Mach-Zehnder Interferometer Design for Optical Isolation

Micaela Saunders, Physics, Ventura College

Paolo Pintus, Electrical Engineering

John Bowers, IEE, Electrical and Computer Engineering

Communication by Light

2016: What happens in an Internet Minute?

*www.excelacom.com/resources/.../**2016**-update-**what-happens**-in-one-**internet-minute***

2.4 Million Search Queries

69,444 Hours Watched

$203,569 In Sales

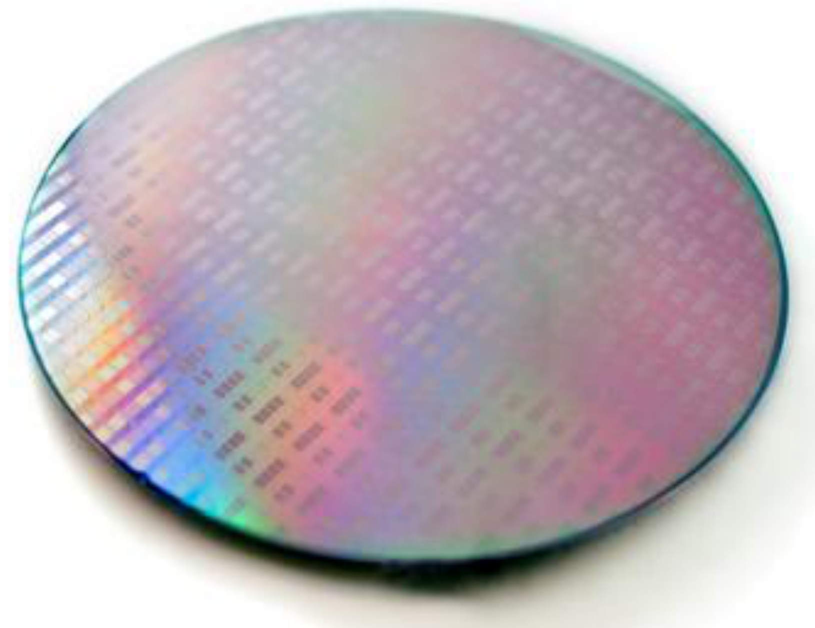
Future communication technology must include:

- **More data transmission**
- **Low power consumption**
- **Faster communication**

UCSB

Integrating Photonics

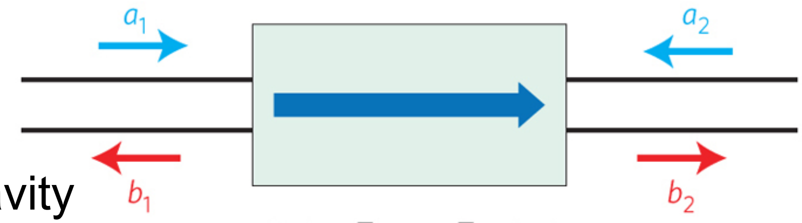
- Combine many device functions on a single chip
  - Small size
  - Large volume of production
  - Low cost
  - Low energy use



Mach-Zehnder Interferometer Design

Optical Isolators

- What is an optical isolator?
  - Light **CAN** propagate in the forward direction
  - Light **CANNOT** propagate in the backward direction
- Why is it important?
  - Avoid back-reflection out a laser cavity

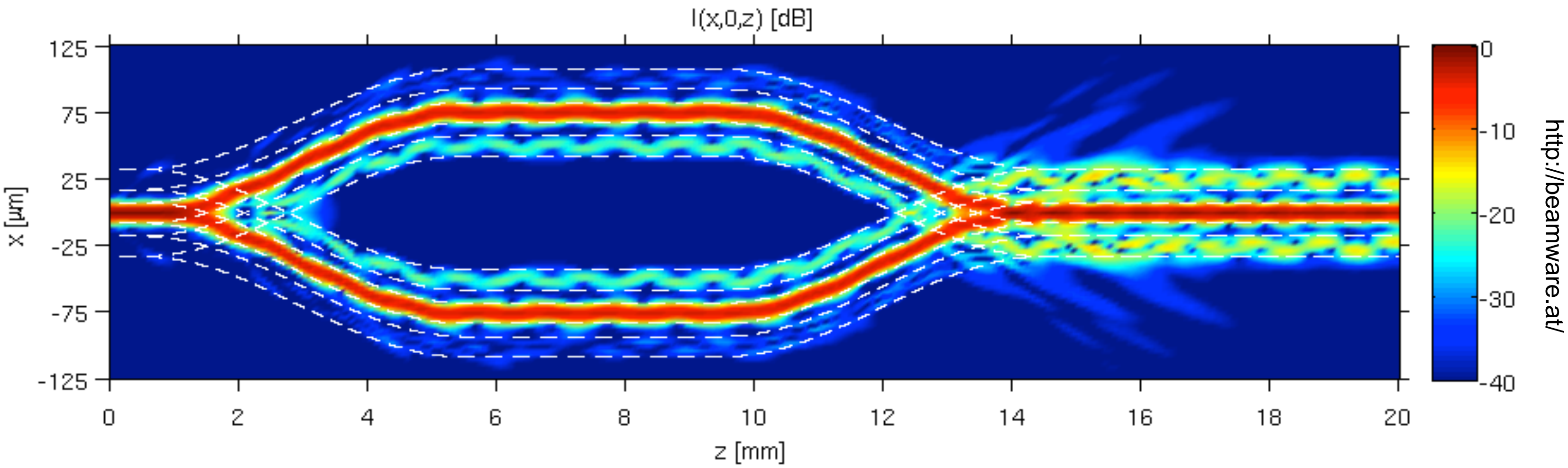


$$\begin{pmatrix} b_1 \\ b_2 \end{pmatrix} = \begin{bmatrix} 0 & 0 \\ 1 & 0 \end{bmatrix} \begin{pmatrix} a_1 \\ a_2 \end{pmatrix}$$

- Which material for an isolator?
  - We need a nonreciprocal material (e.g. Ce:YIG)

http://www.nature.com/nphoton/journal/v7/n8/fig_tab/nphoton.2013.185_F2.html

MZI Modeling

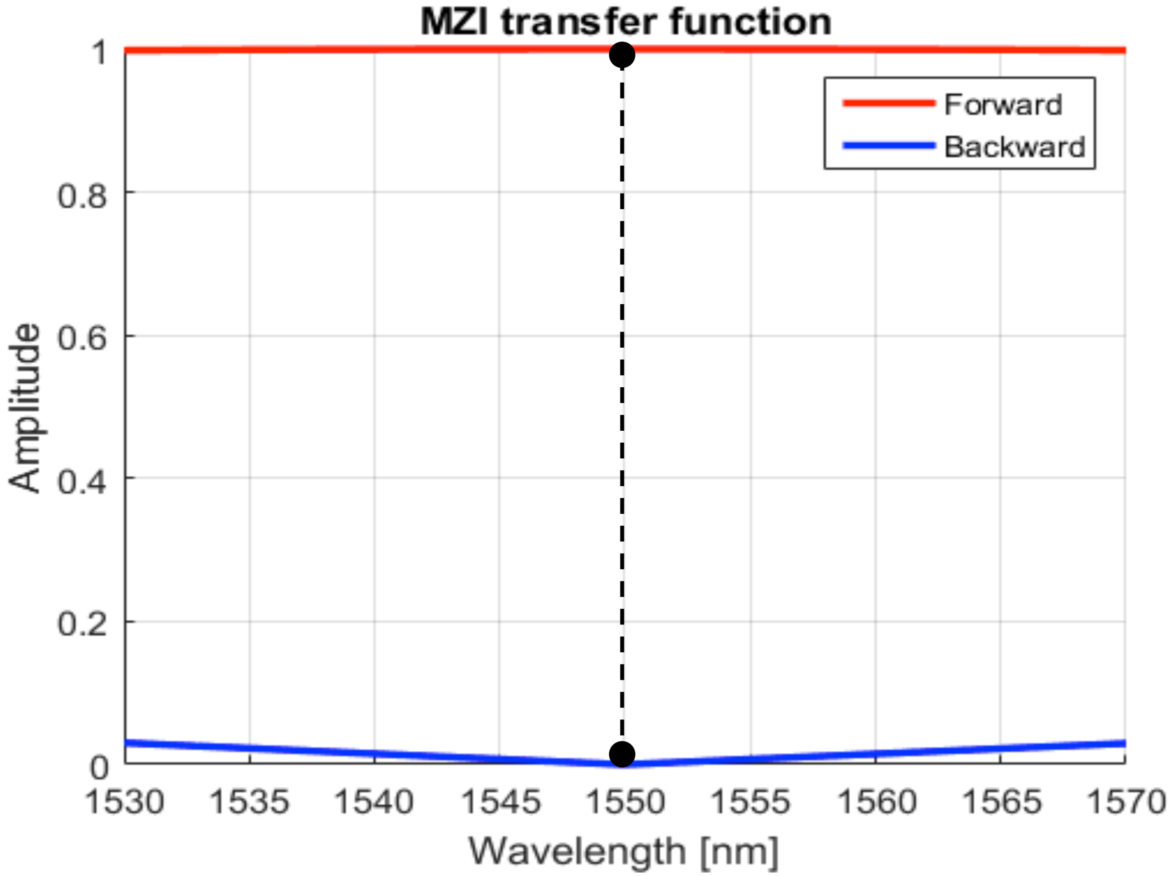


1. Find an equation to describe light propagation through a MZI
2. Implement model into Matlab
3. Engineer the length of two waveguide arms

Ideal Case

L1 = 327.06 µm

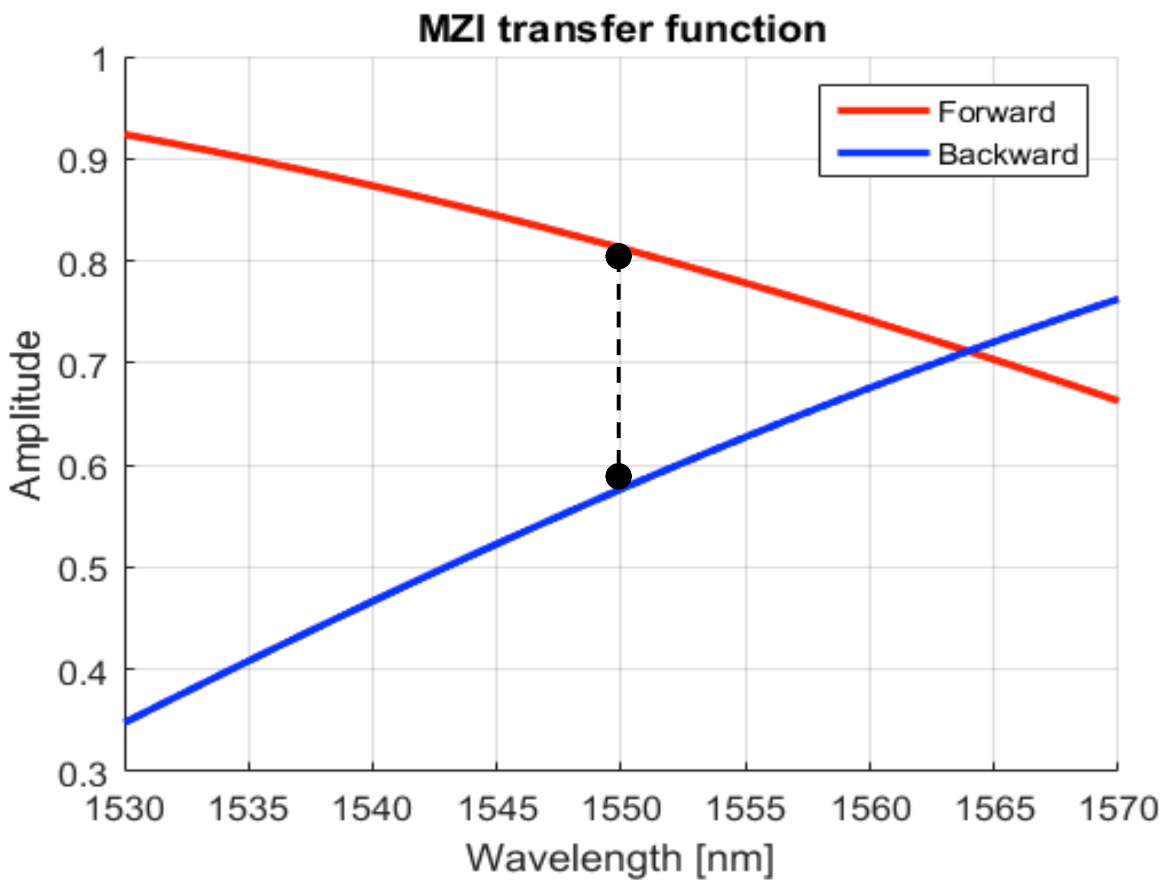
L2 = 327.89 µm



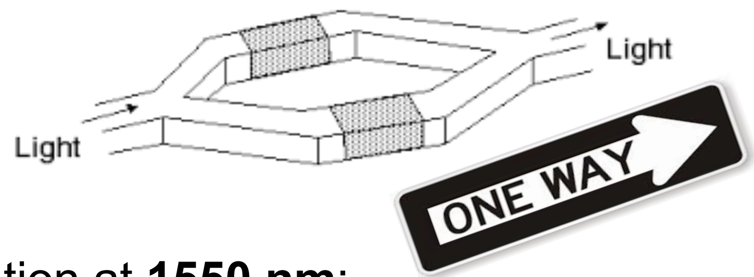
Fabricated Device

L1 = 327.06 µm

L2 = 347.89 µm

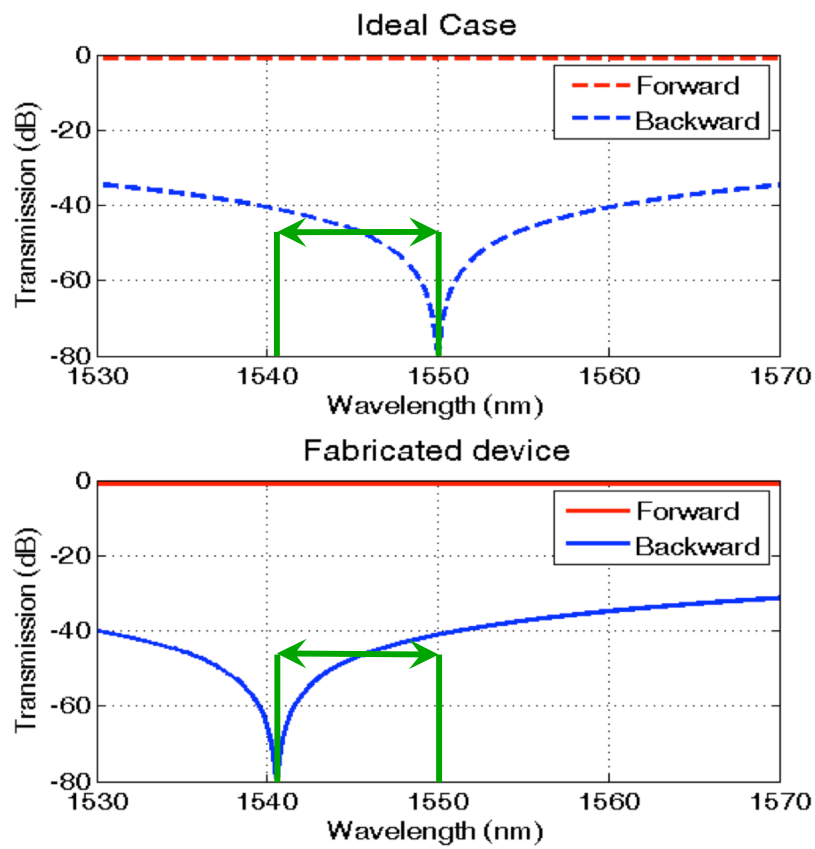


Optical Isolator – Robust Design



Isolation at **1550 nm**:

- Due to **fabrication inaccuracy**, the device might not work correctly (**spectral shift**)
- We want a device with low sensitivity to fabrication error → **robust design**



Optimization for Spectral Shift

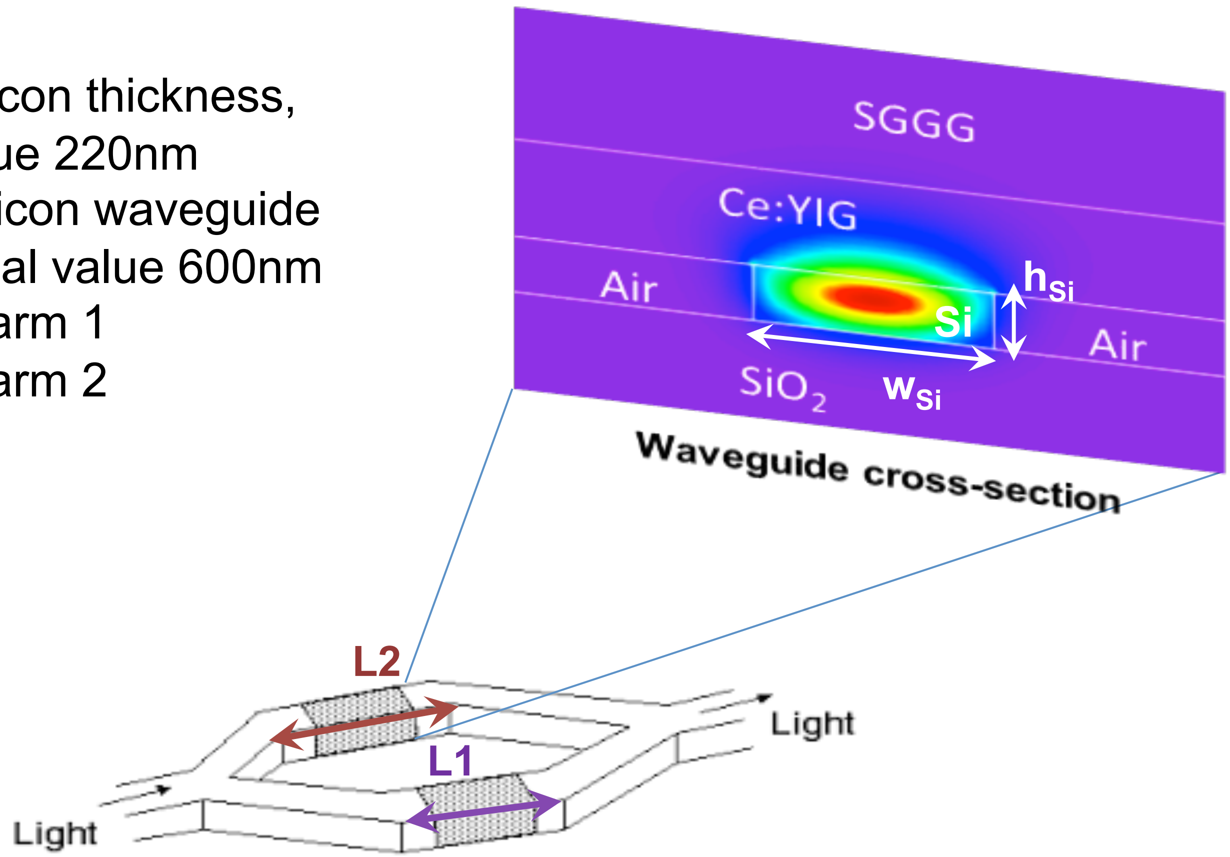
- Previously we found the solution
  - L1 = 327.06 μm
  - L2 = 327.89 μm
- However, multiple solutions exist
  - L1 = 327.06 μm + (m + n)*0.175 μm + (n - m)*655.96 μm
  - L2 = 327.89 μm - (m + n)*0.175 μm + (n - m)*655.96 μm

Where (n , m) integers of resonance

Where is the *minimal* shift? What is n and m?

Waveguide Cross-Section

- h_{Si} is the silicon thickness, nominal value 220nm
- w_{Si} is the silicon waveguide width nominal value 600nm
- **L1**: Length arm 1
- **L2**: Length arm 2



Shift Caused by Error of 1 nm

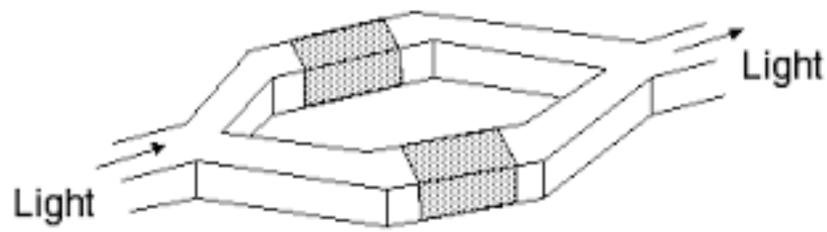
$$L_1 = \frac{\pi}{4\delta k} + \frac{\pi}{4k} + (n-m)\frac{\pi}{2\delta k} + (m+n)\frac{\pi}{2k}$$

$$L_2 = \frac{\pi}{4\delta k} - \frac{\pi}{4k} + (n-m)\frac{\pi}{2\delta k} - (m+n)\frac{\pi}{2k}$$

n	m	L1 (μm)	L2 (μm)	Δλ (nm) w_{Si}	Δλ (nm) h_{Si}	
0	0	327.06	327.89	-0.456	-0.659	Solution
0	1	-327.71	-328.24	X	X	Not a solution
0	-1	983.85	984.02	0.761	3.897	
-1	-1	327.71	328.24	0.301	2.202	
-1	0	328.07	327.89	-0.456	-0.659	Solution
1	1	328.41	327.54	0.1	1.426	

Steps for Optimization

- Modeling a MZI for optical isolation (Math/Physics)
- Implementing the model in Matlab (Coding)
- Simulating a MZI (Analysis)
- Design a robust MZI (Synthesis)



- What happens if we change the optical length of the arm?
- Modify to have a more robust design (e.g., thermal control)

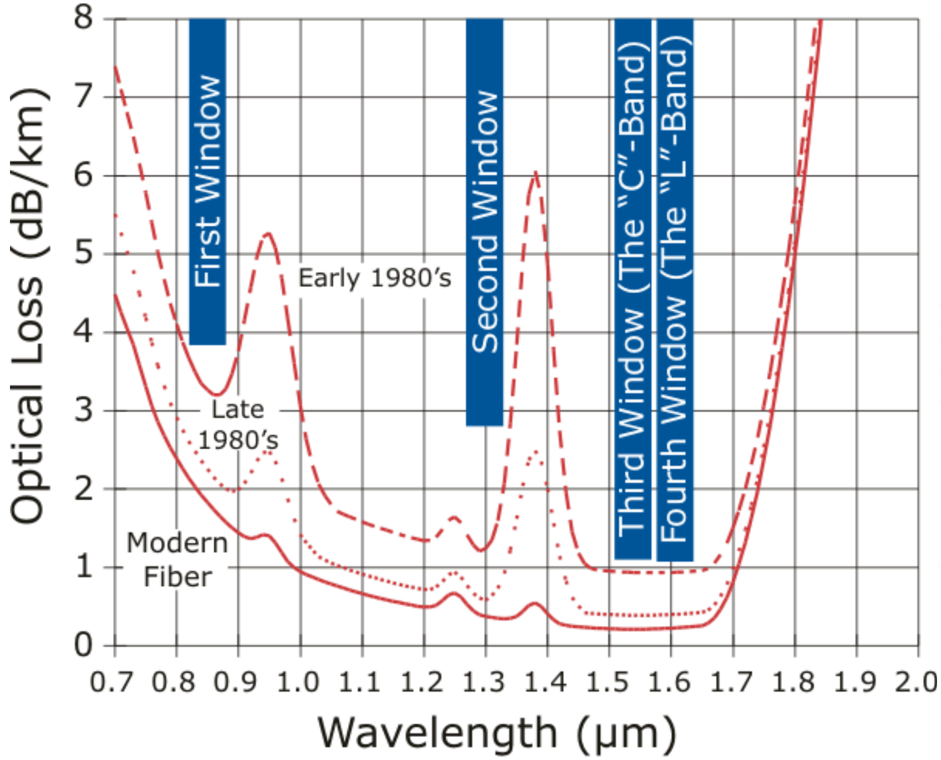
Acknowledgements

Paolo Pintus

John Bowers

Wendy Ibsen

1550 nm



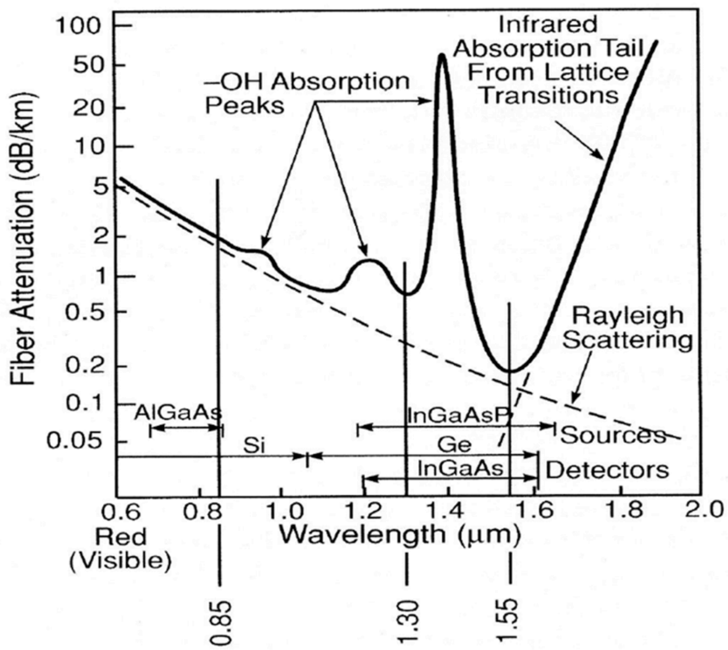


Figure 2 – Optical Fibre Transmission Spectrum

Reflections