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Searching for Higher Order Cladding Modes in Fiber Optic Based Optical Levers

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Outline

- Optical Lever System
- Single Mode Optical Fibers
- Fiber Modes
- Beam Propagation
- Results

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Optical Lever System

- Diode laser
- Coupled to single-mode optical fiber
- Projected through telescope, reflected off test mass and onto quadrant photodiode
- Max telescope throw 66m

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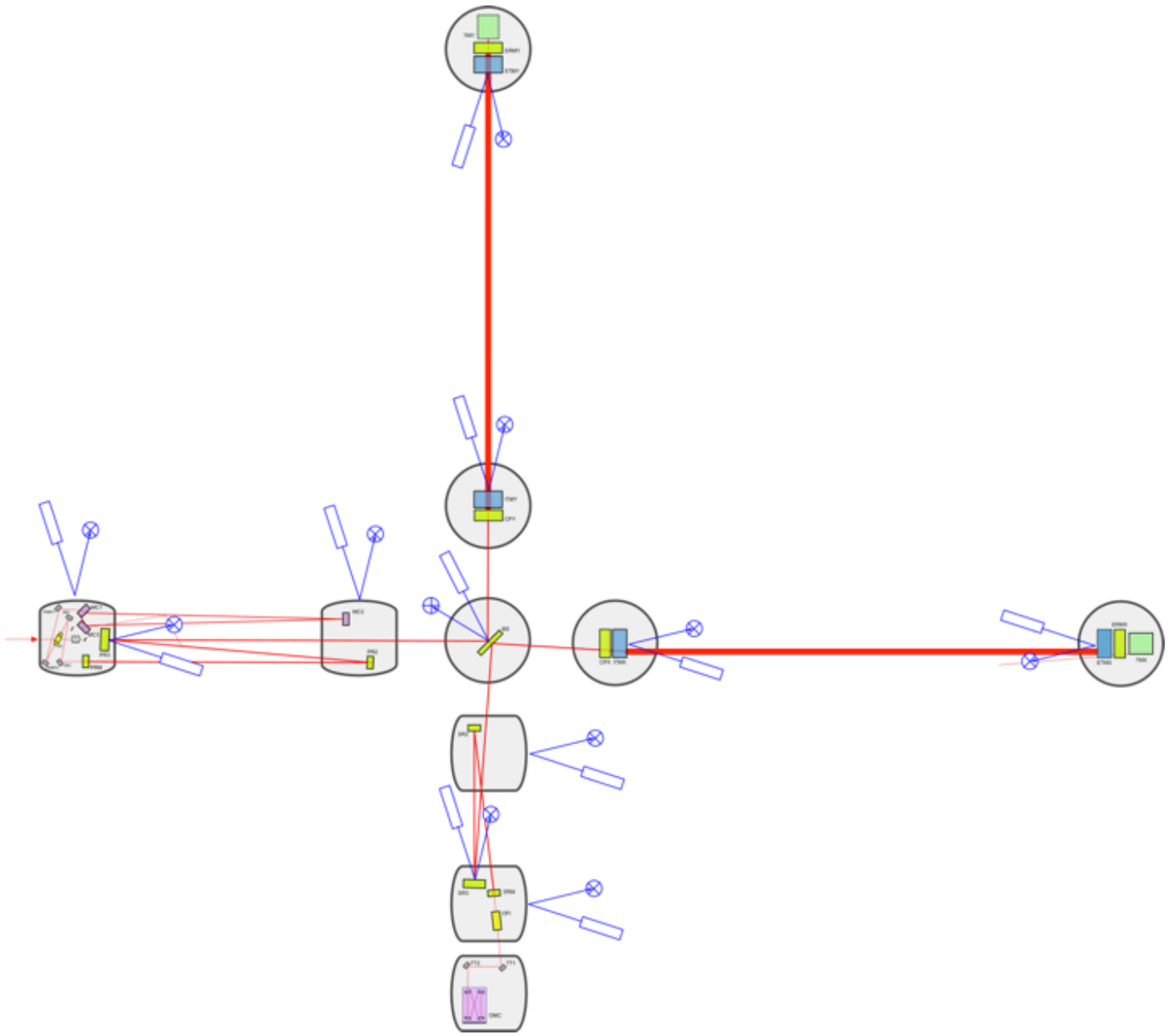
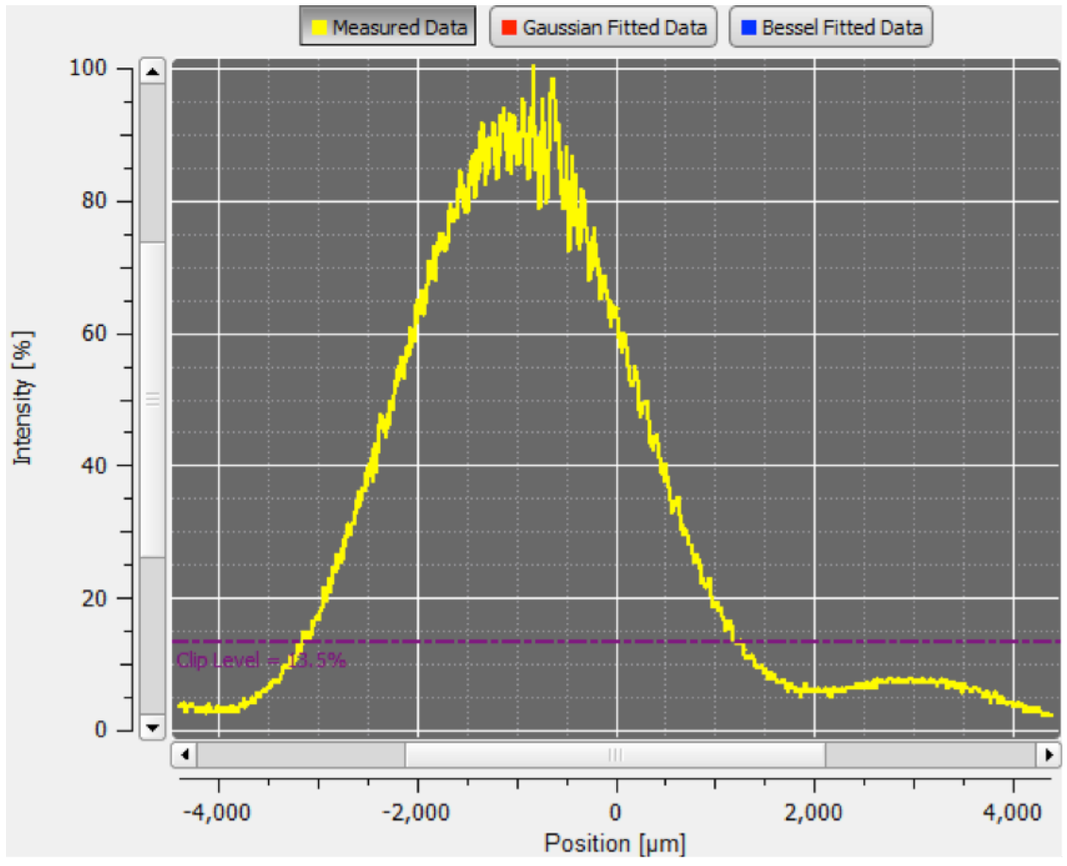
Optical Lever System



Optical Lever System Problems

- Power shift associated with change in pointing of beam
- Ring at about 3-4% power



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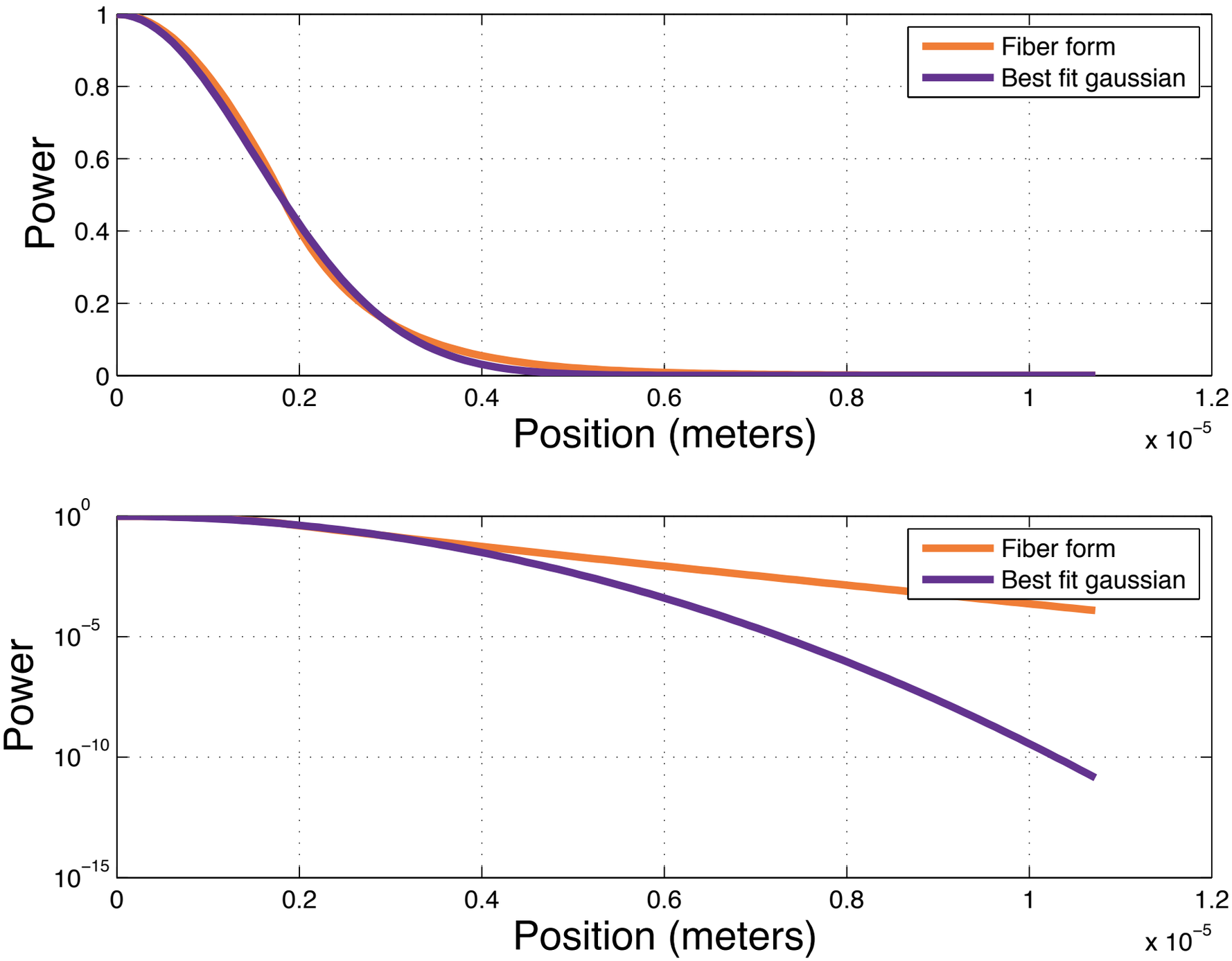
Single Mode Optical Fiber

- Light only transmitted down the fiber (single mode)
- V number $V = \frac{2\pi}{\lambda} a \sqrt{n_{core}^2 - n_{cladding}^2} = \frac{2\pi}{\lambda} a \mathrm{NA}$
- V < 2.405 for single-mode (ours ~2.08)
- Fiber mode

$$H_{x0} = -\sqrt{2/\pi}(\epsilon_0/\mu_0)^{1/4} \frac{W}{aV J_1(U)} \sqrt{n_2 P} \begin{cases} J_0(U\frac{r}{a}) & : r \le a \\ \frac{J_0(U)}{K_0(W)} K_0(W\frac{r}{a}) & : r \ge a \end{cases}$$

Fiber Modes


Power
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
1.2
Position (meters)
x 10^-5
Fiber form
Best fit gaussian
Power
10^0
10^-5
10^-10
10^-15
0
0.2
0.4
0.6
0.8
1
1.2
Position (meters)
x 10^-5
Fiber form
Best fit gaussian

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Beam Propagation

- Propagating gaussian remains gaussian, can use ABCD propagation methods
- Propagating fiber form changes
- Use Hankel transform method to propagate fiber profile through free space and lenses

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Searching for Higher Order Fiber Modes

- Use beam profiler to look at output of fiber
- Hard to look at output — large angle of divergence out of fiber
- Take two sets of data, saturating the beam profiler to see into the wings
- Look at output of fiber both directly and through a lens with short focal length

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Searching for Higher Order Fiber Modes

- Take fiber profile from beam profiler
- Propagate through free space and any lenses, compare with propagated theoretical fiber form
- Compare fiber in multiple physical orientations, with a different laser

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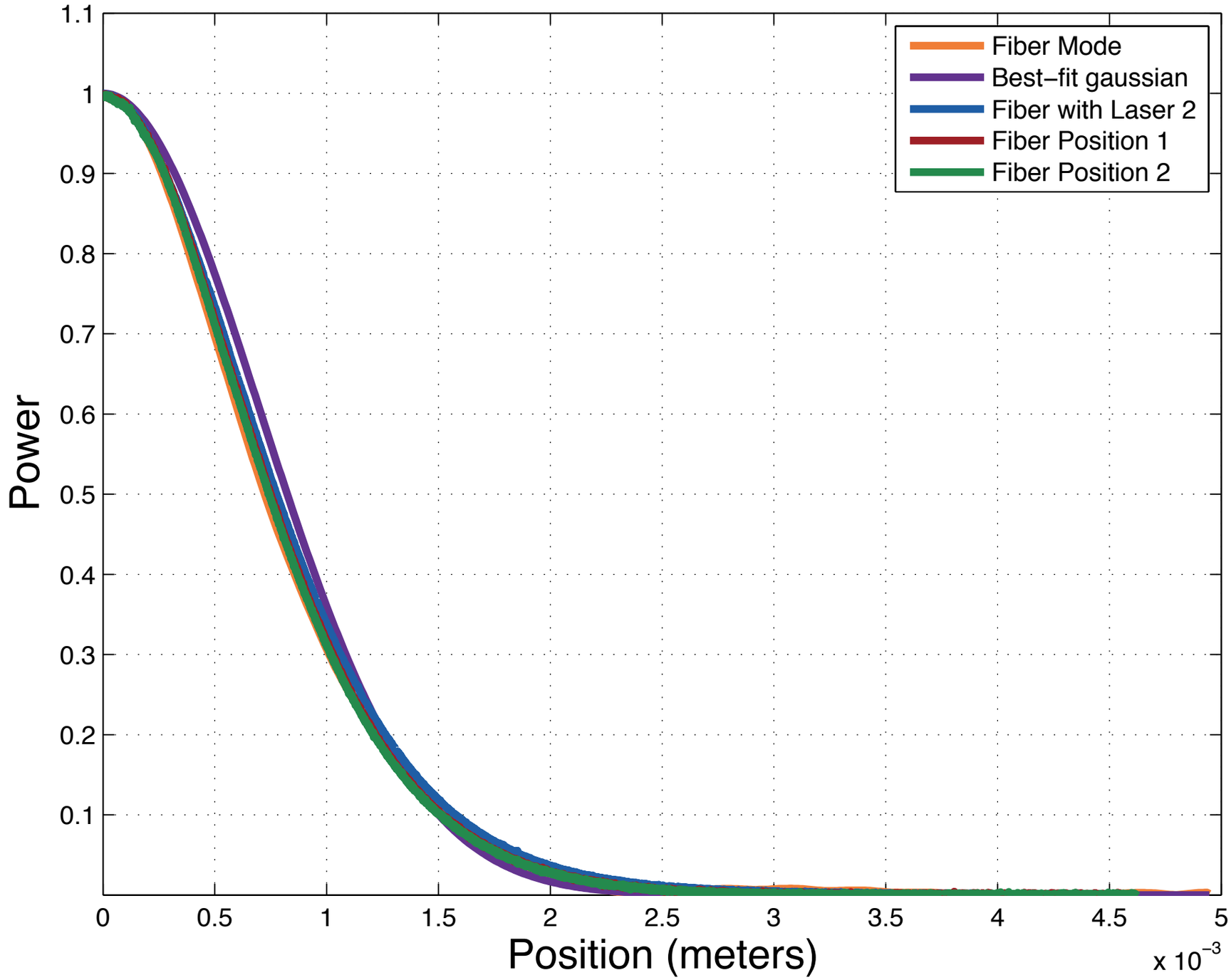
Comparing Fiber Modes



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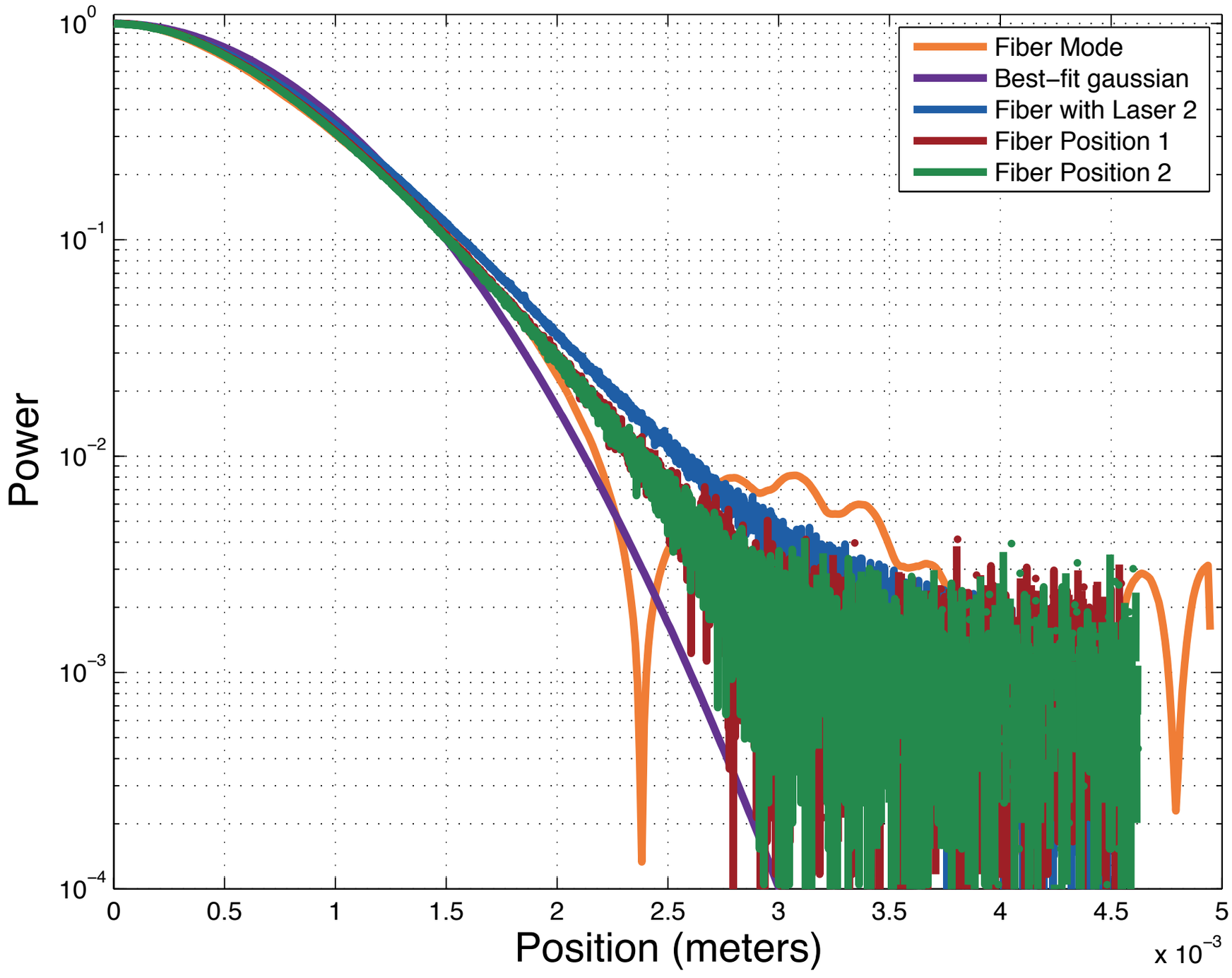
Comparing Fiber Modes



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Fiber Mode Results

- The fiber laying in different positions doesn't alter its profile
- Changing the laser doesn't change much either
- It appears that higher order fiber modes aren't affecting the optical lever system

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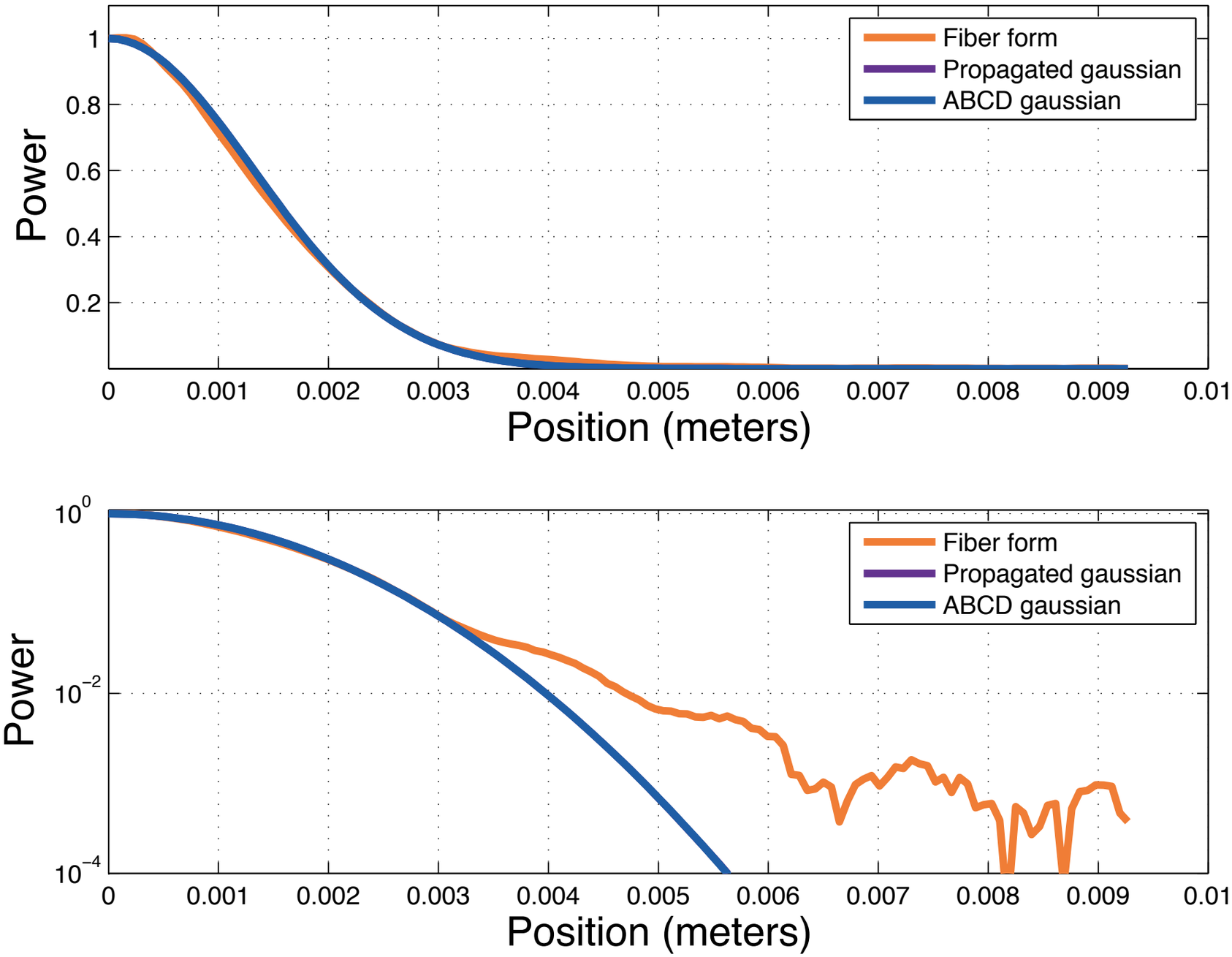
Searching for the Ring

- Use same beam propagation to simulate telescope
- Propagate fiber profile and gaussian to see if ring pattern occurs
- If lens clips the beam, diffraction might occur, causing ring

Searching for the Ring at 66 meters



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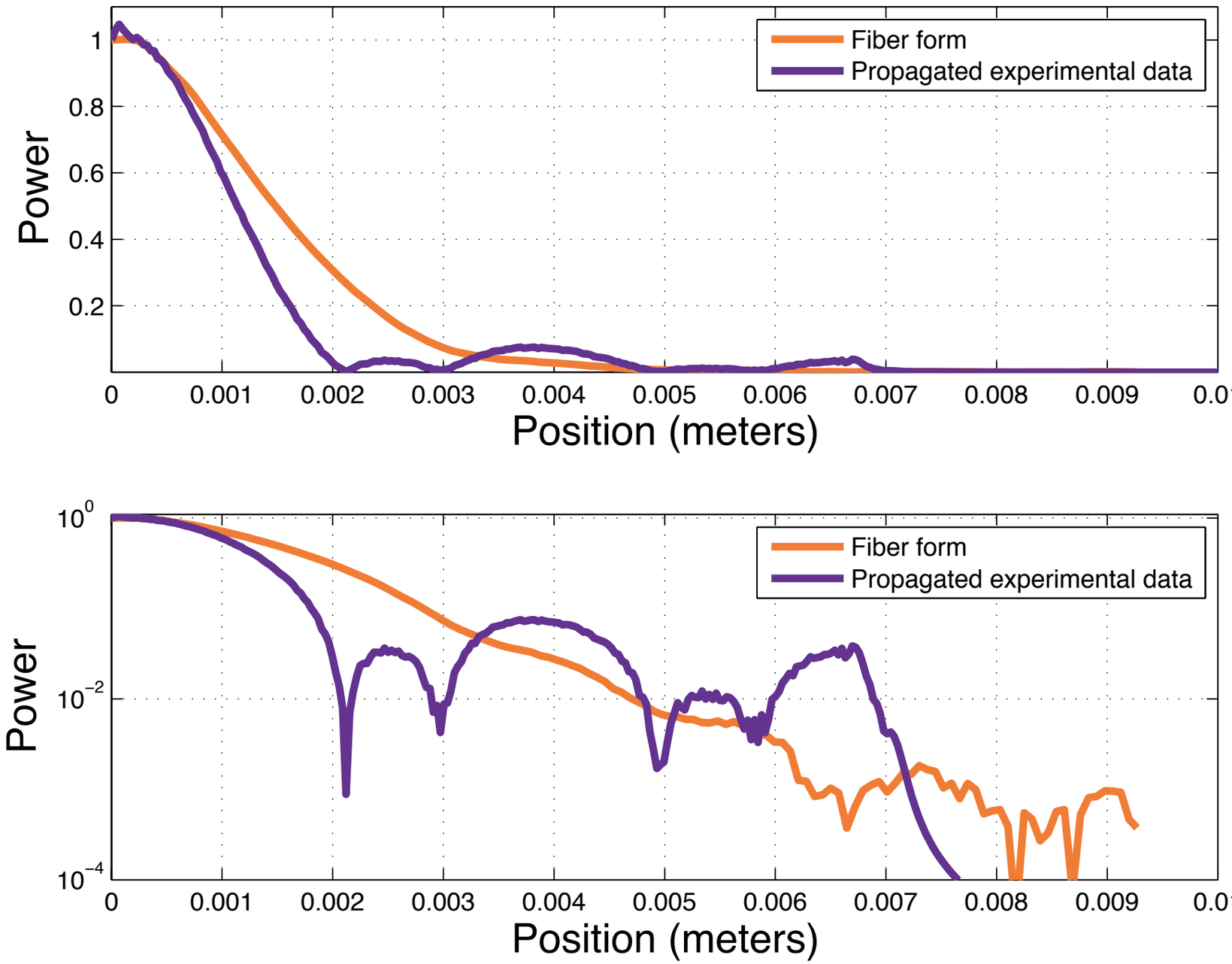
Searching for the Ring

- Ring doesn't seem to occur when propagating the theoretical fiber mode
- Take beam profile measurement at beam waist after sending through the first lens of the telescope, propagate through the second lens and into the far-field

Searching for the Ring at 66 meters



Possible Sources of the Ring

- Propagation code assumes thin lenses, but we have thick lenses

- If beam isn't perfectly centered or lens is tilted, lens causes aberrations

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Future Work

- Simulate thicker lenses in propagation code
- Make measurement of beam profile using a power meter and translation stage
- Use HeNe laser instead of fiber-coupled diode laser as input of telescope

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