Optical fiber-fault surveillance for passive optical networks in S-band operation window

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Abstract: An S-band (1470 to 1520 nm) fiber laser scheme, which uses multiple fiber Bragg grating (FBG) elements as feedback elements on each passive branch, is proposed and described for in-service fault identification in passive optical networks (PONs). By tuning a wavelength selective filter located within the laser cavity over a gain bandwidth, the fiber-fault of each branch can be monitored without affecting the in-service channels. In our experiment, an S-band four-branch monitoring tree-structured PON system is demonstrated and investigated experimentally.

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References and links

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1. Introduction

Passive optical networks (PONs) are the major role in alleviating the last mile bottleneck for next generation broadband optical access network. For the enormous communication capacity of the fiber link, any service outage due to fiber cut will lead to tremendous loss in business. Furthermore, a simple and effective monitoring configuration is highly desirable for timely fault identification along the fiber link. Moreover, the monitoring should be performed constantly while other channels are still in service to maximize the link utilization. In a tree-structured PON, fiber failure detection by an optical time domain reflectometer (OTDR) is not suitable because the Rayleigh back-scattered light from different branches cannot be distinguished at the OTDR. To overcome this drawback, several methods based on multi-wavelength OTDR [1, 2], and reflection of optical amplifier’s residual amplified spontaneous emission (ASE) [3-5], have been proposed. However, in practical application of the

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conventional PON systems, the wavelength of 1490 nm is allocated for downstream channel from an optical line terminator (OLT) and the 1310 nm is for upstream data service from each ONU. Recently, an S-band (1470 to 1520 nm) amplification technique, which employs the erbium-doped silica fiber with depressed cladding design and 980-nm pump laser to generate EDF gain extension effect, has been reported [6,7]. Therefore, a fiber-fault monitoring technique is expected to extend to S-band by using this S-band amplifier module. And than, unitization of an S-band amplifier and the fiber Bragg gratings (FBGs) can be employed to monitor the fiber-fault of the passive branches in PON architectures.

In this paper, we describe results obtained for the proposed fiber-fault monitoring system based on an S-band erbium-doped fiber (EDF) laser scheme, which uses the fiber Bragg grating as a feedback element on each branch of the tree-structured PON in front of the optical network unit (ONU). By tuning a wavelength selective filter located within the laser cavity over the S-band gain bandwidth, the proposed laser selectively lases from each of the Bragg wavelengths of the reflectors. Experimental results retrieved using the four-branch monitoring system in an S-band region are presented.

2. Principle and experiment

Figure 1 shows the proposed fiber laser configuration for the fiber-fault monitoring in tree-structured PON, and the length of each passive branch is nearly 10 km long between the optical splitter (OS) to FBG. The experimental setup composes of an S-band EDFA, which consists of two stage EDFA and a power-sharing 980 nm laser, a fiber Fabry-Perot tunable filter (FFP-TF), a 2×2 optical coupler, a 2×4 optical splitter (OS) and the four different central wavelength FBGs. The central wavelength and reflectivity of the FGB_1 to FBG_4 are 1511.39 nm and 91.8%, 1513.42 nm and 93.1%, 1515.69 nm and 95.9%, and 1517.37 nm and 82.9 %, respectively.

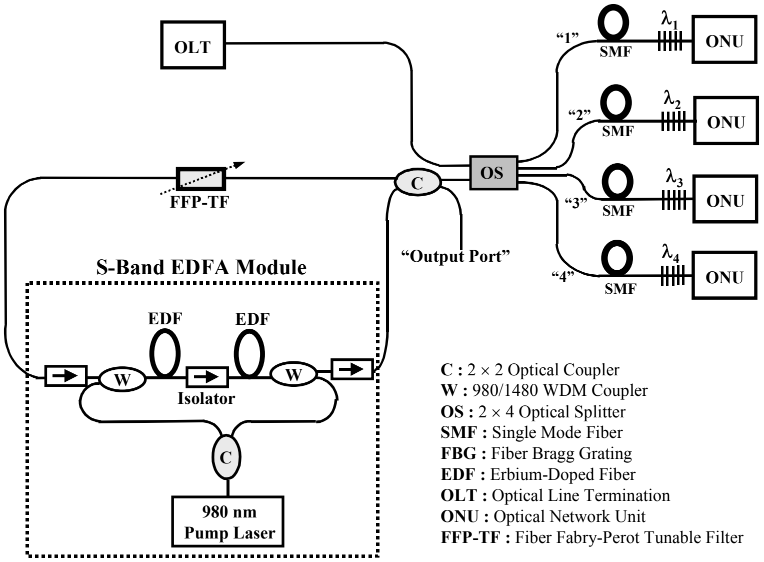

Fig. 1. Experimental setup of the proposed S-band EDF laser scheme for monitoring the fiber-fault in passive optical networks.

The S-band EDF inside EDFA module has a depressed cladding design in order to provide a sharp, high-attenuation, long-wavelength cutoff filter into active fibers. The erbium-doped fibers in the first and second stages have different characteristics. The fiber in the first stage has the fiber length of 20 m, and can provide low noise figure and medium gain by forward pumping. The fiber in the second stage has the fiber length of 30 m, and can produce large output power by backward pumping. In addition, the optical isolator between these two stages can reduce backward amplified spontaneous emission (ASE) and improve noise figure performance. The gain and noise figure can reach 32 dB and 5.7 dB at 1500 nm for input power of 25 dBm, and the saturated output power at 1500 nm can be up to 14 dBm for input power of 0 dBm. The total pump power of this amplifier module can be up to 280 mW while the bias current is operated at 356 mA. The FFP filter is an all-fiber device having a widely tunable range, low insertion loss (<0.5 dB), and low polarization-dependent loss (~0.1 dB). This FFP filter having the free spectral range (FSR) of 44 nm, the finesse of ~110 and 3 dB bandwidth of 0.4 nm can provide wavelength selection in the ring laser cavity by applying external voltage (< 12 V) on the piezoelectric transducer (PZT) of FFP filter. The optical output results are observed by an optical spectrum analyzer (OSA) with a 0.05 nm resolution.

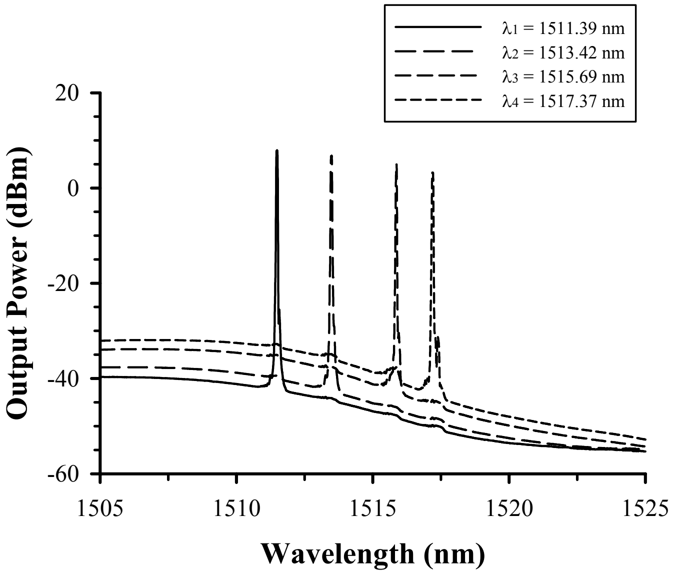

Fig. 2. Laser output at four different lasing wavelengths corresponding to the four FBG wavelengths.

The proposed fiber laser configuration containing the S-band erbium-doped gain section is a loop reflected which operates in a unidirectional manner due to the inclusion of an isolator. The other cavity reflection point is provides by one of a parallel of FBG elements at nominally different wavelengths on each passive branches. The FBG elements serve as the reflectors, and can be connected as part of the cavity via a fiber. Due to the inclusion of the wavelength filter within the loop reflector, lasing of the system occurs only when the filter transmission passband is aligned in wavelength with one of the fiber Bragg elements. However, the insertion loss of the OS will slightly reduce the output power of the lasing lightwave. In our proposed S-band passive fiber-fault monitoring method, the 1490 nm downstream wavelength of B-PON or GE-PON may be interfered due to the proposed test signal source (1470 to 1520 nm). To avoid the drawback, we apply the different central wavelength of FBG used to isolate the 1490 nm wavelength for avoiding the optical interference effect.

3. Results and discussion

Figure 2 shows the output lasing wavelengths of the PON system for the case where the FFP-TF is tuned to sequentially address each FBG on each corresponding breach. As can be seen, the fiber ring laser is forced to lase at a series of wavelengths: 1511.39, 1513.42, 1515.69, and 1517.37 nm, as determined by each central wavelength of the FBG. Between these points, the net cavity gain in the system was less than unity, and thus only ASE was observed at the output port. Figure 3 shows the ASE spectrum of the S-band EDFA. The effectively operation

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bandwidth is from 1478 to 1526 nm while the output power level is higher than –40 dBm. It is noted that by using an output coupler between the FFP-TF and gain section to observe the laser output, the out-of band ASE signal could be largely rejected.

To verify the fiber-fault monitoring technique based on the proposed fiber laser scheme in tree-structured PON, each FBG should be linked at each optical network unit (ONU). According to the proposed operation principle, the different lasing wavelength will represent the fiber-fault behavior. So, each fiber branch has its accordingly lasing wavelength. While the fiber fault occurs on the passive branch "2" and "3", then the lasing wavelength will only show the wavelength λ_1 and λ_4 in the proposed architecture, as shown in Figure 4. Even if the FBGs are installed in the branch fibers and rejects a part of the light source, the effective rejection ratio is not enough in order to test the in-service lines. Because the fiber fault occurs on the one fiber of the branch fibers of PON, the others are still on-service. As a result, when the external variation causes the fiber-fault of the passive branch, the proposed fiber laser scheme can monitor the broken branch by observing the accordingly lasing wavelengths (FGBs) in the tree-structured PON.

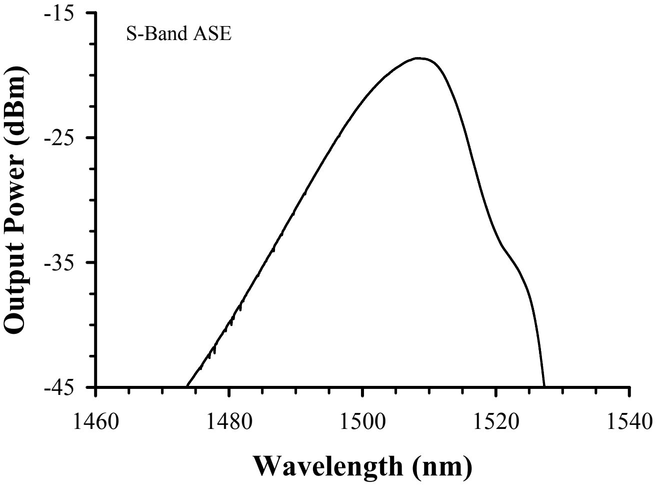

Fig. 3. The ASE spectrum of the S-band EDFA.

4. Conclusion

In summary, we have studied the operation of a novel method for addressing a parallel of FBG sensor elements configured as feedback elements of an S-band EDF ring laser. The S-band laser uses a unidirectional loop reflector, which contains a tunable wavelength selective filter. Tuning of this element provide for selective operation of the laser at each of the Bragg wavelengths. Determination of the Bragg wavelengths can then be used to monitor fiber-fault on each passive branch in tree-structured PON.

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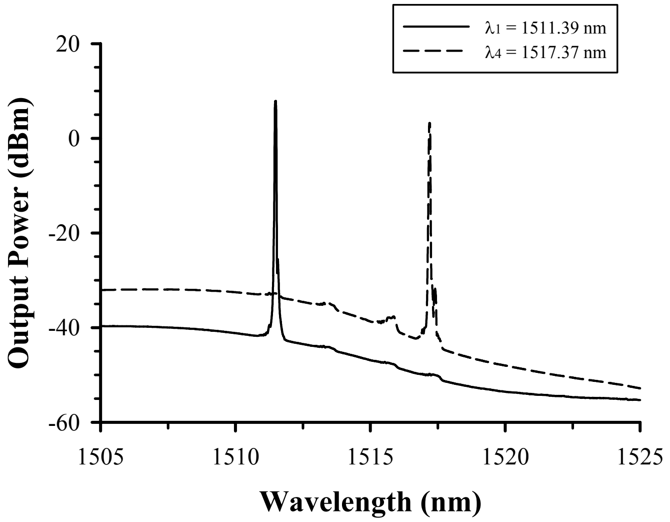

Fig. 4. Two output lasing wavelengths of λ_1 and λ_4, while the fiber fault occurs at the passive branch "2" and "3".

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