Optical signal polarization state instability on erbium doped fibers

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ABSTRACT

Polarization state of the optical signal in erbium doped fiber is experimentally checked. Dependencies with the pump power, the input signal power and with the spectrum are reported.

Keywords: Polarization, erbium doped fiber, ASE, fiber Bragg grating

1. INTRODUCTION

The erbium doped fiber (EDF) has attracted a great importance in several areas of photonics owing to its capacity to achieve high gain to optical signal. In some of the applications, the stability of the polarization state (PS) of the light can be a key issue or, at least, a topic that must be taken into account because of its influence on the system behaviors.

In digital optical fiber communications the polarization mode dispersion (PMD) becomes an important limit factor for periodically amplified lightwave systems [1]. Other polarization effects in fiber amplifiers, for example, polarization mode dispersion (PMD), polarization hole burning (PHB), polarization dependent loss (PDL) and polarization dependent gain (PDG) are prejudicial to long-distance systems because lead to degradation of the signal-to-noise ratio (SNR) and the Q of the system. Recently, new digital format based on the polarization of light are in study. In this study, each digit is represented by an area on the Poincaré sphere. The stability of PS is of primordial importance.

In the context of optical fiber active sensors, the erbium doped fiber can be used to enhance the sensitivity, to improve the accuracy of optical interrogation units [2] or to compensate optical losses and, therefore, to increase the number of sensors in the sensing networks [3]. In particular, in sensing techniques based on interferometry [4] and fiber laser sensors [5], random fluctuations in the PS of the optical signal are specially important[6].

Avoiding the instabilities of PS of the amplified optical signal is highly desirable when an EDF is incorporated in an optical system. Some techniques can be used to preserver an arbitrary input PS regardless any perturbations [7] [8]. However, in spite of the use of these techniques, random variations of PS of the optical signal take place and, as consequence, there are an increase of noise and polarization cross-talk. To our knowledge, these instabilities haven't been fully characterized up to date.

In this paper, results from an experimental study of aspects such as the influence of the characteristics of a conventional fiber amplifier (gain, ASE noise, input optical signal, wavelength) on the stability of the PS are presented and analyzed.

The experimental set-up is describes briefly in section 2. The experimental results attained will show in section 3 and, finally, section 4 outlines the conclusions.

2. EXPERIMENTAL SET-UP

The set-up shown in the figure 1 is used in order to measure the evolution of the PS of the amplified optical signal. The light from the tunable laser (HP-8168), in the band that ranges from 1470 to 1570 nm, through a polarization controller, is launched in the EDF using a wavelength division multiplexer (WDM).

The light from the EDF-end is connected to the optical polarization analyzer (OPA) (HP-8509B) via a tunable band-pass filter in order to reduce the amplified spontaneous emission (ASE). Each PS of the optical signal at the output of the filter is represented on a Poincaré sphere generated by the OPA.

Second European Workshop on Optical Fibre Sensors, edited by
José Miguel López-Higuera, Brian Culshaw, Proceedings of SPIE Vol. 5502
(SPIE, Bellingham, WA, 2004) 0277-786X/04/$15 · doi: 10.1117/12.566708

The erbium doped fiber (EDF) used is 26 m long with an absorption peak of 5 dB/m that corresponds to 300 ppm of Er+3 concentration in the core. A 1480 nm laser doted with an optical isolator is used as pump source.

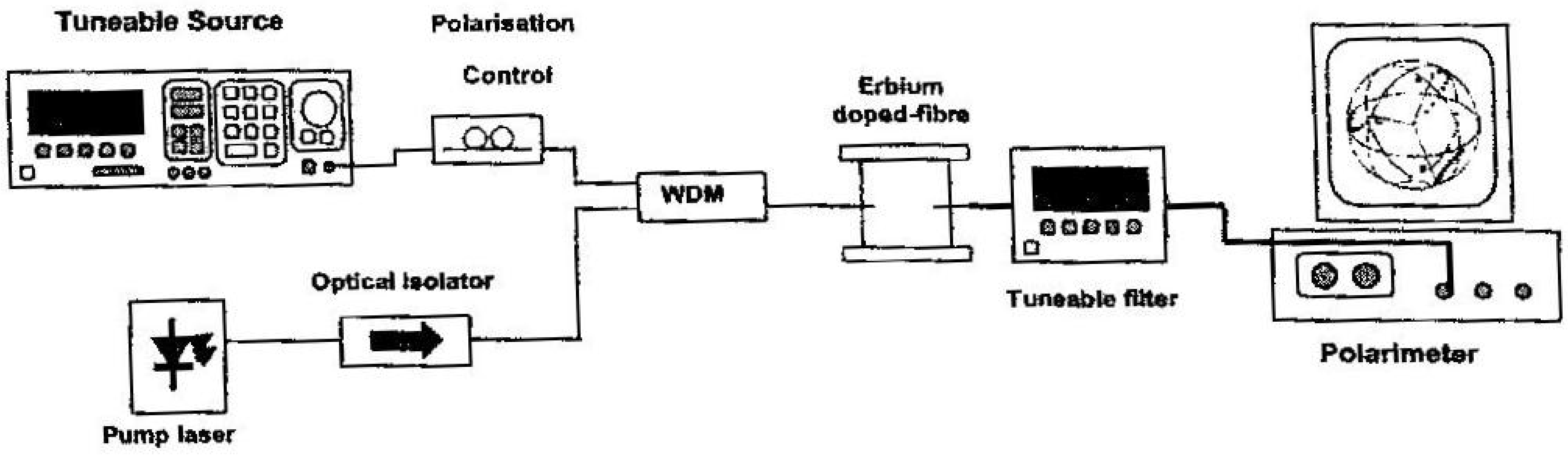


Figure 1. Experimental set-up.

3. RESULTS

The evolution of the PS in a wide range of EDF conditions is measured experimentally. A sample of the obtained results is shown in figure 2. The variation of the PS of the output optical signal for two values of the input signal power is represented on the Poincaré spheres. An increase in the instability of the PS is noticeable. The smaller the input signal power induces the higher the PS fluctuations of the output signal for a given pump power. For each input signal power, the fluctuations of the PS can be included inside an area S on the Poincaré sphere.

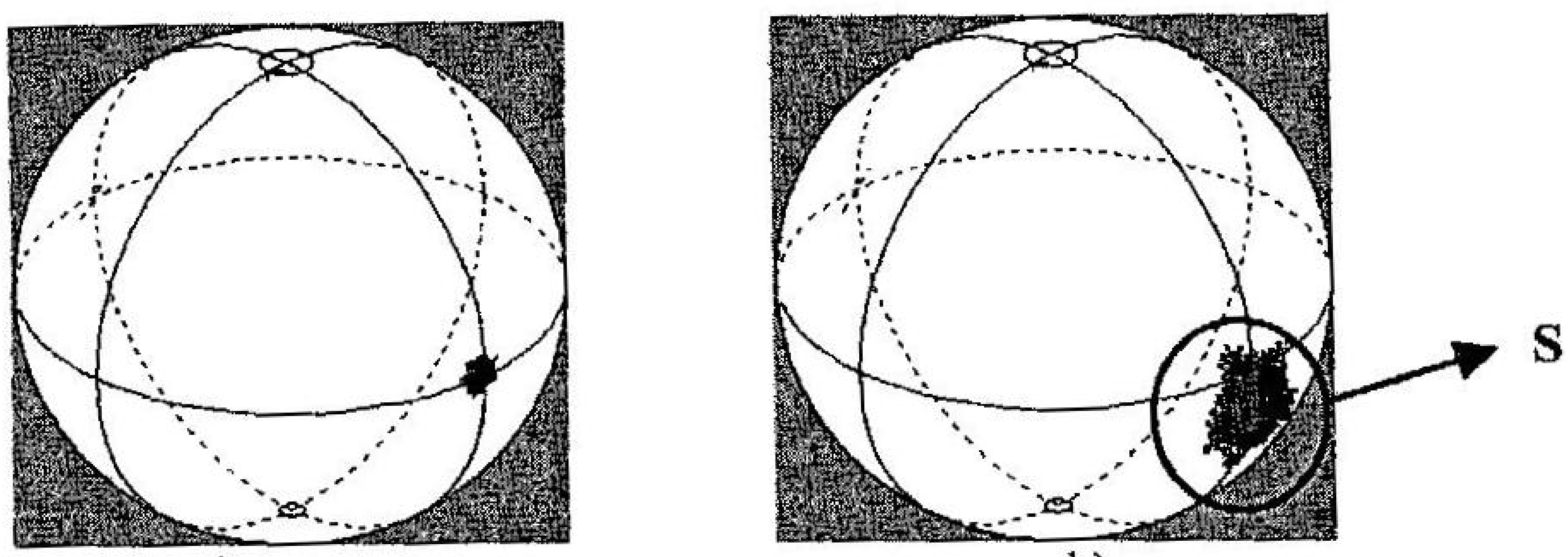


Figure 2. Evolution of the PS of the amplified optical signal for a pumping power of 20 dBm ,λ=1555 nm and input signal powers of: a) P_{input}=-5 dBm and b) P_{input}=-15 dBm.

Each PS is specified by two variables: the azimuth (α) and the ellipticity (ε). In order to quantify the instability of the PS of the output optical signal, the azimuth variance (V_{AZI}) and the ellipticity variance (V_{ELLIP}) were defined [10] as follows:

$$V_{AZI} = \frac{1}{N} \cdot \sum_{i=1}^{N} (x_i - \eta_{AZI})^2$$

$$V_{ELLIP} = \frac{1}{N} \cdot \sum_{i=1}^{N} (y_i - \eta_{ELLIP})^2$$

where N is the number of measured points on the same working conditions of the EDF, x_i and y_i are, respectively, the azimuth and ellipticity values at each measurement time (T_i), η_{AZI} and η_{ELLIP} are the azimuth and ellipticity averages of the N PS's recorded during the N×Ti seconds of the experiment. In this paper, all the measurements have been carried out with N=6000 and N×Ti = 60 seconds, because during this time, the variances are not expected to increase further for a specific working conditions of the EDF. In order to determine the S surface in figure 2, a variable V is defined like the medium of the azimuth variance (V_{AZI}) and the ellipticity variance (V_{ELLIP}).

Experimental results of V as function of the signal wavelength and the input signal power are shown in figure 3. From the latter, it can be deduced that V is wavelength dependent with a maximum centered around λ=1560 nm. There are also two signal wavelengths at which V presents minimums, these are λ=1540 nm and λ=1570 nm. V decreases with the input optical power, but their sensitivity to the input optical power is maximum at the same wavelengths at which the variances are maximum.

It has been observed that this variance have a similar behavior with the working conditions to that of the gain of the EDF. The gain and the variance have its maximums and its minimums at the same wavelengths. On the other hand, the slopes of both the gain and the variance behave in a similar manner with respect to the input signal power.

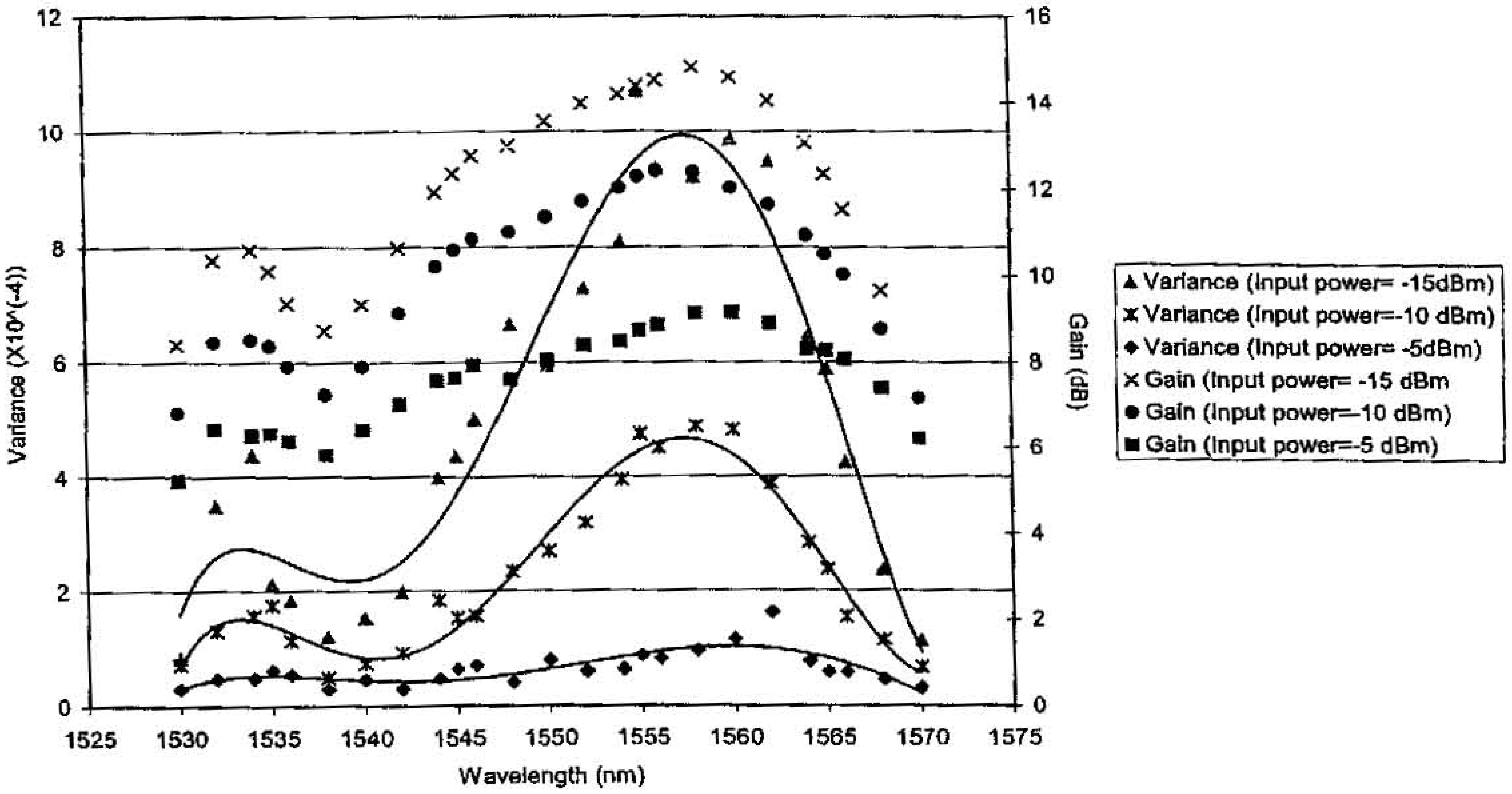
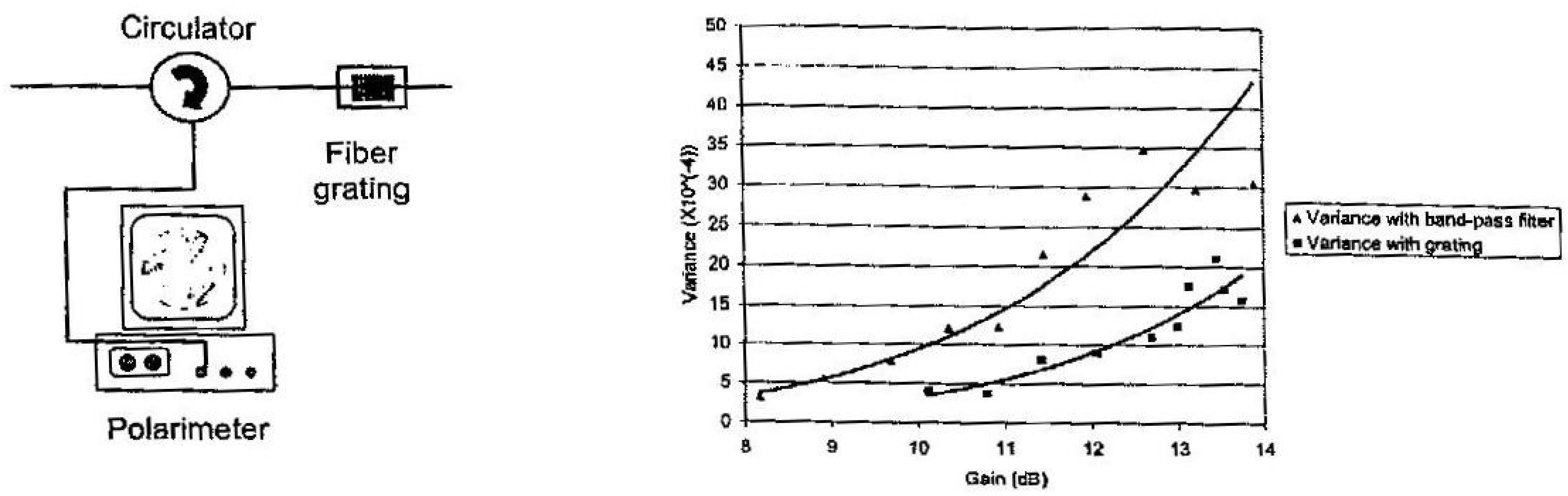


Figure 3. Amplifier gain versus the signal wavelength and V versus the signal wavelength for three input signal powers and for a pump power of 20 dBm. The solid lines are the tendency lines of the variance for each input power

In the EDF saturation regime, the observed change in the ASE spectrum approximately corresponds to the gain spectrum change within 1 dB accuracy [11]. Therefore, it is expected that the variance V will be ASE dependent. In EDF, some excited erbium ions decays with spontaneous emission before it has time to meet with an incoming signal. Thus a photon is emitted with a random phase and random direction and as consequences, the ASE causes the random change of the PS of the output optical signal.

The fluctuations of the PS of the optical signal can be minimized with a carefully control the EDF design to minimize the ASE. There are other techniques to reduce the ASE power level as to incorporate optical bandpass filter to filter out the broadband ASE [9]. This last technique went used to filter the ASE in the set-up of figure 1.

In order to achieve a bigger reduction of the ASE power, a narrower band pass filter based on fiber Bragg grating technology is used. This filter scheme is shown in figure 4 a, and it is located after erbium doped fiber in the set-up of figure 1. The fiber Bragg grating employed has the Bragg wavelength at 1550 nm and a linewidth of 0.23 nm, which is approximately half of the tunable band-pass filter. As shown in figure 4 b, a reduction of fluctuations of PS with the fiber Bragg grating is obtained.



a) b)

Figure 4. a) Filter scheme based on fiber Bragg grating. b) V as functions of the gain for a band-pass filter and a filter based on fiber Bragg grating for a pump power of 20 dBm

CONCLUSIONS

In this paper, the influences of EDF parameters on the PS of the amplified signal have been measured. PS dependencies with the input signal and with the pump power are observed. The variance of the PS of the output signal is defined and experimentally measured. Spectrum ranges of the minimum and maximum variances values with input signal power and with pump power are determined. Maximums around the 1560 and minimums around the 1570 nm and 1540 nm respectively were measured. Also, it has been observed that the behavior of the variance is directly related to the gain and to the ASE of the EDF. Finally due to the later, PS instabilities reduction is observed using narrower optical band pass filters.

ACKNOWLEDGEMENTS

This work is co-funded by the Spanish Ministry of Science and Technology through the SuGAROS (TIC'2001-0877-C02-01) and EOAMOP (TIC'2002-01259) R&D projects.

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