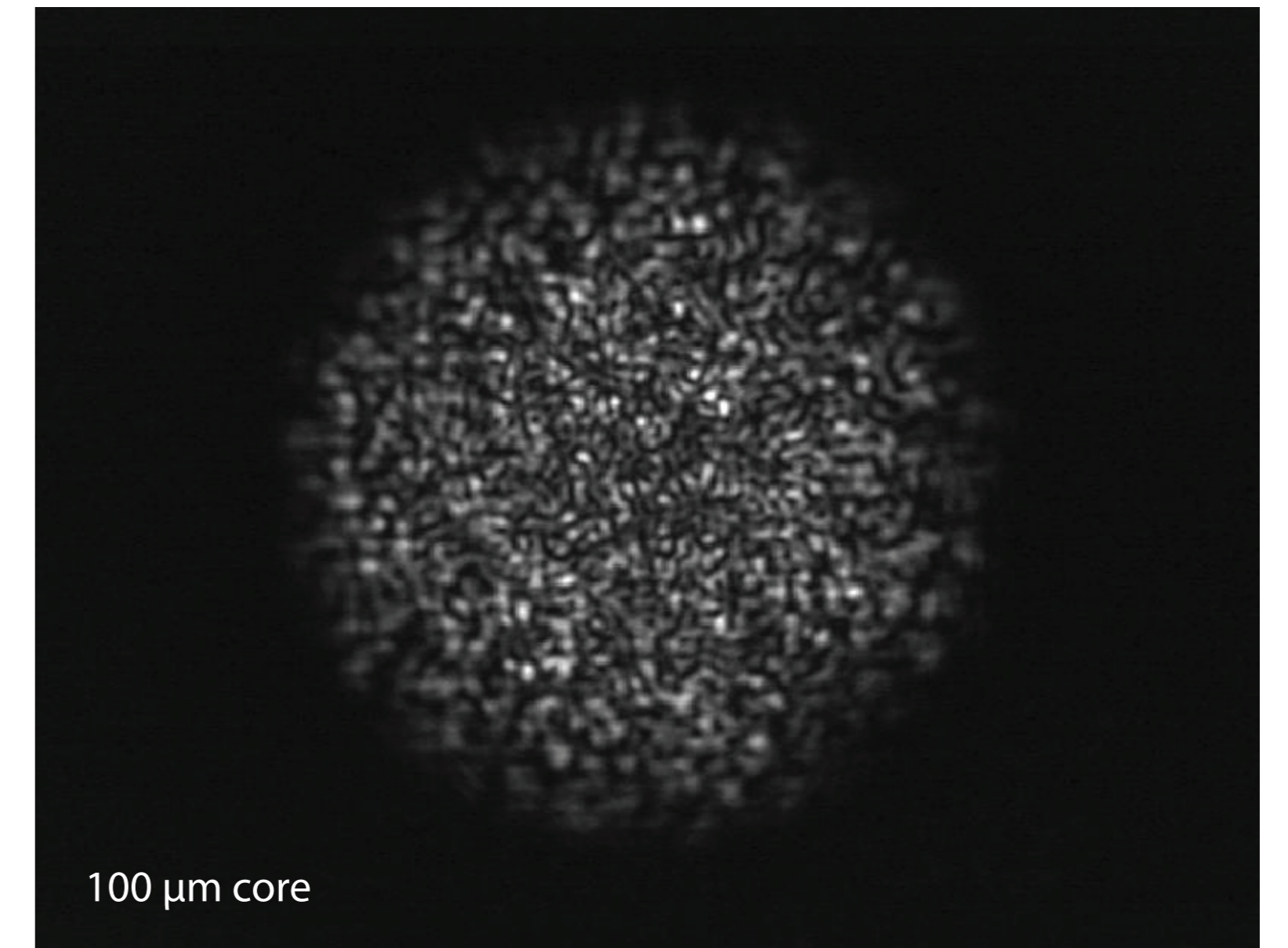
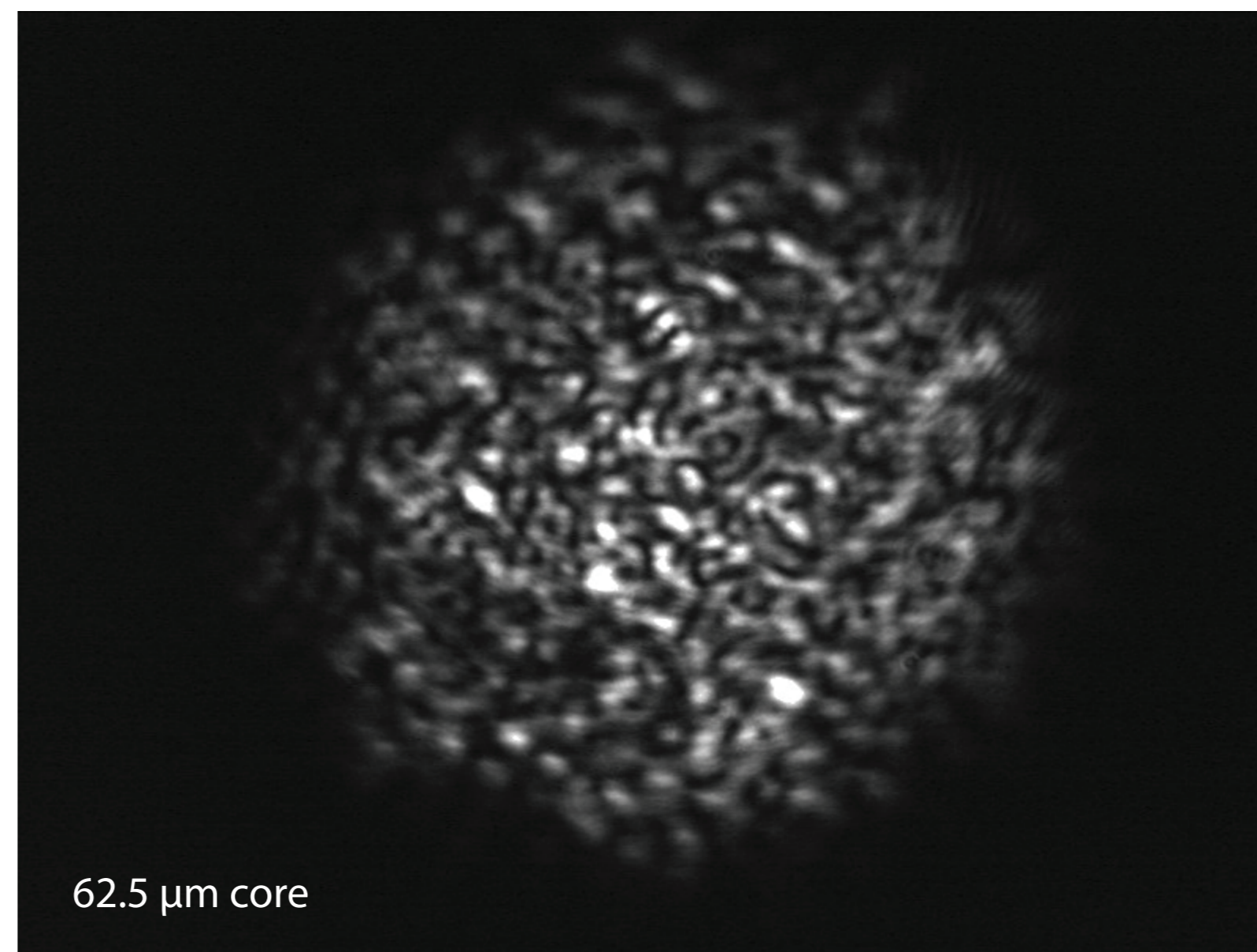
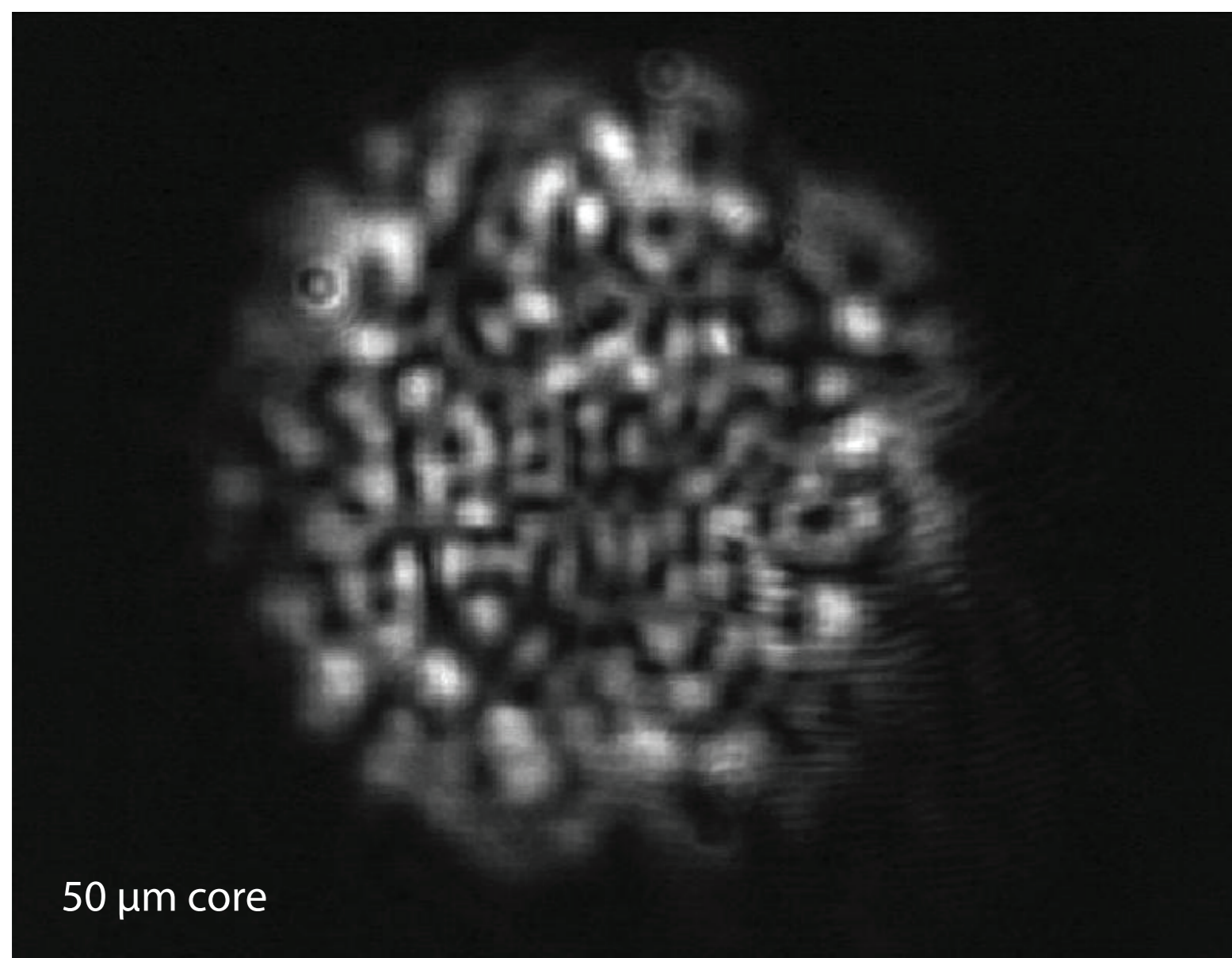


Renata Bartula, Ben Conrad, and Scott T. Sanders

cite as: R. J. Bartula, B. L. Conrad, and S. T. Sanders, "Estimation of Noise Induced by Multimode Optical Fibers in Optical Sensor Systems," poster presented at the Gordon Research Conference on Laser Diagnostics for Combustion, Oxford, United Kingdom, 8 August 2007 (<http://digital.library.wisc.edu/1793/28229>).

Pictures of light transmitted through MMF

Approximately collimated beams, 770 nm input wavelength:



• Larger fibers (and/or larger fiber NA values) result in more speckles, smaller speckles

Introduction to multimode fiber noise

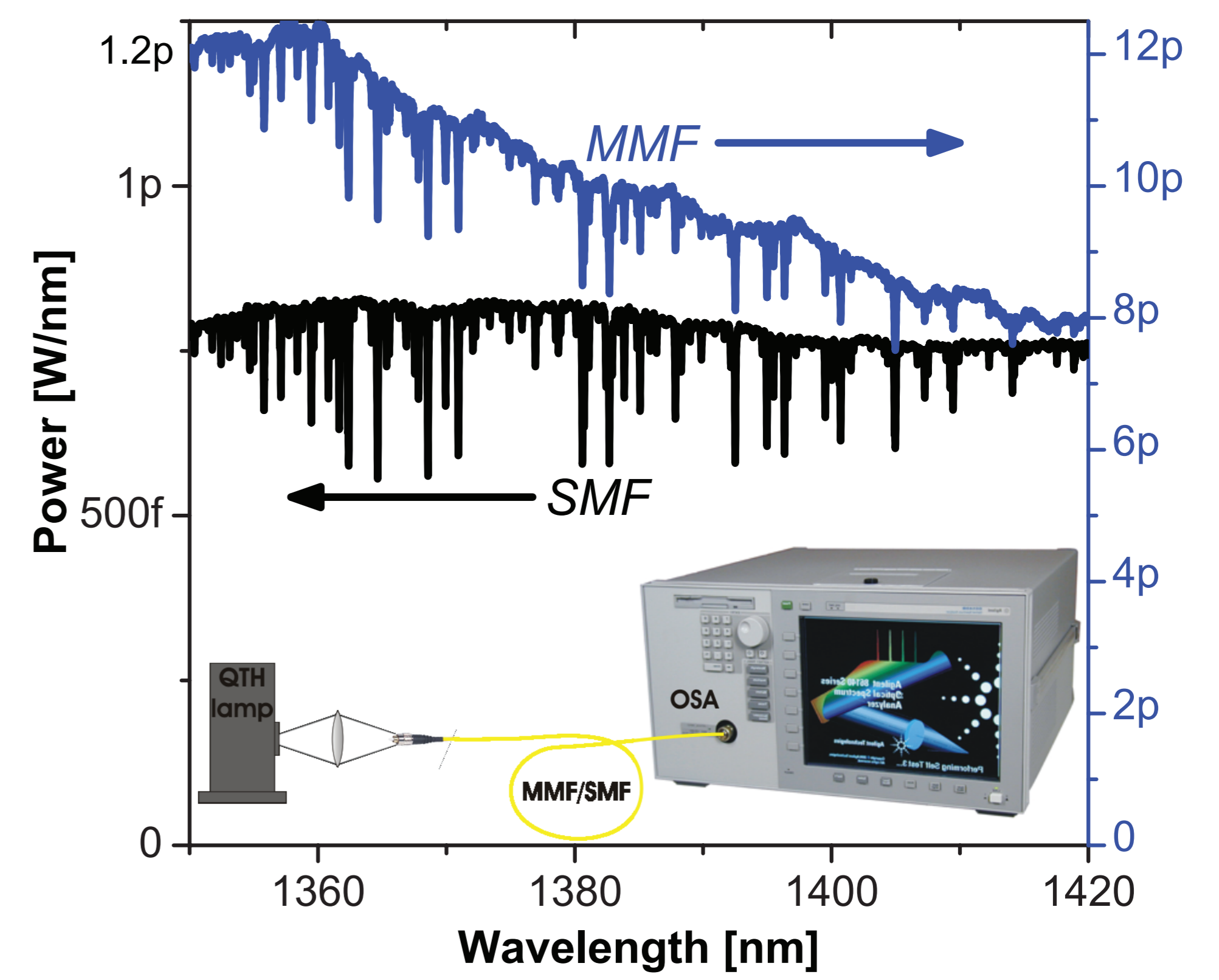
Experiment goals:

- Measure ambient H₂O absorption in the 1350 -1420nm range

Experimental arrangement:

- Quartz Tungsten Halogen lamp one-to-one imaged onto the experimental fiber using a high NA lens
- Experimental fiber (MM/SM) coupled to the optical spectrum analyzer
- OSA settings:
 - resolution = 0.06 nm
 - data = 8750 points
 - sensitivity = -93.98 dBm
- Optical input at the OSA was short SMF patchcord

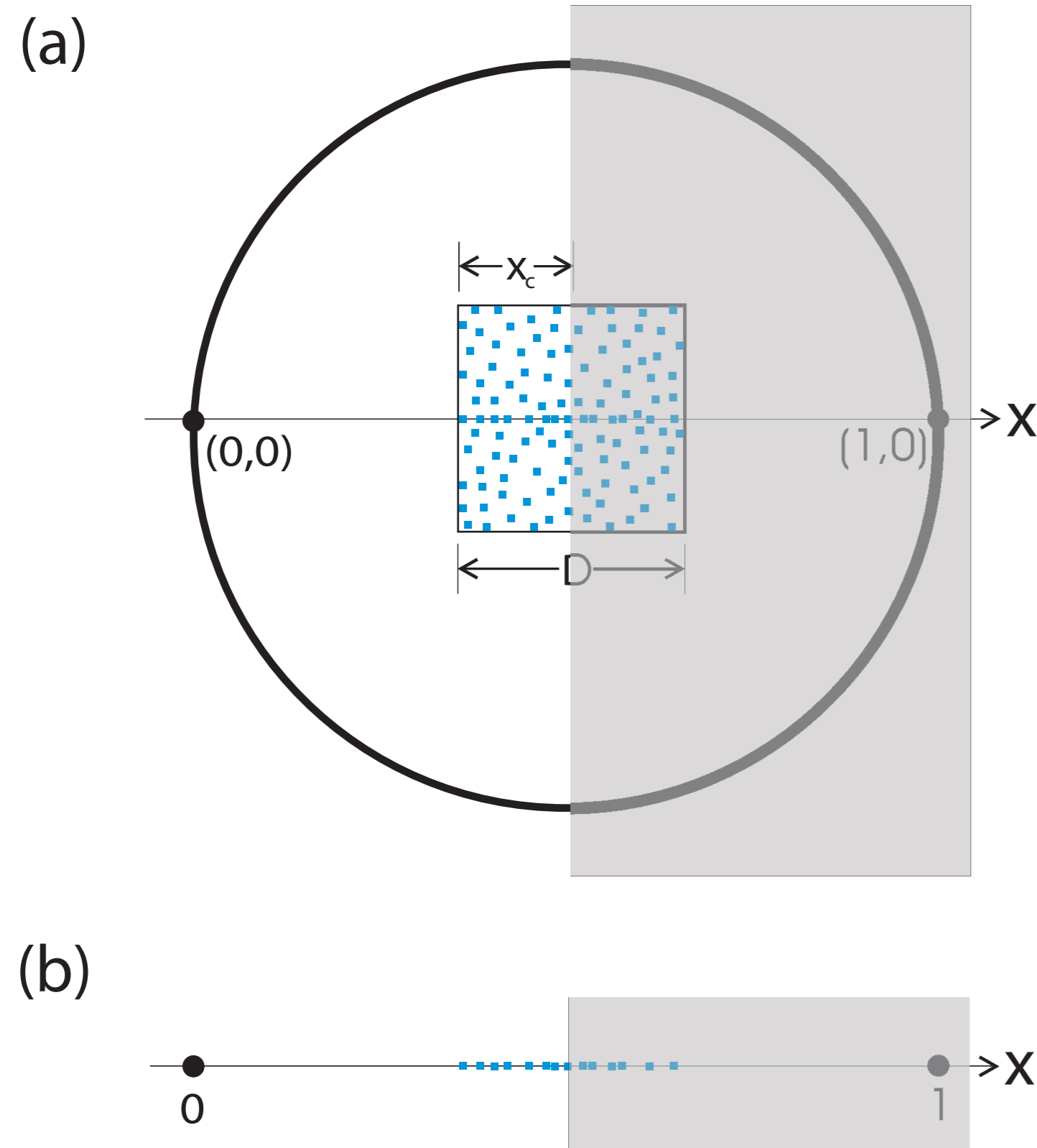
Multimode versus single mode fiber performance results:



• MMF collects more power, but introduces 'mode noise'

Quantification of mode noise

Problem set-up:



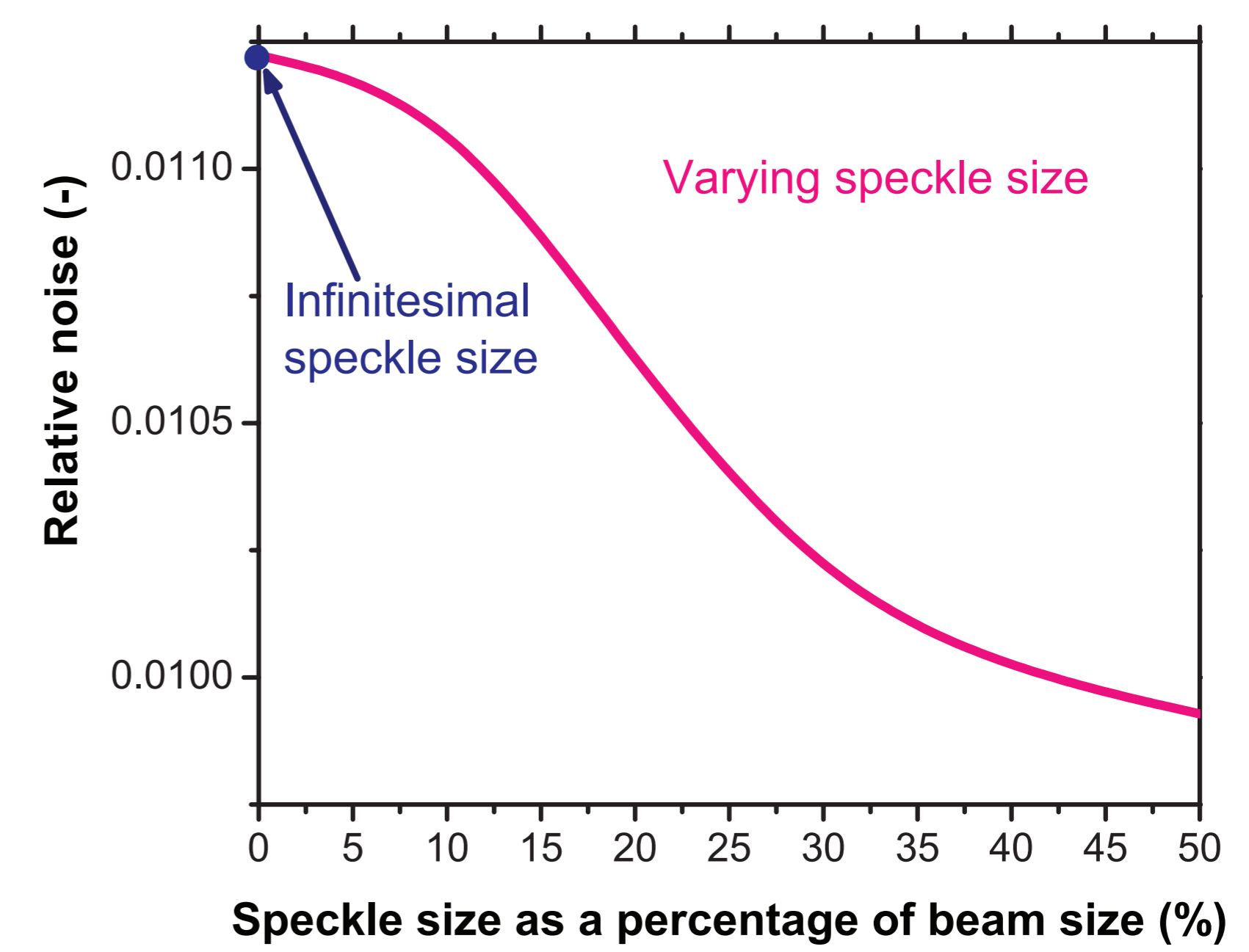
(a) Multimode beam of size DxD incident upon a large perfect detector. The gray box represents a source of obscuration.

(b) The 2-D problem is converted into a 1-D problem.

Assumptions:

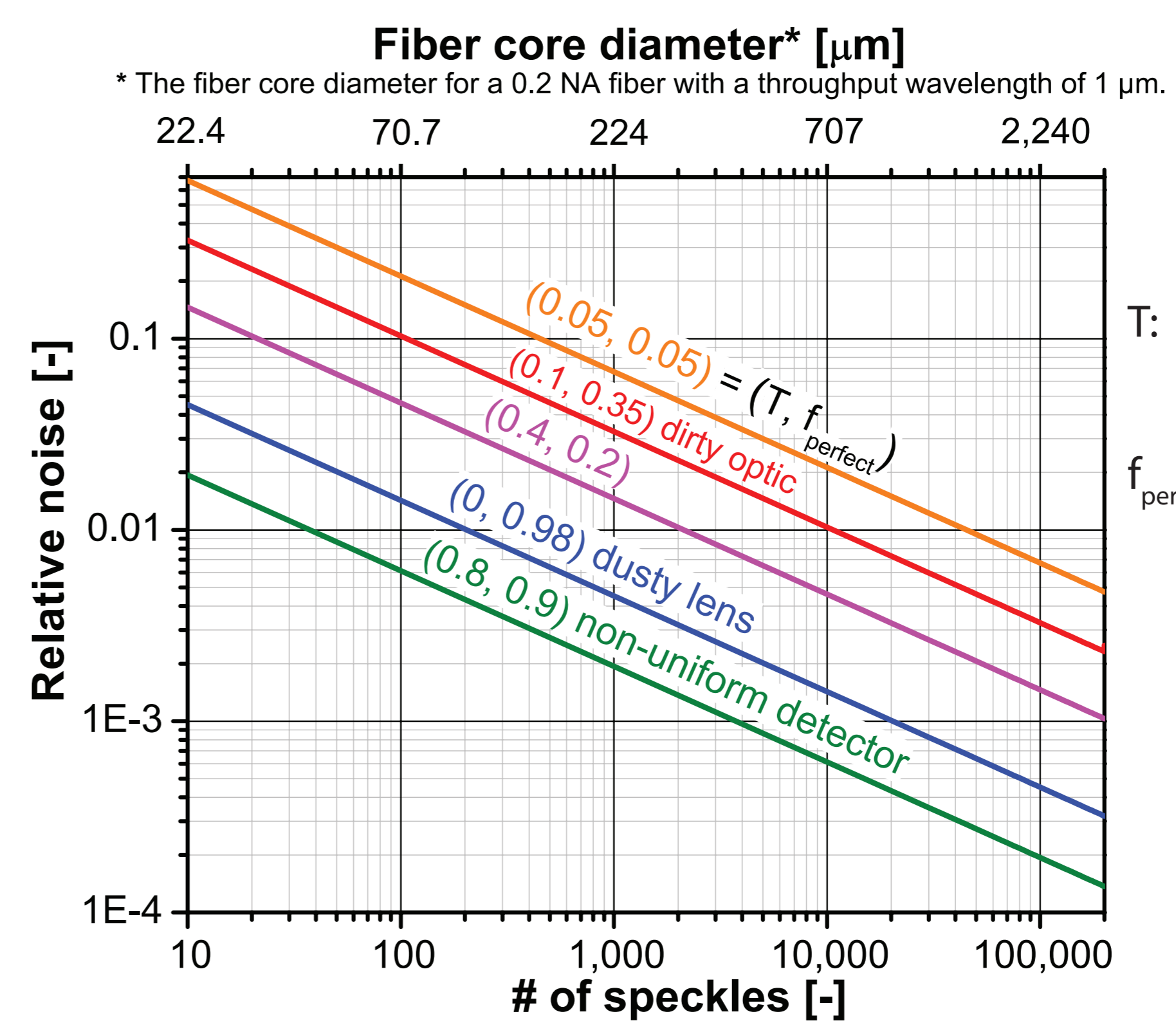
- Fully filled mode condition
- Multimode fiber incident upon a large perfect detector of any shape
- Detector much larger than incident beam
- Detector responsivity perfectly uniform
- Multimode beam composed of numerous speckles
- Speckles are infinitely small

Speckle size assumption verification:



• Infinitesimal spot size assumption valid in most situations

Results of the study, for selected practical situations:



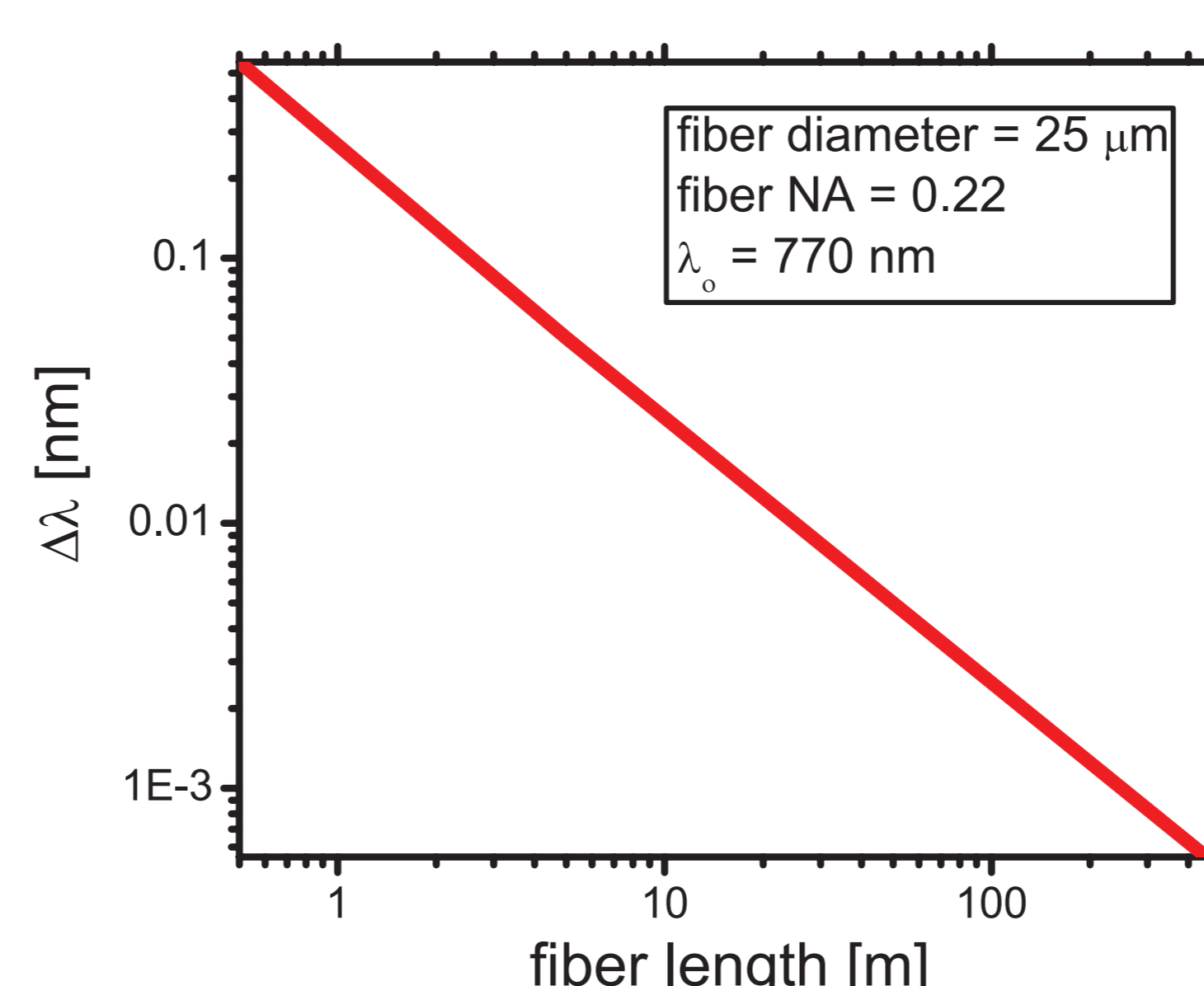
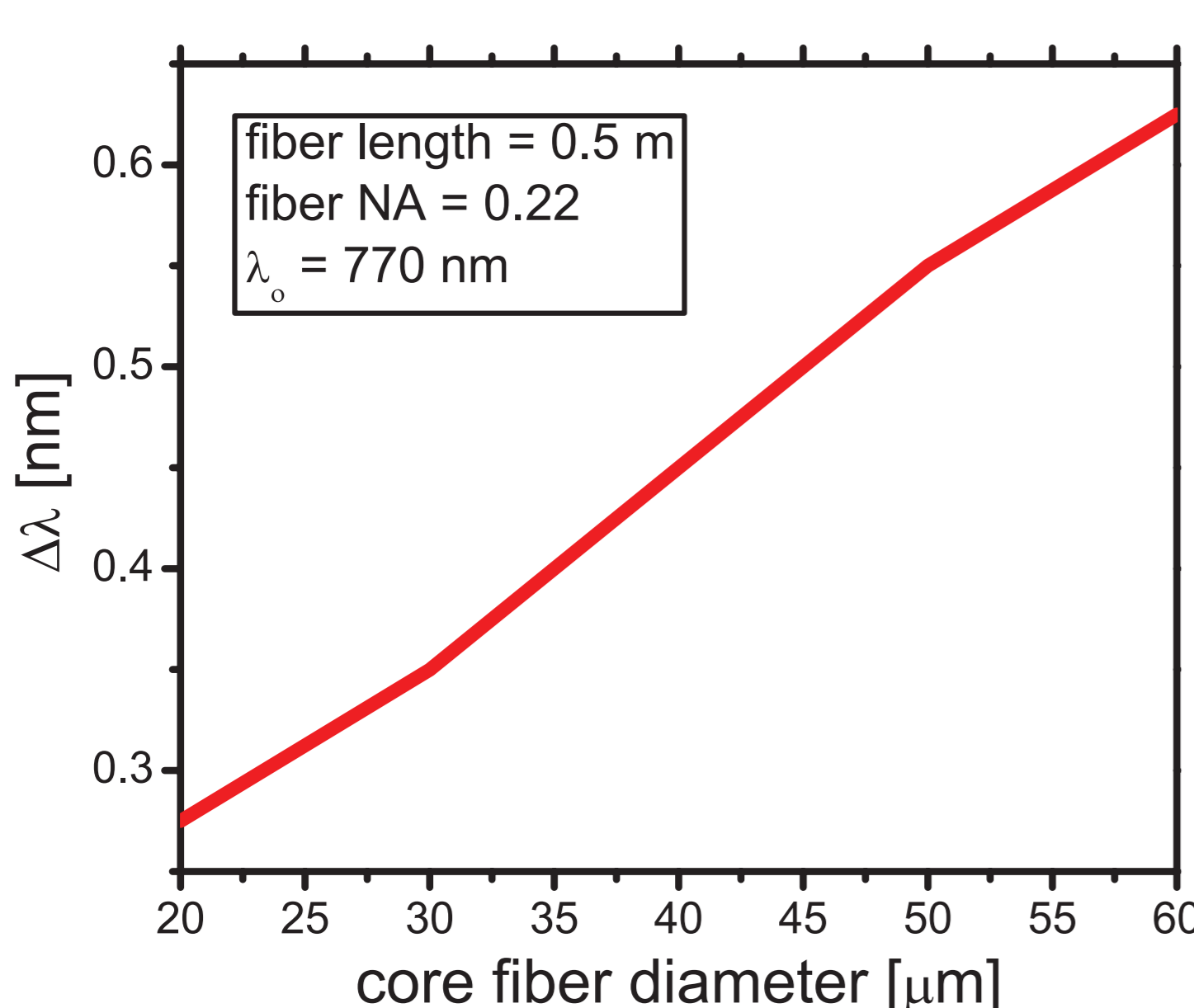
T: transmission through the source of obscuration

f_{perfect}: fraction of area that is perfect or unmasked

• Key conclusion: large fiber has lower mode noise

Spectral averaging to remove mode noise

$\Delta\lambda$ represents the change in wavelength that causes the speckles to move to new positions; it is computed using a cross-correlation.



• $\Delta\lambda$ is especially small for long fibers; this means a small change in input wavelength produces a new speckle pattern. If one averages over many speckle patterns (using polychromatic light in the MMF), mode noise is reduced.

Conclusions

To minimize multimode fiber noise use:

1. Single- or few-mode fibers (in these cases, mode noise is spectrally smooth)
2. Large core diameter fibers (in these cases, there are so many speckles that the noise becomes small)
3. Long fibers transmitting broadband light, ultimately measured with low spectral resolution (in these cases, mode noise is reduced by spectral averaging)