Integrated In-Band OSNR Monitor Based on Planar Lightwave Circuit

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Abstract *We propose a novel integrated in-band optical signal-to-noise ratio (OSNR) monitor based on planar lightwave circuit (PLC) technology. We successfully demonstrate a 10-25 dB in-band OSNR measurement with errors of less than 0.6 dB.*

Introduction

Monitoring the optical signal-to-noise ratio (OSNR) is becoming important in optical networks[1]. The OSNR was conventionally estimated by linearly interpolating the amplified spontaneous emission (ASE) noise spectrum. However, in reconfigurable wavelength division multiplexing (WDM) networks, where each channel is filtered through different routes, the noise level may differ channel by channel. This means conventional out-of-band monitoring cannot correctly measure the actual OSNR. To overcome this problem, in-band OSNR monitoring techniques that measure the OSNR within the signal bandwidth have been proposed including methods that use a polarisation technique[2], degree of polarisation (DOP)[3], uncorrelated beat noise[4-5], and a fibre loop mirror[6]. Optical monitors for use in commercial networks must also be low-cost and have a small footprint.

In this paper, we propose a novel integrated in-band OSNR monitor based on planar lightwave circuit (PLC) technology, and demonstrate excellent performance of a compact in-band OSNR monitor module.

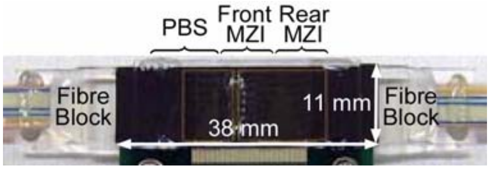
Proposed in-band OSNR monitor

Figure 1 shows the configuration of our proposed in-band OSNR monitor. It is composed of a polarisation beam splitter (PBS) and a two-stage cascaded Mach-Zehnder interferometer (MZI). The functions of the PBS, the front MZI, and the rear MZI are to split the input light into transverse electric (TE) and transverse magnetic (TM) modes, to convert light into a single polarisation state and equalise the power splitting ratio, and to maximize the difference of the power output from the two output ports of this device, respectively.

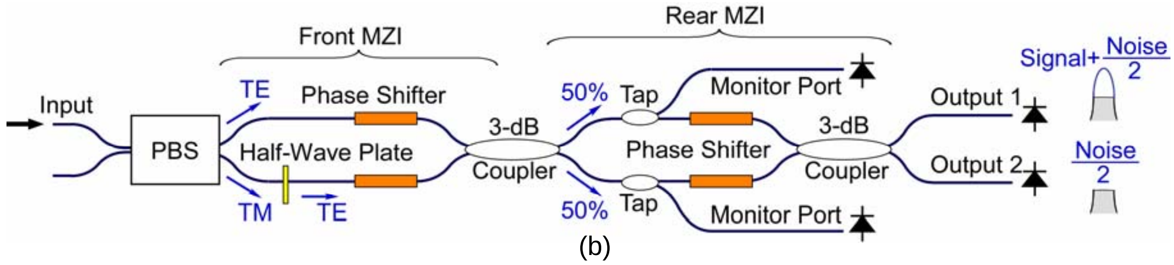
In our PLC-based method, we assume that the optical signals are polarised while the noise is non-polarised. The device splits a non-polarized noise component into two output ports with equal optical power, while it separates a polarised signal component from the input light by using interference of the MZIs.

Next, we describe the operation of our device in more detail. As shown in Fig. 1(b), light input into this device is split into TE and TM modes at the PBS, and the TM mode is converted to the TE mode with a half-wave plate. The TE mode lights transmitted through the front MZI are then coupled with a 3-dB coupler. The ratio of the optical power output from the 3-dB coupler depends on the state of polarisation of the input light. To equalise these optical powers, we operate phase shifters on the front MZI while monitoring the optical power of the tapped monitor ports. The power-balanced TE mode lights are coupled again with a 3-dB coupler at the rear MZI, and then launched from the two output ports.

The optical power of polarised component output from the two output ports change according to the settings of the rear phase shifters. When the difference between the output optical powers of the two output ports is set at its maximum value, the light output from one output port will consist of an optical signal and noise, while the light output from the other output port will consist solely of noise, and thus, by measuring the output power difference, we can directly acquire the in-band OSNR.



(a)



(b)

Fig. 1: (a) Eight arrayed in-band OSNR monitors integrated in a PLC module, and (b) a schematic diagram of the proposed PLC-type in-band OSNR monitor

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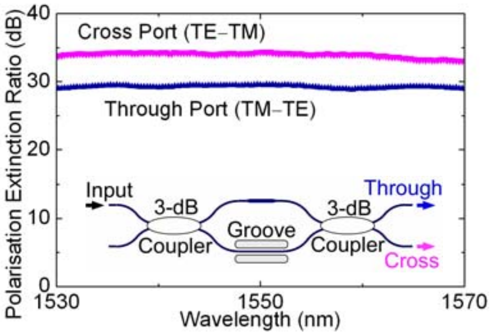

Fig. 2: Measured polarisation extinction ratio of the designed MZI-type waveguide PBS

Circuit design

The dynamic range of the proposed OSNR monitor is related to the polarisation extinction ratio of the PBS and the coupling ratio variation of the 3-dB couplers constituting the MZIs. To operate this OSNR monitor for various WDM channels, we require a wideband PBS and optical couplers.

For polarisation splitting, we used an MZI-type waveguide PBS[7], but employed a new design to achieve wideband operation. We formed a groove near one of the waveguide arms to provide strong birefringence, and achieved a compact PBS about 10 mm in length. Figure 2 shows the measured polarisation extinction ratio of our designed MZI-type waveguide PBS. We obtained a high polarisation extinction ratio of greater than 25 dB over the whole C-band wavelength range.

We used wavelength insensitive couplers (WINCs) for the 3-dB couplers in order to obtain a uniform coupling ratio over a wide wavelength range[8]. We also used a WINC for the tap.

Experimental Results

The proposed OSNR monitor was fabricated on 1.5%-Δ silica based waveguide with a core size of 4.5 x 4.5 μm. The PLC chip integrating eight in-band OSNR monitors was 38 x 11 mm. A half-wave plate was inserted in the bottom waveguide arm of the front MZI. Thin film heaters were patterned on the MZI arm waveguides as phase shifters, and heat insulating grooves were formed near the heaters to reduce power consumption. Optical fibre blocks were attached to the input and output of the circuit, and the device was assembled in a module (Fig. 1(a)).

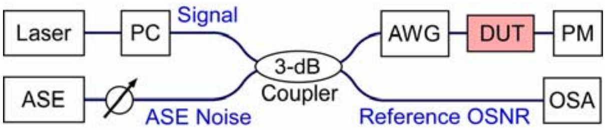

Fig. 3: Experimental set-up

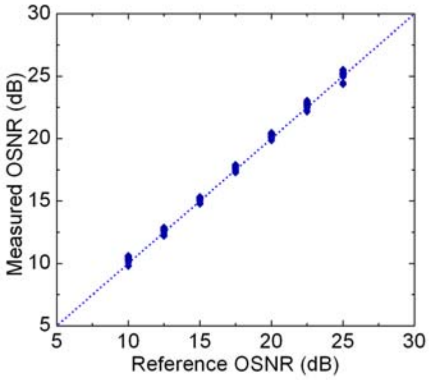

Fig. 4: In-band OSNR measured with our proposed OSNR monitor

Figure 3 shows the experimental set-up. A laser was used as a signal source, and a polarisation controller was connected to produce various states of polarisation. An ASE was used as a noise source, and an attenuator was connected to the ASE to control the noise level. The signal and the noise were then combined with a 3-dB optical coupler, and one output was used for a reference OSNR measurement and the other was used for our device measurement. A single WDM channel filtered with an arrayed waveguide grating (AWG) was launched into our device and the optical power output from the device was measured with a power meter. The intensity of the laser was set so that the optical power of the signal at the input of the module was -25 dBm. The attenuator connected to the ASE noise source was controlled to change the OSNR in a 10 to 25 dB range.

Figure 4 shows the in-band OSNR measured with our device with respect to the reference OSNR. Each measurement was performed for over 30 different states of polarisation. The power consumption for setting the phase shifters was approximately 50-100 mW. We successfully measured an OSNR up to 25 dB with an error of less than 0.6 dB. Since a PLC-type optical monitor is compact and simple[9], our proposed device would be excellent for performance monitoring in WDM networks.

Conclusion

We proposed a novel integrated in-band OSNR monitor based on PLC technology. We fabricated the proposed circuit on 1.5%-Δ silica-based waveguide, and demonstrated that the device can measure an in-band OSNR in the 10-25 dB range with an error of less than 0.6 dB.

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