Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 8 (23): 4464-4467, 2008
ISSN 1812-5654

Determination of Minimum Temperature Coefficient of C Band EDFA

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Abstract: In this study, the temperature dependence of the gain variation in conventional band erbium-doped fiber amplifier between 0 and 60°C are investigated. Experimental results demonstrate a decrement in the temperature-dependent gain by increasing input signal power. At -10 dB m input signal the lowest temperature sensitivity (average gain 18.27 dB, average temperature-dependent gain variation 0.16 dB and temperature-dependent gain coefficient 0.0027 dB/°C) and at -40 dB m input signal the greatest temperature sensitivity (average gain 27.85 dB, average temperature-dependent gain variation 1.24 dB and temperature-dependent gain coefficient 0.02 dB/°C) is obtained.

Key words: Gain variation, temperature coefficient, input signal power, C band EDFA

INTRODUCTION

The Erbium-doped fiber amplifiers are attractive devices for long haul fiber optic communication systems. Many advantages of EDFAs include low noise, high optical power, polarization independence, high gain, linearity, wide bandwidth, wavelength transparency and fiber compatibility. They revolutionized optical communications by effectively removing the transmission and splitting loss barriers (Yamada *et al*., 1990; Naji *et al*., 2006).

The temperature dependent gain characteristics of the EDFAs are the key parameters, especially in WDM applications (Yamada *et al*., 1992; Bolshtyansky *et al*., 2000; Kemtchou *et al*., 1997). There is no certain rule for the prediction of temperature dependence of EDFAs (Bolshtyansky *et al*., 2000). Have modeled the temperature dependence of the EDFAs using linear extrapolation techniques Lee and Park (1998a, b). McCumber's theory seems another alternative to model the temperature dependence (McCumber, 1964; Miniscalco and Quimby, 1991; Goktas and Yucel, 2008).

To date, theoretical and experimental temperature dependences of signal gain and noise properties of EDFAs have been investigated. Their temperature dependencies of signal gain, fiber length, pump wavelength and signal wavelength have been reported by Yamada *et al*. (1992) and Flood (2001). For low temperature sensitivity, Kemtchou *et al*. (1997) used a roughly flat gain WDM amplifier in association with gain equalization. In this study, it is experimentally showed that the temperature dependencies of gain variation in C band EDFA depending on the input signal power. In addition, the structure of the designed system is simple without the need of additional expensive components. Moreover, this system has the potential to be used in the dense wavelength division multiplexing applications because of its simplicity and low cost. Also, it is reported that, the experimental results for the temperature dependencies of gain variation for various input signal powers of Ge/Al co-doped Er^{3+} fiber pumped by the 980 nm. Since temperature dependency of noise figure is very low, it is not taken into account (Kagi *et al*., 1991).

MATERIALS AND METHODS

The experimental setup used to measure the gain characteristics is shown in Fig. 1. Ge/Al co doped EDF was forwardly pumped with a 980 nm pump laser diode stabilized by a fiber Bragg grating that constantly set to 100 mW (due to the smaller gain variation with respect to 1480 nm, 980 nm pump was chosen) (Kemtchou *et al*., 1997; Flood, 2001; Kagi *et al*., 1991). The pump and signal light (between 1530 and 1566 nm 24 signal transmitted by a Santec TSL-210 V tunable laser source) are launched into the inlets of a WDM coupler. Both inlets were fusion spliced to the pump laser and to the optical isolator. The outlet was fusion spliced to the erbium doped fiber. The erbium-doped fiber coil was put into the thermal chamber within the temperature range of 0 to 60°C except for both ends, which were located outside in order to avoid possible change in the splice loss due to the temperature. In the measurement process for each temperature step which was approximately 60 min maintained to ensure that the coils reach the thermal equilibrium. An ANRITSU MS9710B optical spectrum analyzer measured the output

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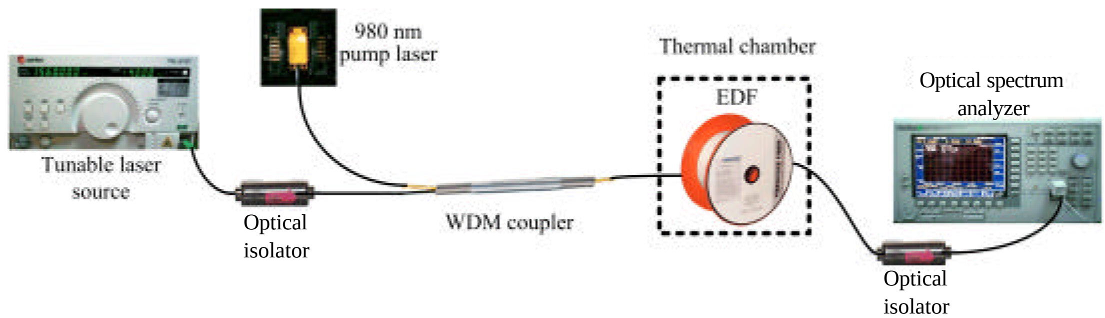

Fig. 1: Experimental setup used to measure EDFA gain spectrum

Table 1: The characteristics of the EDF

Fiber type	Coractive EMP980
Fiber length	13.5 m
Erbium concentration	226.67 ppm
Erbium radius	1.68 µm
Core radius	1.77 µm
Numerical aperture	0.19
Life time	10 ms

signal from the erbium-doped fiber. During the experiment, the temperature of other passive components kept constant at room temperature. The characteristics of the EDF used in this experiment are shown in Table 1. The experimental setup was optimized using OptiAmplifier 4.0 software. Then the best configuration found by simulation was used. While the input power was varied from -40 to 0 dB m, the EDF temperature was controlled by a thermal chamber.

RESULTS AND DISCUSSION

Figure 2 shows measured temperature coefficient for C band EDFA. The launched signal power was cycled from -40 to 0 dB m. The pump power is fixed 100 mW. The experiments were made between 0 and 60°C. As shown in Fig. 2, the temperature coefficient increased with decreasing input signal power. The maximum temperature coefficient was obtained at the smallest input power of -40 dBm with gain variation of about 1.24 dB in C band. At the highest input power, 0 dB, the gain variation was obtained about 0.122 dB. Due to the relatively low gain at this input power level, the result was not applicable result in practice.

Figure 3 shows the spectral gain variation for various temperatures. The launched signal power was -10 dB m in Fig. 3a and -40 dB m in Fig. 3b. In Fig. 3a, the gain variation was measured as 1.73 dB for -10 dB m input signal power under the temperatures of 0, 20, 40 and 60°C. In contrast to small variation of gain for -10 dB m, Fig. 3b shows considerably higher gain variation of 12.21 dB for -40 dB m signal power and 0, 20, 40 and 60°C temperatures.

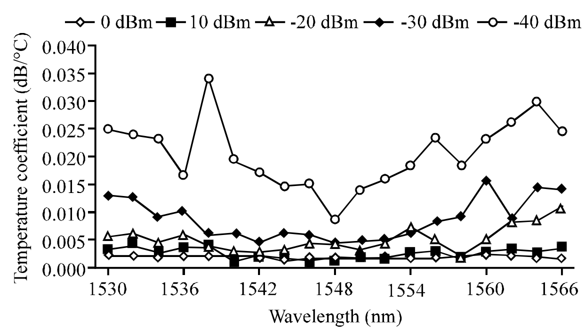

Fig. 2: Temperature coefficient within the range of 0°C from 60°C for each input signal gain along C band EDFA

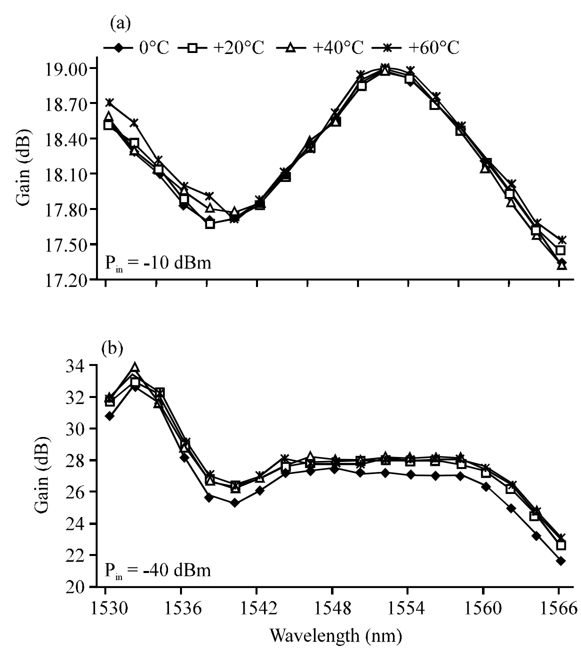

Fig. 3: The gain spectra for various temperatures (a) for -10 dB and (b) for -40 dB m input signal power

Table 2: Summarized temperature dependent characteristics for C band EDFA

Pump wavelength (nm)	Input signal range (nm)	Input signal power (dB m)	Temperature range (°C)	Gain variation (dB)	Temperature coefficient (dB/°C)	References
980	1530-1562	-20	-10-80	0.700	0.0077	Flood (2001)
980	1530-1566	-10	0-60	0.162	0.0027	Present study
980	1530-1566	-20	0-60	0.315	0.0052	Present study
980	1530-1566	-30	0-60	0.526	0.0087	Present study
980	1530	-38	-20-85	0.400	0.0040	Kagi *et al.* (1991)
980	1530-1566	-40	0-60	1.240	0.0206	Present study
1480	1530-1562	-20	-10-80	2.000	0.0222	Flood (2001)
1480	1540-1554	-19	-40-80	1.200	0.0100	Kemtchou *et al.* (1997)
1480	1530	-38	-20-85	7.000	0.0700	Kagi *et al.* (1991)

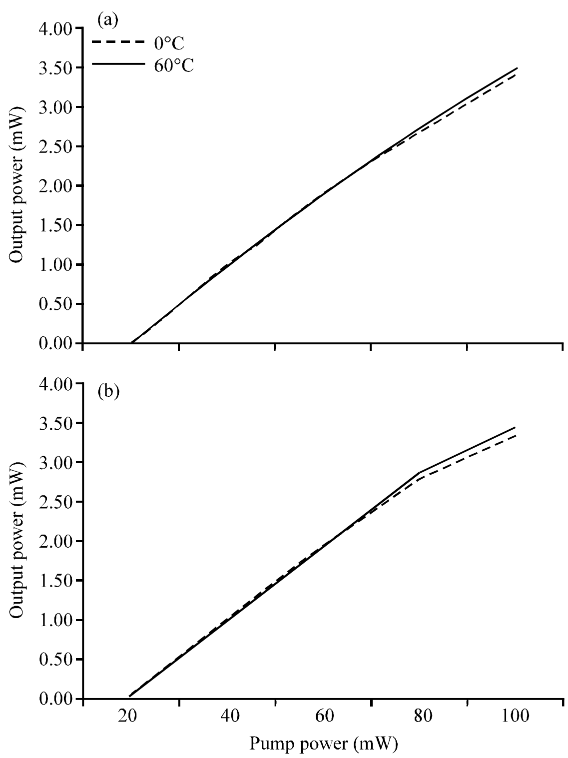

Fig. 4: Pump power versus output power for various temperature (a) input signal wavelength is 1532 and (b) 1552 nm

Figure 4 show the pump power versus output power for the temperatures 0 and 60°C. Input signal wavelength is 1532 nm in Fig. 4a and 1552 nm in Fig. 4b. The temperature dependent output power change is very small for higher pump power levels. Hence, small pump power levels are not influenced by the temperature.

Table 2 shows the summary of temperature dependent characteristics of C band EDFA for different studies. In the earlier studies some experimental studies can be found for comparison. However, these studies were not focused on the input power dependence of temperature coefficient. While in the study of Flood (2001) temperature coefficient is measured as 0.0077 dB/°C, the same coefficient is measured as 0.0052 dB/°C at the input power of -20 dB m. The other studies in Table 2 show a general opinion. For example pump wavelength of 1480 nm increases temperature coefficient. The gain variation and temperature coefficient are the lowest for the input signal power of -10 dB m. To date, experimental temperature dependences of signal gain properties have been investigated but the best results were obtained in this study for the power level of -10 dB m.

CONCLUSION

When flat gain requirements of optical WDM systems, are considered, the temperature dependent gain variations are one of the major problems of EDFAs. This problem can be minimized by carefully choosing the input signal power level. In this study, it was found that temperature-insensitive input signal may be obtained where the temperature coefficient of signal gain became close to zero (Yucel and Goktas, 2008).

It is examined that the temperature dependence of the gain characteristics in conventional band erbium-doped fiber amplifier for various input signal power levels of -40, -0 dB m. The experiments were conducted between 0 and 60°C for input signals: -40, -30, -20 and -10 dB m. For which, 980 nm pump power was used. It is obtained that temperature coefficients for five different input signal power levels. Experimental results showed that the temperature coefficients and gain variations increased when decreasing input signal.

Experimental results demonstrate that the input signal power of -10 dB m provided minimal gain variation along C band. The -10 dB m input signal shows the lowest temperature sensitivity. (Average gain 18.27 dB, average temperature-dependent gain variation 0.16 and temperature-dependent gain coefficient 0.0027 dB/°C).

ACKNOWLEDGMENT

This research has been partially supported by Office of Scientific Research Project in Gazi University (Project No. 07/2007-26).

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