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# ***Subminiature Solution for 2003***

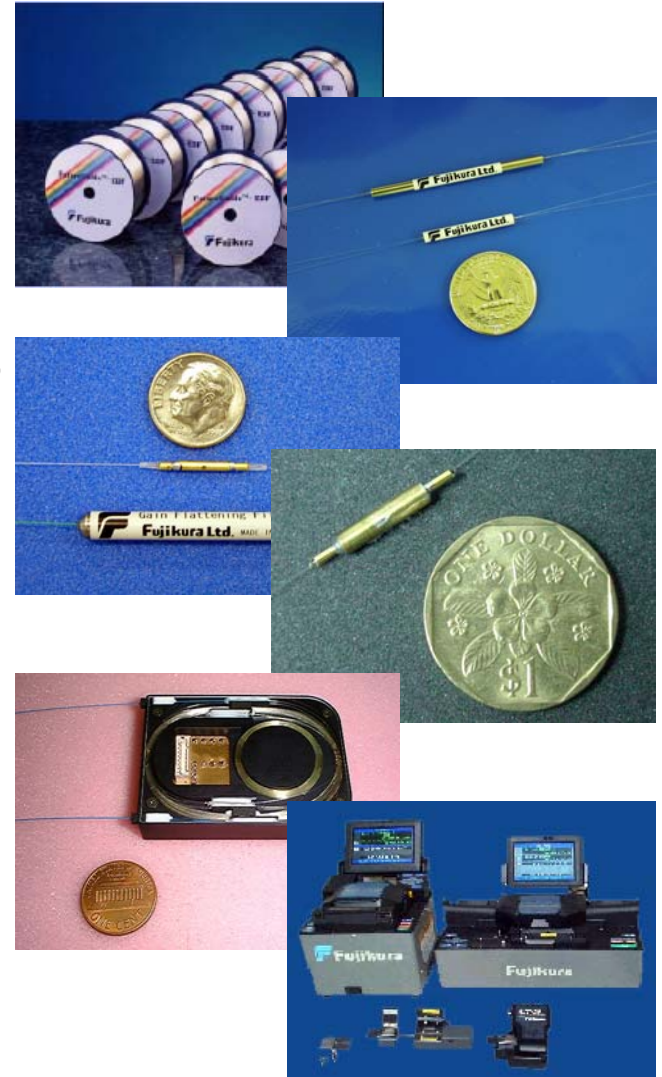
Fujikura's Subminiature Optical Components with 80  $\mu\text{m}$  Pigtail Fiber

**Fujikura Ltd.**

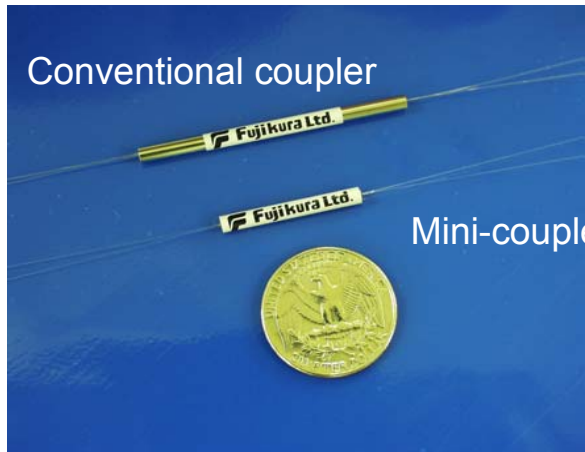
**November, 2002**

# Subminiature Solution

- **RC-fibers (80  $\mu\text{m}$  clad)**
  - SMF
  - EDF
  - PANDA
- **Subminiature Collimated Beam devices**
  - Gain Flattening Filter (GFF)
  - Optical Isolator
  - C-WDM module
- **Subminiature Fused Fiber Couplers**
  - Tap Coupler
  - 980/1550 WDM Coupler
- **Subminiature Optical Amplifier**
- **RC- fiber Fusion Splicer**



# Subminiature Fused Fiber Couplers



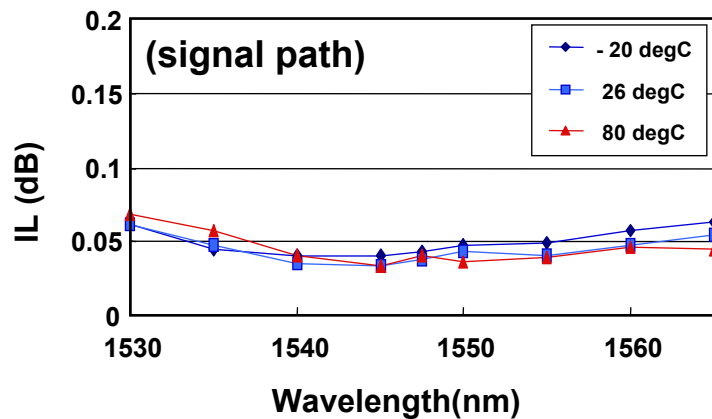
## Menu

- 980/1550nm WDM Coupler
- Tap Coupler

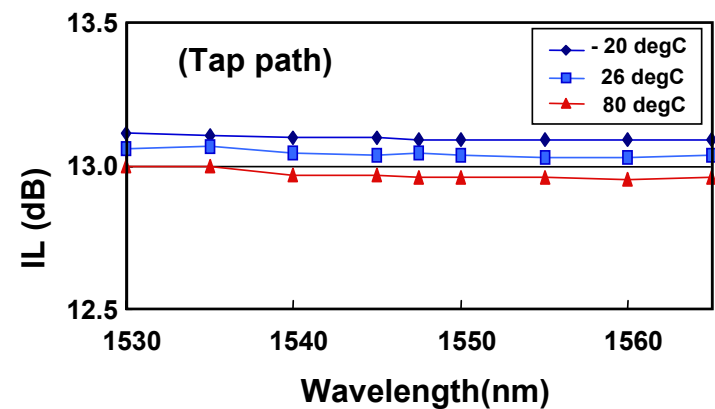
## Feature

- Ultra small package  
3.0 mm $\phi$  x 25.4 mmL (Tap),  
3.0 mm $\phi$  x 28 mmL (WDM)
- Low excess loss

### Insertion Loss of 980/1550nm WDM coupler

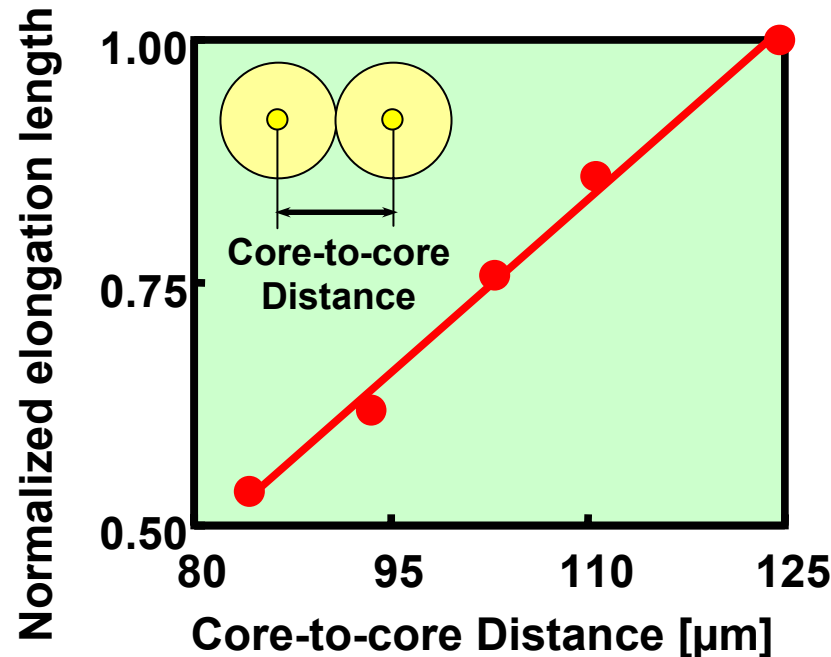


### Insertion Loss of 5% Tap coupler



# Size Reduction in Fused Elongation Portion

- Elongation length can be cut in half by reducing core/core distance from 125  $\mu\text{m}$  to 80  $\mu\text{m}$ .



*Required elongation length for fused taper coupler*

# Specifications of Subminiature Fused Couplers

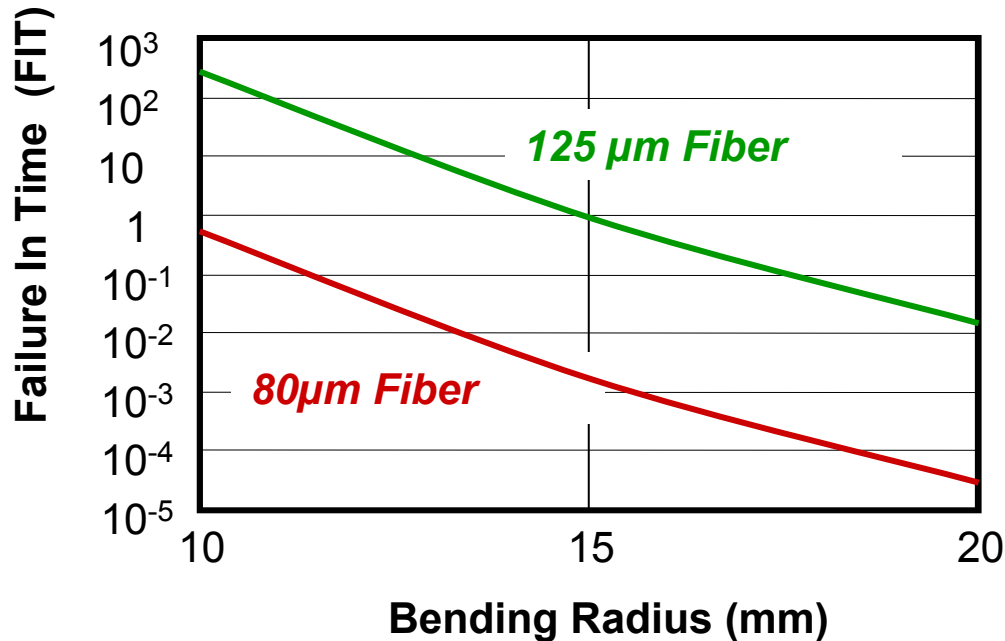
		<b>C-band 5% Tap Coupler</b>	<b>980/1550nm WDM Coupler</b>
Operation Wavelength	nm	1530 to 1565	1530 to 1565 (Signal port) 970 to 990 (Pump port)
Operation Temperature	deg C	0 to 80	
Maximum Insertion Loss	dB	0.35 (Signal path) 14.0 (Tap path)	0.08(Signal path) 0.08(Pump path)
Wavelength Dependent Loss	dB	$\leq 0.12$	-
Isolation	dB	-	$\geq 20$
Return Loss / Directivity	dB	$\geq 50$	
Polarization Dependent Loss	dB	$\leq 0.10$ (Tap path)	$\leq 0.04$
Fiber		Fujikura Specialty fiber	BF06681-02 (ofs) (*1)
Dimensions	mm	$\phi 3.0 \times 25.4$	$\phi 3.0 \times 28$

(\*1) The fiber will be soon replaced by Fujikura Original Specialty fiber for WDM coupler.

# 80 $\mu\text{m}$ SM Fiber for Subminiature Fiber Couplers

## ■ Mechanical Reliability

Fiber handling with a bending radius  $R=10\text{mm}$  is allowable level for 80  $\mu\text{m}$  clad fiber, but not for 125  $\mu\text{m}$ .



### Evaluation Condition:

Proof test level  $\sigma_p = 2\%$

Fatigue const.  $n = 14$

Weibull const.  $m = 10$

Number of failure

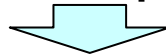
in proof test  $N_p = 1/\text{km}$

Fiber Length  $L = 1\text{m}$

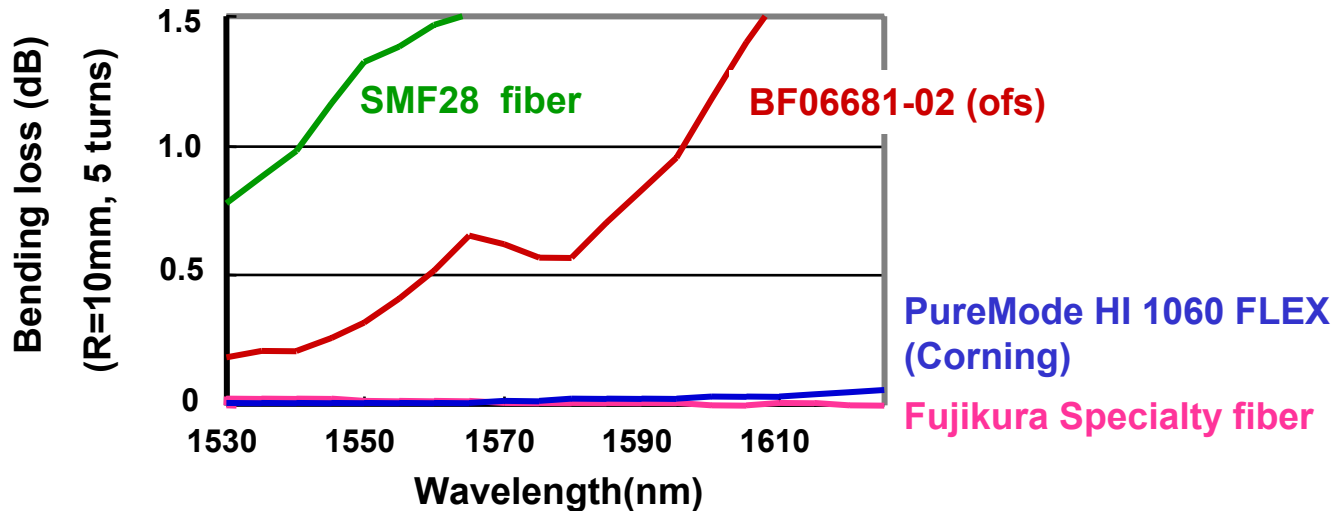
# 80 $\mu\text{m}$ SM Fiber for Subminiature Fiber Couplers

## ■ Bending Loss Characteristics

- 1) Tap coupler, Fujikura 80 $\mu\text{m}$  fiber shows excellent bending loss characteristics.
- 2) WDM coupler, ofs fiber (currently used in our WDM coupler) shows larger bending loss compared with Corning HI 1060 FLEX.

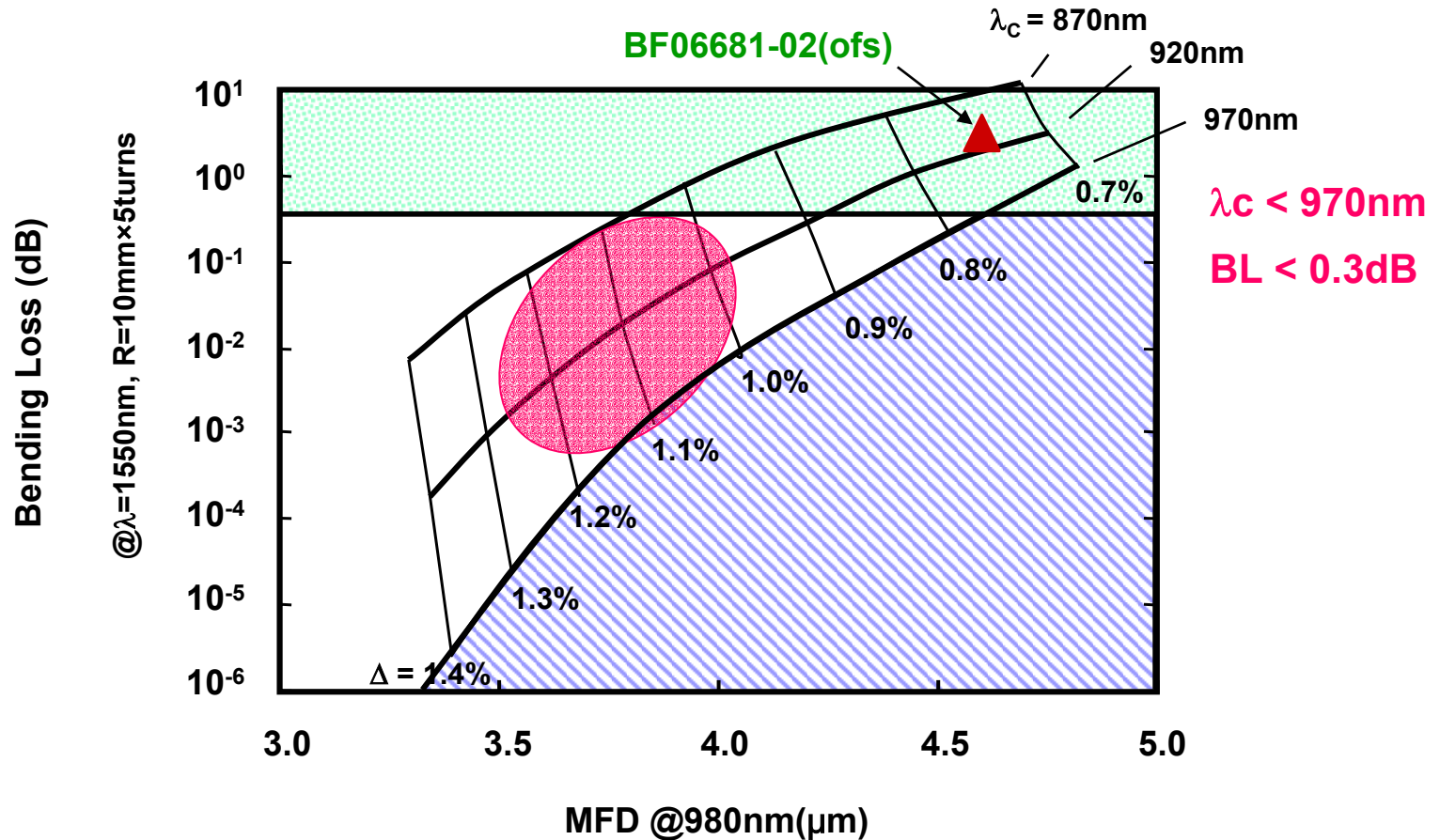


We are preparing a low bending loss fiber for WDM coupler, by optimizing refractive index profile.



# 80 $\mu\text{m}$ SM Fiber for Subminiature Fiber Couplers

## ■ Refractive Index Design



# 80 $\mu\text{m}$ SM Fiber for Subminiature Fiber Couplers

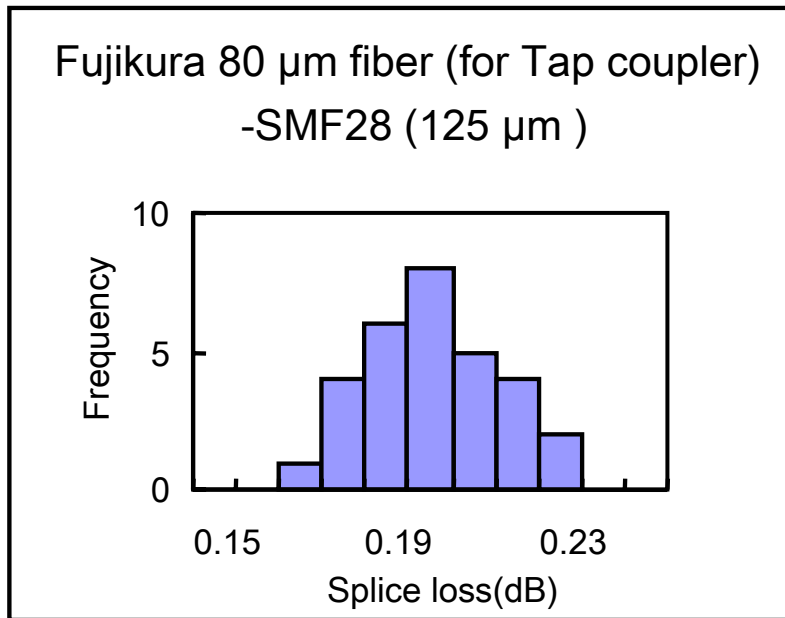
## ■ Typical Optical Performance (Not Specification)

	Unit	FJK Specialty Fiber for Tap Coupler	BF06681-02(ofs)	FJK Specialty Fiber for WDM Coupler
Cladding Diameter	$\mu\text{m}$	80	80	80
Coating Diameter	$\mu\text{m}$	165	165	165
Cutoff Wavelength (typ.)	nm	<1310	<960	<970
Mode-field Diameter (*1) (typ.)	$\mu\text{m}$	6.5 @1550 nm	4.6 @980 nm 7.3 @1550 nm	3.8 @980 nm 6.0 @1550 nm
Core eccentricity (*1)	$\mu\text{m}$	0.2	0.2	0.2
Bending Loss (*1) @1550nm, R=10mm x 5turns	dB	0.1	3.0	0.3
Proof Test	%	2	2	2

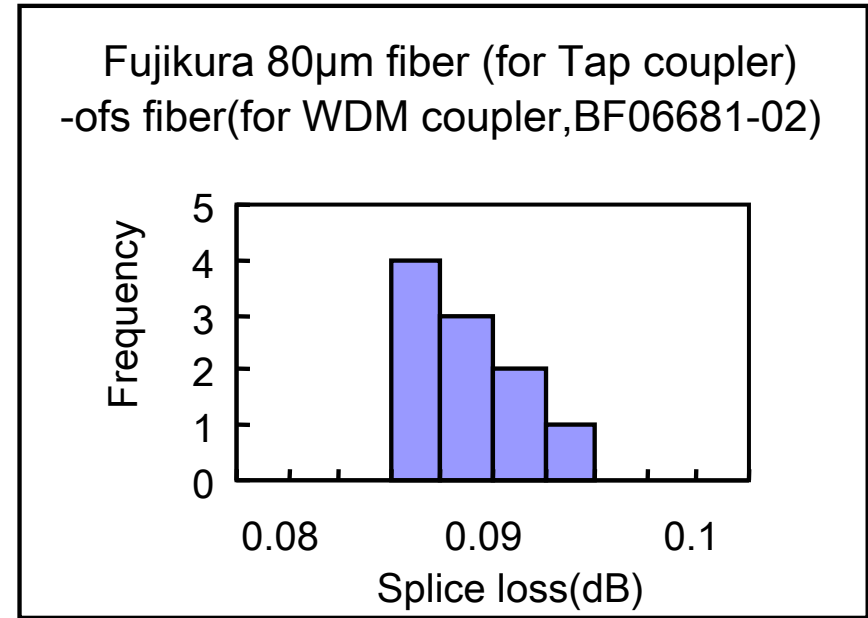
(\*1) Measured by Fujikura

Target values

# Splice loss



The average loss value is a little higher.  
We are maintaining R&D on reducing splice loss.

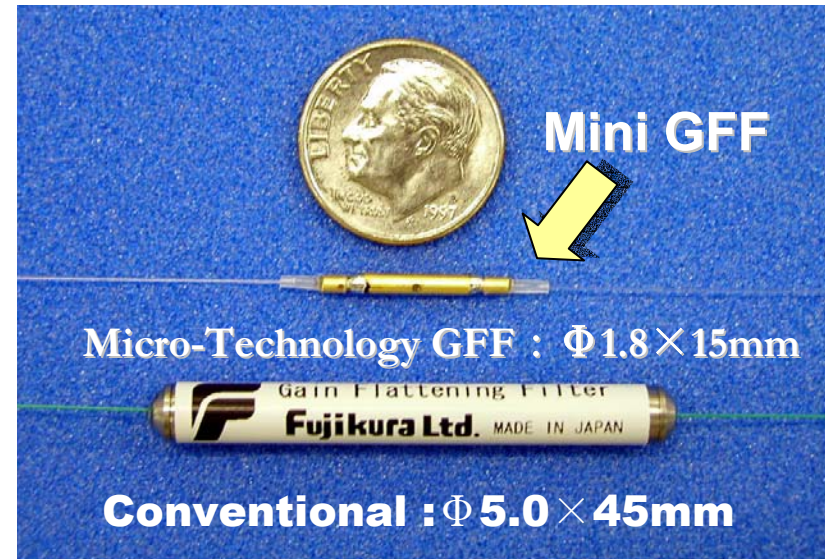


Splice loss between 80 $\mu\text{m}$  fibers is low.

# Subminiature Gain Flattening Filter (GFF)

## Key technologies

- **Micro Quartz Rod Lens**
  - Package size reduction
- **Lens-Fiber fusion splice**  
(Epoxy-free in optical path)
  - High optical power durability
- **Hermetic seal**
  - Excellent environmental stability
- **80  $\mu\text{m}$  fiber pigtail**
  - Package size reduction

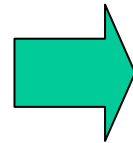


**World Smallest GFF\***

**(\* ) 95% Space saving compared with conventional GFF !**

# How to miniaturization...

A collimator size is  
the main obstacle



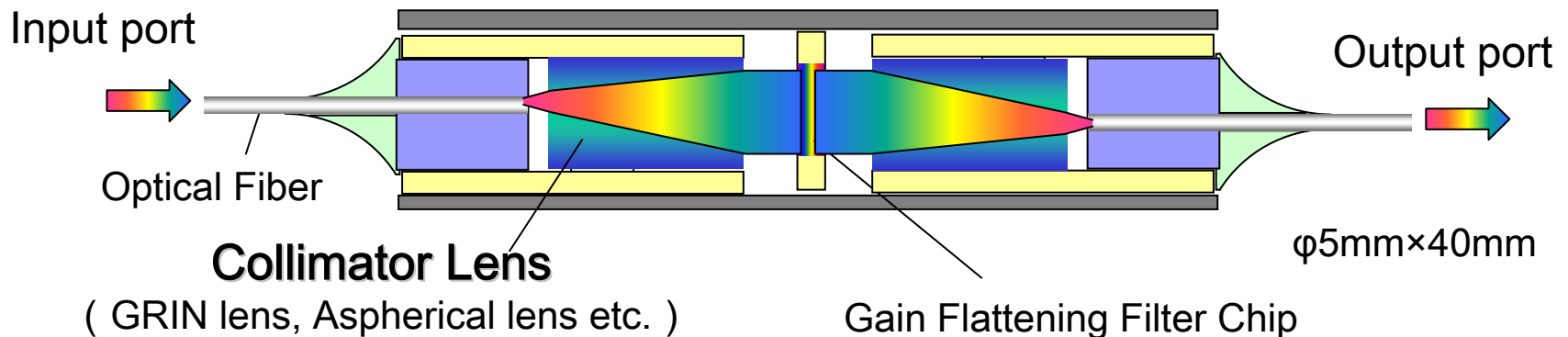
Development of  
the Micro Collimator

Size of Selfoc® :  $\Phi 1.8\text{mm} \times 4.8\text{mm}$

Size :  $\Phi 0.4\text{mm} \times 1.7\text{mm}$

98% volume reduction

## General structure of a Gain Flattening Filter



# Subminiature GFF

## Features

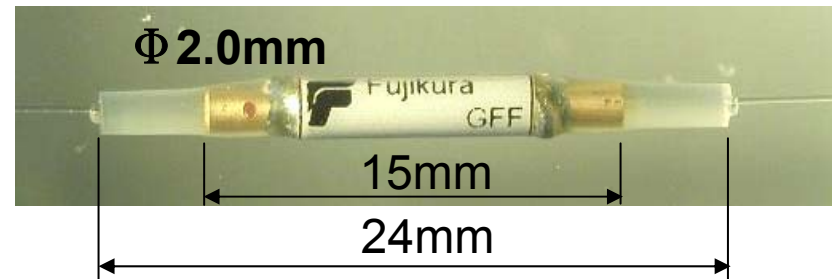
- *World's Smallest size Packaging*
- *Epoxy Free in Optical Path*
- *Low Insertion Loss*
- *Wide Operating Wavelength*

## Range

- *Excellent Thermal Stability*
- *80 $\mu$ m fiber pigtail*

## Release Schedule

- *2002 Q3 Sample Shipping*
- *2003 Q1 Mass-production*
- *2003 Q1 Expand line-up to all TFF devices*



## Applications

- *EDFA for C & L band*

Micro Quartz Rod  
Lens Collimator

Low melting  
temp. glass

### Fixing method

✦ Collimator to body : Solder

✦ Filter element to body : Low melting

temp. glass

Fusion splicing by  
CO2 Laser

Filter element



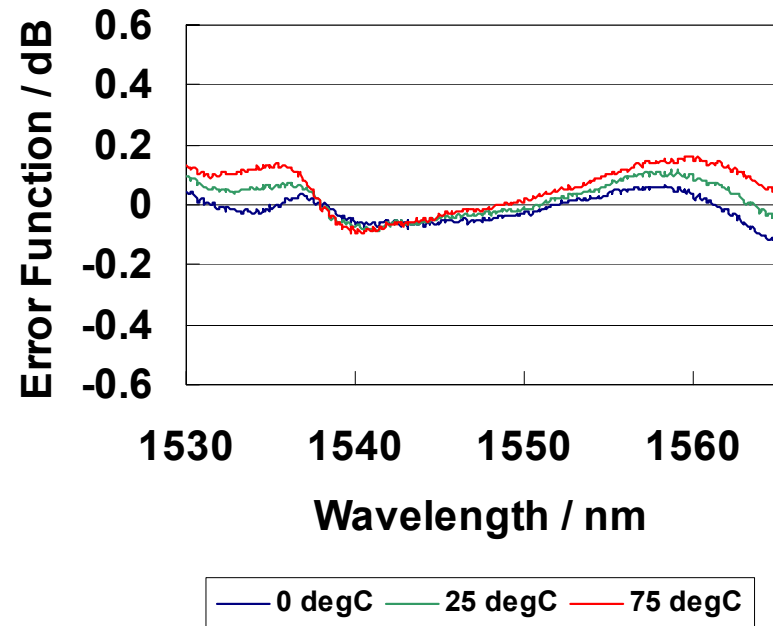
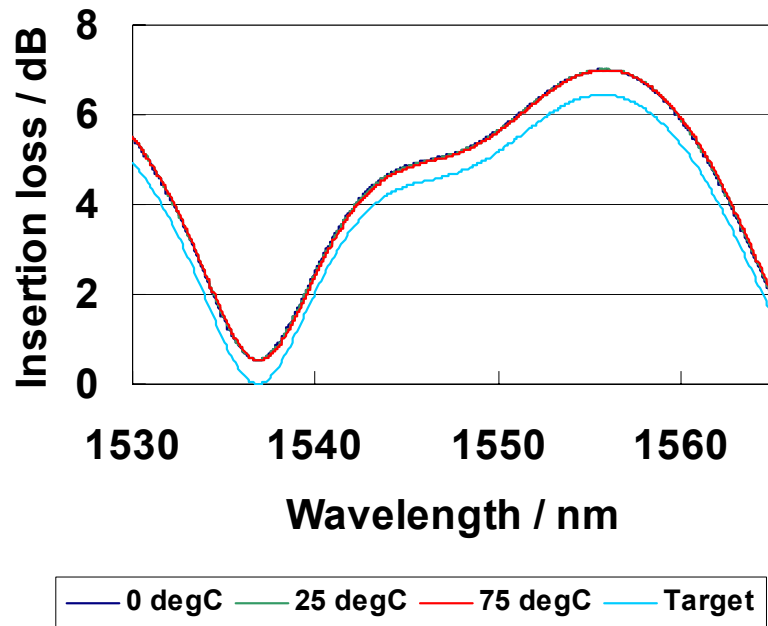
# Subminiature GFF Specifications

Parameters	Unit	Specifications
Wavelength range*	nm	C-Band 1529 – 1565 L-Band 1570 – 1610
Insertion Loss	dB	< 1.0
Peak to Peak Error Function**	dB	< 0.5
Return Loss	dB	> 55
PDL	dB	<0.1
PMD	ps	<0.1
IL Thermal Stability	dB/degC	<0.005
Wavelength Stability	pm/degC	<1.0
Maximum Optical Input Power	W	1.0
Operating Temperature	degC	0 – 70
Storage Temperature	degC	-40 - 85
Dimensions	mm	24L x 2φ

\*Custom wavelength range requirement is acceptable.

\*\*Values may vary with different custom loss curves.

# Example of Error Function



Typical Insertion Loss Spectrum for C-Band GFF

# Subminiature Optical Isolator

## Key technologies

- **Micro Quartz Rod Lens**
  - Package size reduction
- **Lens-Fiber fusion splice**  
(Epoxy-free in optical path)
  - High optical power durability
- **Hermetic seal**
  - Excellent environmental stability
- **80  $\mu\text{m}$  fiber pigtail**
  - Package size reduction



**World Smallest ISOLATOR\***

(\* ) 75% Space saving compared with conventional Isolator !

# Subminiature Optical Isolator

## Features

- *World's Smallest size Packaging*
- *Epoxy Free in Optical Path*
- *High Isolation & Low Insertion Loss*

## *Loss*

- *Excellent Thermal Stability*
- *80 $\mu$ m fiber pigtail*

## Applications

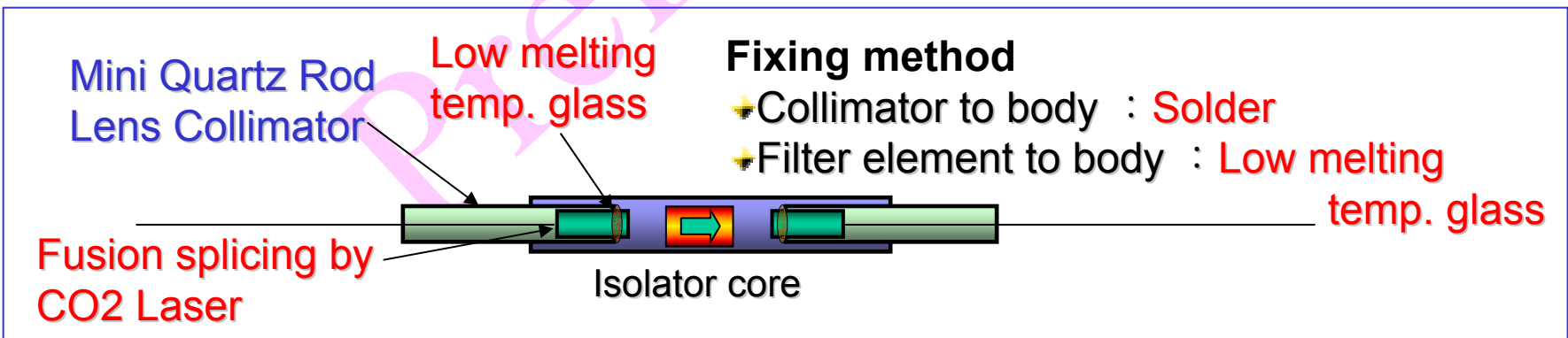
- *EDFA for C & L band*

## Release Schedule

- *2002 Q4 Sample Shipping*
- *2003 Q1 Mass-production*
- *2003 Q1 Expand line-up to Hybrid devices*



$\Phi 2.8\text{mm} \times 18\text{mm}$

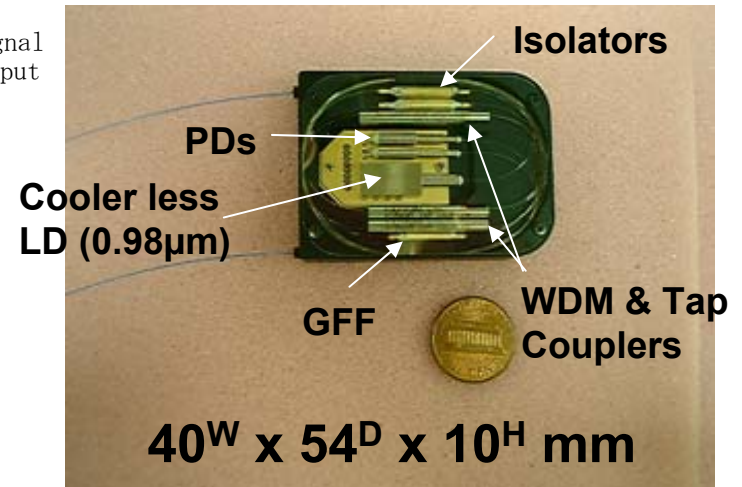
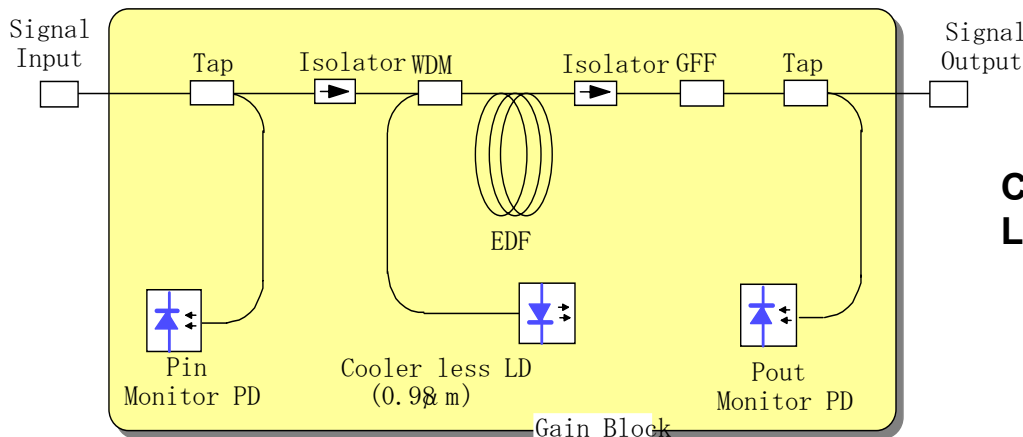
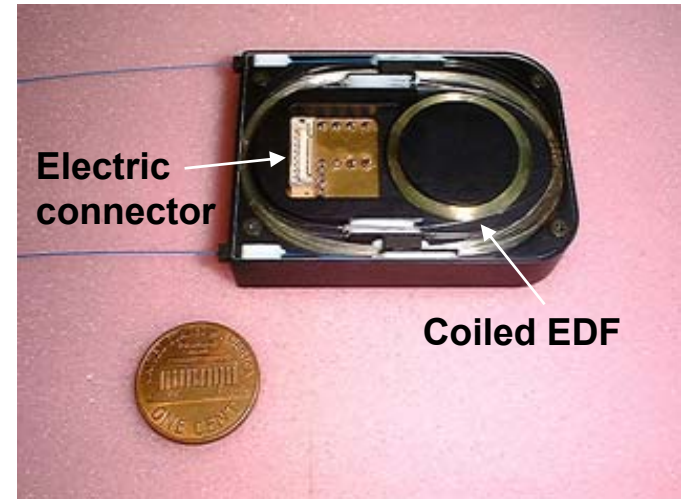


# Subminiature Optical Isolator Specifications

Parameters	Unit	Specifications
Wavelength range	nm	C-Band 1530 – 1570
Isolation	dB	> 42 @all $\lambda$ range, 25degC
		> 35 @all $\lambda$ range, 0 to 60degC
Insertion Loss	dB	< 0.9
Return Loss	dB	> 55
PDL	dB	< 0.1
PMD	ps	< 0.05
Maximum Optical Input Power	W	< 1.0
Operating Temperature	degC	0 – 60
Storage Temperature	degC	-40 - 85
Dimensions	mm	18L x 2.8 $\phi$

# Micro Optical Amplifier

- Ultra compact package (40 x 54 x 10 mm) utilizing a coiled RC-EDF and subminiature fused-fiber and collimated-beam optical components.



# Micro Optical Amplifier Specifications

Parameter	Unit	Performance (Example)								
		Single Channel Model (Pre-Amp Version)			Single Channel Model (Post-Amp Version)			WDM Model		
		min	typ.	max	min	typ.	max	min	typ.	max
Wavelength	nm	1528	-	1562	1528	-	1562	1528	-	1562
Signal Input Power	dBm	-30			-6			-6.5 (Total)		
Signal Output Power	dBm	-5			10			11.5 (Total)		
Gain	dB	25			16			18 (Total)		
Gain Flatness	dB							-	-	1.4
Noise Figure	dB	-	-	5.5	-	-	6.0	-	-	5.5
Return	dB	30	-	-	30	-	-	30	-	-
LD Forward Current	mA	-	-	350	-	-	350	-	-	350
LD Threshold Current	mA	-	-	45	-	-	45	-	-	45
Power Consumption	W	-	-	1	-	-	1	-	-	1
Input Monitor Sensitivity	A/W	0.032	-	0.063	0.030	-	0.075	0.032	-	0.063
Output Monitor Sensitivity	A/W	0.004	-	0.025	0.004	-	0.025	0.004	-	0.025
Operating Case Temperature	°C	0	-	65	0	-	65	0	-	65
Storage Temperature	°C	-40	-	85	-40	-	85	-40	-	85

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***Thank you!***