DESIGN AND DEVELOPMENT OF IN-LINE OPTICAL AMPLIFIERS

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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Chairman : Associate Professor Mohamad Khazani Abdullah, Ph.D.

Faculty : Engineering

Fiber optic technology is not entirely perfect, even with its amazing capabilities. As the transmissions cover larger distances, signal loss occurs and amplification is required. Hence, to transmit information over longer distances, the optical signals need to be boosted. The conventional method of boosting these signals is by using the electrical repeaters. The concept of electrical repeaters may sound attractive, but it poses several problems. This is because repeaters can only work at specific bit rate, wavelength and modulation format. The need for optical amplifiers has arisen because the repeaters concept delays the transmission and may introduce noise in the signal.

Optical signals require amplification at different points on communications links. There are three types of amplifiers located along this link. The first type is the power amplifiers that are placed directly after the optical transmitter. Secondly, there are the

in-line amplifiers that operate with a signal in the middle of a fiber-optic link and lastly, the pre amplifiers, which magnify the signal before it reaches the receiver. In this research, the design and development of optical amplifiers focused only on in-line amplifiers. Among the variety of optical amplifiers, Erbium doped fiber amplifiers were chosen as the optical amplifiers because erbium is the most efficient active medium that allows optical signals to be transmitted over very long distances without the need for signal regeneration.

In this thesis, the hands-on experiments of the in-line optical amplifiers design were carried out. The design models comprised single and double stages of Erbium doped fiber amplifiers setups. At the single stage device level, testing was conducted to study the effects of the design parameters that are pump power, Erbium doped fiber length, signal wavelength and input power. The analysis on the double stage Erbium doped fiber amplifier was carried out for the device level testing based on the effects of the performance parameters i.e., gain, output power, noise figure and Amplified Spontaneous Emission level with the inclusion of tunable band pass filter.

The results showed that the double stage amplifiers had a greater advantage compared to the single stage. The double stage Erbium doped fiber amplifiers with tunable band pass filter and the utilization of the backward pumping scheme had increased the gain more than that with the forward pumping scheme. The noise problem created in the Erbium doped fiber amplifiers was the main source that contributed to the high Amplified Spontaneous Emission. The concatenated chain caused the Amplified

Spontaneous Emission to accumulate. Hence, inserting a tunable band pass filter in the design reduced the noise figure.

Varying the parameters and selecting the suitable setup can improve the performance of the in-line amplifier system. The results of the study showed the most suitable design setup is the double stage Erbium doped fiber amplifiers, which increase the gain but reduce the noise level.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

MEMBINA DAN MEREKA BENTUK PENGUAT OPTIC DALAM TALIAN

Oleh

SHARIFAH NORIZA BINTI SYED IBRAHIM

Mei 2004

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Teknologi gentian optik bukanlah benar–benar sempurna walaupun ia mempunyai keupayaan yang mengkagumkan. Semakin jauh jarak penghantaran, kehilangan isyarat akan berlaku dan ini memerlukan penguatan. Oleh itu, bagi penghantaran maklumat jarak jauh, isyarat perlulah dikuatkan. Kaedah lama untuk meningkatkan isyarat-isyarat ini adalah dengan menggunakan penggulang elektrik. Konsep penggulang elektrik adalah menarik tetapi menimbulkan beberapa masalah. Ini adalah kerana penggulang elektrik hanya boleh berfungsi pada kadar bit, panjang gelombang dan format modulasi yang tertentu sahaja. Keperluan bagi penguat optik timbul kerana konsep penggulang melengahkan penghantaran dan boleh menimbulkan hingar dalam isyarat.

Penguatan isyarat diperlukan pada titik-titik yang berbeza di dalam talian komunikasi. Terdapat tiga jenis penguat yang boleh ditempatkan di talian ini. Jenis yang pertama

adalah penguat kuasa yang diletakkan selepas daripada pemancar optik. Yang kedua adalah penguat dalam-talian yang terletak ditengah talian gentian optik dan yang terakhir adalah pra penguat yang berfungsi untuk membesarkan isyarat sebelum isyarat tersebut sampai ke penerima. Dalam penyelidikan ini, pembinaan dan rekabentuk penguat optik ditumpukan kepada penguat dalam-talian. Di antara jenis-jenis penguat optik, penguat gentian terdop Erbium dipilih, kerana Erbium merupakan satu media aktif yang paling berkesan untuk membenarkan penghantaran isyarat optik jarak jauh tanpa perlu di jana semula.

Di dalam thesis ini, ujikaji ke atas rekabentuk penguat optik dalam-talian telah di jalankan. Model rekabentuk terdiri dari peringkat tunggal dan berganda bagi penguat gentian terdop Erbium. Pada tahap peranti penguat peringkat tunggal, pengujian dijalankan untuk mempelajari kesan-kesan parameter rekabentuk seperti kuasa mengepam, panjang gentian terdop Erbium, panjang gelombang isyarat dan kuasa masukan. Analisa ke atas penguat gentian terdop Erbium peringkat berganda dijalankan bagi pengujian tahap peranti berpandukan kepada kesan parameter prestasi seperti gandaan kuasa keluaran, angka hingar, tahap pemancaran penguatan spontan dengan penambahan penapis lulus jalur bolehlaras.

Keputusan menunjukkan penguat peringkat berganda mempunyai kelebihan berbanding dengan penguat peringkat tunggal. Penguat peringkat berganda gentian terdop Erbium dengan penapis lulus jalur bolehlaras dan penggunaan pengepaman arah belakang dapat meningkatkan gandaan berbanding pengepaman arah hadapan. Masalah hingar yang

terjadi pada penguat gentian terdop Erbium merupakan sumber utama yang menyumbang kepada pemancaran penguatan spontan. Rantaian berkaskad menyebabkan pemancaran penguatan spontan semakin betambah. Angka hingar dapat dikurangkan dengan menambah penapis lulus jalur bolehlaras ke dalam rekabentuk.

Prestasi sistem penguat dalam talian akan dapat ditingkatkan dengan mengubah parameter dan memilih model yang sesuai. Keputusan menunjukkan rekabentuk yang paling sesuai adalah penguat peringkat berganda penguat gentian terdop Erbium yang akan meningkatkan gandaan dan mengurangkan tahap hingar.

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I certify that an Examination Committee met on 5th May 2004 to conduct the final examination of Sharifah Noriza binti Syed Ibrahim on her Master of Science thesis entitled " Design and Development of In-line Optical Amplifiers" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and University Pertanian Malaysia (Higher Degree) Regulation 1981. The Committee recommends that the candidate be awarded the revelant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

SHARIFAH NORIZA BT SYED IBRAHIM

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