Photonic Communications Laboratory

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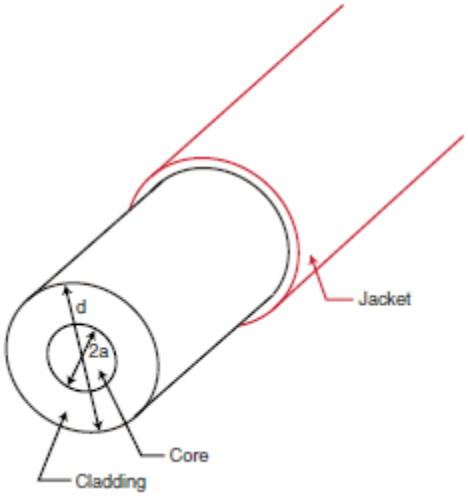
Lab session

Project 1: Handling optical fibers, numerical aperture

- Prepare fiber for use in experiments (cleaning, stripping, cleaving)
- Observation of fiber geometry using a microscope
- Measure fiber's NA



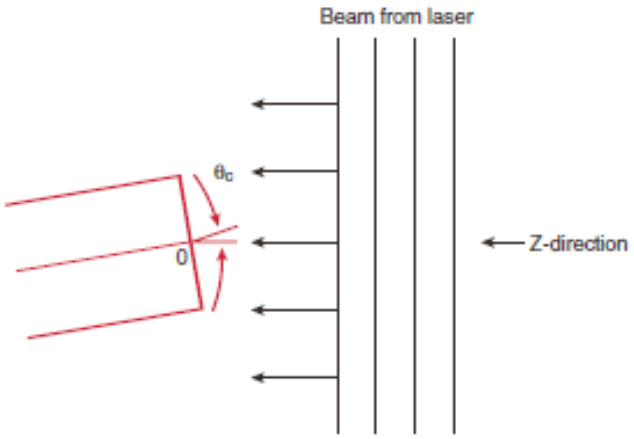
Fiber stripper

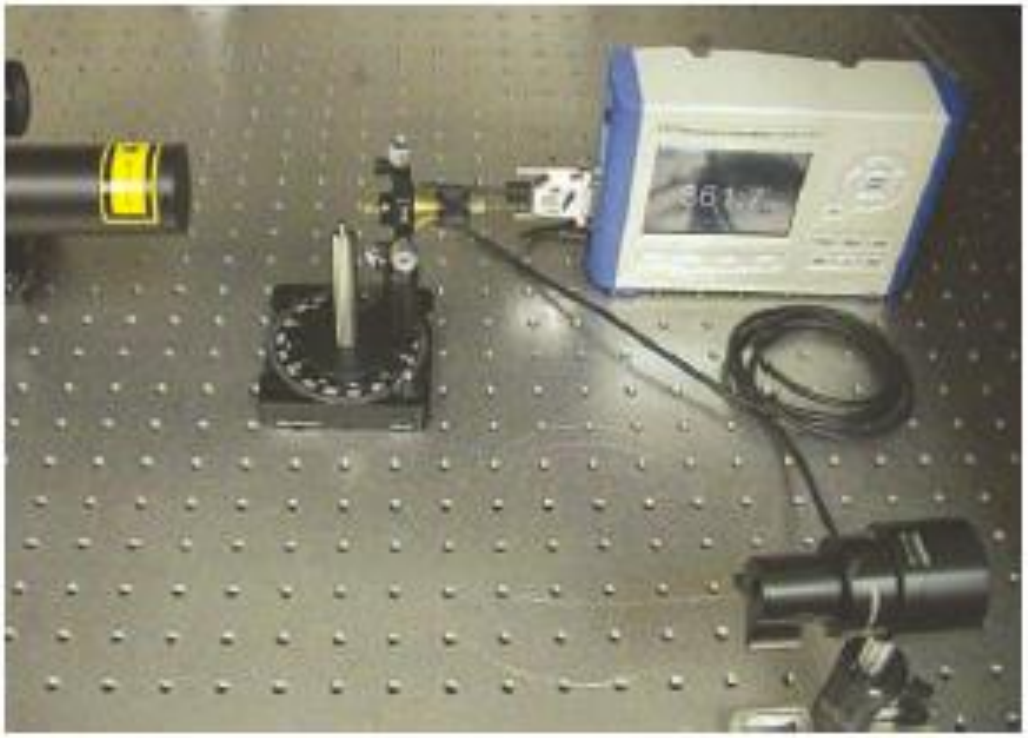
Fiber cleaver

Fiber cleaver

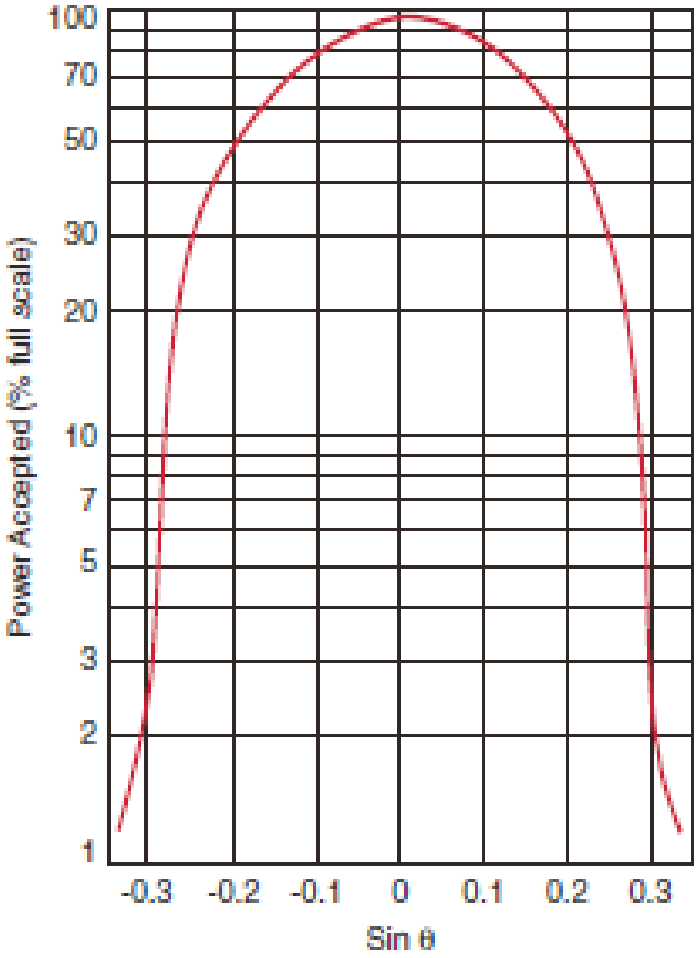
Laser power meter

Project 1: Handling optical fibers, numerical aperture





Project 1: Handling optical fibers, numerical aperture



Take the angle at 90 degree

Why fiber optics?

Applications of fiber optic communication include:

- Telephones
- Internet
- LANs - local area networks
- CATV - for video, voice and Internet connections
- Utilities - management of power grid
- Sensing – Bridges or buildings monitoring
- Research

There are also many other applications such as fiber lasers, fiber sensor

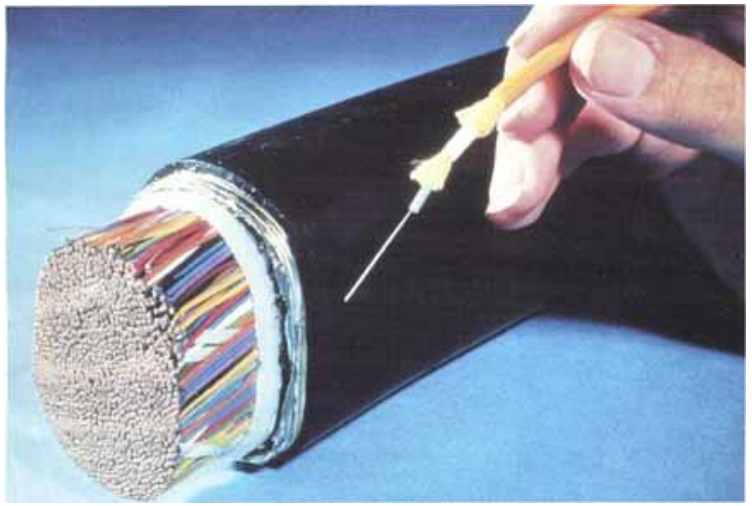
Why fiber optics?

Groups at OSC that use fiber optics:

- Khanh Kieu
- Naser Peyghambarian
- Jason Jones
- Bob Norwood
- Daewook Kim
- Russell Chipman
- Poul Jessen
- Art Gmitro, Urs Utzinger
- Mahmoud Fallahi
- Milorad Cvijetic
- Rongguang Liang
- Tom Milster
- Brian Anderson
- Raymond Kostuk
- Jennifer Barton

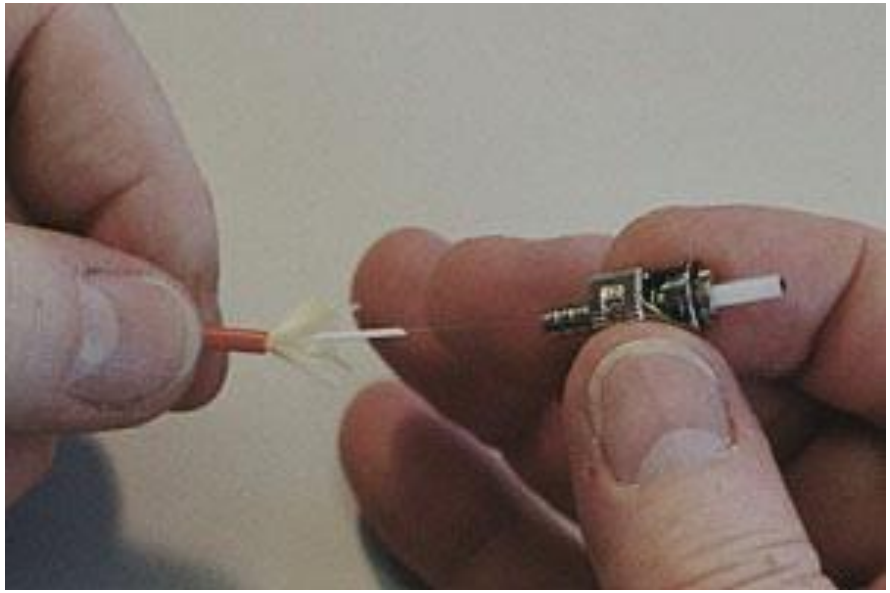
Why fiber optics?

- Economics: Fewer repeaters
- Capacity: Much wider bandwidth (> 10 GHz)
- Distance
- Weight/size
- Freedom from interference
- Safety: Electrical isolation
- Security: More difficult to tap
- Robust operation
- Low cost



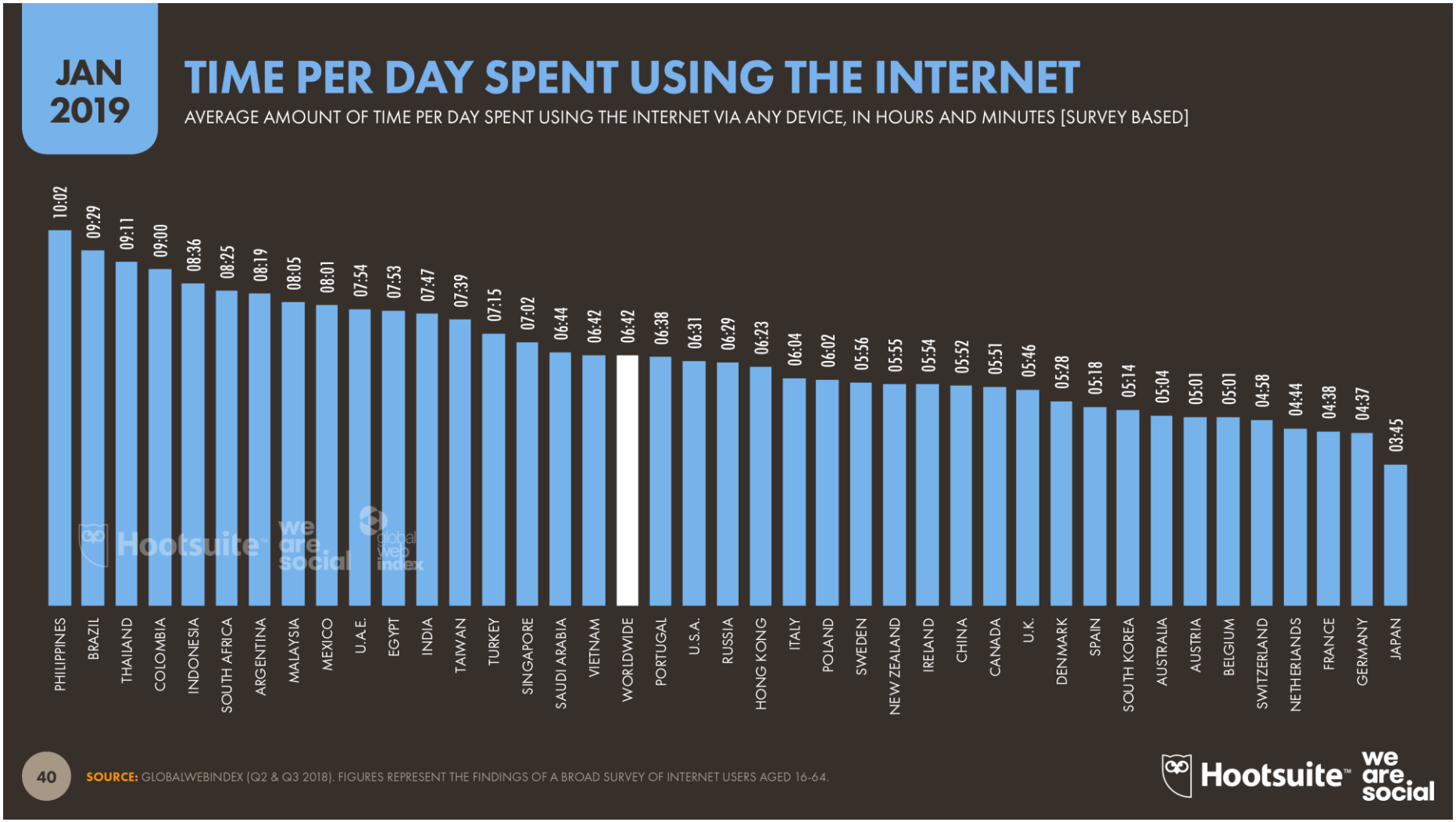
Challenges

- Higher initial cost in installation
- More expensive to repair
- Strength: Lower tensile strength
- Special training required



Photonics Communication

Photonics Communication



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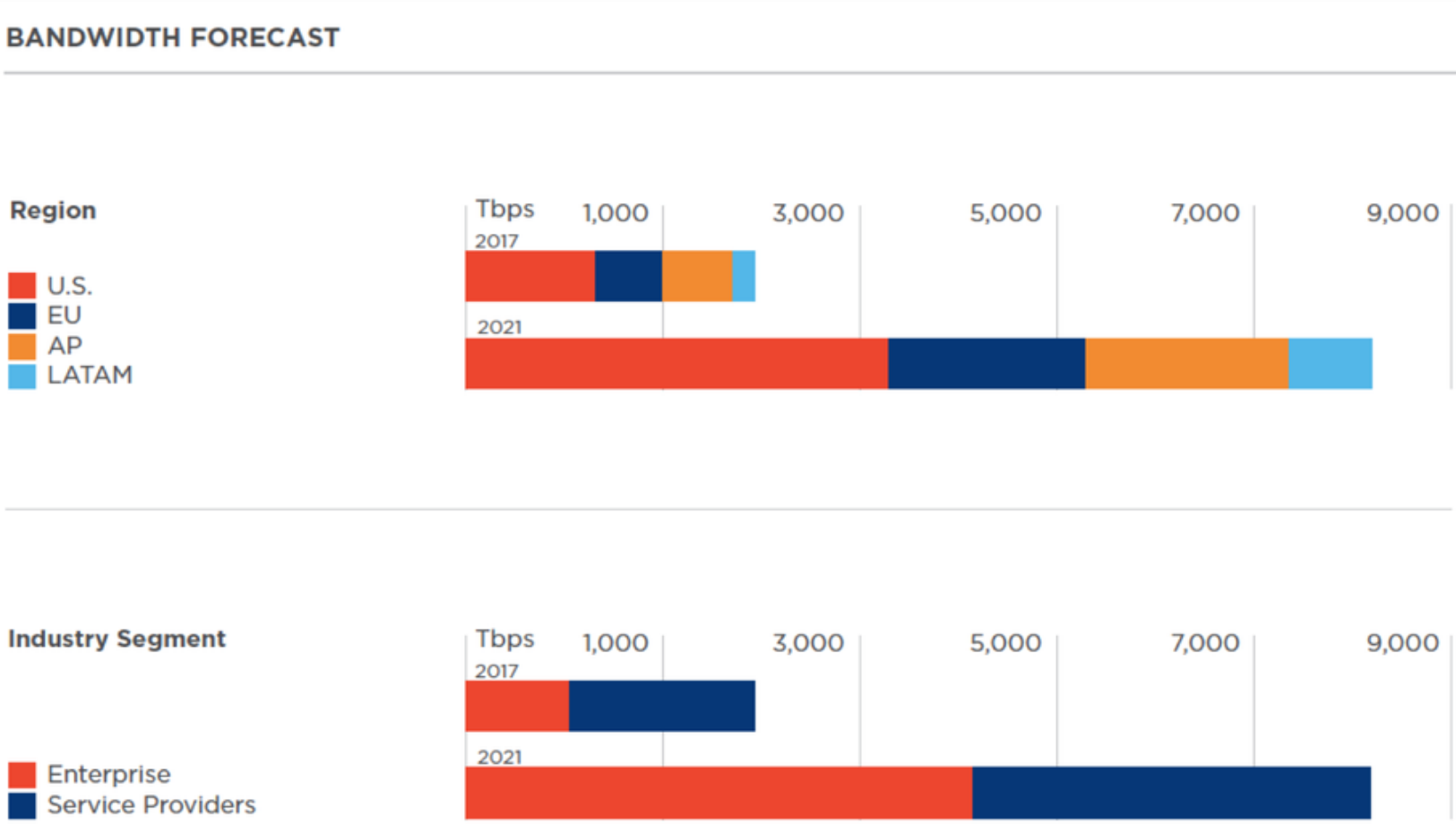
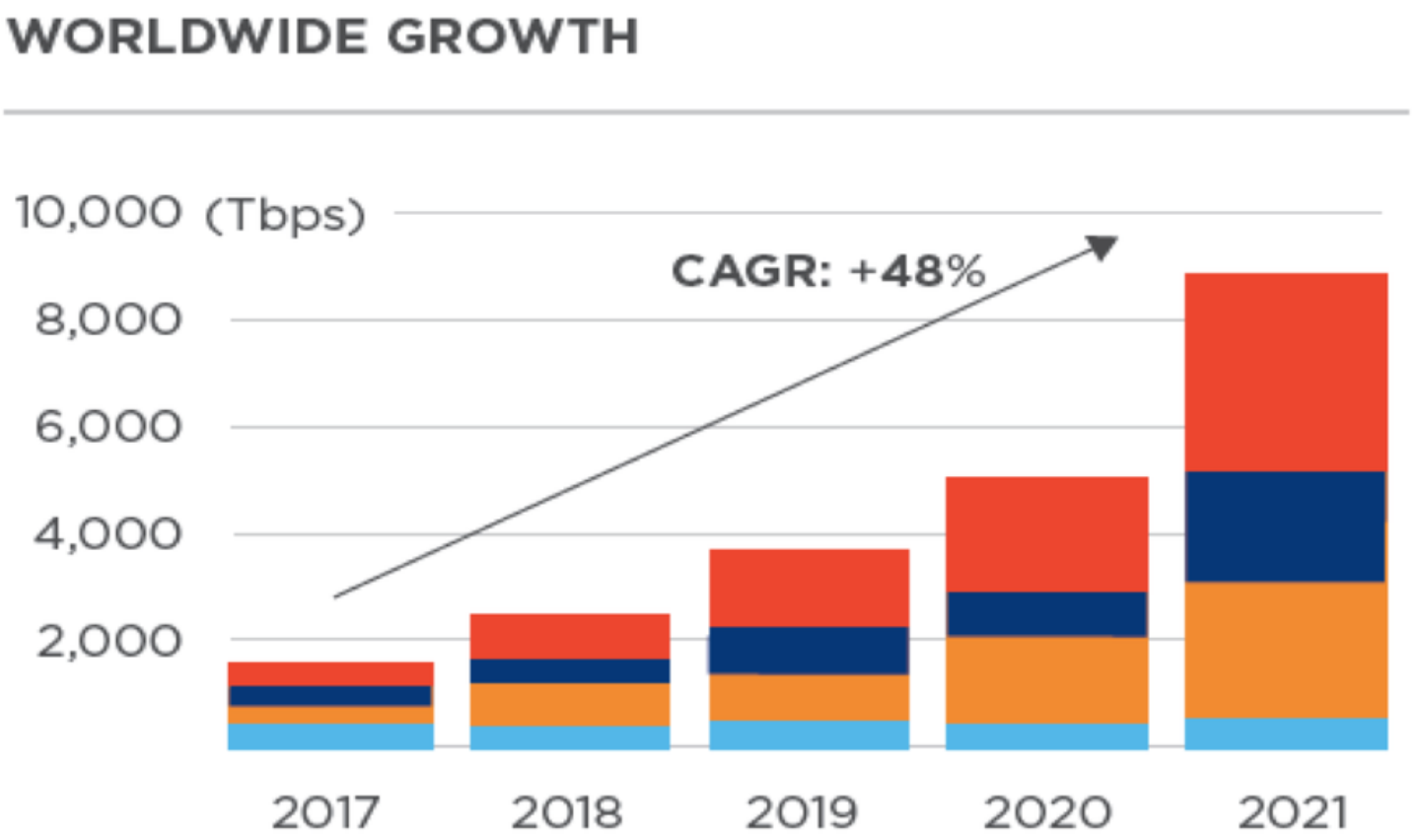


https://www.forbes.com/sites/tomcoughlin/2018/09/24/bandwidth-growth-drives-storage-demand/#6f8dbf05543b

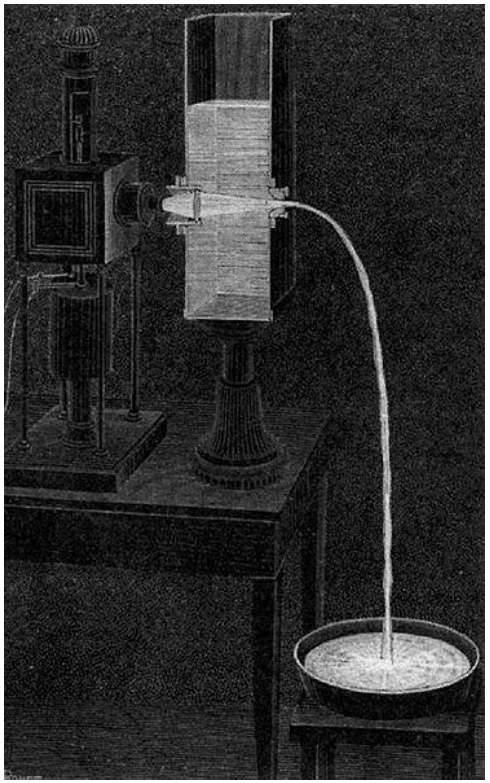
Photonics Communication



https://www.forbes.com/sites/tomcoughlin/2018/09/24/bandwidth-growth-drives-storage-demand/#6f8dbf05543b

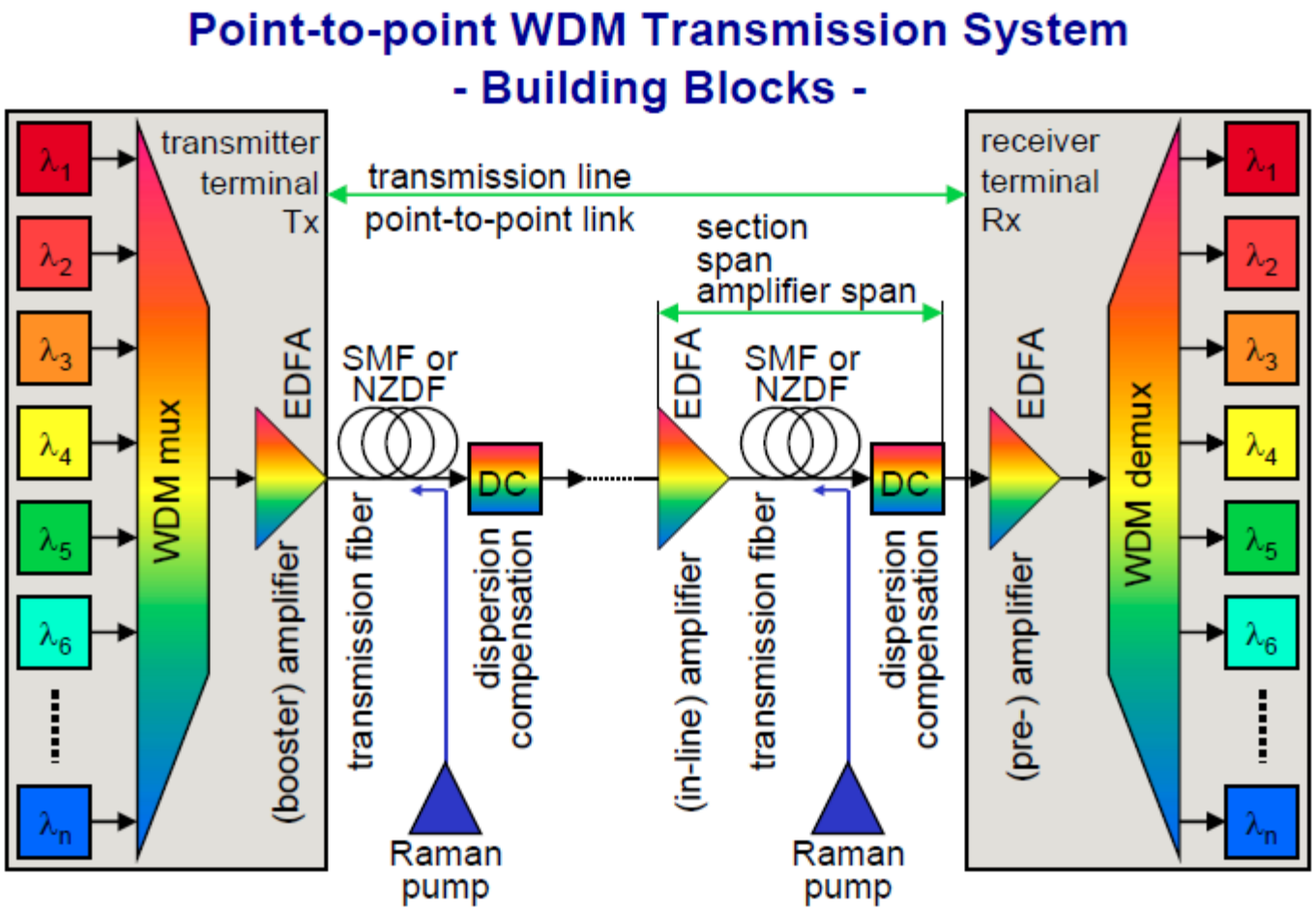
Brief history

1841: Daniel Colladon demonstrates light guiding in jet of water Geneva
1842: Jacques Babinet reports light guiding in water jets and bent glass rods Paris
1880: William Wheeler invents system of light pipes to illuminate homes from an electric arc lamp in basement, Concord, Mass.
January 2, 1954: Hopkins and Kapany and van Heel publish separate papers in Nature. Hopkins and Kapany report imaging bundles of unclad fibers; van Heel reports simple bundles of clad fibers
December 8, 1956: Curtiss makes first glass-clad fibers by rod-in-tube method
May 1961: Elias Snitzer of American Optical publishes theoretical description of single-mode fibers
July 1966: Kao and Hockham publish paper outlining their proposal in the Proceedings of the Institution of Electrical Engineers
Summer 1970: Maurer, Donald Keck, Peter Schultz, and Frank Zimar at Corning develop a single-mode fiber with loss of 17 dB/km at 633 nanometers by doping titanium into fiber core



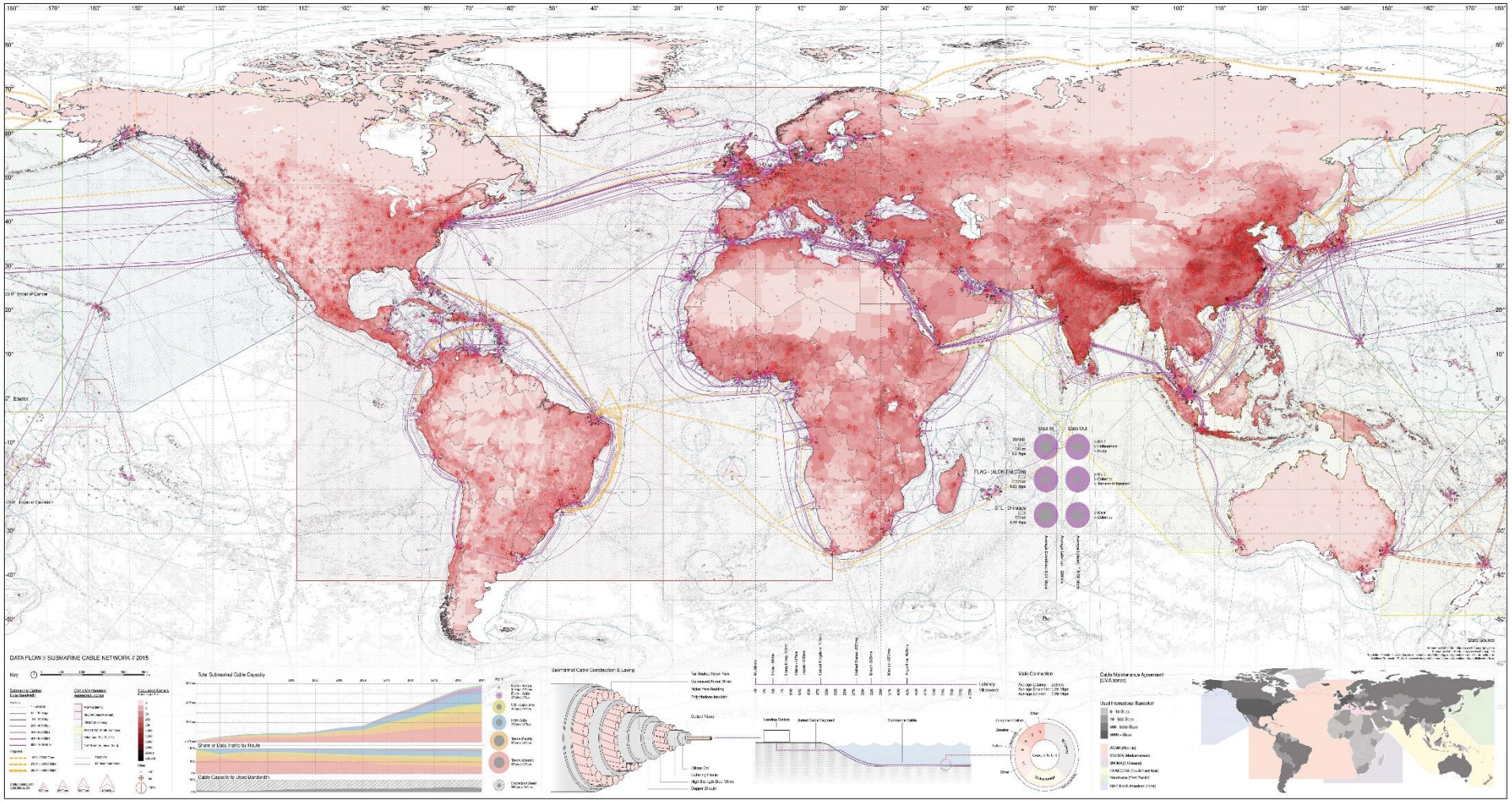
(credit: J. Hecht)

Fiber Optic Telecommunication



Optical fiber plays the central role!

Photonics Communication



https://www.businessinsider.com/map-the-worlds-network-of-undersea-cables-2017-8

Significant progress

The first trans-US communication system was completed in ~1915 (AT&T). Signals were transmitted through copper wires on wooden poles. There were 130,000 poles connecting New York and San Francisco.

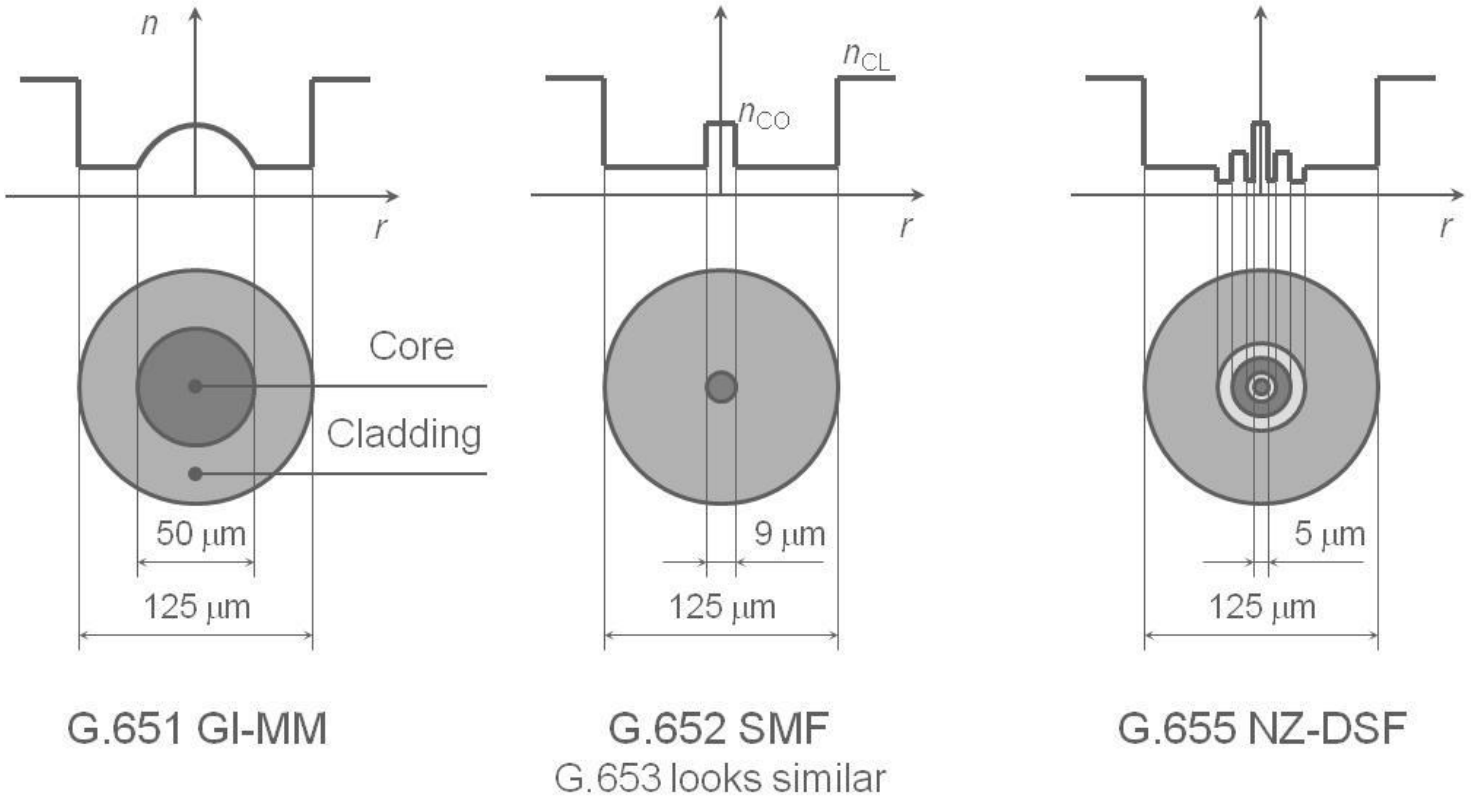
The cost of a 3 minutes phone call at that time was ~$20.7 (~$500 in today's money)

Source: Fagen, ed., A history of engineering and science in the Bell System, p264

Enabling technologies

- Low cost, reliable diode lasers
- Low loss optical fibers
- Transistors
- Amplifiers

Optical Fibers



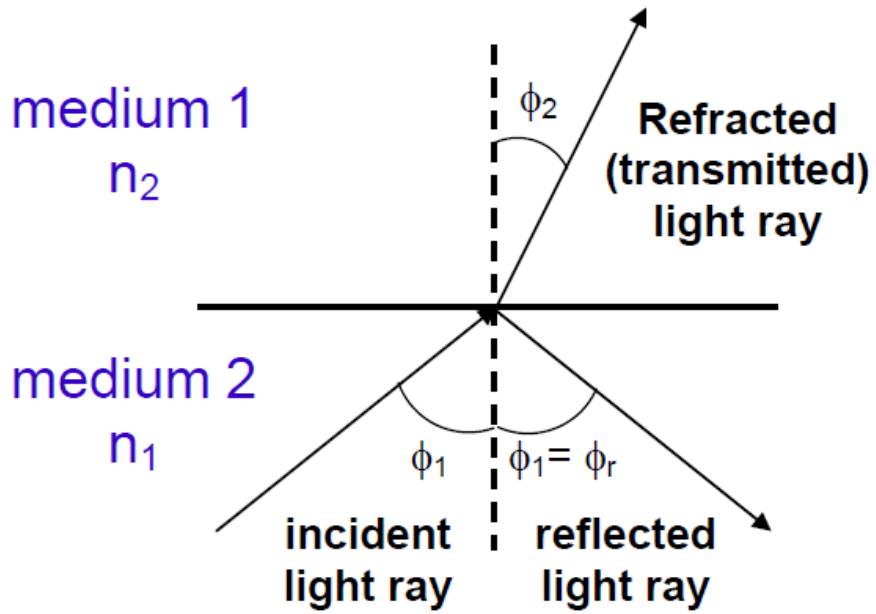
G.651 GI-MM

G.652 SMF
G.653 looks similar

G.655 NZ-DSF

Light is kept in the core by total internal reflection

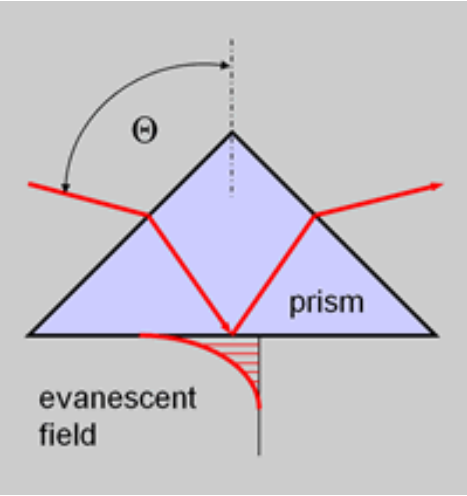
Total internal reflection

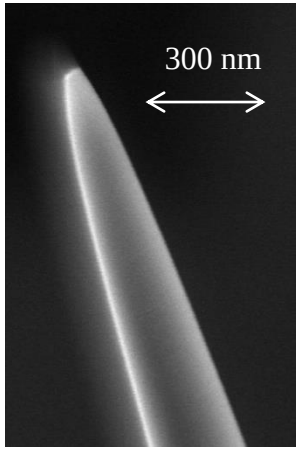


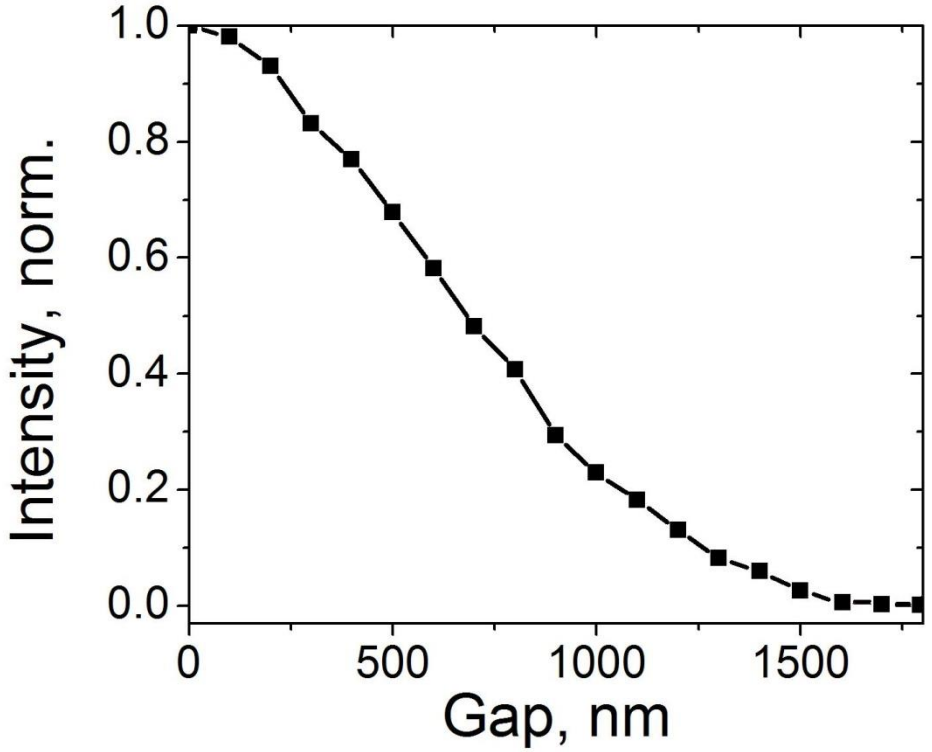
TIR happens at angles $\geq$ critical angle:

$$\sin(\phi_1) = n_2/n_1$$

Evanescent field

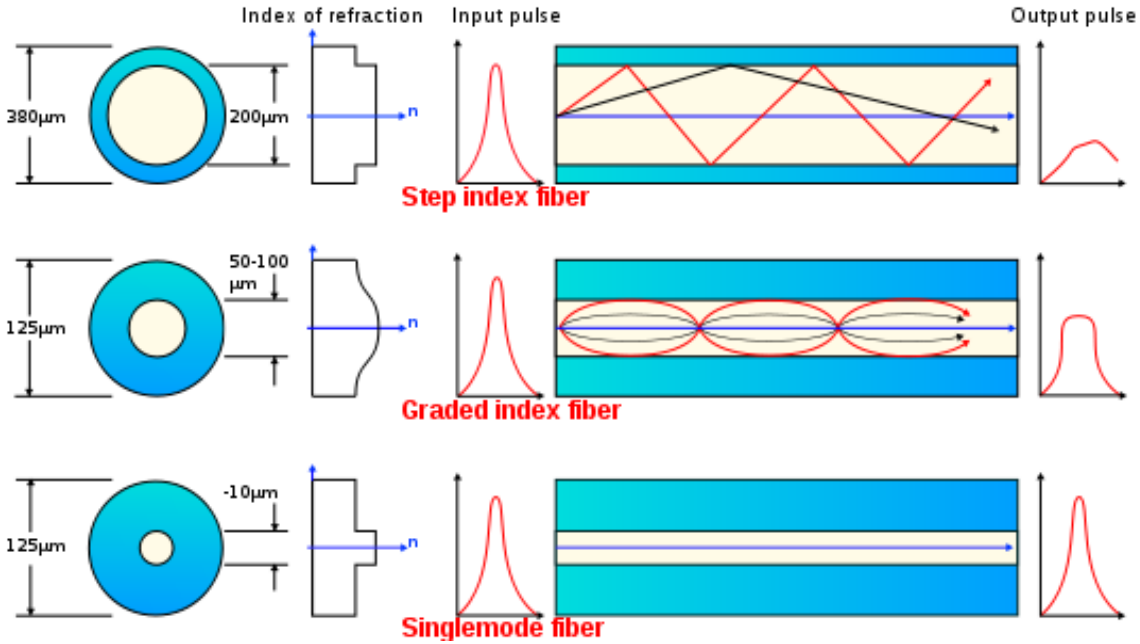




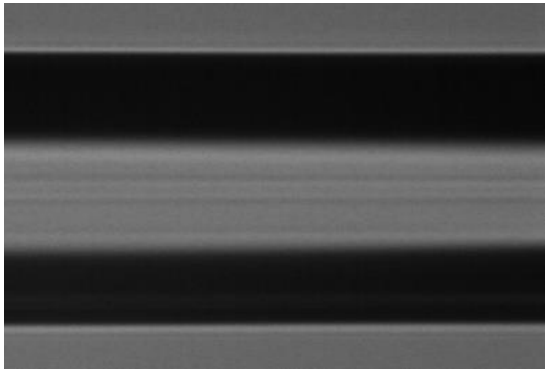


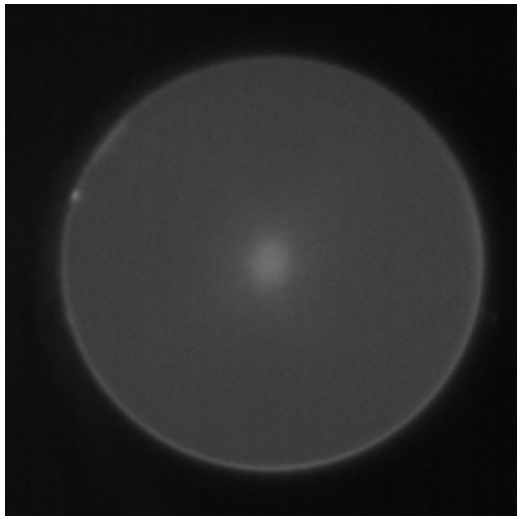
Measurement of the evanescent field using a near field optical probe

Fiber optics: Basics



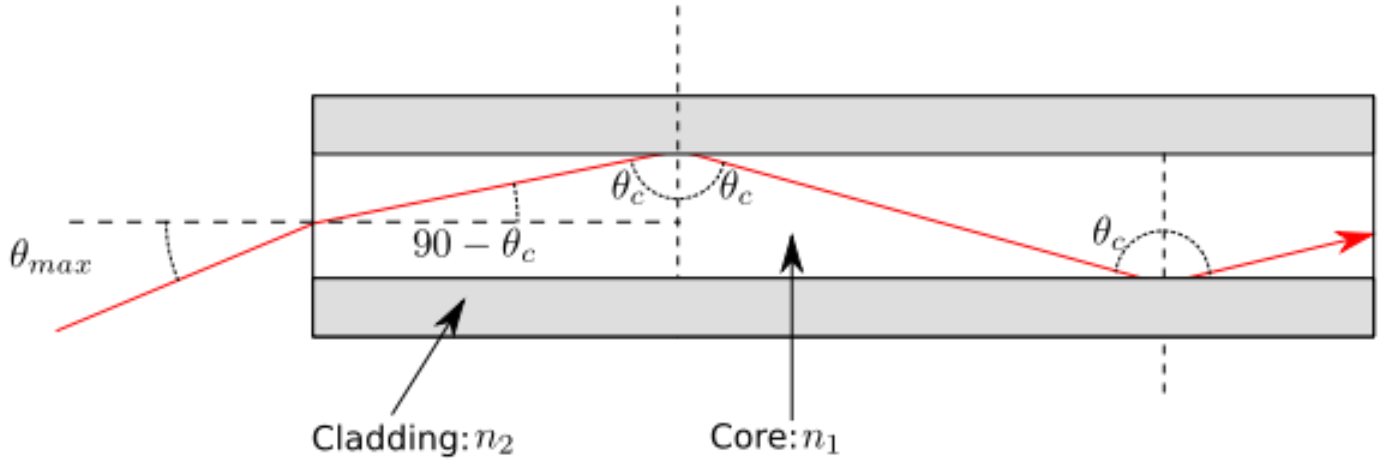
(http://en.wikipedia.org/)





- NA
- V number
- Core size, MFD
- Polarization maintaining or not polarization maintaining
- Dispersion

NA of an optical fiber

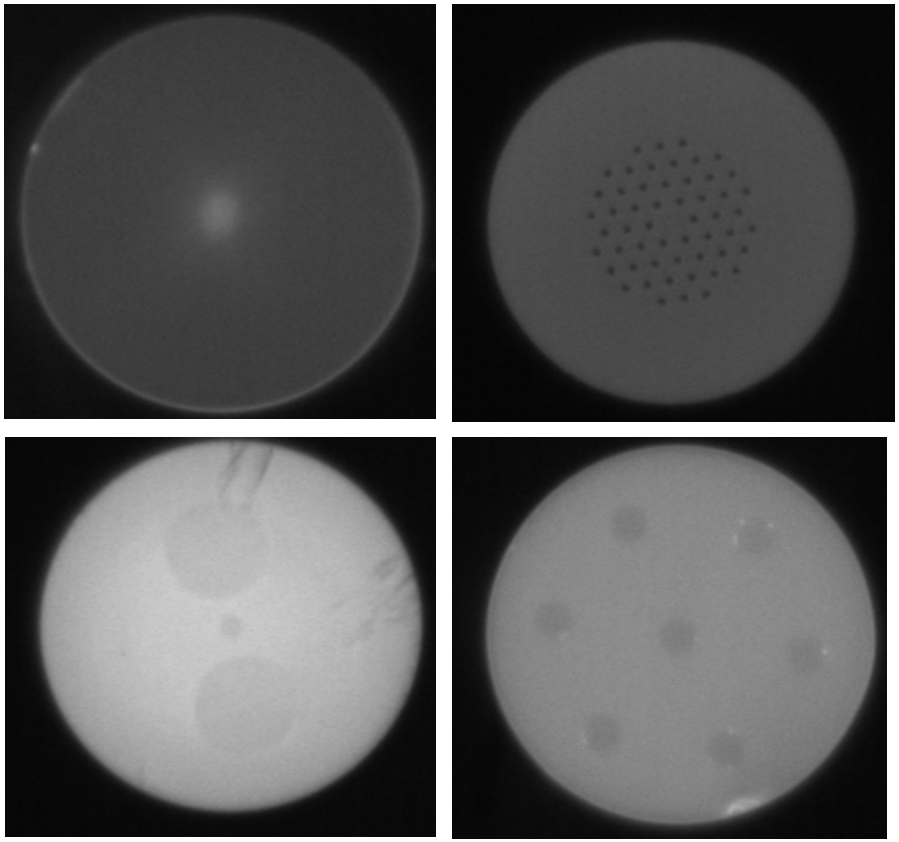


$$NA = (n_1^2 - n_2^2)^{1/2}$$

Fiber optics: Basics

Types of fiber by construction:

- step index
- graded index
- PM fiber
- photonic crystal fiber
- multi-core fiber



Types of fiber by functionality:

- passive fibers
- active fibers

Question for thoughts

- What is the smallest possible size of the core of an optical fiber?
- What is the smallest NA?
- Can you use Fresnel's law to measure the index difference between core and cladding of an optical fiber?
- What are the other techniques that can be used to measure NA?
- How can one make an optical fiber at home?
- What will happen in the next 10 (50) years in the field of fiber optics?