

**DEVELOPMENT AND CHARACTERIZATION OF
MULTI-WAVELENGTH FIBER LASER LIGHT SOURCES BASED
ON ERBIUM AND BRILLOUIN GAIN**

**By
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**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in
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This thesis presents the research works that has been carried out in the development and characterizations of light sources based on two gain medium, namely Erbium and Brillouin. The laser gain medium used in the research work is in the form of optical fiber rather than bulk piece of doped crystal or glass. The physical structure of the gain medium makes it easy to be spliced with other optical components in the Fiber laser configurations. The Brillouin gain comes from a standard single mode fiber used in the optical fiber communication system. The aim of the research work is to investigate various techniques in Fiber laser that allow the generation of multiple laser output (or multi-wavelength) from a single light source unit. The techniques differ from each other in the wavelength selection mechanism and the gain medium used in the configurations.

In the first experiment, optical fiber Bragg grating has been chosen as the wavelength selective technique. Through this configuration, a dual and switchable laser output can be constructed. The output of the laser can be made to switch between single wavelength or with both wavelengths lases simultaneously. A moderate laser output power (about 10 mW at 60 mW EDF pump power) has also been achieved with both output power has a uniform power level. The multi-wavelength output can be easily increased through the addition of more optical fiber Bragg grating.

Through a linear fiber laser configuration which incorporates Fabry-Perot band-pass filter, a dual laser output system has been demonstrated. A novel technique has been suggested which allows for a uniform output power levels at any wavelengths within the EDF allowable gain profile. This was achieved by varying the optical attenuator values placed at one of the laser cavity loops such that it changes the cavity loss at that particular wavelength of interest.

Finally, by combining two gain medium within a laser cavity, a fiber laser system that is capable of achieving high number of laser outputs is being constructed. The mechanism that is responsible for the generation of the multiple laser output is the Stimulated Brillouin scattering phenomena and the feedback loop that is incorporated within the laser cavity. Output of more than 20 laser lines could be achieved with such configuration. Besides producing a high number of laser lines, the output can also be made tuneable within a wide range. A tuning range of up to 34 nm has been demonstrated for a ring laser configuration and 17 nm for linear laser configuration. The work presented in this thesis also reported for the first time a tuneable L-band Brillouin/Erbium fiber laser system adopting a linear laser cavity. A tuning range of up to 11 nm can be achieved with average laser output of 10 signals.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**PEMBANGUNAN DAN PENCIRIAN
PUNCA CAHAYA LASER GENTIAN OPTIK PELBAGAI KELUARAN
BERDASARKAN PENGGANDA ERBIUM DAN BRILLOUIN**

Oleh

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Tesis ini membentangkan aktiviti penyelidikan dan pencirian yang telah dilaksanakan terhadap punca cahaya berdasarkan dua jenis perantara pengganda iaitu Erbium dan Brillouin. Perantara pengganda laser yang digunakan didalam ujikaji ini adalah di dalam bentuk gentian optik sebagai ganti kepada bongkah optik terdopan jenis kristal atau kaca. Pengganda Erbium yang digunakan adalah di dalam bentuk gentian optik yang memudahkan ia disambung kepada komponen optik yang lain. Pengganda Brillouin pula diperolehi dalam bentuk gentian optik yang biasa digunakan di dalam sistem komunikasi gentian optik. Matlamat penyelidikan ini adalah untuk menyelidiki pelbagai teknik di dalam laser gentian yang boleh menghasilkan keluaran pelbagai laser dari satu punca cahaya. Teknik yang digunakan berbeza di antara satu sama lain dari segi cara pemilihan jarak gelombang dan jenis pengganda laser yang digunakan di dalam konfigurasi laser gentian yang diselidiki.

Ujikaji pertama menggunakan gentian optik parutan Bragg sebagai teknik untuk pemilihan jarak gelombang operasi laser. Melalui konfigurasi ini, dua keluaran laser yang boleh disuis telah diperolehi. Laser jenis ini boleh disuis untuk menghasilkan isyarat laser tunggal atau sekaligus kedua isyarat keluaran. Kuasa keluaran laser yang sederhana (sekitar 10 mW pada kuasa mengepam EDF 60 mW) telah dicapai dengan kedua-dua isyarat laser mempunyai tahap keluaran kuasa yang hampir sama. Keluaran laser boleh ditingkatkan dengan cara menambah bilangan dan menyambung gentian optik parutan Bragg ke sistem laser yang sedang di kaji.

Tiga kaedah pemilihan jarak gelombang telah digunakan di dalam ujikaji iaitu gentian optik parutan Bragg, penapis lulus jalur dan jarak gelombang yang diperolehi dari anjakan frekuensi isyarat Stoke yang dipam oleh punca laser yang lain. Oleh itu, tesis ini mengandungi beberapa ujikaji yang menunjukkan keupayaan setiap teknik di dalam penghasilan punca cahaya laser pelbagai keluaran. Selain daripada

keupayaan keluaran pelbagai, penyelidikan terhadap keupayaan talaan setiap teknik turut dilaksanakan.

Turut diketengahkan di dalam tesis ini ialah satu teknik yang mampu menghasilkan laser pelbagai keluaran yang boleh ditala ialah melalui teknik gentian laser linear yang mengandungi penapis lulus jalur jenis Fabry-Perot. Satu teknik untuk menghasilkan keluaran kuasa laser yang setara untuk kedua isyarat laser pada sebarang jarak gelombang di dalam profil gandaan EDF yang dibenarkan telah berjaya dikemukakan. Ia dihasilkan dengan cara mengubah nilai alat perosot yang diletakkan di dalam salah satu rongga gelung laser supaya kehilangan di dalam rongga laser dapat diubah untuk jarak gelombang yang diinginkan.

Dengan menggandingkan dua pengganda laser di dalam satu rongga laser, satu sistem yang mampu mencapai keluaran laser pelbagai yang tinggi dapat dihasilkan. Mekanisma yang bertanggungjawab ke atas penjanaan bilangan keluaran laser yang tinggi ini adalah fenomena yang dikenali sebagai penyerakan Brillouin terangsang dan gelung suap balik di dalam sistem rongga laser. Keupayaan sistem ini boleh mencapai sehingga 20 keluaran laser pelbagai. Selain dari keluaran laser pelbagai yang tinggi, keluaran sistem ini mampu ditala untuk julat yang lebar. Jarak talaan sehingga 34 nm telah diperolehi untuk konfigurasi gegelang dan 17 nm untuk konfigurasi linear.

Penyelidikan terhadap sistem laser pelbagai keluaran pada jalur L turut dikaji melalui laser gentian linear yang menggandingkan pengganda Erbium dan Brillouin. Jarak talaan sehingga 11 nm telah dicapai dengan keluaran laser sebanyak 10 isyarat.

This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirements for the degree of Doctor of Philosophy. 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.

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Date: 13 June 2006

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