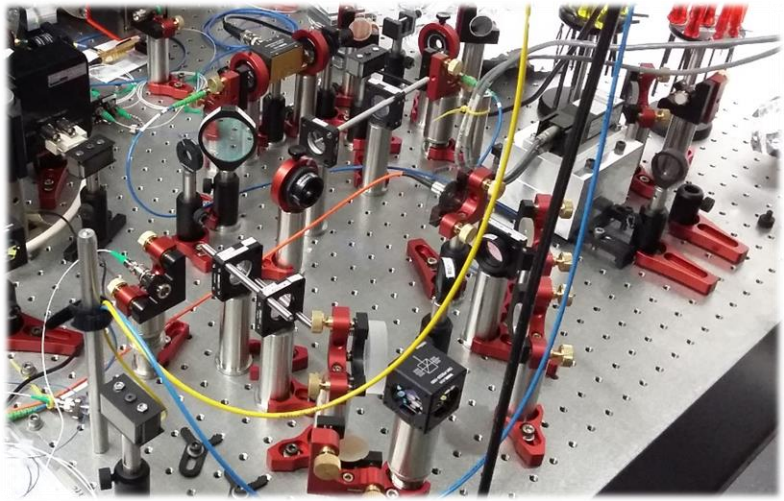
Waveguide Experiment – Hands-On Optical Fibers

Relevance of Optical Fibers

Fiber-optic communication -
“Information Age”

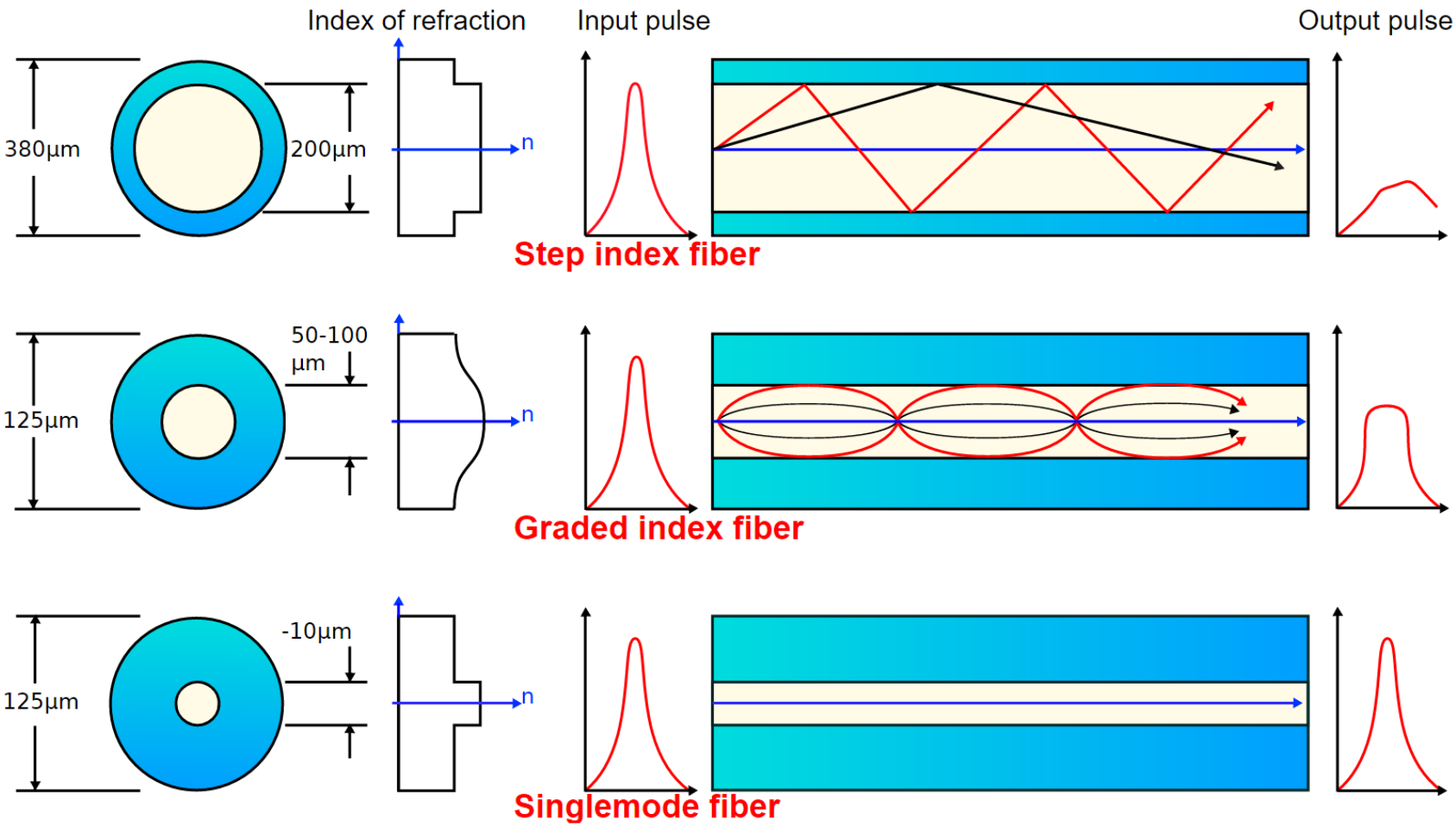
- Used for Phone, TV, Internet
- Low losses: < 0.3 dB/km (scattering & absorption)
- High bandwidth (record in 2012: 1 Pbit/s with a 12 core fiber over 50 km)
- No crosstalk



Fiber-optics -
research and development

- Compact setups with low maintenance
- Improved stability of experiments
- Fibers as mode cleaners/filters

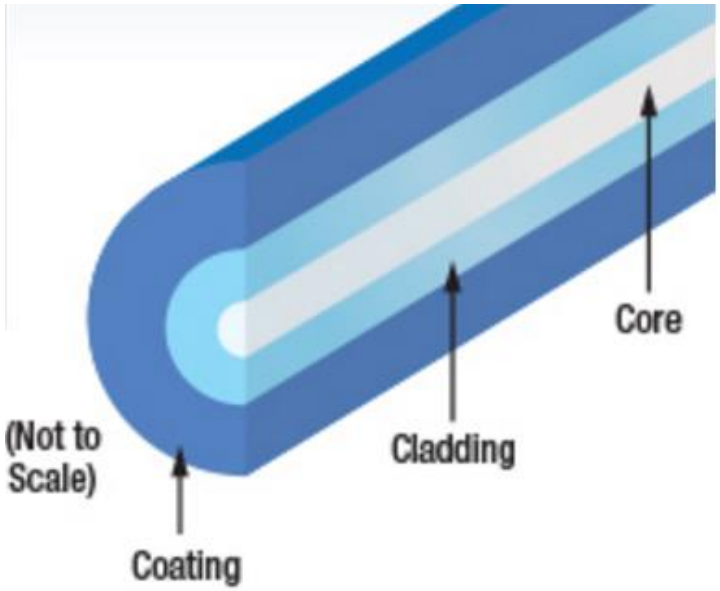
Different Types of Fibers



Different Types of (Step-Index) Fibers

- Multi-mode fiber
  - Cheap
  - Core $> 50\ \mu m$
  - Easy to couple light in
  - Problem: multi-mode distortion via transvers modal dispersion & polarization mode dispersion
- Single-mode fiber
  - More expensive due to high precision fiber connectors
  - Core $< 10\ \mu m$
  - Hard to couple light in (mode matching)
  - More reliable, higher bandwidth for communication

Our Single-Mode Fiber SM450 (Thorlabs) for 532 nm Light



Single Mode Fiber Cross Section

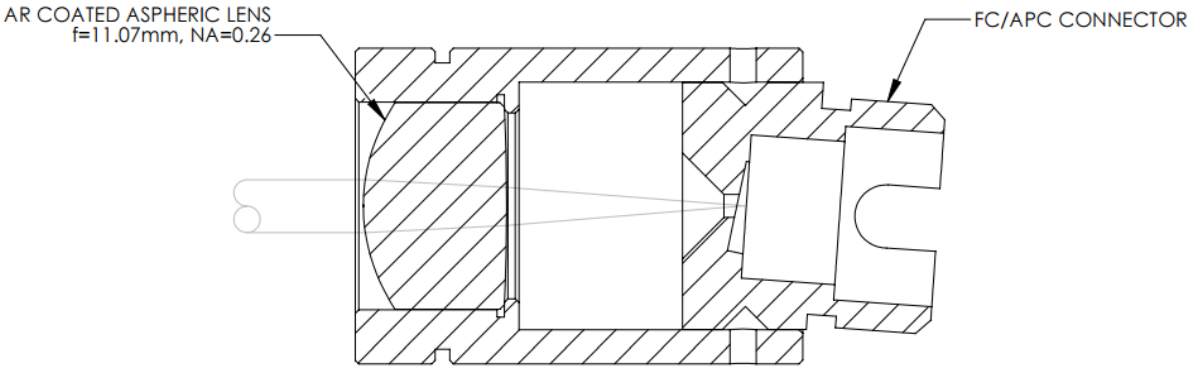
Our Single-Mode Fiber SM450 (Thorlabs) for 532 nm Light

Specifications

Geometrical & Mechanical	
Cladding Diameter	125 ± 1.0 µm
Coating Diameter	245 ± 15 µm
Core-Cladding Concentricity	≤0.75 µm
Coating-Cladding Offset	≤5 µm
Coating Material	Dual Acrylate
Proof Test Level	1%, 2%, or 3% (100, 200, or 300 kpsi)
Operating Temperature	-55 to 85 °C

Optical	
Numerical Aperture (Nominal)	0.10 - 0.14
Attenuation[1]	≤50 dB/km @ 488 nm
Operating Wavelength[2]	488 - 633 nm
Cut-Off Wavelength	350 - 470 nm
Mode Field Diameter[3]	2.8 - 4.1 µm @ 488 nm

Launching Light Into a Single-Mode Fiber – Gaussian Beam Optics



$$\mathrm{NA}_{\mathrm{fiber}} = \frac{2\lambda}{0.82\pi\ \mathrm{MFD}} \qquad MFD = 2w_0^{(\mathrm{fiber})} \qquad w_0^{(\mathrm{collimator})} = f \times \frac{NA_{\mathrm{fiber}}}{1.22}$$

Mode matching efficiency:

$$\eta = \frac{\left| \int E^*_{\mathrm{fiber}} E_{\mathrm{collimator}}\, dA \right|^2}{\int |E_{\mathrm{fiber}}|^2 dA \int |E_{\mathrm{collimator}}| dA} \approx \left(\frac{2w_{\mathrm{collimator}} w_{\mathrm{beam}}}{w^2_{\mathrm{collimator}} + w^2_{\mathrm{beam}}} \right)^2$$

References & Sources

1. https://en.wikipedia.org/wiki/Fiber-optic_communication
2. https://upload.wikimedia.org/wikipedia/commons/0/0e/Optical_fiber_types.svg
3. http://www.thorlabs.de/thorcat/12600/SM450-SpecSheet.pdf
4. http://www.thorlabs.de/thorcat/21900/F220APC-780-AutoCADPDF.pdf
5. Joyce, W. B., & DeLoach, B. C. (1984). Alignment of Gaussian beams. *Applied Optics*, *23*(23), 4187. http://doi.org/10.1364/AO.23.004187