Jurnal Teknologi, 40(D) Jun. 2004: 17–24

SIMULATION OF EDFA SYSTEM USING EDFA_DESIGN SOFTWARE

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Abstract. This paper presents the evaluation of the EDFA_Design software capability in simulating the EDFA system. Simulation results of the EDFA characteristics such as amplified spontaneous emission, gain, noise figure, and gain spectrum are compared with corresponding experimental values. The comparisons made between the simulation and experimental results show that the simulated values are generally in good agreement with the experimental values. The discrepancy in the low signal and high pump region is less than 1 dB. However, in the large signal region, this dicrepancy increases up to 2.6 dB and is worse in the low pump region. Overall, the EDFA_Design software proves to be a useful tool in simulating EDFA characteristics.

Keywords: EDFA, simulation, EDFA_Design, evaluation

Abstrak. Kertas kerja ini mempersembahkan penilaian kebolehan perisian EDFA_Design dalam simulasi sistem EDFA. Hasil simulasi ciri-ciri EDFA seperti pancaran spontan berganda, gandaan, nilai hingar dan spektrum gandaan dibandingkan dengan hasil eksperimen yang sejajar. Perbandingan yang dibuat antara hasil simulasi dan hasil eksperimen menunjukkan bahawa nilai simulasi secara amnya mempunyai persetujuan yang baik dengan nilai eksperimen. Perbezaan yang timbul pada isyarat rendah dan kuasa pam tinggi adalah kurang daripada 1 dB. Walau bagaimanapun, dalam kawasan isyarat tinggi, perbezaan yang wujud meningkat kepada 2.6 dB dan merosot lagi di kawasan kuasa pam rendah. Pada keseluruhannya, perisian EDFA_Design ternyata merupakan satu alat yang berguna bagi simulasi ciri-ciri EDFA.

Kata kunci: EDFA, simulasi, EDFA_Design, penilaian

1.0 INTRODUCTION

EDFA_Design software from Optiwave Corporation, Canada, is one of the softwares for basic EDFA design and it offers accurate algorithms for simulations. It is designed to model the physical parameters of the set-up easily [1]. In this paper, the simulation results of standard EDFA system are compared with the experimental values in order to evaluate the software. This is an important step in using the software to design and perform fast verification of new EDFA designs.

The EDFA_Design software performs calculations and derives values such as power, wavelength, gain, noise figure, and more for EDFA systems that are configured on the

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software's Layout Editor. The simulated results are dependent on the options chosen and the parameter values set. The EDFA_Design offers several options such as absorption and emission cross-section files, consideration of Rayleigh back-scattering constant, backscatter capture, concentration quenching effects as well as choice of algorithm, optical distribution, and power dependence [2].

2.0 EXPERIMENTAL RESULTS AND DISCUSSION

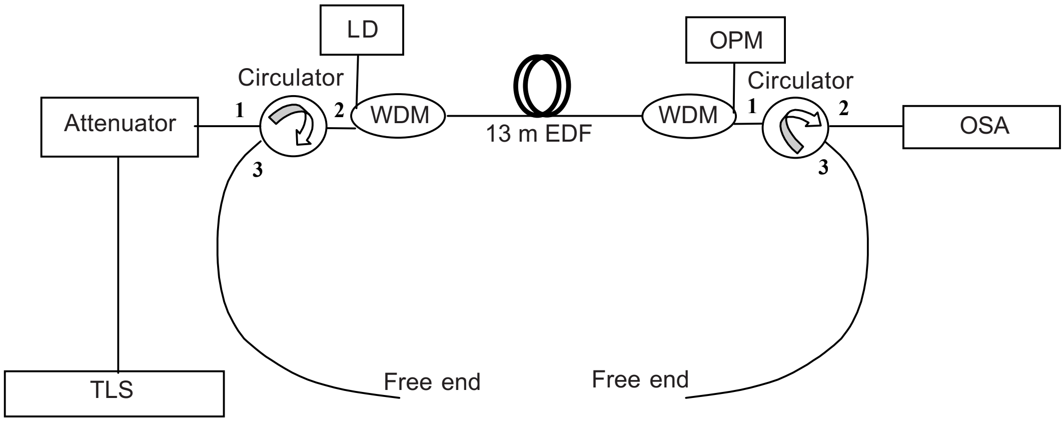

Figure 1 The typical EDFA system configuration. Tuneable Laser Source (TLS), Laser Diode (LD), Wavelength Division Multiplexer (WDM), Erbium-Doped Fibre (EDF), Optical Power Meter (OPM), and Optical Spectrum Analyser (OSA)

The set-up above shows the design of a typical EDFA. It comprises of a length of 13 m erbium-doped fibre (EDF) of the DF1500F type from Fibercore. The circulators are placed in exchange of the isolators, to allow the measurement of the backward amplified spontaneous emission (ASE) at port 3 of the first circulator. Meanwhile, the amplified signal and the forward ASE propagates together and are emitted at port 2 of the second circulator. The comparisons between the values obtained from the simulation and experimental measurements for various EDFA characteristics such as ASE, gain and noise figure profile as well as the gain spectrum are given below. Similar set-up were used in simulations whereby, the parameters resemble the actual experimental set-up.

Figure 2 shows the simulated and experimental backward ASE profiles obtained at pump power of 109 mW. The simulated backward ASE levels are observed to be higher than the experimental backward ASE levels. Such observation is also noted for forward ASE profiles. As the pump power decreases, the discrepancy between the simulated ASE profiles and the experimental ASE profiles changes in a similar pattern. Generally, the simulated ASE levels is about 13 dB higher than the experimental ASE levels at high pump power.

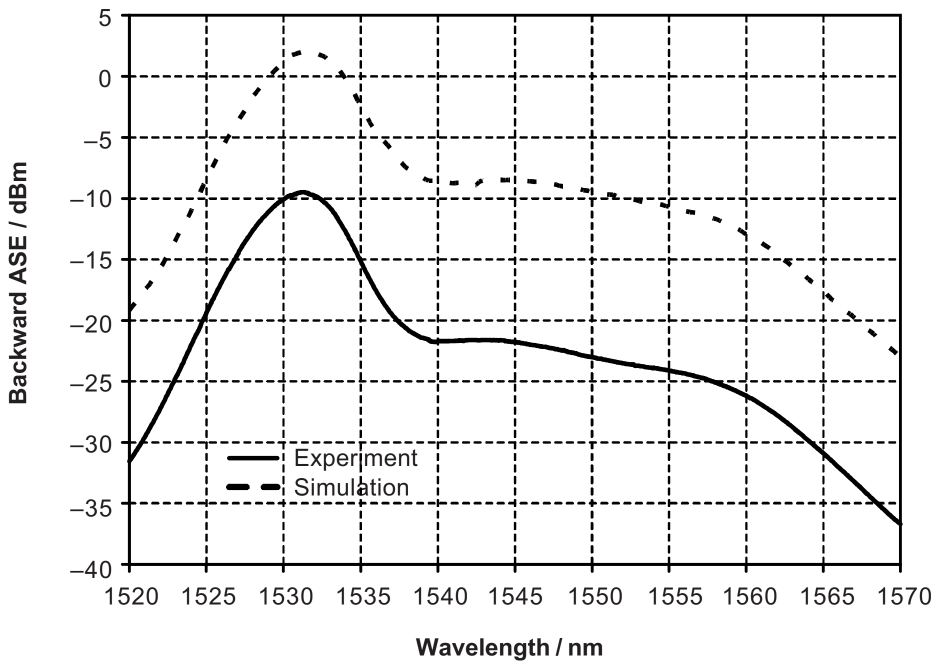

Figure 2 Backward ASE at 109 mW pump of the standard EDFA system: comparison between experimental and simulation results

Although this may prove the inaccuracy of the software, the following comparisons done for the amplifier gain and noise figure (which are the two most critical amplifier characteristics) may prove otherwise. The large inaccuracy in the simulation of the ASE does not show high significance in simulating the gain and noise figure. However, improvement may improvise the simulation of the EDFA system, especially in the low pump region or low signal region, where the ASE is significant [2].

Figure 3 depicts the gain versus pump power profiles for signal at input signal power values of –40 dBm, –20 dBm, and 0 dBm measured at pump power of 109 mW. Analysis of the gain across the input signal power shows good agreements between the experimental and the simulation values, especially at the input signal level of –40 dBm in the high pump power region. The error in this region is only about 0.9 dB, less than 3% error. The simulated gain values in the lower pump power region, however, shows deviation. The error in this region for input signal at –40 dBm is about 2.1 dB. The inaccuracy in the lower pump region can also be attributed to the significance of the ASE (which is not simulated accurately) in this region. As the signal power is increased, the amplifier now becomes more saturated and since ASE plays negligible role in the performance of the saturated amplifier, the error caused by the inaccuracy in the simulation of the ASE has a lesser impact on the gain [3].

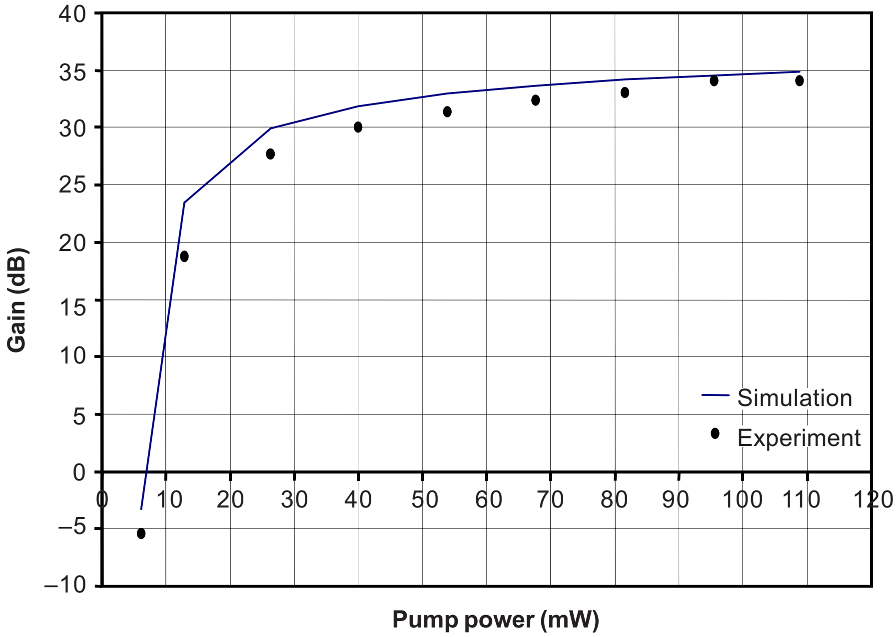

Figure 3 Gain versus pump power for input signal levels at –40 dBm

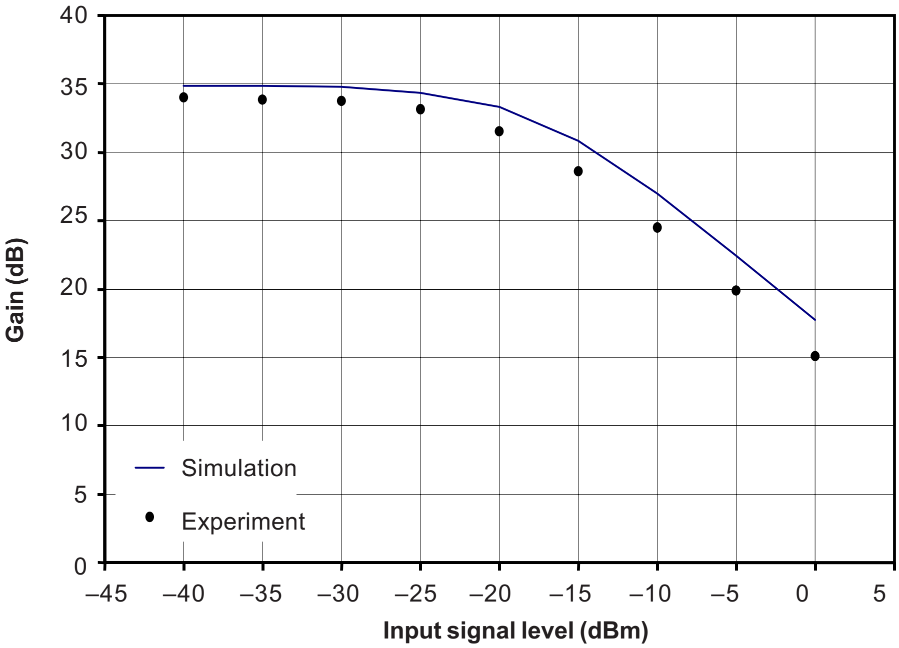

Figure 4 Gain versus input signal level for pump power at 109 mW

In the high pump region, differences between the simulated and experimental values across the various input signal power is highlighted in Figure 4. At the pump power of 109 mW, the difference between the simulated and experimental gain values, reduces from 2.6 dB at the input signal power of 0 dBm to 0.9 dBm at the input signal power of –40 dBm. The larger discrepancy between the simulated and experimental values in the large signal region is caused by inaccurate simulation of the amplifier saturation. This however, can be improved by incorporating quenching effects. Simulation using the combined homogeneous and inhomogeneous effect improves the discrepancy between the simulated and experimental gain values in the large signal region. Unfortunately, this tends to increase the discrepancy in the small signal region. The right amount of increasing influence of the quenching effect in the simulation of gain across increasing input signal power would provide a more accurate result. This factor differs from one EDFA system to another.

The simulated noise figure values are also close to the experimental values, revealing a good match between the simulated and experimental values. The differences between the two values are generally less than 1 dB, with the simulated values being higher than the experimental values. In the lower pump power region, discrepancies are found to be about 2 dB higher than the discrepancies at higher pump region. This is similar to the higher gain discrepancy observed at high low pump region, subject to inaccurate simulation of the ASE in this region.

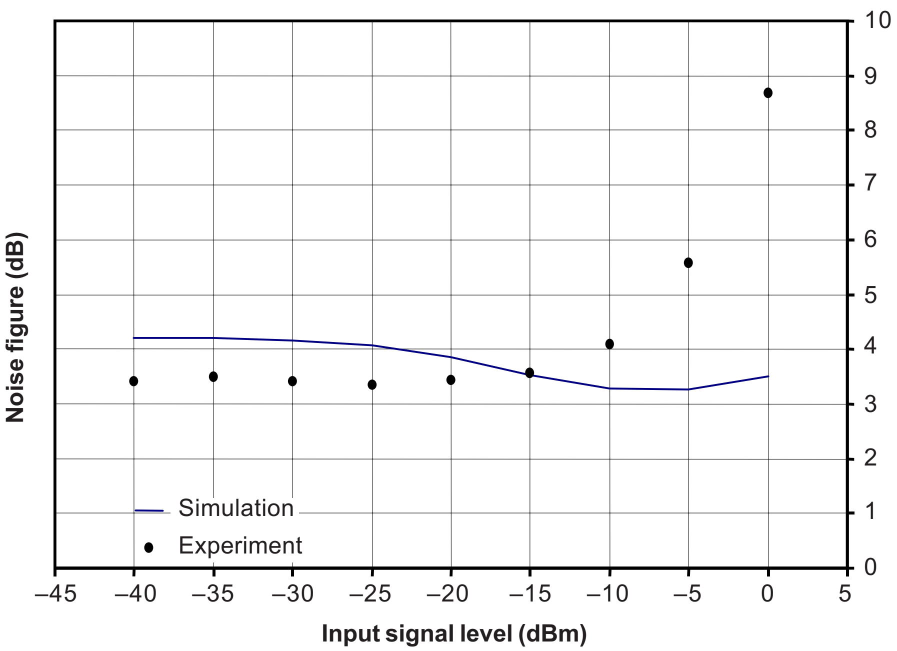

Figure 5 Noise figure characteristics as a function of input signal level for pump power of 109 mW

At very large input signal power values (above –25 dBm), the difference between the experimental and simulation results becomes larger, even at pump power of 109 mW. This can be observed in Figure 5. At input signal power 0 dBm, the difference between the experimental and simulation values reaches up to about 5 dB. Exponential growth is seen in the experimental values but not in the simulation values. The signal employed for the simulation is an ideal form of signal, without source spontaneous emission. Real laser signals as those from the TLS have source spontaneous emission that affects the EDFA noise figure. The level of the source spontaneous emission differs from one TLS to another. It increases with increasing signal power and results in higher noise figure, as observed in Figure 4. A single EDFA system will display different noise figure values when different signal sources are used.

The simulated gain spectral profile of the EDFA compared with the experimental gain profile measured over the 1525 nm to 1565 nm region for various input signal values in the above figure. The profile patterns have an identical match, except for the difference in the values. In the region of low input signal power, the simulated values and experimental values are almost the same. The mismatch between the experimental and simulated gain values, however, arises in the region of high input signal power, as observed in the previous EDFA gain measurements.

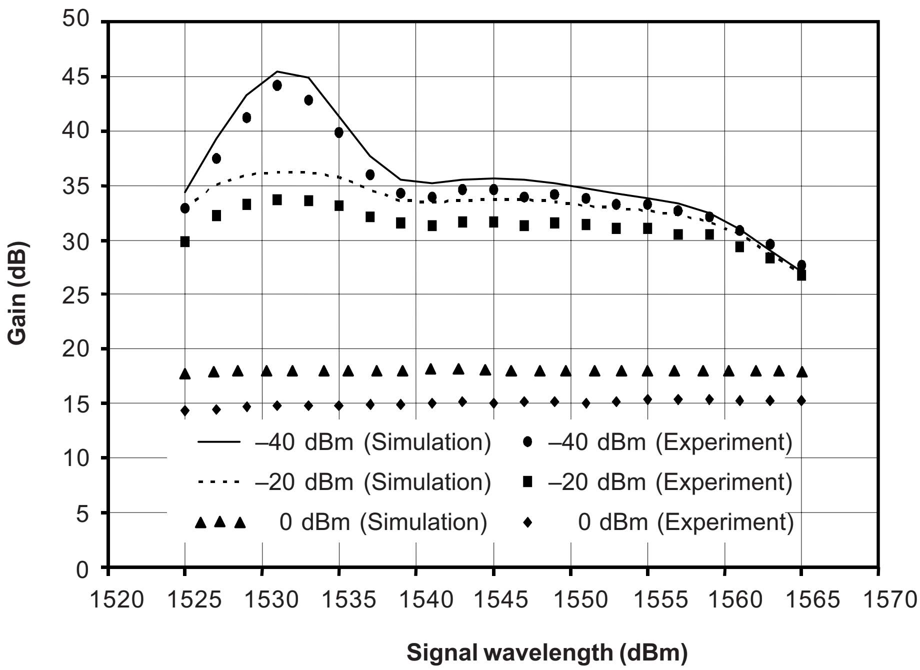

Figure 6 Gain versus signal wavelength at input signal levels; –40 dBm, –20 dBm, and 0 dBm

3.0 CONCLUSION

Comparisons made between the simulation and experimental results show that the simulated values are generally in good agreement with the experimental values, especially in the higher pump power region for small signals, where the discrepancy is lower than 3%. The EDFA_Design software is found to be very useful in simulating the gain and noise figure of the standard EDFA. In addition, the EDFA_Design version 2.0 software is based on the BPM, thus the software should be able to perform the characterisation of other types of EDFA such as the Gain-Clamped EDFA.

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