INVESTIGATION OF FABRICATION TECHNIQUES, CHARACTERISTICS AND APPLICATIONS OF MICROFIBER DEVICES

LIM KOK SING

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Name of Candidate: LIM KOK SING (I.C/Passport No: 840618-14-6215)
Registration/Matric No: SHC090004
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Field of Study: PHOTONICS

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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/°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/A² 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.

berubah apabila aliran arus elektrik melalui dawai tembag. Perubahan panjang gelombang adalah disebabkan oleh perubahan fasa optik kerana penambahan haba yang dihasilkan oleh aliran arus elektrik. Kecerunan penalaan sebanyak 51.3 pm/A² telah dicapai dengan konfigurasi dawai-tunggal.
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LIM KOK SING
Department of Physics, Faculty of Science,
University of Malaya.

June, 2011
ACRONYMS

Some jargons used in this thesis are listed as follow:

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>MLR</td>
<td>Microfiber Loop Resonator</td>
</tr>
<tr>
<td>MKR</td>
<td>Microfiber Knot Resonator</td>
</tr>
<tr>
<td>MCR</td>
<td>Microfiber Coil Resonator</td>
</tr>
<tr>
<td>MMZI</td>
<td>Microfiber Mach-Zehnder Interferometer</td>
</tr>
<tr>
<td>SMF</td>
<td>Single Mode Fiber</td>
</tr>
<tr>
<td>EDF</td>
<td>Erbium-doped Fiber</td>
</tr>
<tr>
<td>EDFA</td>
<td>Erbium-doped Fiber Amplifier</td>
</tr>
<tr>
<td>HOM</td>
<td>Higher Order Mode</td>
</tr>
<tr>
<td>LP</td>
<td>Linearly Polarized</td>
</tr>
<tr>
<td>SOA</td>
<td>Semiconductor Optical Amplifier</td>
</tr>
<tr>
<td>WDM</td>
<td>Wavelength Division Multiplexing</td>
</tr>
<tr>
<td>ASE</td>
<td>Amplified Spontaneous Emission</td>
</tr>
<tr>
<td>OSA</td>
<td>Optical Spectrum Analyzer</td>
</tr>
<tr>
<td>PC</td>
<td>Polarization Controller</td>
</tr>
<tr>
<td>RI</td>
<td>Refractive Index</td>
</tr>
<tr>
<td>RIU</td>
<td>Refractive Index Unit</td>
</tr>
<tr>
<td>FSR</td>
<td>Free Spectral Range</td>
</tr>
<tr>
<td>RER</td>
<td>Resonance Extinction Ratio</td>
</tr>
<tr>
<td>HF</td>
<td>Hydrofluoride Acid</td>
</tr>
<tr>
<td>GVD</td>
<td>Group Velocity Dispersion</td>
</tr>
<tr>
<td>FUT</td>
<td>Fiber under Test</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<td>--------------</td>
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<tr>
<td>FWHM</td>
<td>Full Wave At Half Maximum</td>
</tr>
<tr>
<td>PBS</td>
<td>Polarizing Beam-Splitter</td>
</tr>
<tr>
<td>FWM</td>
<td>Four-wave Mixing</td>
</tr>
<tr>
<td>TOC</td>
<td>Thermal-Optic Coefficient</td>
</tr>
<tr>
<td>TEC</td>
<td>Thermal Expansion Coefficient</td>
</tr>
<tr>
<td>SOP</td>
<td>State Of Polarization</td>
</tr>
<tr>
<td>NPR</td>
<td>Nonlinear Polarization Rotation</td>
</tr>
<tr>
<td>HNLF</td>
<td>Highly Nonlinear Fiber</td>
</tr>
</tbody>
</table>
# CONTENTS

ORIGINAL LITERARY WORK DECLARATION ii
ABSTRACT iii
ABSTRAK iv
ACKNOWLEDGEMENTS vi
ACRONYMS vii
CONTENTS ix
LIST OF FIGURES xi
LIST OF TABLES xv

**Chapter 1: INTRODUCTION**
1.1 Introduction 1
1.2 Recent Development of Microfiber Devices 2
1.3 Scope and Objective 3
1.4 Thesis Outline 4
References 6

**Chapter 2: LITERATURE REVIEW**
2.1 Introduction 10
2.2 Fabrication techniques 10
2.2 Optical Properties of Tapered Fibers 13
2.3 Applications and Functionalites 18
References 20

**Chapter 3: FABRICATION OF TAPERED FIBERS / MICROFIBERS** 27
3.1 Introduction 27
3.2 Fabrication of Fiber Taper by Using Chemical Etching Technique 28
3.3 Fabrication of Microfiber by Using Flame Brushing Technique 31
3.3.1 Fiber Tapering Rig 32
3.3.2 Motor Control 35
3.3.3 Fabrication of Tapered Fiber 36
3.4 Adiabaticity Criteria 39
3.4.1 Theoretical Analysis on Shape of Tapered Fiber 42
3.5 Throughput power of a degrading tapered fiber 47
3.6 Embedding Microfiber Photonic Devices in Low-index material 49
3.7 Transmission Spectrum Variation During Embedding Process 51
3.8 Packaging tapered fiber in a Acrylic Case 53
3.9 Dispersion Analysis and Measurement 58
3.10 Summary 63
References 65

**Chapter 4: OPTICAL MICROFIBER DEVICES** 70
4.1 Introduction 70
4.2 Microfiber Loop Resonator (MLR) 71
4.2.1 Fabrication of MLR 72
4.2.2 Theoretical Analysis 73
4.2.3 Transmission Spectra of MLRs 79
4.2.4 Polarization Dependent Characteristic 81
# LIST OF FIGURES

**Chapter 2:** LITERATURE REVIEW  
Figure 2.1: Graph of absolute spot size $\omega/\rho$ versus $V$-numbers of core and cladding.  
Figure 2.2: (a) Relationship between the fractional power inside an air-clad silica micro- / nanofiber and its diameter with wavelengths of 633 nm and 1550 nm. (b) Schematic illustration of evanescent field.  
Figure 2.3: A 360 nm diameter silica nanofiber with a minimum bending radius of about 3 µm  
Figure 2.4: Optical microscope image of a ~300 µm-diameter silica microsphere.

**Chapter 3:** FABRICATION OF TAPERED FIBERS / MICROFIBERS  
Figure 3.1: Schematic illustration of the fiber tip formation from a flat end (left) to sharp tip (right).  
Figure 3.2: Fiber taper formation at (a) 15 minutes (b) 30 minutes and (c) 40 minutes  
Figure 3.3: Conical tapered fiber fabricated by Tube Etching technique.  
Figure 3.4: Picture of the fiber tapering rig assembled in the laboratory. $M_1$ and $M_2$ are the stepper motors of the linear stage and sliding stage respectively.  
Figure 3.5: Torch flames at different oxygen supply pressure (a) none (b) equivalent pressure with fuel gas pressure (c) high oxygen pressure  
Figure 3.6: The movement of sliding stage is guided by (a) the linear bearings and (b) steel shafts while linear stage is guided by (c) leadscrew and (d) the gear shaft.  
Figure 3.7: System Diagram of the Motor Control in the fiber tapering rig  
Figure 3.8: Motor Driver and Unipolar Stepper Motor  
Figure 3.9: Schematic illustration of flame brushing technique  
Figure 3.10: (a) The diameter variation of a biconical tapered fiber fabricated in the laboratory (b) Optical microscope image of taper waist, 1.7 µm in diameter (c) SEM image of a 400nm waist diameter tapered fiber  
Figure 3.11: Output spectra from a microfiber with 10 cm long and ~3 µm waist diameter. Input spectrum from EDFA (dashed), adiabatic taper (solid) and non-adiabatic taper (dotted)  
Figure 3.12: Typical diameter profile of a tapered fiber  
Figure 3.13: Illustration of the taper transition  
Figure 3.14: (a) The cylinder illustrates a heated SMF (b) A short while later, the diameter of the heated SMF has been reduced when it is stretched  
Figure 3.15: (a) Shape of a fiber at the beginning ($t = 0$) (b) shape of a tapered fiber after tapering ($t = t$)
Figure 3.16: A tapered fiber with decaying-exponential profile fabricated using a constant hot-zone \( L_0 = 10 \text{ mm} \).

Figure 3.17: Three linear taper profiles (a-c) with its smallest waist point at different positions on the tapered fibers. Profile (a) has its smallest waist point at the center of the tapered fiber.

Figure 3.18: The diameter of tapered fiber is linearly decreasing from \( \sim 128 \mu \text{m} \) to \( \sim 10 \mu \text{m} \) along the 15 cm transition.

Figure 3.19: The throughput power of the 10 cm long and \( \sim 3 \mu \text{m} \) diameter tapered fiber degrades over time.

Figure 3.20: Illustration of microfiber device embedded in a low refractive index material and sandwiched between two glass plates.

Figure 3.21: The image of the end product of an embedded MLR in the low-index resin.

Figure 3.22: Embedding an MKR in a low-index material. The time in each graph indicates when the output spectrum of the MKR is recorded. a) MKR is freestanding in the air b) some low-index resin applied on the MKR c) UV curing is initiated and d) resin is solidified.

Figure 3.23: Optical microscope image of an MKR embedded in UV-curable resin.

Figure 3.24: Schematic illustration for tapered fiber packaging process

Figure 3.25: A reinforced 20 cm long fiber taper case by additional acrylic pieces (in dashed circles).

Figure 3.26: The 6 days comparison of (a) output spectrum and (b) total output power of the 10 cm long and \( \sim 3 \mu \text{m} \) diameter tapered fiber packaged in acrylic case.

Figure 3.27: Schematic diagram of the dispersion measurement setup based on Michelson interferometer.

Figure 3.28: The (a) phase function and the (b) output spectrum of the interferometer. The circles represent the experimental result and the fitting curve is the analytical result.

**Chapter 4:** OPTICAL MICROFIBER DEVICES

Figure 4.1: Optical microscope image of an MLR

Figure 4.2: Manufacture of MLR by using two three-dimensional stages.

Figure 4.3: Schematic illustration of a self-touching loop resonator. The dashed arrows indicate the direction of waves in the resonator.

Figure 4.4: Typical transmission spectrum of an MLR. The labels in the graph indicates the terminology used in the thesis.

Figure 4.5: Transmission Spectra of an MLR with increasing FSR (from top to bottom).

Figure 4.6: The fitting of experimental data (circles) with the characteristic equation (solid line). (a) Q-factor \( \sim 18,000 \) and finesse \( \sim 9.5 \) (b) Q-factor \( \sim 5700 \) and finesse \( \sim 3.8 \)

Figure 4.7: Experimental set-up to investigate the polarization dependent characteristic of the MLR. Polarized wideband source from EDFA is acquired with the aid of PBS (Dashed box). An unpolarized wideband source can be obtained by removing PBS from the setup.
Figure 4.8: The spectra of two MLRs for different input wave SOP. (a) FSR = 0.162 nm at 1530 nm (b) FSR = 0.71 nm at 1530 nm.

Figure 4.9: Optical microscope image of an MKR

Figure 4.10: Transmission Spectra of an MKR with increasing FSR (from top to bottom)

Figure 4.11: The transmission spectra of MKR in the air (solid) and propan-2-ol solution (dashed)

Figure 4.12: The offset experimental data (circles) with its best fit curve (solid line) (a) air, RI ~1.00 (b) propan-2-ol, RI ~1.37.

Figure 4.13: The experimental data (circles) with its best fit curves (solid lines) in different mediums (a) air, RI ~1.00 (b) low-index resin, RI ~1.36.

Figure 4.14: Example of an MKR with decreased RER after it is immersed in the water (RI ~1.33).

Figure 4.15: (a) The output spectra of an MKR at temperature of 30°C(solid), 35°C(dashed) and 40°C (dotted) (b) The temperature response of the MKR has spectral sensitivity of 50.6 pm/°C.

Figure 4.16: Schematics (a)-(c) provide an illustration of the fabrication procedure for an MMZI

Figure 4.17: Schematic illustration of an MMZI.

Figure 4.18: Image of an MMZI injected with visible red laser. The arrows indicate the propagation directions of the waves.

Figure 4.19: Transmission spectrum of an MMZI with RER 7 dB and 0.2 nm FSR

Figure 4.20: Transmission Spectra of an MMZI with increasing wavelength spacing

Figure 4.21: The experimental data and its best-fit curve based on the values of ΔL = 2.23 mm, a = 0.518 and b = 0.482.

Figure 4.22: Schematic illustration of an MMZI sways the air due to air-turbulence. (i) Bent arm stands vertically on top of the straight arm (ii) Bent arm lays in a horizontal plane with the straight arm.

Figure 4.23: Spectra (a)–(c) show three sets of transmission spectra based on three different MMZIs. Spectra (i) and (ii) from each set show the transmissions with the highest and the lowest recorded RERs respectively.

Chapter 5: APPLICATIONS OF MICROFIBER BASED RESONATORS

Figure 5.1: Schematic diagram of the experimental setup

Figure 5.2: The transmission spectra of the fabricated MLR for different input SOP (i) unpolarized input light (ii) polarized input light with smallest resonance (iii) polarized input light with the highest resonance.

Figure 5.3: Output spectrum of the multiwavelength laser (a) with PBS (b) without PBS

Figure 5.4: Output spectrum of the proposed laser against time. The output spectrum is scanned for every 5 minutes.

Figure 5.5: The output spectrum of the proposed MLR
Figure 5.6: Schematic illustrations of the experimental setups of different configurations (a) conventional single pass HNLF (b) double pass HNLF

Figure 5.7: Output spectra of the laser based on single pass configuration (a) without HNLF and (b) with HNLF

Figure 5.8: The output spectrum of the proposed configuration and the phase mismatch.

Figure 5.9: SUCCESSIVE spectra of the multiwavelength laser at interval time of 5 minutes.

Figure 5.10: Packaging of the MLR.

Figure 5.11: Transmission spectrum of the fabricated MLR.

Figure 5.12: Transmission spectra of the fabricated MLR obtained at temperatures (a) 27°C (b) 40°C (c) 60°C.

Figure 5.13: Variation of resonance extinction ratio with the increasing temperature.

Figure 5.14: Optical microscope image of MKR tied on a copper wire.

Figure 5.15: Resonance wavelength shift of the MKR tied on a copper wire loaded with different current. Inset shows unchanged FSR with the increasing current.

Figure 5.16: Schematic illustrations of microfiber knot tied on (a) single copper wire (b) two copper wires with identical wire diameter of ~200 μm.

Figure 5.17: Current response of MKRs based on single-wire and two-wire configurations. The calculated resistance of the single copper wire and two copper wire are 0.53 $\Omega \cdot m^{-1}$ and 0.26 $\Omega \cdot m^{-1}$ respectively.

Appendix A: MATLAB CODES

Figure A.1: The graph of absolute spot size against V-number

Figure A.2: A typical transmission spectrum of an MKR. The experimental data (circles) with its best-fit theoretical curve.

Figure A.3: A typical transmission spectrum of an MMZI. The experimental data (circles) with its best-fit theoretical curve.
LIST OF TABLE

Table 3.1: Fitting parameters and values