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Optimization of the Loop Loss of an Optically Amplified Feedback Circuit for Optical Power Sensing Systems

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Abstract **We propose a novel configuration using optically amplified feedback circuit (OAFC) for investigating the loop loss dependence of the performance of the OAFC for optical power sensing systems. In this paper, we experimentally optimize the loop loss of the OAFC, and achieve a significantly large improvement factor of 403 at the optimum loop loss of ~7.5 dB.**

1. Introduction

Optical power sensing is an essential function in the photonics systems, such as optical communication and optical measurement [1-5]. We proposed the "optically amplified feedback circuit (OAFC) method" as a novel method in the photonics systems that can significantly improve the optical power resolution [5-11]. In this paper, we have experimentally investigated the loop loss dependence of the performance of the OAFC and clarified the optimum value of the loop loss. A significantly large improvement factor of 403 was obtained at the optimum loop loss of ~7.5 dB.

2. Experimental Configuration

The experimental configuration of our proposed OAFC is shown in Fig. 1. We use the pump light of erbium doped fiber (EDF) as the input light of this system. The input light can be chosen as the signal light of the EDF, if needed, as in the cases of [6, 7]. The input light (pump light) was emitted from a pump light source (PLS), which was a Fabry-Perot laser diode module. The wavelength of the input light was ~1470 nm. The PLS is driven with a constant current and an optical variable attenuator (VOA_{in}) is installed at the rear stage of the PLS to change the input optical power at the EDF input. The input light is branched for monitoring its power by a branch fiber module (BR) and measured by an optical power meter (PM1).

The gain medium of the OAFC is an EDF and the feedback path has a fiber ring configuration. An optical isolator (ISO) is set at each side of the EDF in order to eliminate the counter-clockwise propagating light and the residual reflection. The input light is coupled into the fiber ring circuit using an optical coupler (CP) and the residual pump emitted from the EDF is eliminated by a pump rejection optical filter (PR). An optical bandpass filter (OBPF) is set after the EDF section. The center wavelength of the OBPF is 1558 nm. A polarization controller (PC) is set after the OBPF. Moreover, another branch fiber module (BR) is set after the PC. Another variable optical attenuator (VOA) is installed after BR in the loop in order to change the loop loss. The value of VOA was set at 0.00, 1.25, 2.50, 3.75, and 5.00 dB. The loop loss from point *B* to *A* was ~7.5 dB with the VOA set value of 0.00 dB. The insertion loss of the VOA was ~1.5 dB.

We obtain the light branched by the BR in the loop as the output light of the OAFC. The optical power and wavelength of the output light are measured by an optical power meter (PM2) and an optical spectrum analyzer (OSA), respectively, where PM2 and the OSA are set after the BR in the loop. The input and output light powers of the OAFC are labeled as P_{in} and P_{out}, respectively.

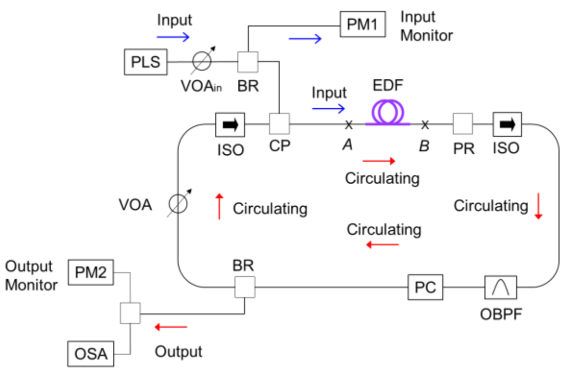

Fig. 1　Experimental configuration.

3. Experimental Results

We clarified the performance of the OAFC against the loop loss. Figure 2 shows P_{out} as a function of P_{in} in the cases with the VOA set values (L_{VOA}) of 0.00, 1.25, 2.50, 3.75, and 5.00 dB.

Figure 2 also shows that P_{out} increases nonlinearly with P_{in}. P_{out} and P_{in} both were measured in dBm. The P_{out}-P_{in} curves show the transition regions that correspond to the built-up of laser oscillation.

The slope (S) is shown as a function of P_{in} in Fig. 3. The slope S is defined as the ratio of the variation in P_{out} in dB ($\triangle P_{out}$) to the variation in P_{in} in dB ($\triangle P_{in}$): $S =$

$\triangle P_{out}/\triangle P_{in}$. The slope S indicates the value of an improvement in the optical power resolution thanks to using the OAFC method [5]. Let denote the maximum value of S to be S_{max} for each curve in Fig. 3. S_{max} is 403 at L_{VOA} of 0.00 dB and P_{in} = −23.76 dBm. Moreover, S_{max} is 304 at L_{VOA} of 1.25 dB and P_{in} = −23.70 dBm, S_{max} is 239 at L_{VOA} of 2.50 dB and P_{in} = −23.47 dBm, S_{max} is 181 at L_{VOA} of 3.75 dB and P_{in} = −23.34 dBm, and S_{max} is 147 at L_{VOA} of 5.00 dB and P_{in} = −23.05 dBm.

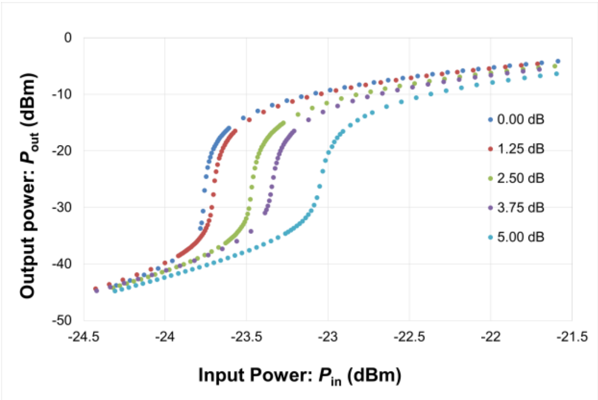

Fig. 2 Output power as a function of the input power.

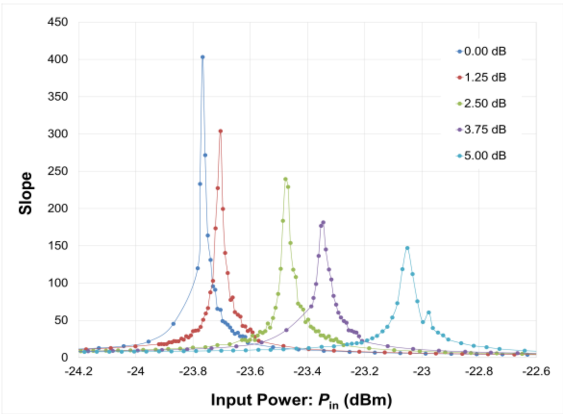

Fig. 3 Slope as a function of the input power.

From Figs. 2 and 3, the nonlinear response in the input vs. output relation in the optical powers is the origin of the improvement in the optical power resolution. It is considered that the nonlinear response is caused by the optical power transfer process from the input- to output-lights and the optical filtering effects of amplified spontaneous emission in the circulating loop.

From the curves of plots shown in Fig. 3, we can more accurately measure and determine the peak values of the slope if we set the input power by a smaller step. Therefore, the measured peak values are approximate values at this time. We will measure the slope by a smaller step and will show the results based on the experiment in another paper in the future.

The stability and reproducibility of the input-output relation of optical powers of the OAFC were evaluated in our earlier study [5]. Some sufficient degree of reproducibility was confirmed in a few minutes of the operation duration of the OAFC in the case of a slope of ~32 in the study. It is considered that sufficient degrees of reproducibility will be achieved if there are no excess noise in the OAFC, whereas the excess noise is considered to be caused by some changes in the environmental conditions such as temperature and vibration. There were no significant time variations of the measured output powers in this experiment. The details of the stability and reproducibility of the OAFC described in this paper will be confirmed and reported in another paper in the future.

Figure 4 shows S_{max} as a function of L_{VOA}. As shown in the figure, S_{max} increases when L_{VOA} decreases. S_{max} are 403, 304, 239, 181, and 147 at L_{VOA} of 0.00, 1.25, 2.50, 3.75, and 5.00 dB, respectively. From these results, it has been clarified that the optimum L_{VOA} is 0.00 dB, where the loop loss is ~7.5 dB.

The optimum value of L_{VOA} is the smallest value available in the setup of this experiment. The reason why the smallest loop loss gives the largest slope is not clear at this time. We think the reason is an important issue in the future.

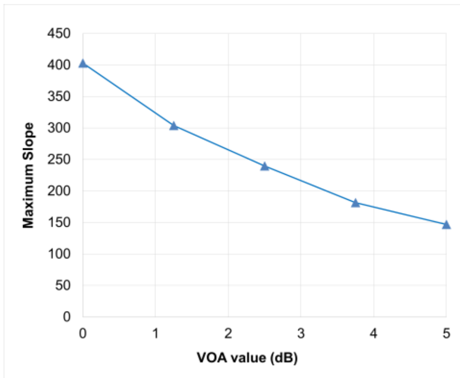

Fig. 4 Maximum slope as a function of the VOA set value.

We will show some results on the optical spectrum of the output light emitted from the OAFC in another paper in the future. We can further understand the operation and characteristics of the OAFC from the results.

4. Conclusion

We investigated the loop loss dependence of the performance of the OAFC. We experimentally confirmed that the slope *S* increased when the loop loss decreased. We achieved a maximum slope value $S_{\max}$ of 403 at the optimized loop loss of ~7.5 dB (VOA set value of 0.00 dB), where $S_{\max}$ equals to the improvement factor in the optical power resolution for the optical sensing applications.

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