.

Eye diagram and bit-error rate (BER) curves versus received power at 9.95328 Gbit/s are analyzed both for the FBG and single-ended MZDI with NRZ-DPSK format. Impairments due to laser frequency off-set are evaluated as well. Both tested devices have a low polarization dependence, which is investigated by employing a polarization scrambler to continuously modify the received signal state of polarization (SOP) during the measurements.

DPSK demodulators description

The FBG-based DPSK demodulator employed in our comparative study is a dispersion-less filter synthesized by the layer-peeling technique as described in [9] to mimic, in reflection, the spectral response of a MZDI. The grating turns out to be periodic (i.e. not chirped) with an index profile depicted in Fig.1(a), which corresponds physically to a sequence of nearly-lumped gratings forming a multiple Fabry-Perot structure. The corresponding spectral reflectance and group delay of the synthesized filter are shown in Fig.1(b) and 1(c), respectively. The 7-cm-long grating is fabricated in a hydrogen-loaded germanium-doped fiber by a continuous writing technique, in which the grating is impressed step by step using a phase mask and focusing onto the fiber core the 244 nm wavelength radiation emitted by a frequency-doubled Ar-ion laser.

The demodulator based on MZDI is a newly developed and compact device, realized by silicon-oxinitride (SiON) with very high index contrast (4.5%) between the guide core and the substrate/upper cladding. The device thus occupies a few millimeters square area.

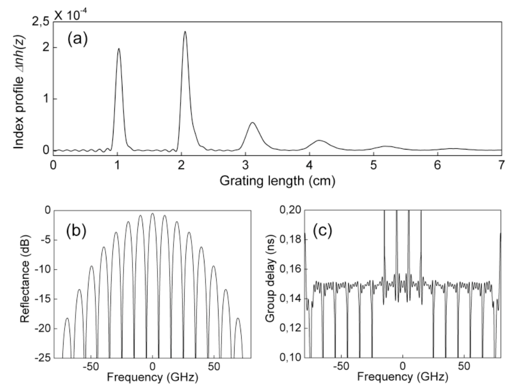

Figure 1: Refractive index profile (a), corresponding calculated power reflectance (b) and group delay curves (c) of the DPSK-FBG filter.

In Fig.2 the FBG measured reflection transfer function is compared with the MZDI one, for the two input signal eigen SOP's. While the MZDI has negligible polarization dependence, the FBG shows a slight shift in the transfer function due to residual birefringence. Moreover the filter shape is slightly larger than the MZDI one, influencing the back-to-back DPSK performance as shown in following measurements.

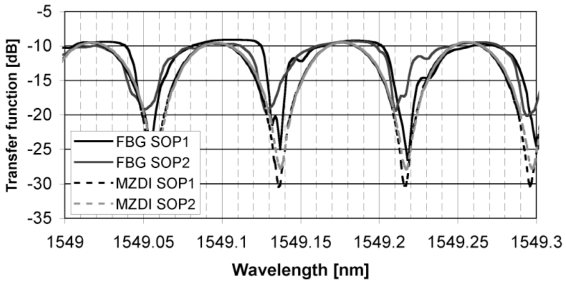

Figure 2: Comparison between measured transfer functions of MZDI (dashed line) and FBG (back reflection) for the two input signal eigen SOP's (black and gray line).

Experimental results

Fig.3 shows the back-to-back BER curves versus received power at the 10-GHz PIN photodiode. At 10^{-6} of BER the FBG filter (white circles) outperforms the MZDI (white squares) in single-ended configuration of nearly 2 dB. This performance is matched by the larger eye opening visible in Fig.4. On the other hand, through balanced detection, MZDI performance can gain almost 3dB as shown in Fig.3 by the dashed black line.

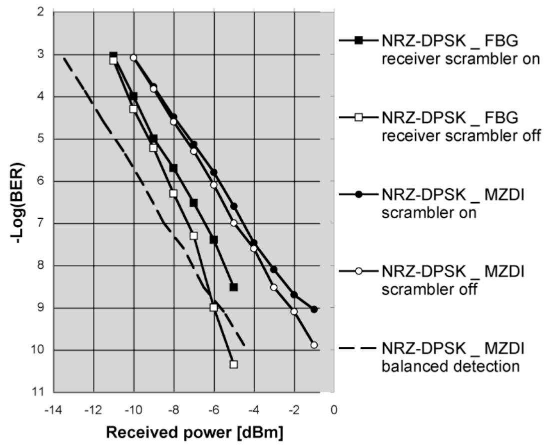

Figure 3: Back to back BER curves versus received power for FBG receiver (circles), MZ-single-ended receiver (squares) and MZ–balanced receiver (dashed line). Polarization scrambler is on for white symbols and off for black one.

SOP dependence is investigated by comparing the above-mentioned BER curves with those obtained with SOP scrambler at the input of the demodulating device (black symbols). As expected from Fig.2, almost no penalties are present for the MZDI, while less than 1 dB is found for the FBG.

Finally the sensitivity to operating point stability has been checked. BER versus signal frequency detuning is shown in Fig.5. The MZDI performance variation is within one BER decade for ±1GHz, while for FBG the corrisponding detuning is ±0.5GHz. Obviously the SOP scrambler presence, reduces the detuning tolerance, in particular for the FBG.

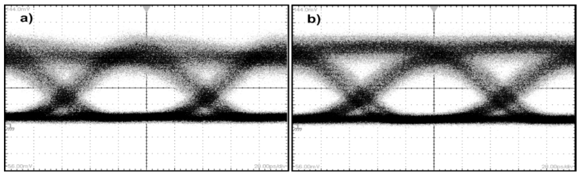

Figure 4: Back to back received eye diagram for FBG (a) and MZDI (b). Same received power.

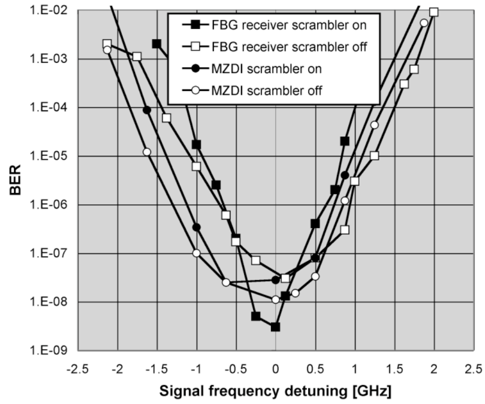

Figure 5: NRZ-DPSK receiver sensitivity to signal frequency detuning for FBG (circles) and MZDI (squares) with and without SOP scrambling (black and white symbols respectively).

Conclusions

In conclusion we have compared the performance of a FBG structure suitably-designed for 10Gb/s-DPSK demodulation with a MZDI in single-ended configuration. In back-to-back FBG outperforms the MZDI though demonstrates slightly higher polarization dependence and signal frequency detuning sensitivity.

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