

Contents

Chinese Abstract	I
English Abstract	II
Acknowledgements	IV
Contents	VI
List of Figures	IV
List of Tables	XIII
List of Acronyms	XIV

Chapter 1

Introduction

1.1 Review of Evanescent Wave Fiber Components and Fabrication Methods..	1
1.2 Review of Dispersion of Evanescent Wave Fiber Components.....	2
1.2.1 Material Dispersion.....	3
1.2.2 Waveguide Dispersion.....	4
1.3 Organization of the Dissertation.....	5
References.....	7

Chapter 2

Fabrications of Side-Polished Fiber Components

2.1 Overview.....	12
2.2 Side-Polished Single-Mode Fiber with a Long-Interaction Length.....	12
2.2.1 Fabrication.....	13
2.2.2 Calibration and Measurement.....	15
2.3 Fused-Polished Fiber Coupler.....	15
2.3.1 Introduction.....	16

2.3.2 Experimental Results and Discussion.....	17
2.4 Narrowband Grating-Assisted Channel-Dropping Filter.....	19
2.4.1 Introduction.....	19
2.4.2 Experimental Results and Discussion.....	21
References.....	24

Chapter 3

Influence of Material Dispersion on Spectral Characteristics of Evanescent Wave Fiber Components

3.1 Overview.....	39
3.2 High-Cutoff-Efficiency Fundamental-Mode Cutoff.....	39
3.2.1 Side-Polished Wideband Tunable Short-Pass Filters.....	40
3.2.2 Fused-Tapered Wideband Tunable Short-Pass Filters.....	45
3.3 Local Fundamental-Mode Cutoff in Er ³⁺ -Doped Fiber.....	48
3.3.1 Thermo-Optic Tunable Fiber Ring Laser.....	48
3.3.2 Experimental Results and Discussion.....	51
3.4 Discrete Fundamental-Mode Cutoff in Er ³⁺ -Doped Fiber.....	54
3.4.1 S- and C+L-bands EDFA.....	54
3.4.2 Experimental Results and Discussion.....	56
3.5 Diffractive-Pumped Evanescent Amplification.....	59
3.5.1 Diffractive-Pumping Method.....	59
3.5.2 Experimental Results and Discussion.....	61
References.....	64

Chapter 4

Influence of Waveguide Structure on Spectral Characteristics of Evanescent Wave Fiber Components

4.1 Overview.....	81
4.2 Side-Polished Endlessly Single-Mode Photonic Crystal Fibers.....	81

4.2.1 Higher-Order Modes Excitation.....	82
4.2.2 Dispersion Slope.....	86
References.....	88

Chapter 5

Conclusions

5.1 Summary for the Dissertation.....	94
5.1.1 Evanescent Wave Fiber Components.....	95
5.1.2 Influence of Material Dispersion.....	95
5.1.3 Influence Waveguide structure.....	97
5.2 Suggestions for Future Work.....	97



List of Figures

Fig. 2.1 Schematics of the (a) side-view of the side-polished fiber and (b) cross sectional view of the side-polished fiber in the V-groove.

Fig. 2.2 (a) Silicon V-grooves. Central V-groove is for side-polished fiber while adjacent two V-grooves are for alignment fibers. (b) Cross sectional view of the side-polished single-mode fiber. A He-Ne laser light is launched into the core.

Fig. 2.3 Wavelength tunability of the short-pass filter using SP-SMF-28 with OCK-433 overlay through thermo-tuning. Resolution: 1 nm. R : 15 m.

Fig. 2.4 Cross sectional view of the fused-tapered fiber coupler. The guiding area is in a dumbbell shape to degrade the polarization isotropy.

Fig. 2.5 Surface roughness of the side-polished fiber measured by AFM. The major two peaks are due to dust.

Fig. 2.6 Schematic of the fabrication of a fused-polished fiber coupler using a moving arc. The sliding silicon V-grooves serve as alignment devices.

Fig. 2.7 (a) Side-view and (b) cross-sectional views of the fused-polished fiber coupler.

Fig. 2.8 Wavelength separation spectrum of the fused-polished coupler where the channel spacing is 44 nm (1521 ~ 1565 nm). The left part noise is due to the weak power level of the C+L band ASE light source below 1500 nm wavelength region.

Fig. 2.9 Schematic diagram of our narrowband channel-dropping filter.

Fig. 2.10 Transmission spectrum of a grating coupler-half in air. The resolution is 0.1 nm.

Fig. 2.11 Measured spectra from (a) drop port and (b) direct-through port of the

assembled channel-dropping filter. The resolution is 0.1 nm.

Fig. 3.1 (a) Schematic of the device. The index profile of the filter is shown at right-hand side. (b) Refractive index dispersion curves. OCK-433 is the dispersive polymer.

Fig. 3.2 Spectral responses of the (a) SP-GF4A (b) SP-SMF-28 with various Cargille index liquids overlay. Resolution: 1 nm. R : 15 m.

Fig. 3.3 Wavelength tunability of the short-pass filter using SP-SMF-28 with OCK-433 overlay through thermo-tuning. Resolution: 1 nm. R : 15 m.

Fig. 3.4 Fused-tapered fiber short-pass filter.

Fig. 3.5 Spectral responses of the tapered fiber short-pass filters using a Cargille liquid with $n_D = 1.456$ at different temperatures. (RES: 1 nm)

Fig. 3.6 Spectral responses of the tapered fiber in the straight and bending conditions.

Fig. 3.7 State (b) of the 1x2 switch can be modified to reconfigure the fiber link for FB(a) Experimental set up of the EDFRL and (b) Device structure of the side-polished fiber based tunable short-pass filter.

Fig. 3.8 Refractive index dispersions of the fiber, Cargille index liquids and thermo-optic polymer OCK-433.

Fig. 3.9 Spectral responses of the EDFRL in air and using two Cargille index liquids on SPF.

Fig. 3.10 Spectral responses of the wavelength tuning of the EDFRL when OCK-433 polymer was cooling down.

Fig. 3.11 (a) Integrated fused-tapered fiber short-pass filters with the whole tapered regions surrounded with a dispersive material. (b) Schematic of the

tunable EDFA covering *S*- and *C* + *L*-bands with 17.5-m-long EDF.

Fig. 3.12 Amplification spectra of the signals in (a) *S*-band at 28.6°C and (b) *C* + *L*-band at 40°C (RES: 0.1 nm). P_i and P_o are input and output signal spectra, respectively.

Fig. 3.13 Schematic of the proposed diffractive-pumping method. The inset shows the conventional evanescent-pumping method where the dispersive evanescent wave tunneling makes the excitation inefficient.

Fig. 3.14 Effective gain profile of Er^{3+} in fluorophosphate glass, β is the minimum population in the upper level. The gain coefficient change with wavelength at different pumping energies.

Fig. 3.15 (a) The measured transmission and reflection spectra of the blazed grating and (b) amplification characteristics of the wavelengths at 1530, 1550, and 1570 nm wavelengths.

Fig. 4.1 (a) SP-PCF can be represented virtually as an unpolished PCF with variable larger air holes (dashed circles) in (b). (c) Cross-sectional views of the polished ESM-12-01 fiber under 1000× CCD microscope from the polishing center (left) toward the polishing boundary (right).

Fig. 4.2 Loss spectra of the SP-PCF with $R = 800$ cm at different remained holey cladding depths. The inset picture shows the central cross-sectional view of the SP-PCF at $h = -8.2$ μm and where a substantial portion of the core was polished away.

Fig. 4.3 Far-field mode patterns from the output end of SP-PCFs ($R = 800$ cm) that are 10 cm away from the polishing center at the wavelength and with various h measurements: (a) 532 nm & 4 μm, (b) 532 nm & -4.6 μm, (c) 633 nm & -4.6 μm, and (d) 532 nm & -8.2 μm.

Fig. 4.4 Spectral responses of SP-PCFs with $h \sim 1.8 \mu\text{m}$ and R of (a) 1500 cm and (b) 800 cm using OCK-433 dispersive polymer overlay at a temperature of 60°C . The blue and red lines are transmission losses of SP-PCFs in air and with a polymer overlay, respectively.



List of Tables

Table 3.1 Fiber Parameters at 1550 nm wavelength.

Table 3.2 Laser linewidth of the EDFRL.

Table 3.3 Measured signal gains in *S*- and *C + L*-bands.

Table 3.4 Parameters of the EDFG.



List of Acronyms

ASE	Amplified Spontaneous Emission
DWDM	Dense Wavelength Division Multiplexing
EDF	Erbium Doped Fiber
EDFA	Erbium Doped Fiber Amplifier
EDFG	Erbium Doped Fluorophosphate Glass
EDFRL	Erbium Doped Fiber Ring Laser
FBG	Fiber Bragg Grating
FP-LD	Fabry-Perot Laser Diode
L-Z	Leminger-Zengerle
MFD	Mode field diameter
NA	Numerical Aperature
OSW	1x2 Optical Switch
OSA	Optical Spectrum Analyzer
PCF	Photonic Crystal Fiber
RID	Refractive Index Dispersion
RES	Resolution bandwidth
SAR	Signal-to-ASE Ratio
SLD	Super Luminescent Diode
SMF	Single Mode Fiber
SNR	Signal-to-Noise Ratio
SPF	Side-Polished Fiber
SP-PCF	Side-Polished Photonic Crystal Fiber
WDM	Wavelength Division Multiplexed