# Optical Fiber Systems for the BigBOSS Instrument

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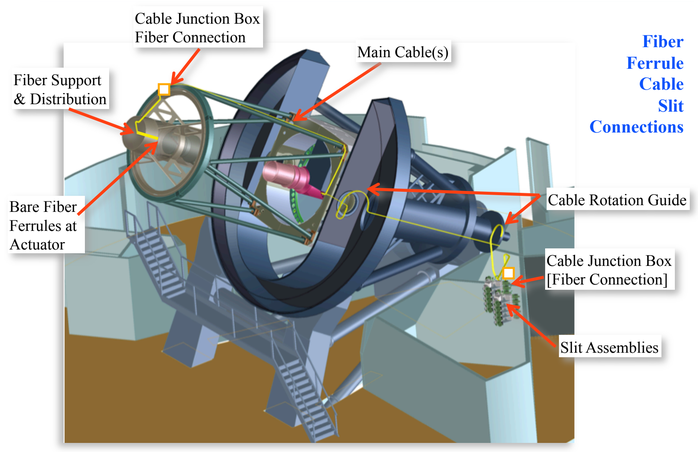
**BigBOSS is a proposed ground-based dark energy experiment designed to study baryon acoustic oscillations (BAO) and the growth of large scale structure through a 14,000 square degree survey of galaxies and QSOs[a,b,c].**

**Each of 5000 fibers is positioned by an actuator at the instrument focal plane. The fibers then traverse the telescope and are terminated at a spectrograph slit[d,e,f,g].**
**We describe the fiber system concepts, requirements & development.**

## Fiber System Requirements

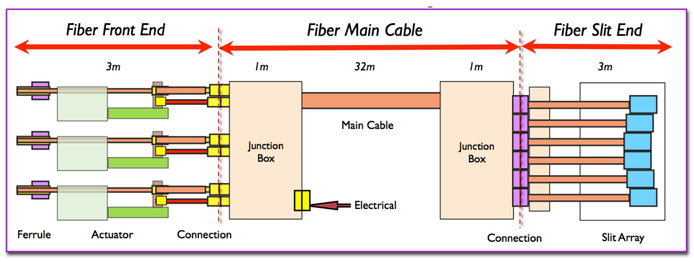
- **Fiber core: 120µm**
- **Optical Input: f/4.5, < 0.5 deg telecentricity**
- **Wavelength range: 360 - 980 nm**
- **Fiber System Throughput: 90% × fiber bulk × AR**
- **Input interface: Fiber actuator, motion compatible**
- **Output interface: Spectrograph compatible**
  - — Match curved focal surface & f/4.0 output pupil
- **In-line connections:**
  - — Provide for component installation & test
  - — Facilitate project fabrication & integration flow

## The Fiber System




## Fiber System Schematic

- *5000 fibers* (direct injection) to each Focal Plane actuator
- Front End Assy = Ferrule, strain relief, [connection]
- Main Cable Assy = 10 cables, 1 per spectrograph unit
- Slit End Assy = 500 fibers per spectrograph unit



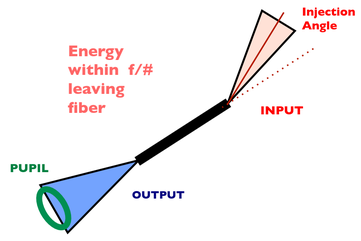

## Fiber Injection / Ejection Efficiency

**Focal Ratio Degradation (FRD)**

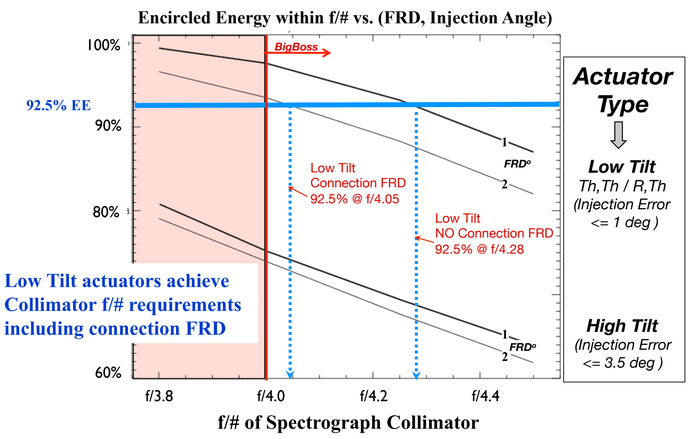
— **Physical FRD**
- Bulk fiber
- Ferrule termination
- Slit termination
- Connections

— **Injection induced FRD**
- Ferrule optical axis
- Corrector Telecentricity (~0.25 deg)
- Actuator angular tolerance (0.2 deg)
- Actuator angular motion (0.1 low-tilt type / 2.75 deg high-tilt type)

— **Ejection induced loss**
- Slit fiber to pupil alignment




## Encircled Energy in Collimator for Actuator

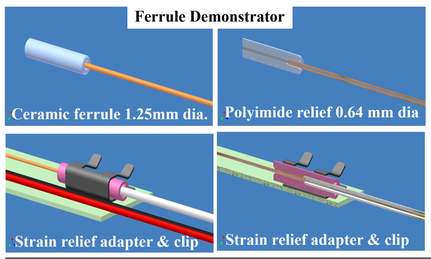



**Low Tilt actuators achieve Collimator f/# requirements including connection FRD**

## Input Ferrule

**Polyimide jacketed fiber bonded in ceramic ferrule, polished & AR coated**

*Requirements*
- FRD performance (bonding stress)
- Ferrule end polish (UV scatter)
- AR coating compatibility
- Ferrule optical axis
- Actuator threading
- Actuator interface
  - Z-axis reference
  - Angular reference
- Fiber flex survival
- Thermal performance




*Ferrule Trade Studies*

| Materials: | Strain relief methods |
|---|---|
| Steel tube vs Ceramic | Ceramic ferrule features |
| Height Reference Sleeve | Monocoil / Hytrel furcation |

## Fiber Connection Investigation[h]

**Fiber Connector Styles**

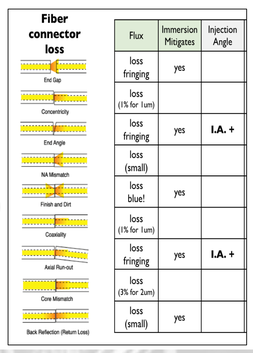
*Non-standard fiber size* 190 µm

*Single fiber*

MIL style (e.g. Glenair GHD)
0.1 - 0.2 dB loss

Cylinder ferrule (e.g. Diamond DMI)
0.1 dB loss

*Multiple fiber*
eg. MTP
32 @ 190 µm
APOGEE / Sloan




| Flux | Immersion Mitigates | Injection Angle |
|---|---|---|
| loss fringing | yes | |
| loss (1% for 1um) | | |
| loss fringing | yes | I.A. + |
| loss (small) | | |
| loss blue! | yes | |
| loss (1% for 1um) | | |
| loss fringing | yes | I.A. + |
| loss (3% for 2um) | | |
| loss (small) | yes | |

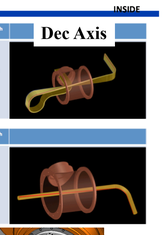
## Cable Routing & Bending[f]

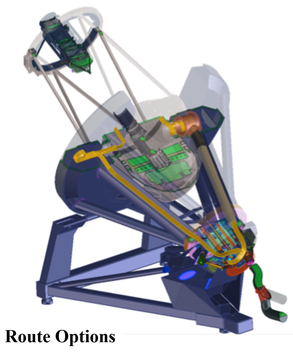
**Studies of Routes & Rotation Mechanisms**

TWISTS INSIDE

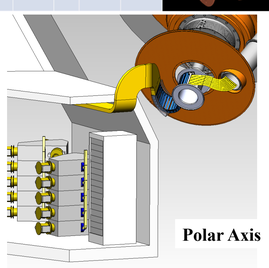
| Flat Ribbon | Max Twist degree | DL/ 90 deg | Axis length mm | Cable length mm |
|---|---|---|---|---|
| 50 mm X 250 mm Flat Ribbon 12 X 25 mm cables | +-90 | -9.5 | 3000 | 3000 |

| Round Cable | Max Twist degree | DL/ 90 deg | Axis length mm | Cable length mm |
|---|---|---|---|---|
| 12 X 25 mm cables In a circular section cable | +-90 | -1.2 | 3000 | 3000 |



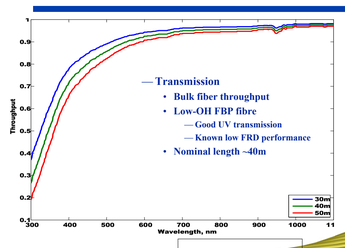



**Route Options**



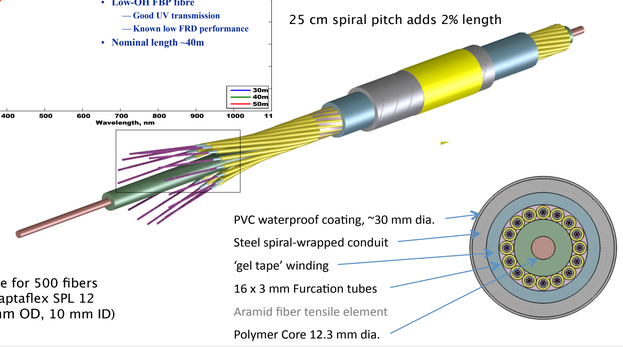
**Polar Axis**

## Cable Assembly




**Per Durham FMOS methods**
32 mm OD cable can handle 1000 fibers
Presume 25 mm OD cable for 500 fibers

25 cm spiral pitch adds 2% length




Min Size for 500 fibers
use Adaptaflex SPL 12
(14.2mm OD, 10 mm ID)

## Fiber Connections

- Decouple fabrication and integration flow
- Facilitate subsystem testing
- Allow for front mounting actuator (10mm focal plane hole)
- Consider mechanical or spliced connectors
- Require throughput &

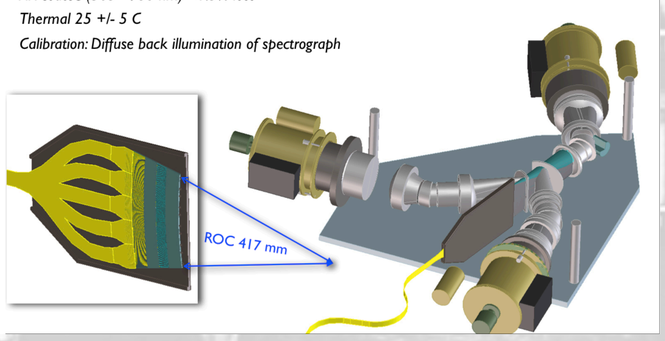
## Fusion Splicing

- Insertion Loss -0.01 - 0.05 dB
- FRD literature sparse

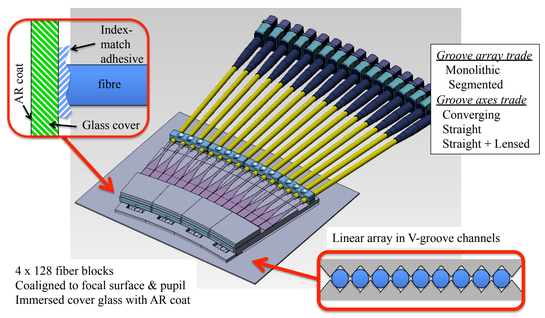
- *Strip (polyimide) Coating*
  Chemical, Plasma, Laser, Knife
- *Cleave*
- *Splice (glass melt)*
  Thermal, Plasma
- *Protection Recoat*
  Shrink tube, Acrylic, polyimide

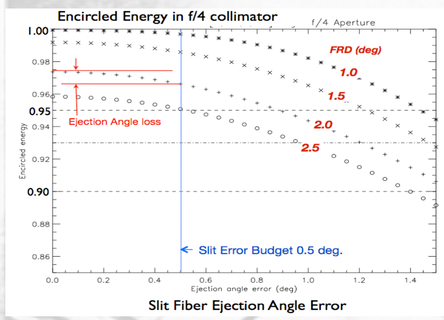
## Fiber Slit Assembly

*500 fibers in 120 mm = 240 µm fiber spacing*
*Total Axial location tolerance +/- 45 µm*
*Common 82.5 mm dia. pupil @ 417 mm (0.042 deg. adjacent angles)*
*Fiber axis co-alignment (1% Pupil Loss)*
*AR coated (365– 980 nm) <1.5% loss*
*Thermal 25 +/- 5 C*
*Calibration: Diffuse back illumination of spectrograph*

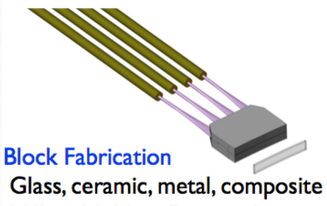



## Fibre Slit Assembly




128 fiber block
Grooves converge to center
-Bond, co-polish fibers to radius
-Bond AR coated 50 µm plate
or
-Cleave or polish fibers
-Butt to curved surface



Block Fabrication
Glass, ceramic, metal, composite
Milling, Molding, Diamond turning

Meniscus Fabrication
Thin, flexible plate (50 µm)
Thick fixed lens
Slumped glass

## Development Plan

*Ferrule performance*
Performance survey of fabrication methods

*Fiber flexure dynamic life*
Accelerated life-time fiber testing with actuator simulators
Examine life of alternate fiber-jacketing types

*Connector performance*
Performance survey, statistical performance testing
Develop zero and single connector fiber project plans

*Slit assembly performance*
Performance survey of fabrication methods
Develop alternate materials and fabrication plans

*Cable assembly & routing performance*
Test sample cable segment
Develop minimum bending routing & support guide methods

*Fiber assurance study*
Develop fiber system fabrication, integration & testing plan

*Fiber Modeling*
Develop fiber performance models and test with measures.

References
a 219.01 - An Overview of the BigBOSS Project, Arjun Dey, etal.
b 219.02 - The BigBOSS Instrument, Natalie Roe, etal.
c 335.05 - BigBOSS - A Proposed Stage IV Baryon Acoustic Oscillation Experiment at the KPNO Mayall 4-m Telescope, Chris Bebek, etal.
d 335.11 - R-Theta Fiber Positioner Study For The BigBOSS Instrument, C. Schenk, etal.
e 335.08 - BigBOSS Optical System, Michael Sholl, etal.
f 335.07 - Integration of the BigBOSS Instrument with the Mayall 4m Telescope, R. Besuner, etal.
g 248.12 - A Spectrograph for BigBOSS, Pierre-Henri Carton, etal.
h 335.06 - Optical Fibre Connection Performance Investigation for BigBOSS, Claire Poppett, etal.

Background Image Courtesy NOAO

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