ABSTRACT

A thorough study on Bismuth-based Erbium-doped fiber (Bi-EDF) is presented for wide-band amplifiers and multi-wavelength fiber laser applications. This fiber allows high Erbium ions concentration to be doped without a significant concentration quenching effect. The high refractive index characteristic in the Bi-EDF has broadened the emission spectrum of Erbium ions to achieve a broader gain spectrum up to extended L-band region compared to normal silica-based Erbium-doped fiber (EDF). The Bi-EDFA performances have been investigated in terms of power conversion efficiency (PCE), quantum conversion efficiency (QCE), gain and noise figure. The highest QCE and PCE for a 215 cm long of Bi-EDF are estimated to be approximately 23.7% and 25.7%, which is obtained at 1605 nm. With bi-directional pumping, the maximum gain of 34 dB is obtained at approximately 1570 nm. The operation of the bi-directional Bi-EDFA covers from C-band to the extended L-band regions. Furthermore, various configurations on the multi-wavelength fiber lasers have been proposed and demonstrated using the Bi-EDF as both the linear and nonlinear effects. Nonlinear effects such as the stimulated Brillouin scattering (SBS) and four-wave mixing (FWM) are used in the fiber lasers to generate multi-wavelength comb lines. The Brillouin Erbium fiber laser (BEFL) is able to produce a stable comb with 50 lines at extended L-band region using only a Bi-EDF as the gain medium. The multi-wavelength fiber laser has also been demonstrated for the first time based on a Bi-EDF assisted by a FWM process. The estimation of the nonlinear parameters of Bi-EDF was also proposed based on the FWM effect. With a simple ring cavity, the laser generates more than 10 lines of optical comb with a line spacing of approximately 0.41nm at 1615.5 nm region using 146 mW of 1480 nm pump power.

ABSTRAK

Tesis ini melibatkan satu pengajian terperinci tentang gentian terdop-Erbium asas-Bismuth (Bi-EDF) untuk kegunaan laser gentian penguat jalur-lebar dan jarakgelombang pelbagai. Gentian ini membenarkan kepekatan ion yang tinggi untuk didopkan tanpa kesan pelindapkejutan kepekatan signifikan. Ciri indek biasan dalam Bi-EDF telah membesarkan spektrum pancaran ion erbium untuk mencapai gandaan lebih luas sehingga ke kawasan jalur-L tambahan jika dibandingkan dengan gentian terdop-Erbium (EDF) asas-silika. Perlakuan Bi-EDFA telah diselidiki dalam sebutan efisiensi pertukaran kuasa (PCE), efisiensi pertukaran kuantum (QCE), gandaan dan angka hingar. Nilai QCE dan PCE tertinggi untuk Bi-EDF 215 cm panjang adalah masing-masing 23.7% dan 25.7% pada 1605 nm. Dengan menggunakan pam dwi-arah, gandaan maksimum sebanyak 34dB terdapat disekitaran 1570 nm. Operasi Bi-EDFA dwi-arah meliputi jalur-C sehingga kawasan jalur-L tambahan. Beberapa konfigurasi laser gentian jarakgelombang pelbagai telah dianjurkan dan dipersembahkan dengan menggunakan Bi-EDF sebagai kesan lelurus dan tak-lelurus. Kesan tak-lelurus seperti penyerakan rangsangan Brillouin (SBS) dan campuran empat-gelombang (FWM) telah digunakan didalam gentian laser untuk menghasilkan garis sisir jarakgelombang-pelbagai. Laser gentian Brillouin Erbium (BEFL) dapat menjanakan sisir yang stabil dengan 50 garis pada kawasan jalur-L tambahan dengan hanya menggunakan Bi-EDF sebagai bahantara gandaan. Laser gentian jarakgelombang-pelbagai telah ditunjukkan bagi kali pertama keatas Bi-EDF dibantu oleh proses FWM. Anggaran bagi parameter-parameter tak-lelurus Bi-EDF adalah berasaskan pada kesan empat-gelombang campuran (FWM). Dengan menggunakan satu rongga gelang mudah, laser tersebut dapat menjanakan lebih dari 10 garis sisir optik dengan jarak garisan beranggaran 0.41 nm pada kawasan 1615.5 nm dengan menggunakan kuasa pam 146 mW pada 1480 nm.

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LIST OF ABBREVIATIONS

A_{eff}	Effective Area
ASE	Amplified Spontaneous Emission
BEFL	Brillouin Erbium Fiber Laser
BFL	Brillouin Fiber Laser
Bi-EDF	Bismuth-Based Erbium Doped Fiber
Bi-EDFA	Bismuth-Based Erbium Doped Fiber Amplifier
BP	Brillouin Pump
BRFL	Brillouin Raman Fiber Laser(s)
BS	Brillouin Stokes
XPM	Cross-Phase Modulation
CW	Continuous Wave
dB	Decibel
dBm	Decibels above/below one milliwatt
DCF	Dispersion Compensating Fiber
DSF	Dispersion Shifted Fiber
DWDM	Dense Wavelength Division Multiplexing
EDF	Erbium Doped Fiber
EDFA	Erbium Doped Fiber Amplifier
ESA	Excited State Absorption
FP	Fabry-Perot

FBG	Fiber Bragg Grating
FWHM	Full Width at Half Maximum
FWM	Four-Wave Mixing
GVD	Group Velocity Dispersion
HNLF	Highly Nonlinear Fiber
IR	Infra-Red
ITU	International Telecommunications Union
IWDM	Isolator Wavelength Division Multiplexing
LD	Laser Diode
LASER	Light Amplification by the Stimulated Emission of Radiation
LED	Light Emitting diode
L_{eff}	Effective Length
LS	Laser Source
MFD	Mode Field Diameter
MBEFL	Multi-wavelength BEFL
MBFL	Multi-wavelength BFL
MBRFL	Multi-wavelength BRFL
NA	Numerical Aperture
NOA	Nonlinear Optical Amplifier
NOLM	Non-Linear Optical Loop Mirror
OC	Optical Circulator
OPO	Optical Parametric Oscillation
OSA	Optical Spectrum Analyzer
PC	Polarization Controller
PCE	Power Conversion Efficiency
PCF	Photonic Crystal Fiber
PMD	Polarisation Mode Dispersion
PMF	Polarization Maintaining Fiber
P_{th}	Threshold Power
QCE	Quantum Conversion Efficiency
REDFA	Rare-Earth Doped Fibre Amplifier

RF	Radio Frequency
RS	Raman Stokes
RP	Raman Pump
RI	Refractive Index
SBS	Stimulated Brillouin Scattering
SRS	Stimulated Raman Scattering
SMF	Single-Mode Fiber
SMSR	Side-Mode Suppression Ratio
SNR	Signal to Noise Ratio
SOA	Semiconductor Optical Amplifier
SPM	Self-Phase Modulation
TLS	Tunable Laser Source
UV	Ultra-Violet
VOA	Variable optical attenuator
WDM	Wavelength Division Multiplexing
WSC	Wave Selective Coupler
XPM	Cross Phase Modulation
ZDW	Zero-dispersion wavelength