Fiber-based components

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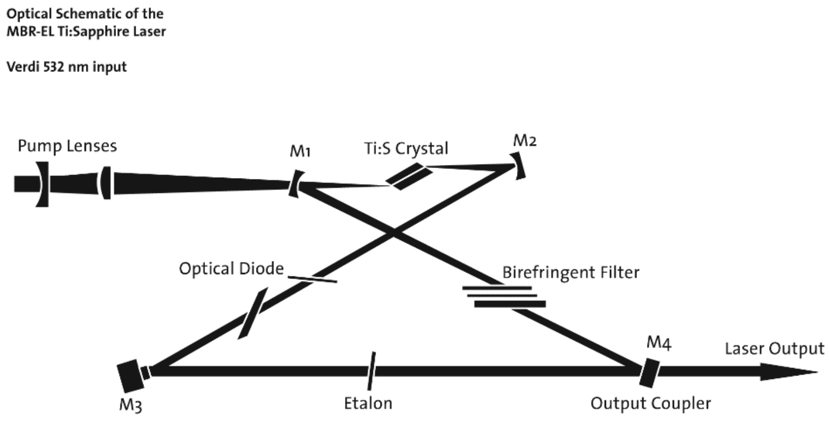
Projects

1. Handling optical fibers, numerical aperture
2. Measurement of fiber attenuation
3. Connectors and splices
4. Free space coupling of laser into fibers
5. Bending loss in optical fibers
6. Components for fiber communication and fiber lasers
7. Fiber lasers and amplifiers
8. Mode-locked fiber lasers
9. Soliton transmission in optical network
10. Fiber optics interferometric sensors

Traditional optics



Ti:sapphire laser

Optical elements are used to split/combine, filter, focus, amplify, attenuate… light

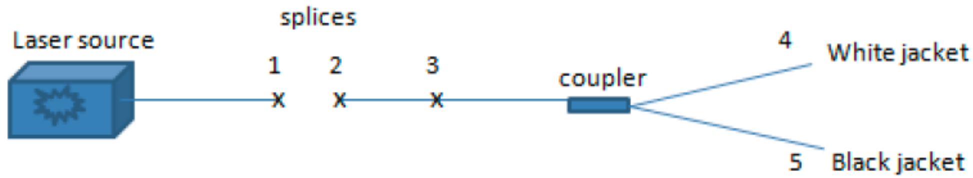
"Fiberization" in Optics

Ti:sa femtosecond laser

Femtosecond fiber laser

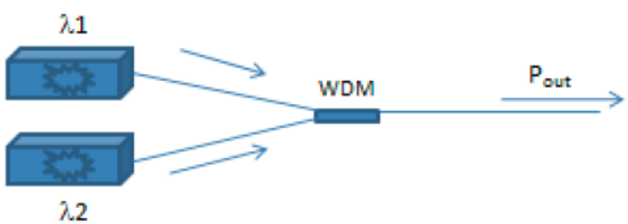
Fiber components

Fiber splitter



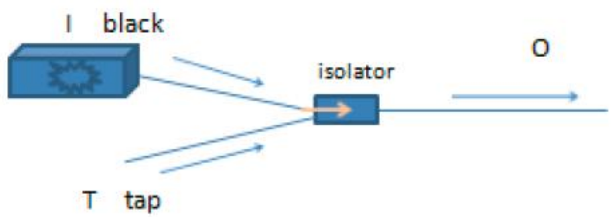
Beam splitter

Fiber WDM



Dichroic mirror

Fiber Isolator

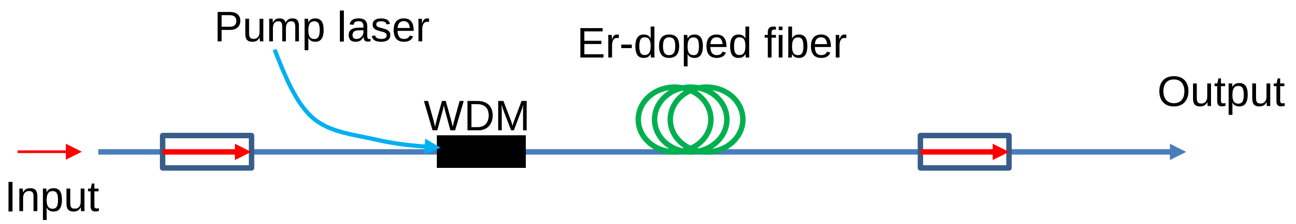


Optical isolator

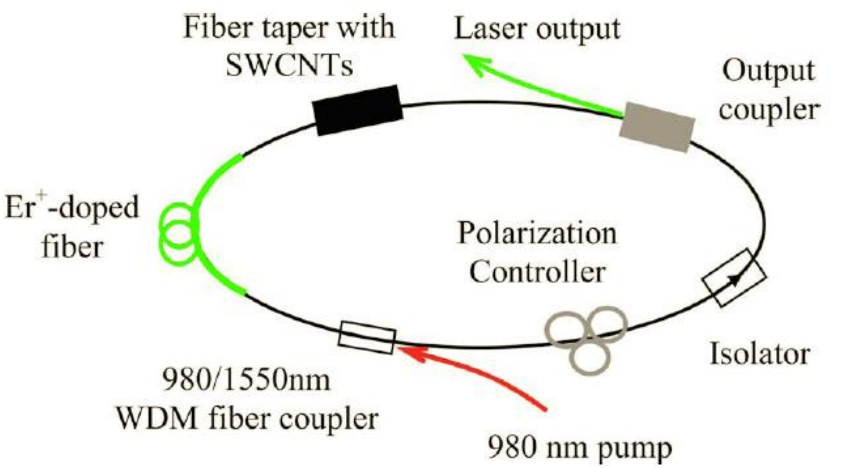
Fiber components

- Fiber coupler
- Variable fiber coupler
- WDM
- Isolator
- Attenuator
- Modulator
- Switches
- Pump/signal combiner
- Polarization splitter/combiner
- Collimator
- Fiber delay line
- Polarizer
- Tunable filter
- Circulator
- Faraday rotator mirror
- …

Example of fiber devices

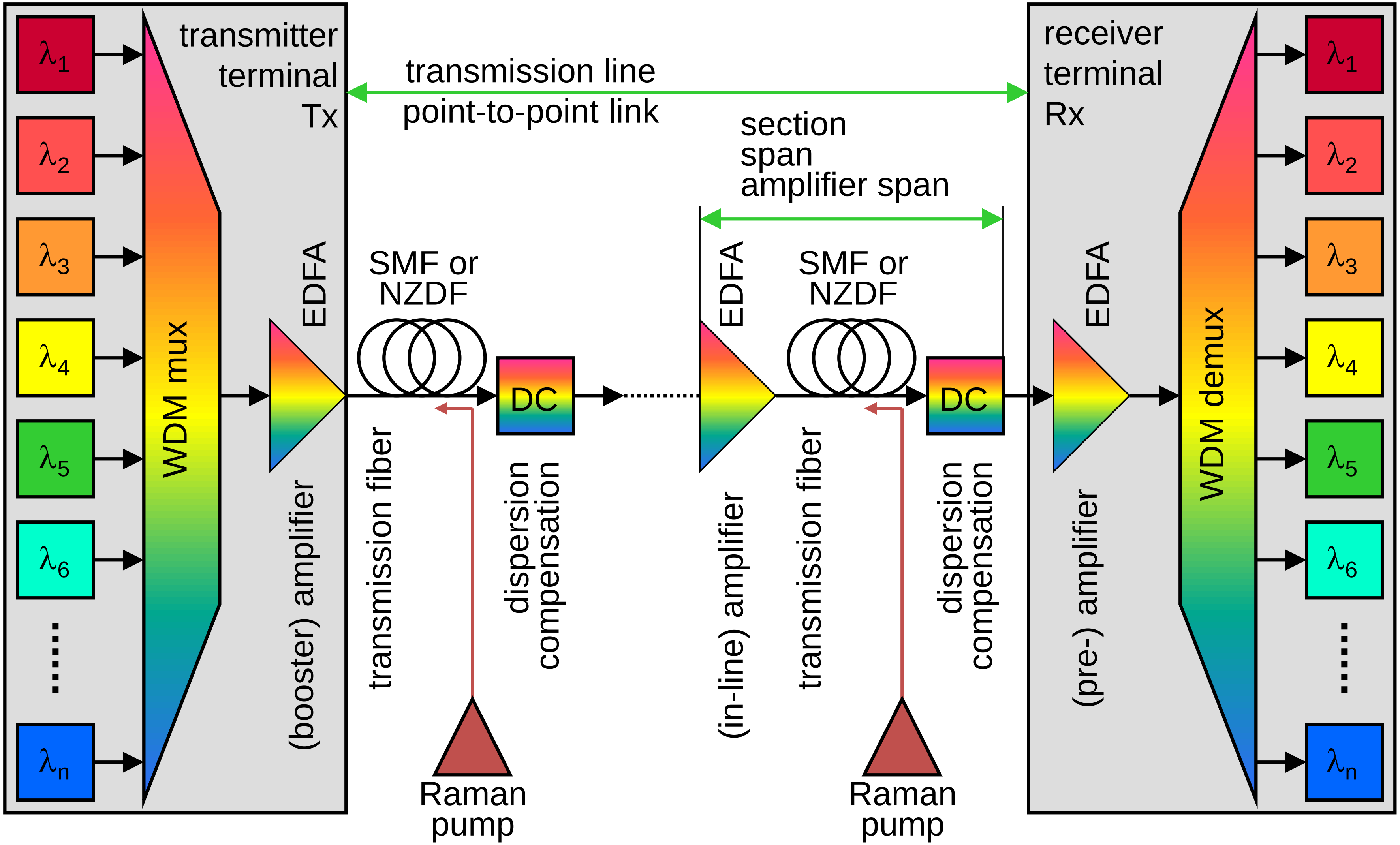


Er-doped fiber amplifier



Mode-locked ring fiber laser

Point-to-point WDM Transmission System
- Building Blocks -



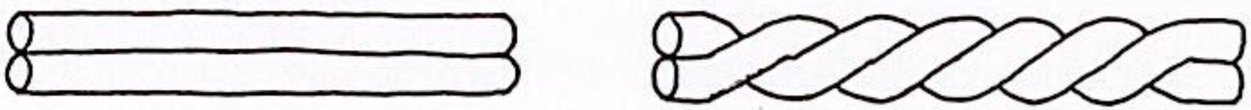
Fiber optic couplers

- Optical couplers either split optical signals into multiple paths or combine multiple signals onto one path
- The number of input (N)/ output (M) ports, (i.e. N x M) characterizes a coupler
- Fused couplers can be made in any configuration, but they commonly use multiples of two (2 x 2, 4 x 4, 8 x 8, etc.)

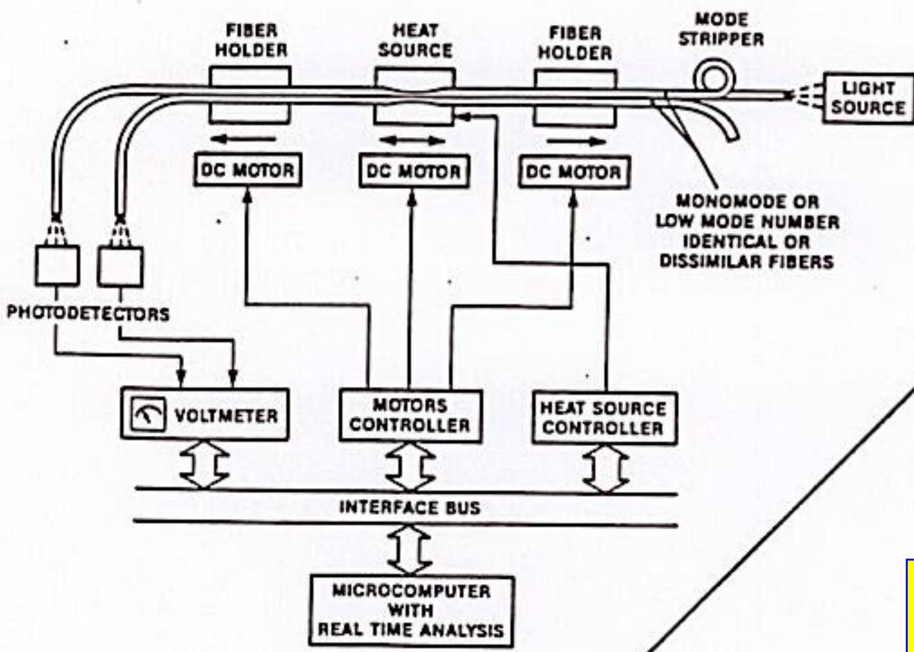
Coupler applications

- Uses
  - Splitter: (50:50)
  - Taps: (90:10) or (95:05)
  - Combiners
- Couplers are key components in
  - Optical amplifiers
  - Fiber lasers
  - Optical switches
  - Mach Zehnder interferometers
  - Fiber-to-the-home networks
  - Optical fiber sensors

Fused biconic taper fabrication



or



example:
experimental set-up
typical parameters

(Bilodeau, et al, JLT, 6, 1476, '8

Completely automated technology with high throughput

Coupling ratio, excess loss, PDL

Coupler performance parameters (I)

- Coupling ratio or splitting ratio:

$$CR = \frac{\text{Power from any single output}}{\text{Total power out to all ports}} = \frac{P_t}{P_{T-out}}$$

$$CR = -10\log_{10}\left(\frac{P_2}{P_1 + P_2}\right)$$

2 x 2 case in dB

- Excess loss:

$$L_e = \frac{P_{in}}{P_{T-out}}$$

$$L_e = 10\log_{10}\left(\frac{P_{in}}{P_1 + P_2}\right)$$

2 x 2 case in dB

Coupler performance parameters (II)

- Insertion loss:

$$L_i = \frac{\text{Power from any single output}}{\text{Power input}} = \frac{P_t}{P_{in}}$$

$$L_i = -10\log_{10}\left(\frac{P_t}{P_{in}}\right)$$

In dB

- Isolation or crosstalk:

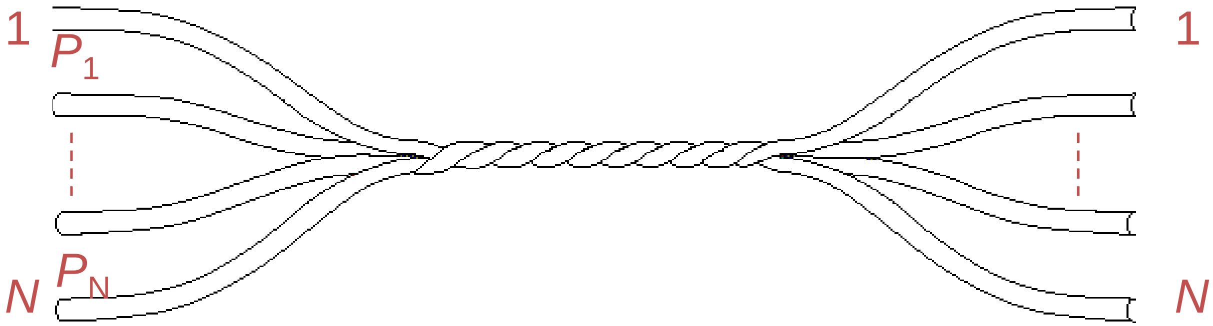
$$L_{iso} = \frac{\text{Input power at one port}}{\text{Reflected power back into other input port}}$$

$$L_{iso} = 10\log_{10}\left(\frac{P_{in}}{P_3}\right)$$

In dB

Fiber star coupler

Combines power from *N* inputs and divided them between *N* outputs



Coupling ratio

$$CR = -10\log_{10}\left(\frac{1}{N}\right) = 10\log_{10} N$$

Excess loss

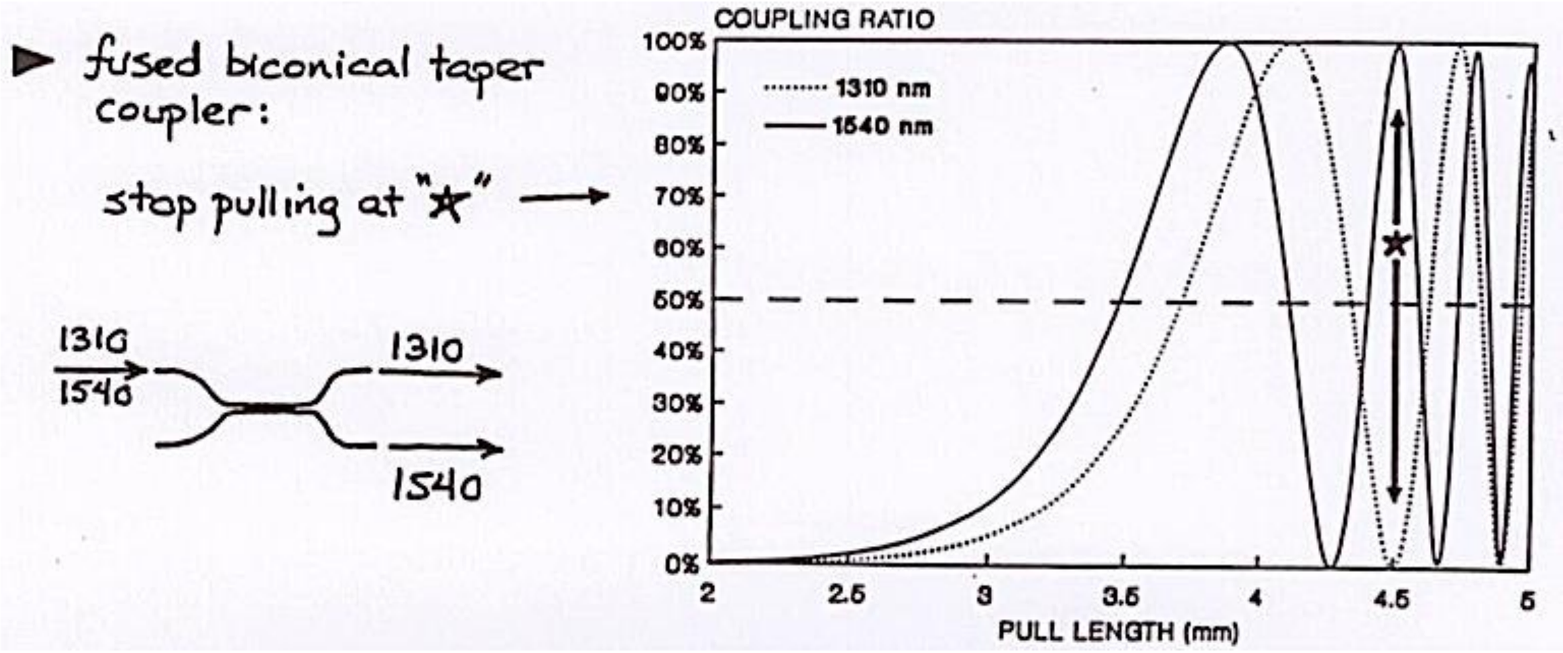
$$L_e = 10\log_{10}\left(\frac{P_{in}}{\sum_i^N P_{out,i}}\right)$$

Wavelength-dependent couplers

- Wavelength-division multiplexers (WDM) types:
  - 3 port devices (4th port terminated)
  - 1310 / 1550 nm ("classic" WDM technology)
  - 1480 / 1550 nm and 980 / 1550 nm for pumping optical amplifiers 1550 / 1625 nm for network monitoring

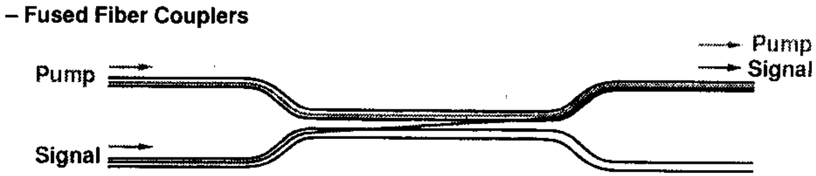
- Insertion and rejection:
  - Low loss (< 1 dB) for path wavelength
  - High loss (20 to 50 dB) for other wavelength

Wavelength-dependent couplers-WDM



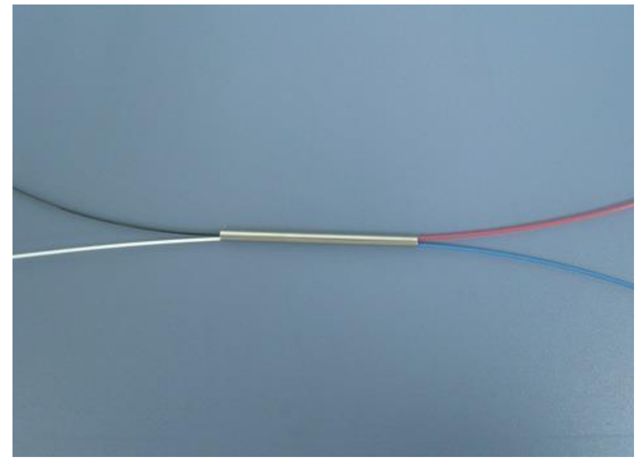
- Fused biconic taper is made and monitored as it is being pulled
- When 1550nm is in the bar state and 1310nm is in the cross state, pulling is stopped - - a coarse WDM filter results

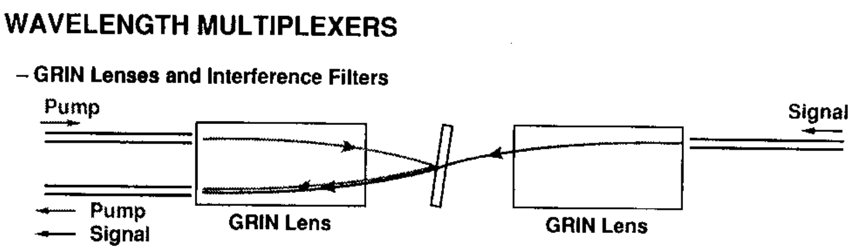
WDM couplers



- Insertion Loss < 0.3 dB
- Isolation –25 ~ –30 dB
- Return Loss –60 dB

Fused coupler type WDM





- Insertion Loss 0.5 ~ 1.0 dB
- Isolation –20 ~ –30 dB
- Return Loss –40 dB

Thin film type WDM

- Low loss (<0.5dB)
- Small size (35x5.5mm)
- Low cost (~$200)

WDM couplers

The Singlemode Wavelength Division Multiplexers combine or separate light at different wavelengths. They offer very low insertion loss, low polarization dependence, high isolation and excellent enviromental stability. These components have been extensively used in EDFA, CATV, WDM networks and fiber optics instrumentation.

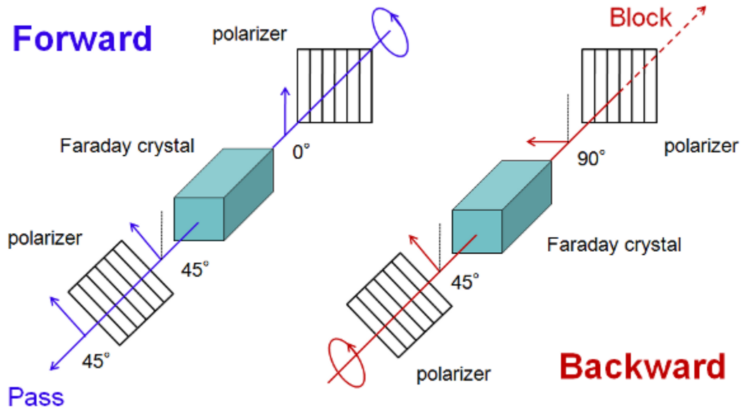
Specifications

Parameter	Unit	Value
Center Wavelength (λc)	nm	980/1550
Operating Wavelength	nm	λc ± 15
Min. Isolation	dB	20
Max. Insertion Loss	dB	0.15
Max. Polarization Dependent Loss	dB	0.1
Thermal Stability	dB/℃	≤ 0.002
Min. Return Loss	dB	60
Min. Directivity	dB	60
Max. Optical Power (Continuous Wave)	mW	300
Operating Temperature	℃	-40 to +75
Storage Temperature	℃	-40 to +85

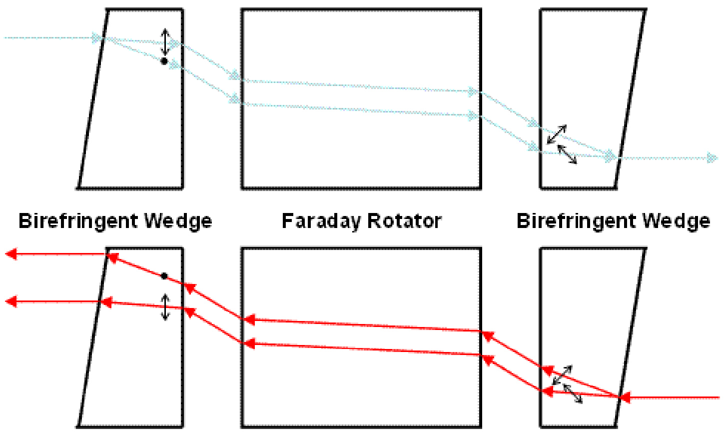
*IL is 0.5 dB higher, RL is 5 dB lower for each connector added.

*Test at central wavelength only.

Isolators



Polarization sensitive isolator



Polarization insensitive isolator

- Low loss (<0.5dB)
- Small size (35x5.5mm)
- Low cost (~$200)

Isolators

The Polarization Insensitive Isolator is designed and manufactured according to Telcordia standard. The unique manufacturing process and optical path epoxy-free design enhance the device high power handling capability. The device is characterized with high performance, high reliability and low cost. It has been widely used in EDFAs, Raman amplifiers, DWDM systems, fiber lasers, transmitters and other fiber optics communication equipments to suppress back reflection and back scattering.

Specifications

Parameter	**Unit**	**Single Stage**		**Dual Stage**	
		Grade P	Grade A	Grade P	Grade A
Center Wavelength (λc)	nm	1310, 1480 or 1550			
Typ. Peak Isolation	dB	42	40	58	55
Min. Isolation, λc ± 10 nm, 23 ℃, all polarization states	dB	30	29	46	45
Typ. Insertion Loss, λc, 23 ℃; all polarization states	dB	0.35	0.5	0.4	0.6
Max. Insertion Loss, λc ± 20 nm, all temperature, all polarization states	dB	0.5	0.7	0.6	0.9
Min. Return Loss (Input/Output)	dB	60/55	60/55	60/55	60/55
Max. Polarization Dependent Loss, 23 ℃	dB	0.05	0.1	0.05	0.15
Max. Polarization Mode Dispersion	ps	0.20	0.25	0.05	0.07
Max. Optical Power (Continuous Wave)	mW	300			
Max. Tensile Load	N	5			
Fiber Type		SMF-28 fiber			
Operating Temperature	℃	-5 to +70			
Storage Temperature	℃	-40 to +85			

*IL is 0.3 dB higher, RL is 5 dB lower for each connector added.

Project #6: Fiber-based components

Goal:

- Learn the working principle of important fiber-based components (fiber splitter, WDM coupler, isolator, etc.)
- Characterize the performance of fiber-based components

Tasks:

- Measure the splitting ratio and insertion loss of a fused fiber coupler
- Measure the wavelength response, insertion loss, and cross-talk of a 980/1550nm WDM coupler
- Measure the isolation and insertion loss of a fiber isolator

Questions for Thoughts

What is the new fiber component that you think may be useful to have?

Can we replace all traditional optics with fiber-based components?

How can you turn your experimental setup into fiber-based?

Where are fiber-based components made?

How can you start a successful company providing fiber components and devices?