INVESTIGATION OF FABRICATION TECHNIQUES, CHARACTERISTICS AND APPLICATIONS OF MICROFIBER DEVICES

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ABSTRACT

Microfiber devices have great potential in numerous applications as they offer a number of unique characteristics and optical properties. In this thesis, the background theory and fabrication techniques of microfiber devices are introduced. A high precision computer-controlled rig based on flame brushing technique was assembled in the laboratory. It is capable of producing tapered fibers with a maximum length of ~230 mm and a minimum waist diameter of ~ 400 nm. Two methods to provide long term protection to the tapered fibers and microfiber devices are demonstrated. The first method is to embed the microfiber device in a low-index resin while the second method involves encasing the long tapered fiber in an acrylic casing to provide the tapered fiber a clean and dry ambient.

Microfiber devices such as Microfiber Loop Resonators, Microfiber Knot Resonators and Microfiber Mach-Zehnder Interferometer were produced. Application of Microfiber Loop Resonator as optical filter in multiwavelength laser was investigated. The lasing quality can be enhanced by manipulating the state of polarization to improve the resonance extinction ratio of the Microfiber Loop Resonator. Microfiber resonators also exhibit unique thermal characteristics. As a temperature sensor, investigation indicates that the extinction ratio and resonance wavelength varies by 0.043 dB/^{o}C and 50.6 pm/°C respectively with the temperature change. In addition, a compact current sensor based on a copper wire wrapped around a Microfiber Knot Resonator has been devised. The resonance wavelength varies when electric current flows through the copper wire. The wavelength shift is due to thermally induced optical phase shifts, a result of heat produced by the flow of current. A tuning slope of 51.3 pm/A^2 has been achieved with the single-wire configuration.

ABSTRAK

Peranti microfiber mempunyai potensi besar dalam pelbagai aplikasi kerana ia mempunyai beberapa ciri-ciri unik dan sifat optik. Dalam tesis ini, latar belakang teori dan teknik fabrikasi peranti microfiber diperkenalkan. Kemudian ciri-ciri dan aplikasi yang disiasat secara terperinci. Mesin pembuatan gentian optik tirus kawalan komputer berdasarkan teknik berusan api telah dibinakan di dalam makmal. Ia mampu menghasilkan gentian tirus dengan panjang maksimum sebanyak ~230 mm dan gentian tirus paling halus yang pernah dihasilkan mempunyai diameter sehalus ~400 nm. Dua kaedah perlindungan jangka panjang untuk gentian optik tirus dan peranti microfiber akan ditunjukkan. Kaedah pertama adalah untuk menanamkan peranti microfiber dalam damar UV yang mempunyai indeks biasan rendah manakala kaedah kedua menyimpankan gentian optik tirus dalam kotak acrylic yang panjang dan dibalutkan dengan pembalut plastik supaya gentian optik tirus dilindungi dalam persekitaran yang bersih dan kering.

Pembuatan tiga jenis microfiber peranti iaitu resonator gelung microfiber, resonator simpulan microfiber dan interferometer Mach-Zehnder microfiber akan ditunjukkan. Dalam aplikasi resonator gelung microfiber digunakan sebagai penapis optik dalam laser multiwavelength, akan ditunjukkan. Kualiti laser boleh dipertingkatkan dengan memanipulasi polarisasi dan meningkatkan nisbah resonans kepupusan resonator gelung microfiber. Resonator microfiber mempunyai ciri-ciri suhu yang unik. Sebagai sensor suhu, penyelidikan menunjukkan bahawa nisbah resonans pupus dan panjang gelombang resonans berubah dengan suhu dengan sensitiviti sebanyak 0.043 dB/°C dan 50.6 pm/°C masing-masing. Di samping itu, sensor padat arus elektrik berdasarkan dawai tembaga yang dililit dalam resonator simpul microfiber telah direkakan. Panjang gelombang resonans

berubah apabila aliran arus elektrik melalui dawai tembaga. Perubahan panjang gelombang adalah disebabkan oleh perubahan fasa optik kerana penambahan haba yang dihasilkan oleh aliran arus elektrik. Kecerunan penalaan sebanyak 51.3 pm/A^2 telah dicapai dengan konfigurasi dawai-tunggal.

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ACRONYMS

Some jargons used in this thesis are listed as follow:

MLR	Microfiber Loop Resonator
MKR	Microfiber Knot Resonator
MCR	Microfiber Coil Resonator
MMZI	Microfiber Mach-Zehnder Interferometer
SMF	Single Mode Fiber
EDF	Erbium-doped Fiber
EDFA	Erbium-doped Fiber Amplifier
HOM	Higher Order Mode
LP	Linearly Polarized
SOA	Semiconductor Optical Amplifier
WDM	Wavelength Division Multiplexing
ASE	Amplified Spontaneous Emission
OSA	Optical Spectrum Analyzer
PC	Polarization Controller
RI	Refractive Index
RIU	Refractive Index Unit
FSR	Free Spectral Range
RER	Resonance Extinction Ratio
HF	Hydrofluoride Acid
GVD	Group Velocity Dispersion
FUT	Fiber under Test

FWHM	Full Wave At Half Maximum
PBS	Polarizing Beam-Splitter
FWM	Four-wave Mixing
TOC	Thermal-Optic Coefficient
TEC	Thermal Expansion Coefficient
SOP	State Of Polarization
NPR	Nonlinear Polarization Rotation
HNLF	Highly Nonlinear Fiber

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