The Abdus Salam
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United Nations
Educational, Scientific
and Cultural Organization

International Atomic
Energy Agency

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Winter College on Fibre Optics, Fibre Lasers and Sensors

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Passive Fibre Components

(PART 2)

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Passive Fibre Components

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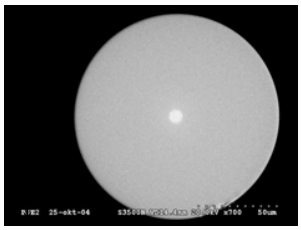
Examples

Couplers/Splitters
Optical Taps
Multiplexers/combiners
Demultiplexers/splitters
Fixed Add/drop Multiplexers
Interleavers
Photonic Lightwave Circuits [AWG]
Twin Core Fibers
Connectors

Isolators
Circulators
Optical Attenuators
Polarisation Related Components
Polarization related problems
Tunable Filters
Interferometers
Polarization control (active)
Polarization switch
Electrooptical fibers

Cleaving fibers



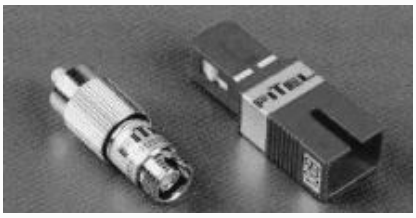
Splicing

Splicing station

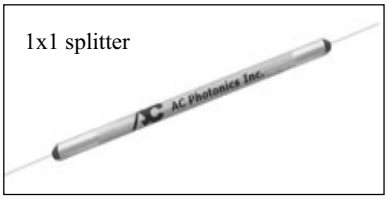
Hand-held

Splice protection

Attenuators



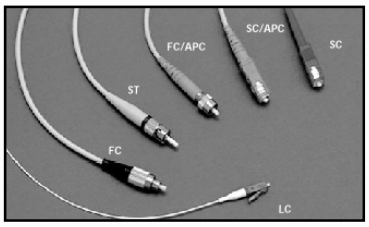
1x1 splitter

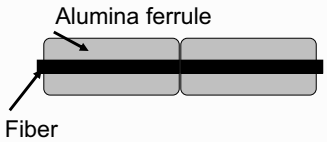


Fiber connectors

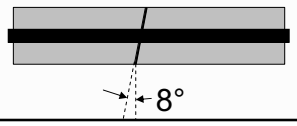
Various Types:
FC/PC, SC, LC, SMA, ST

Polishing quality:
SPC (Super), UPC (Ultra)



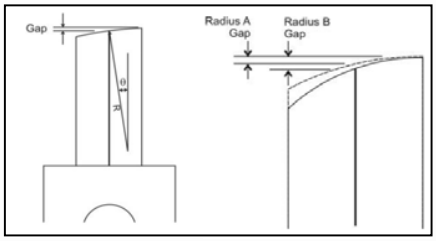


PC = Physical Contact
Insertion loss 0.2 dB
Back reflection –20 dB

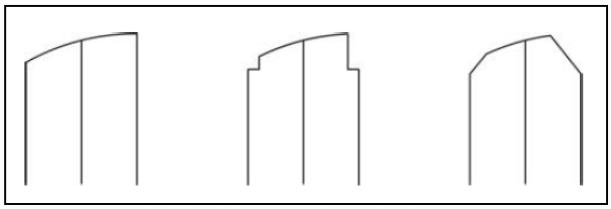


APC = Angled Physical Contact
Insertion loss 0.2 dB
Back reflection –40 dB

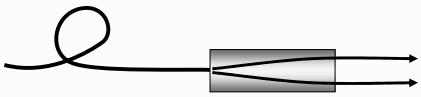
Effect of angle



Angle-polished connectors
APC (angled physical contact)

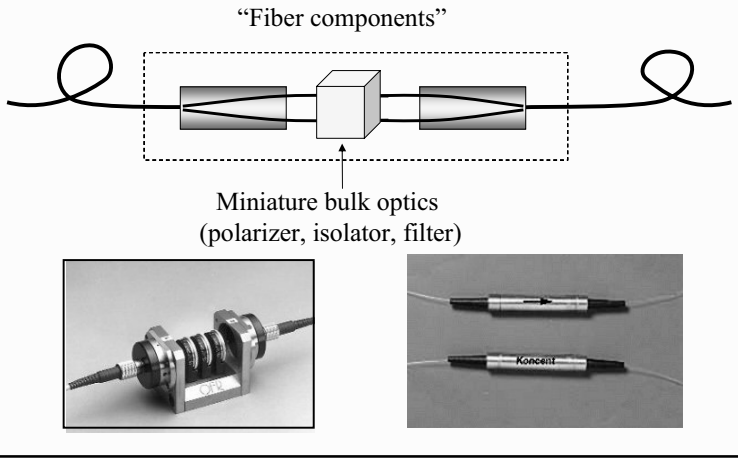


Collimators

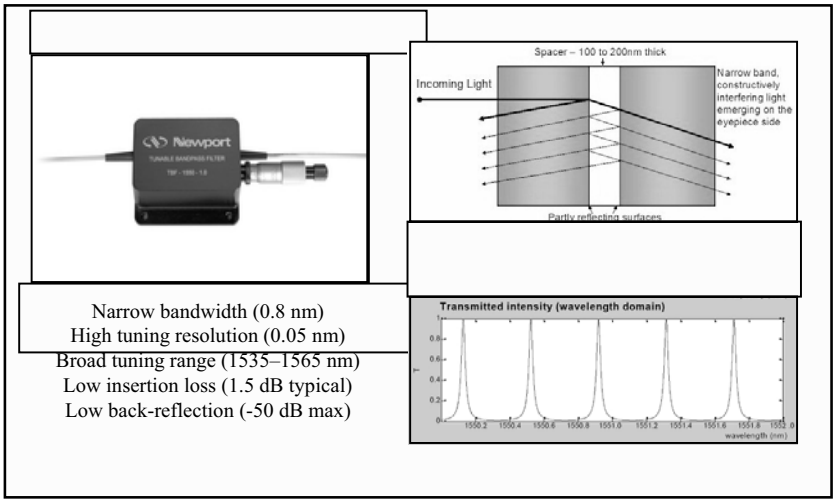


Fiber pigtail Grin lens Collimated light

Microbenches



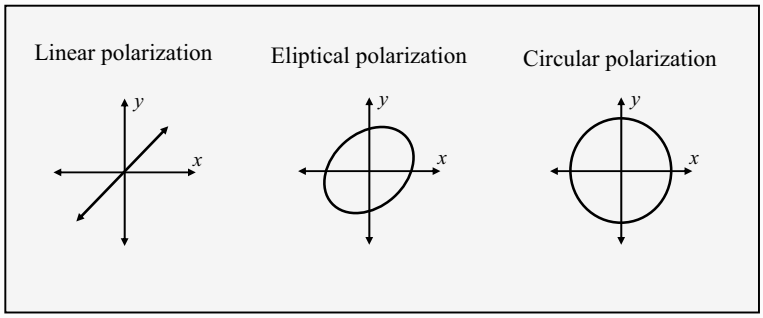
Tunable filters



Narrow bandwidth (0.8 nm)
High tuning resolution (0.05 nm)
Broad tuning range (1535–1565 nm)
Low insertion loss (1.5 dB typical)
Low back-reflection (-50 dB max)

Polarization

Types of polarization



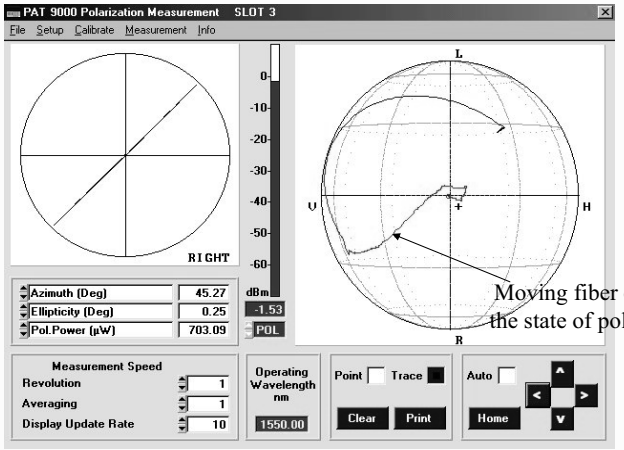
Polarization terms

PDL - Polarization dependent loss (PDG – Pol. dep. gain):
The component has an insertion loss that depends on the state of polarization
e.g., $LiNbO_3$ modulator: PDL ~2.5 dB (compensated ~1 dB)
Polarizer: PDL ~50 dB

DGD – Differential goup delay
The component has a different optical path for the two principal polarization axis.
e.g., HiBi (PM) fiber: DGD ~1 ps/m
Standard fiber: DGD ~0.001 ps/m

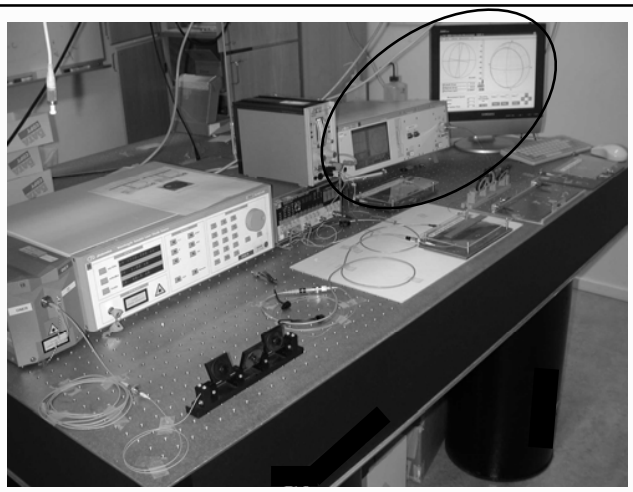
PMD – Polarization mode dispersion
Average value of the expectation value of DGD (could average in time, temp, λ)
e.g, the PMD of good cable could be 4 ps

Poincaré Sphere representation

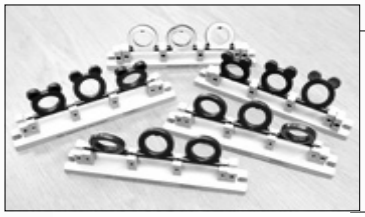


Moving fiber changes the state of polarization

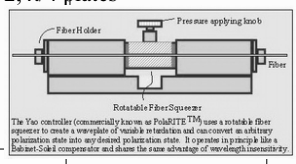
Polarization analysis: polarimeter

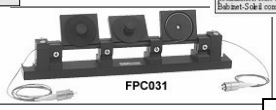


Mechanical polarization controllers



"Mickey mouse" polarization controllers
λ/4, λ/2, λ/4 plates

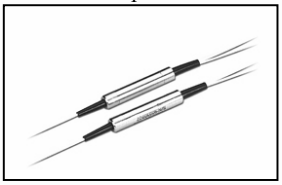




Polarization splitter/combiner

Long fiber coupler where each
polarization couples to one fiber

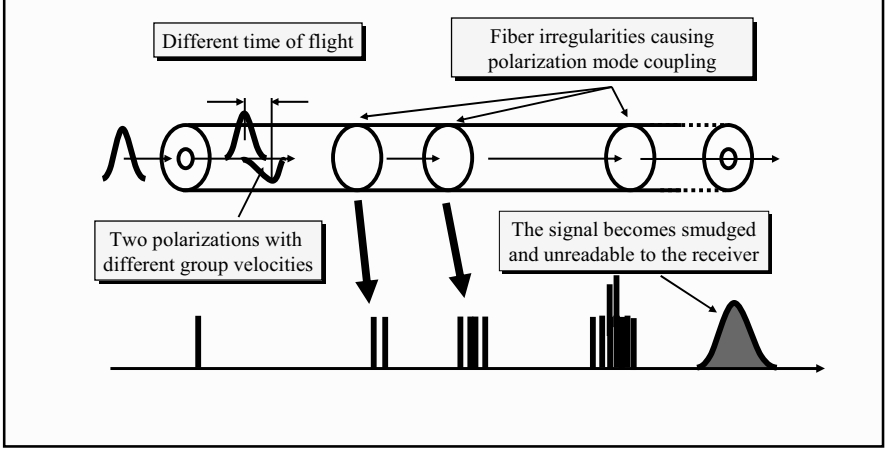
Polarization splitter/combiner



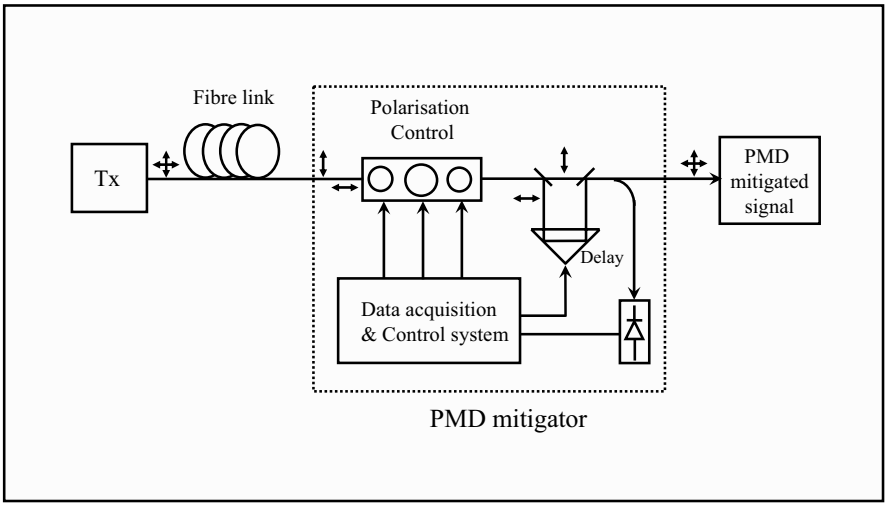
Extinction ratio >20 dB
Can combine pumps for laser

Polarization splitter/combiner

PMD of a fiber link

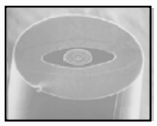


PMD "compensation"



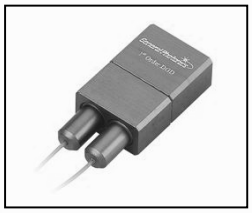
DGD

Fixed differential group delay

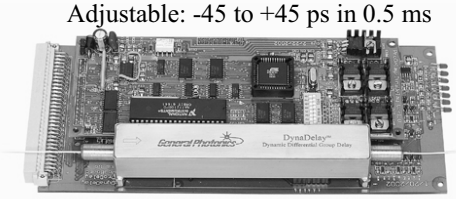


a length of HiBi fiber

Fixed differential group delay



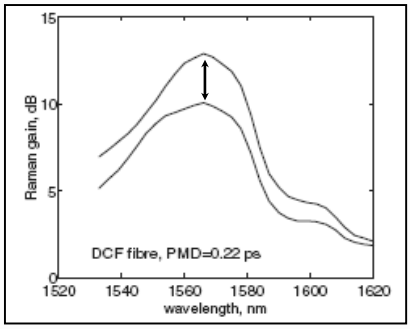
Adjustable: -45 to +45 ps in 0.5 ms

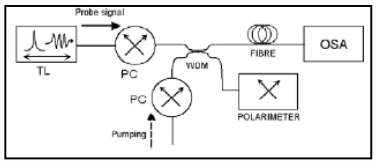


Fiber polariser

Typical extinction ratio:
40 dB

PDG in Raman amplifiers

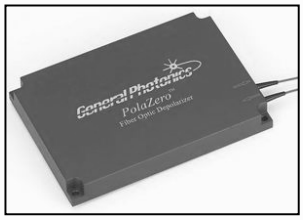




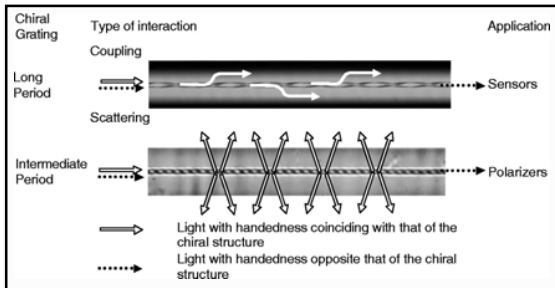
"The impact of pump polarization on the Raman PDG…",
Sergei Popov at al, J. Opt. A: Pure Appl. Opt. **6** (2004) S72–S76

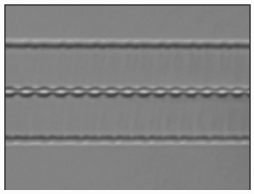
De-polarisers

Destroy polarization coherence
with long PM fiber
Improve performance of Raman Amp.

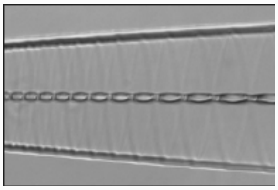


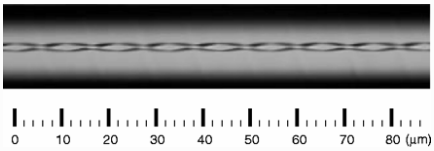
Optical activity (circular birefringence)



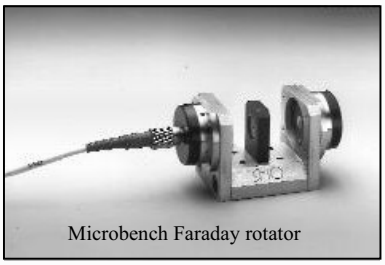


Chiral Photonics





Faraday Rotator



Microbench Faraday rotator

Faraday rotators

Material properties required:
High Verdet constant (magneto-optical)
Low absorption coefficient
High damage threshold
Low nonlinear response (prevent self-focusing, SPM)

Typical materials:
Terbium doped borosilicate glass, Tb gallium garnet (0.7-1.1 μm)
Yttrium Iron Garnet (YIG) (1.3-1.5 μm)

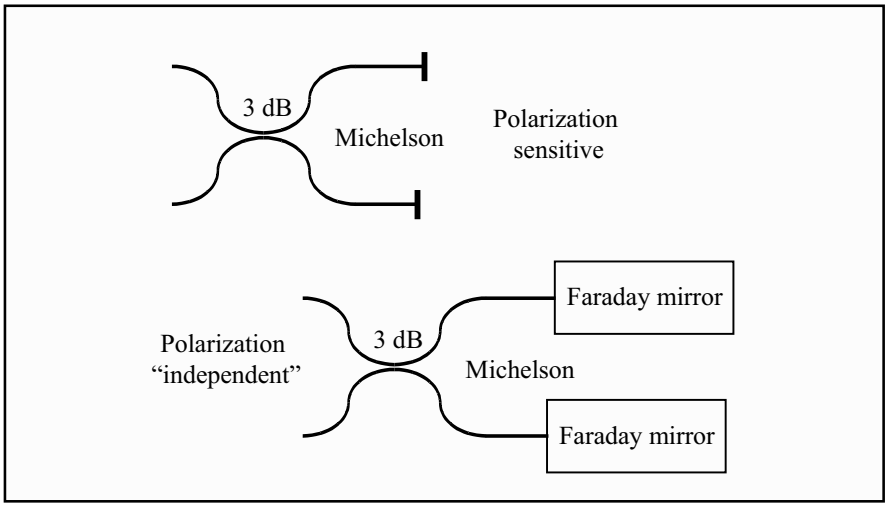
Typical isolation:
>30 dB

http://en.wikipedia.org/wiki/Faraday_isolator

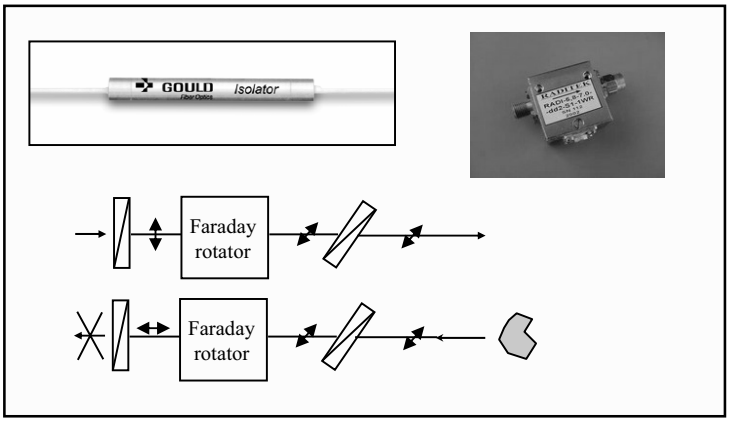
Faraday rotator mirror

Reflected light is rotated by 90°
in relation to input light everywhere in the fiber

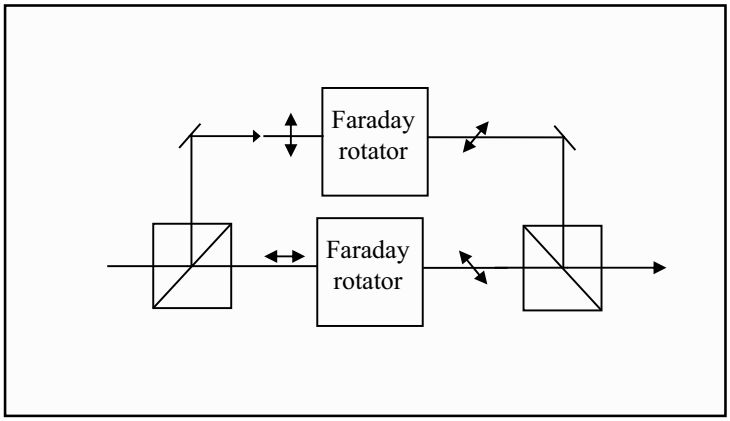
Typical application of Faraday rotator



Fiber isolator

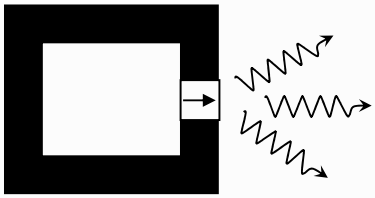


Polarization insensitive fiber isolator



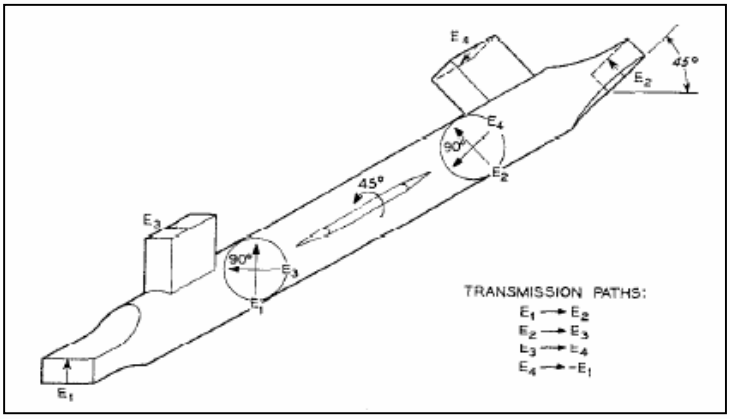
Puzzle from 1900

Can a closed black cavity with a single isolator as window cool the cavity to zero Kelvin by emission of radiation without work?



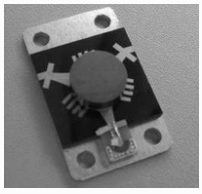
http://www.usna.edu/Users/physics/mungan/Scholarship/FaradayIsolators.pdf

Microwave Circulator



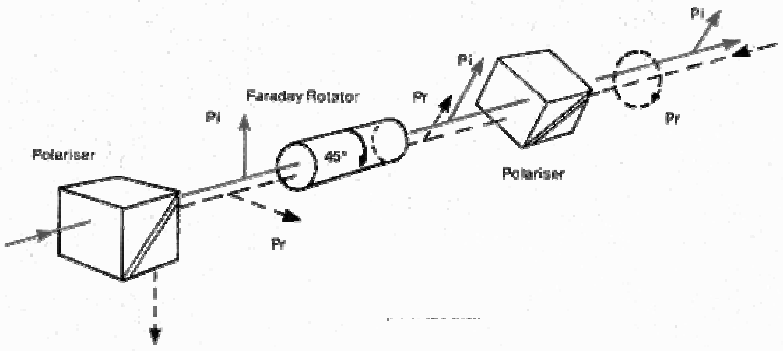
Microwave circulator (parenthesis)

Based on the Faraday effect in magnetic materials



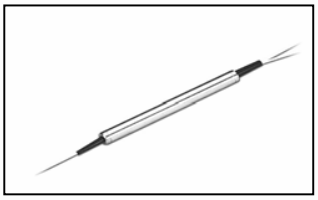
Optical Circulator

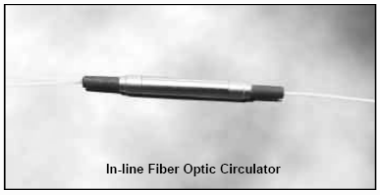
Principle of operation



Fiber circulator

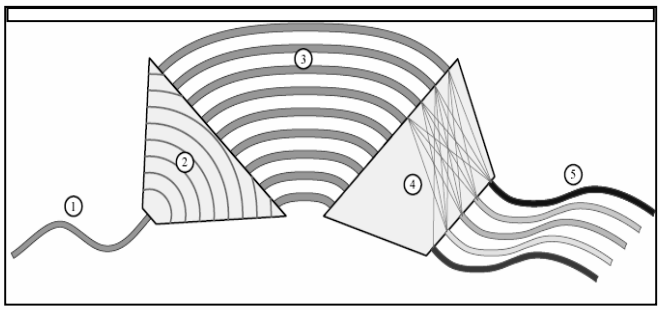
"€ 2000 miracle"





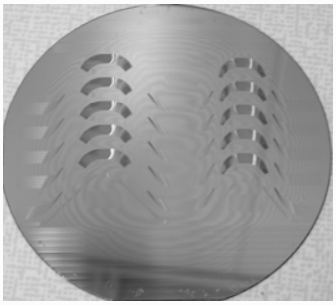
Arrayed Waveguide Gratings (AWG)

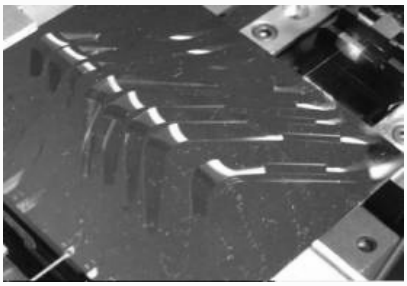
AWG are useful devices in Wavelength Division Multiplexing (WDM) optical communication systems.



An AWG is a device which can separate or combine channels with different wavelengths.

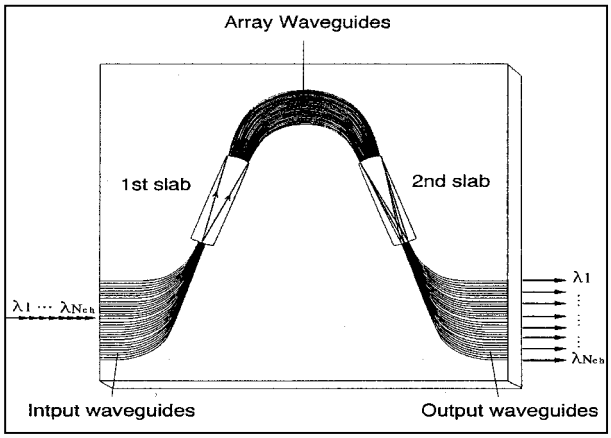
http://en.wikipedia.org/wiki/Array_Waveguide_Grating



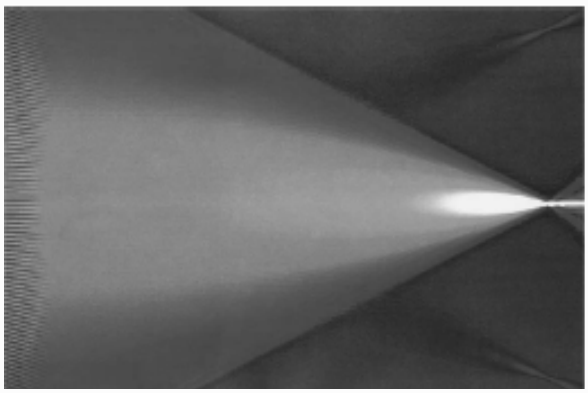


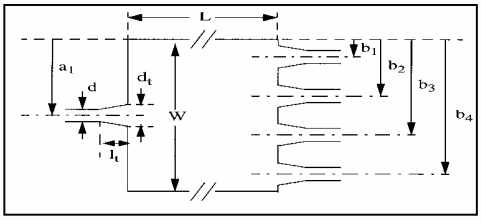
AWGs fabricated with silica-on-silicon technology

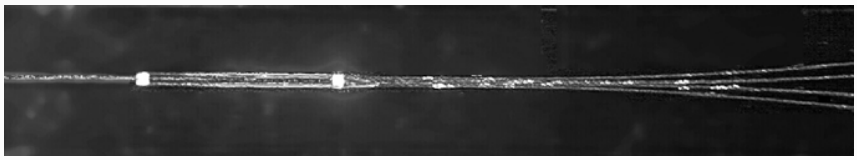
Courtesy: Lech Wosinski (KTH, Stockholm)



BPM simulation of focusing in the second section





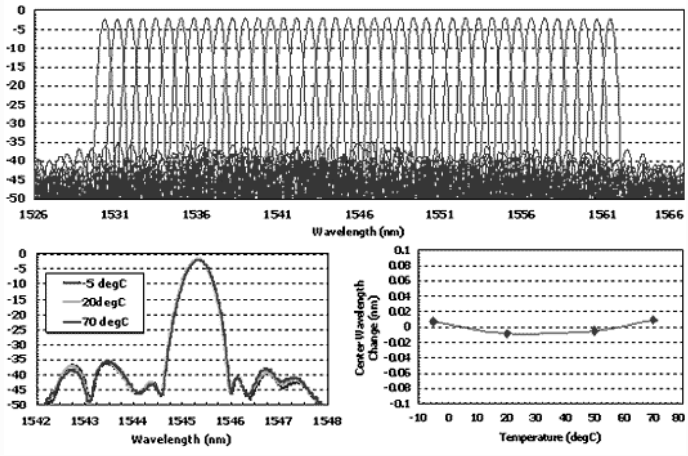


AWG

Optical characteristics of AWG 100 GHz

Parameters	Min	Typ	Max	Unit	Comments
Number of Channels		40			
Channel Spacing		100		GHz	
ITU-Grid Frequency					C-Band or L-Band
Passband	-0.1		0.1	nm	+/-12.5GHz
Center Wavelength Offset from ITU-Grid	-0.05		0.05	nm	Including both Initial Offset and Temperature Dependency
1dB Bandwidth	0.2			nm	
3dB Bandwidth	0.4			nm	
Insertion Loss		2.0	3.5	dB	ITU-T Grid for all Channels including PDL
Uniformity of Insertion Loss			1.0	dB	Difference of ITU-Grid across All Channels
Adjacent Crosstalk			-25.0	dB	Within Passband for All Channels including PDL
Non-Adjacent Crosstalk			-30.0	dB	Within Passband for All Channels including PDL
Total Crosstalk			-21.0	dB	Within Passband for All Channels including PDL
Polarization Dependent Loss			0.5	dB	Within Passband for All Channels
Chromatic Dispersion	-15.0		15.0	ps/nm	Within Passband for All Channels
Polarization Mode Dispersion			0.5	ps	Within Passband for All Channels
Return Loss	45.0			dB	
Optical Input Power			24.0	dBm	

AWG performance example (Datasheet)



Summary

- Splicers, connectors, attenuators
- Collimators and microbenches
- Example: tunable filter
- Polarization; PDL, DGD, PMD
- Pol. Control, Pol. Splitter, Polarimeter
- PMD mitigation
- DGD
- Polarizers, de-polarizers
- Optical activity and Faraday rotation
- Rotators, Isolators, Circulators
- MMI and AWGs