Bit error rate performance on passive alignment in free space optical links using large core fibers

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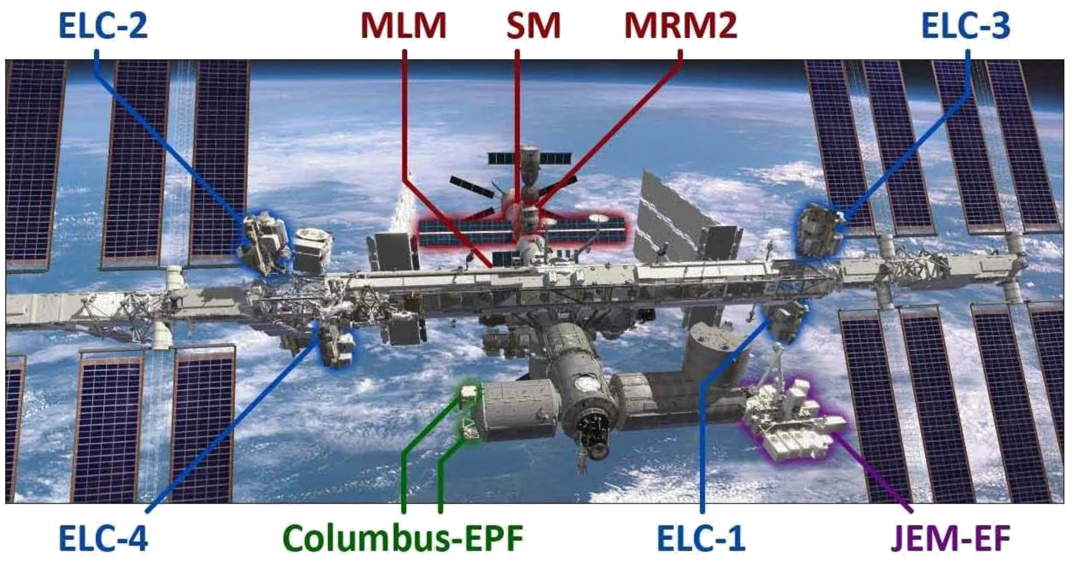
Application

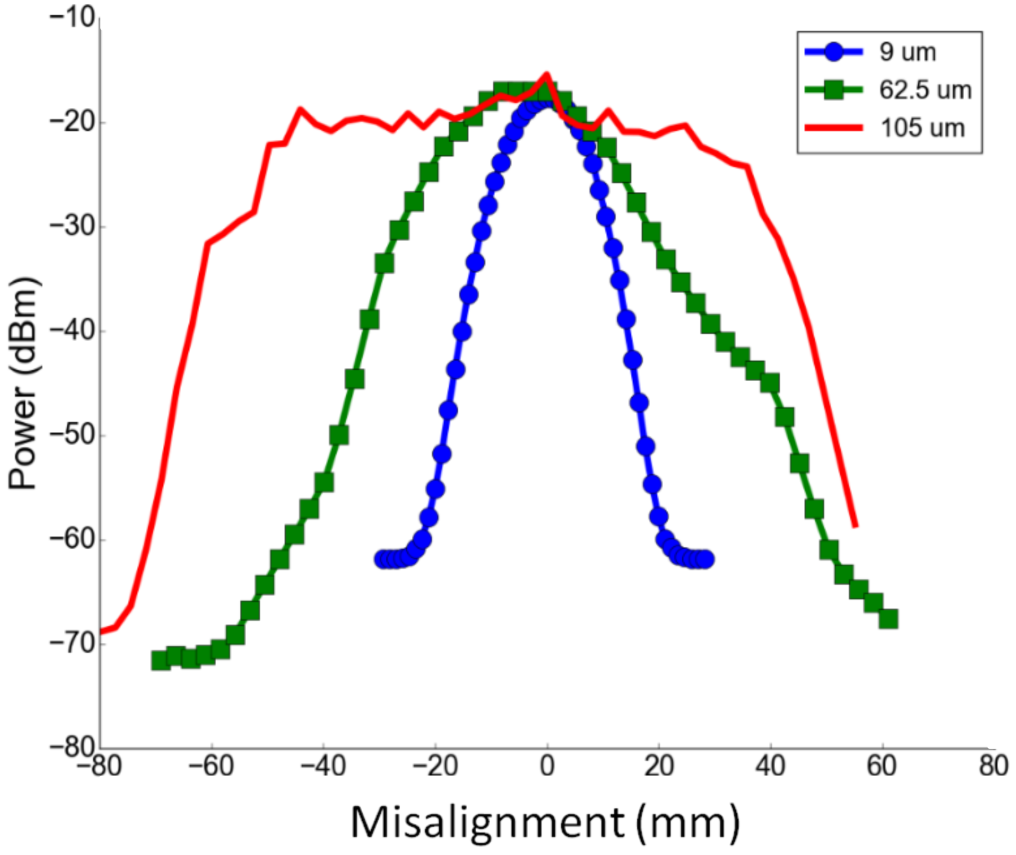
- Intra International Space Station (ISS) payloads sites have limited bus throughput (~10 Mb/s) restricting communicating large quantities of science data



- Free Space Optical Links can implement high rate data transfer with little change in the current infrastructure
- Passive Solutions are being investigated to minimize Size, Weight, and Power (SWaP)
- ELC motion relative to the main cabin is predicted cause up to +/- 5 cm lateral misalignment

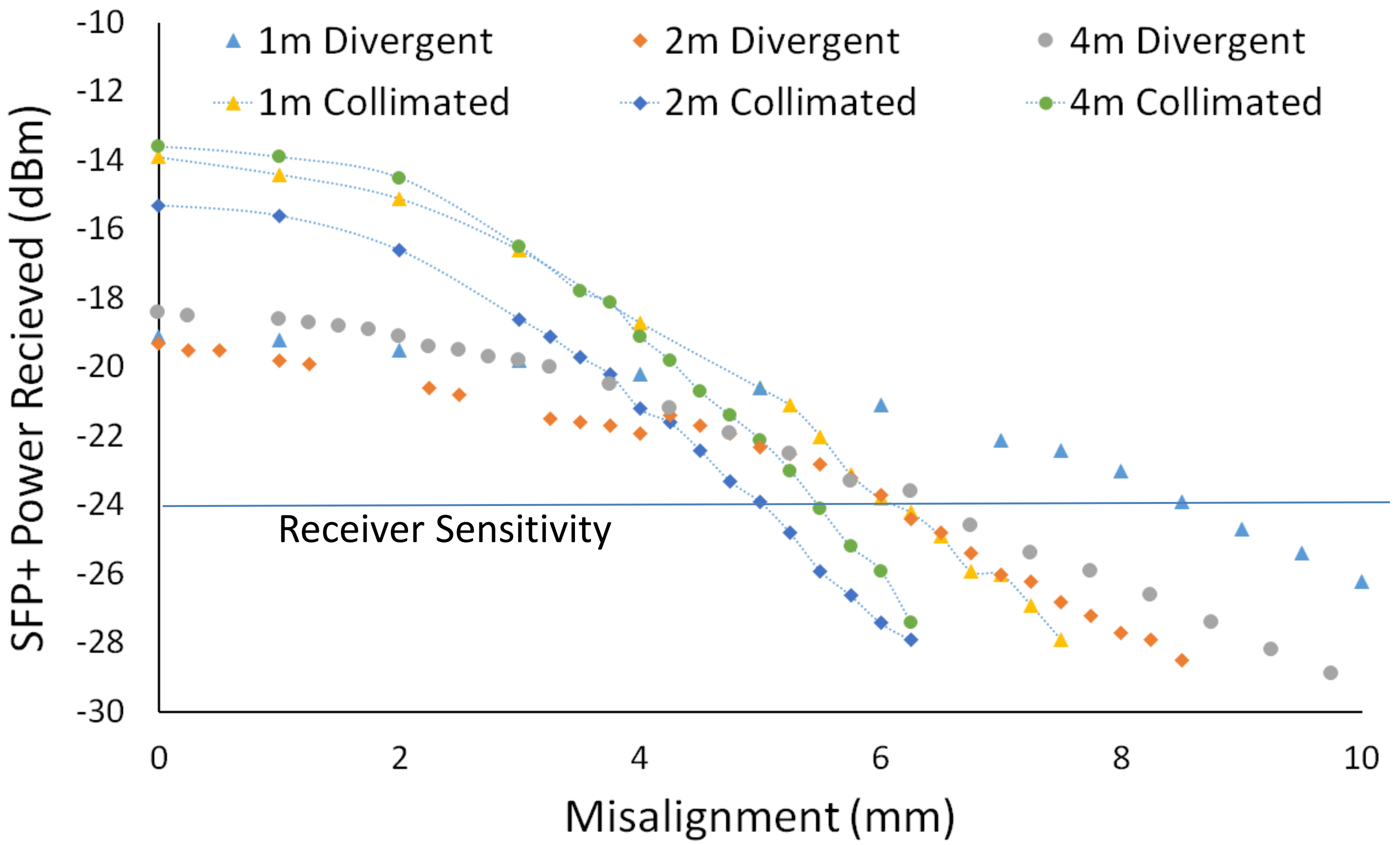
Background: Lateral Misalignment Tolerance

Past Work: A 105 µm core multi-mode fiber (MMF) provides increased receiver field of view



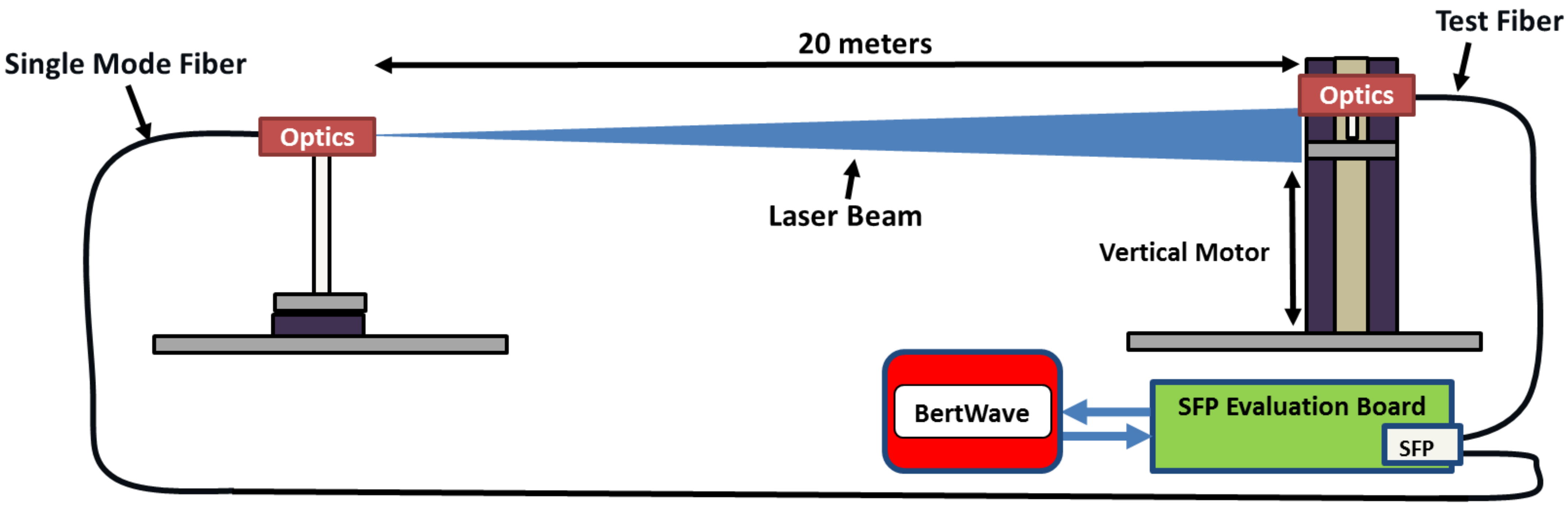
*Data taken with fiber coupled power meter

Present Work: Use a small form factor pluggable (SFP) optical transceiver with a 105 µm core fiber at the receiver



*Data taken with reported SFP+ power

Experimental Setup



Automatic control of beam divergence using linear positioner, lateral misalignment using vertical motor, sfp+ power reading using I2C interface, BertWave measurement using TCP/IP connection

Measurement Automation

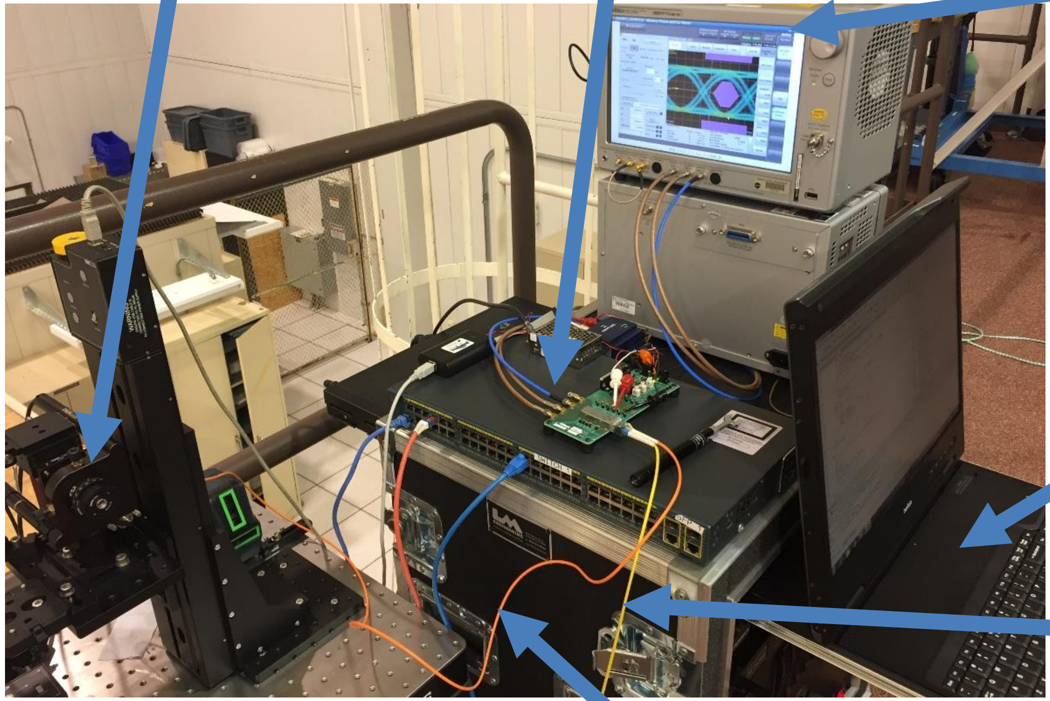
Receive Optical Assembly installed with automatic alignment devices

SFP+ Evaluation PCB with SFP+ installed

BERT will take measurements until a predefined confidence level is met

$$C_L = 1 - e^{-N_{bits} * BER}$$

$$C_{LE} = 1 - \left(e^{-N_{bits} * BER} * \frac{1}{N_{error}!} * \left(BER * N_{bits} \right)^{N_{error}} \right)$$



Control PC to interface with all components

Transmit Fiber (SMF)

Receive Fiber (MMF/DUT)

Receive Optical Assembly

Transmit Optical Assembly

Modal Dispersion: Theoretical Data Capacity

Pulse dispersion

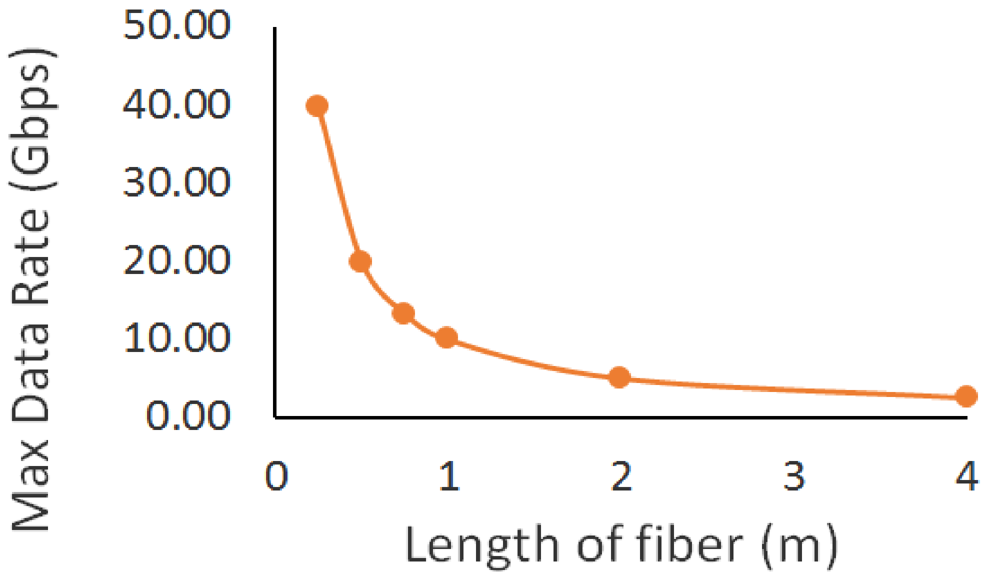
$$\tau_i \approx \frac{L}{2n_1 c}(NA)^2$$

Material dispersion

$$\tau_m = D_m \times L \times \Delta\lambda$$

Max Bit Rate

$$B_{max} = \frac{0.7}{\sqrt{\tau_i^2 + \tau_m^2}}$$



105 µm pure silica core with 125 µm fluorine-doped silica cladding:

n_1 = 1.4439

NA = 0.22

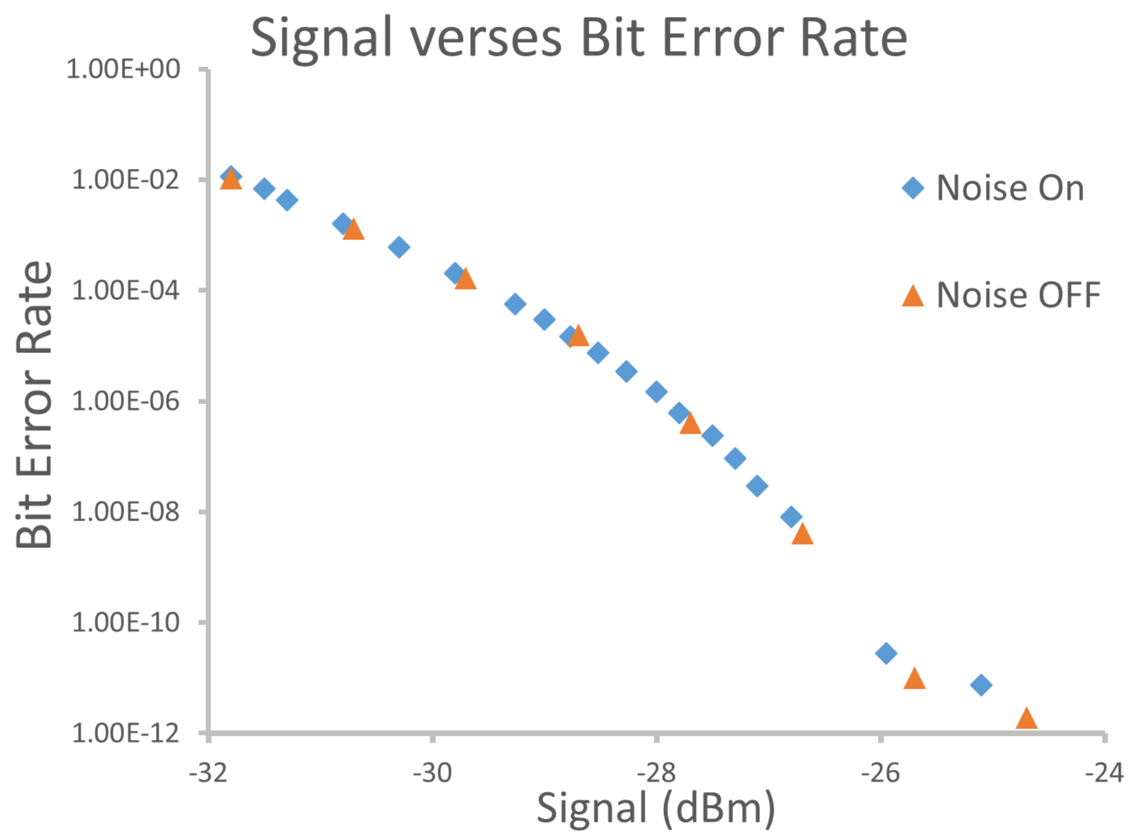
D_m = 21.5187 ps/nm-km

Δλ = 2 nm

c = 3e8 m/s

Test fibers chosen for this experiment are 1 meter, 2 meters and 4 meters to show modal dispersion at 10 Gpbs

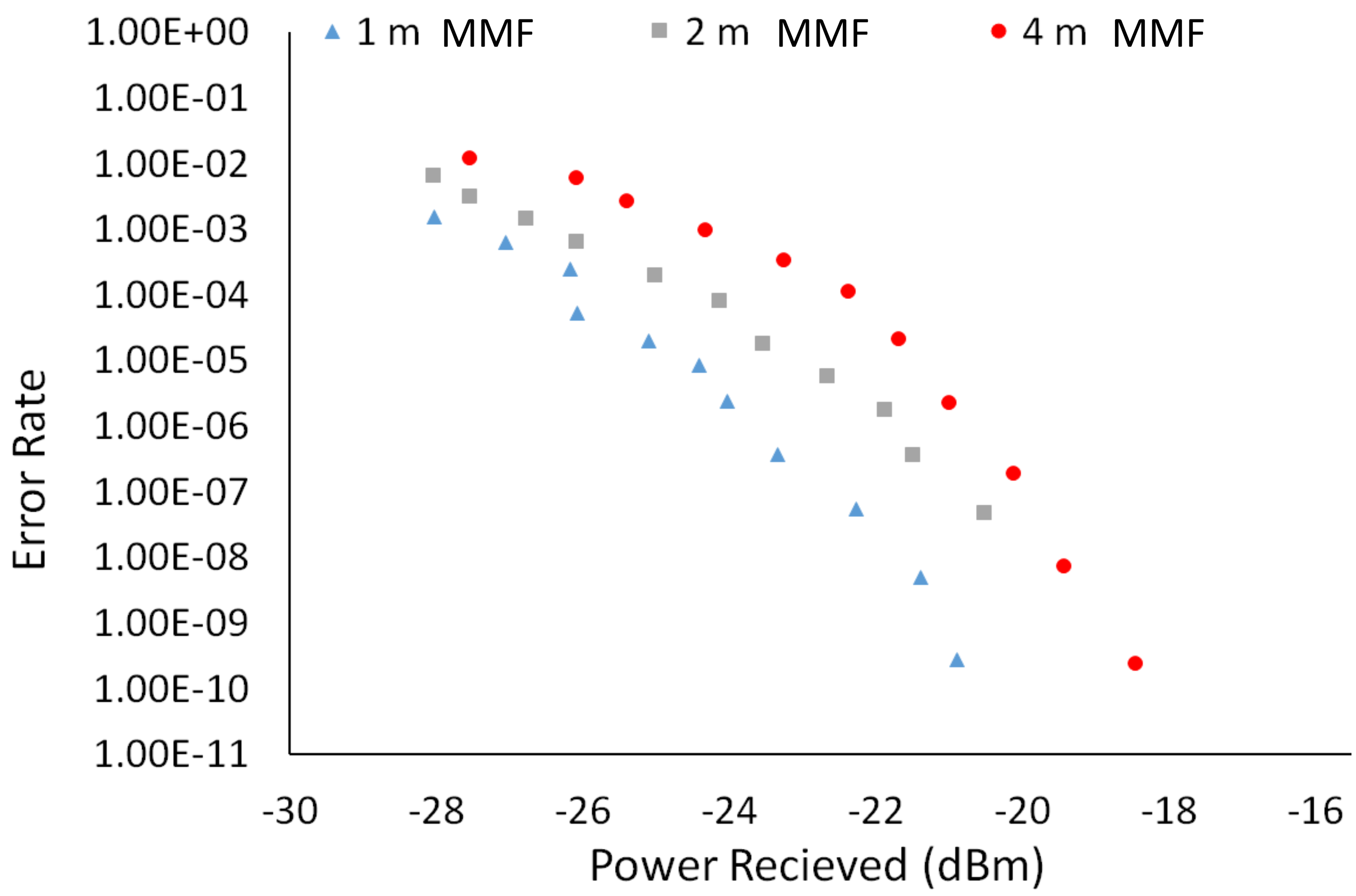
Signal to Noise Ratio: Test



Noise was added to the optical signal using a tungsten light and fiber combiner at the receiver. This increased the optical noise from -78.1 dBm/nm to -61.8 dBm/nm.

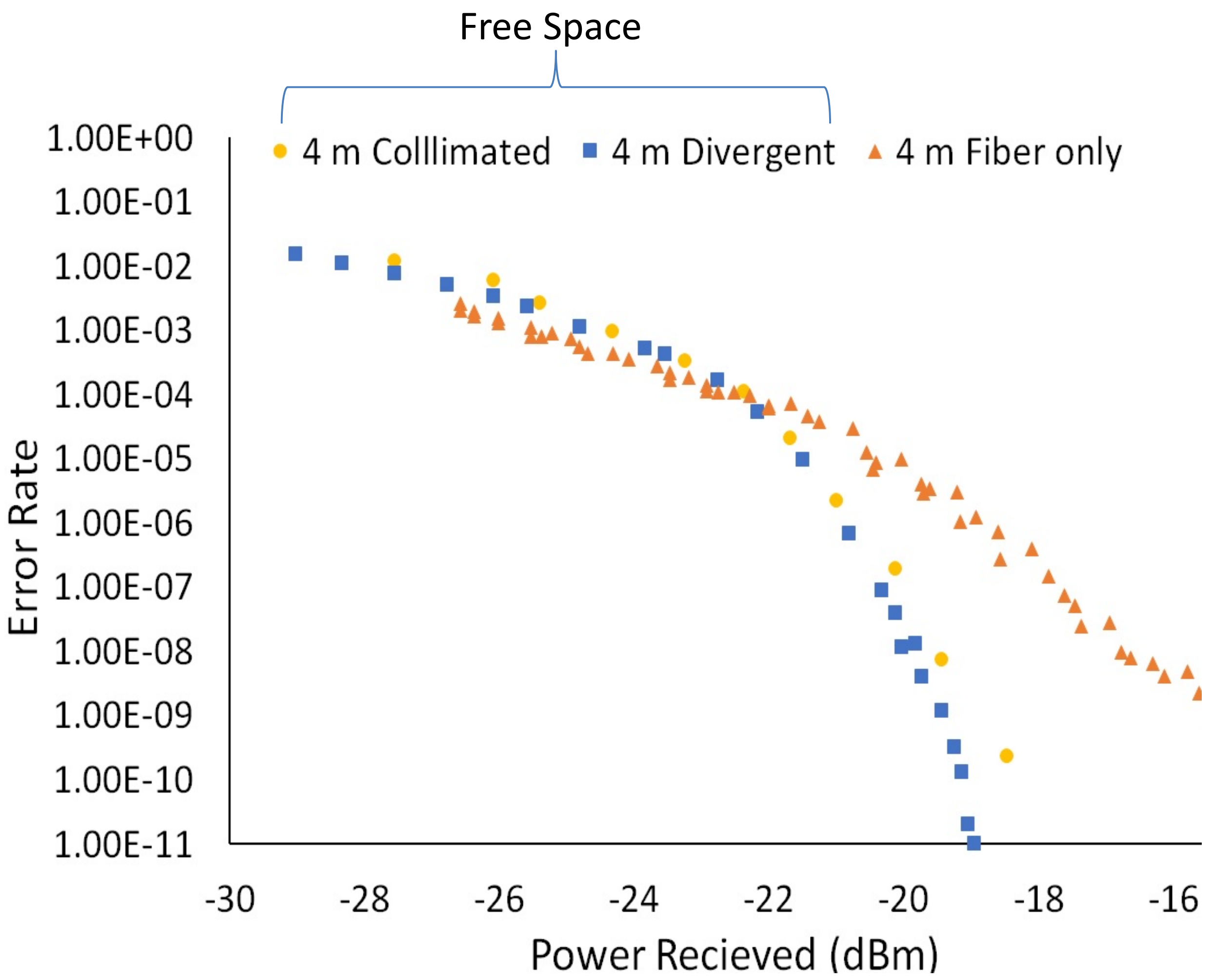
Electrical noise has a greater effect on Bit Error Rate than ambient optical noise for our test system. By adjusting the signal power the noise floor remains constant thus changing the SNR

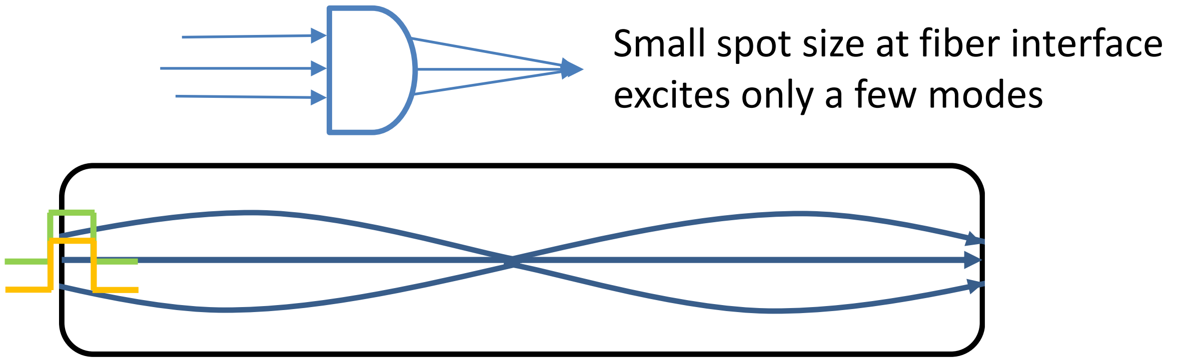
BER vs Power for various MMF cable lengths

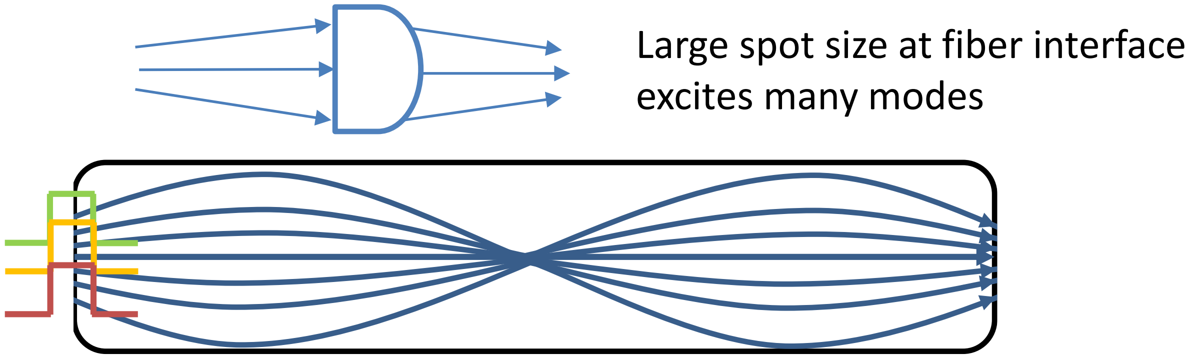


BER performance decreases as cable length increases.

BER vs Power for various Launch Conditions

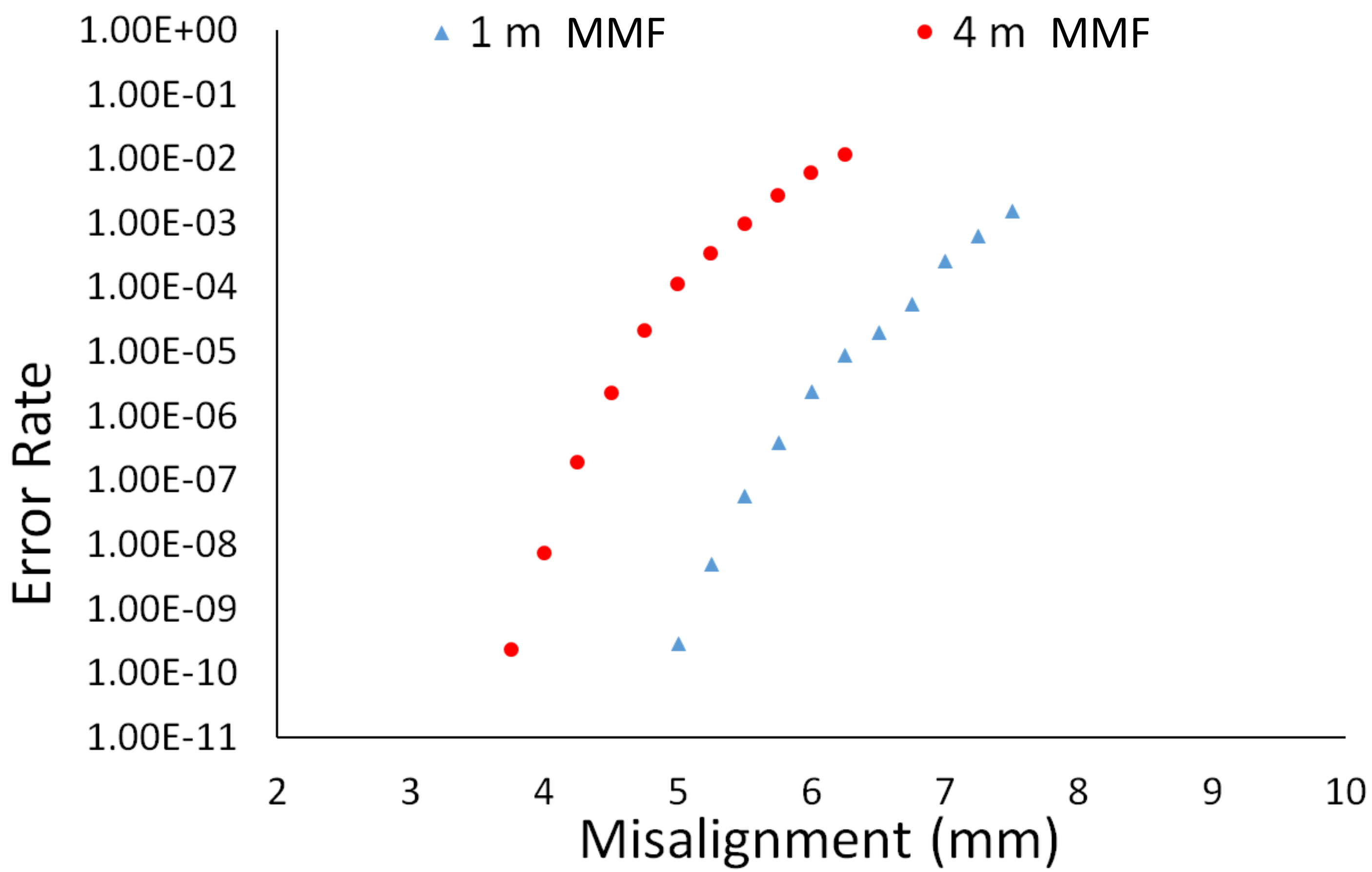






BER performance increases for high SNR points as the number of exited modes is increased due to differential mode delay

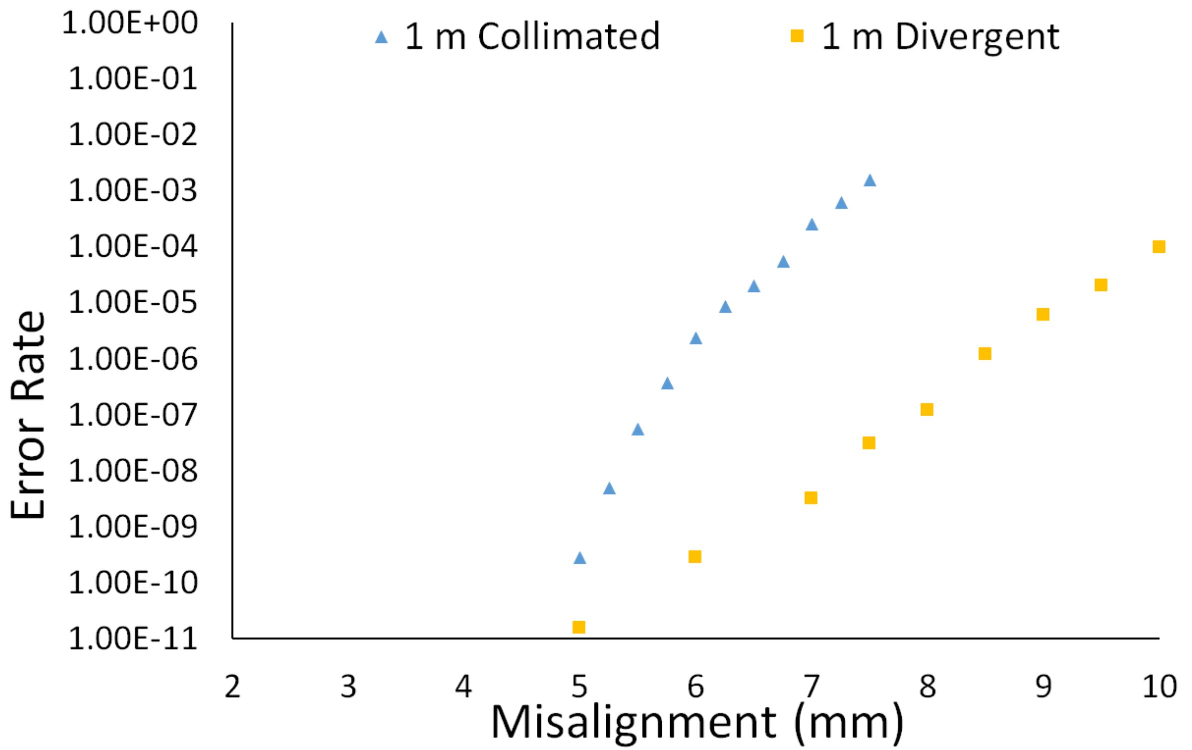
BER vs Misalignment for various MMF cable lengths



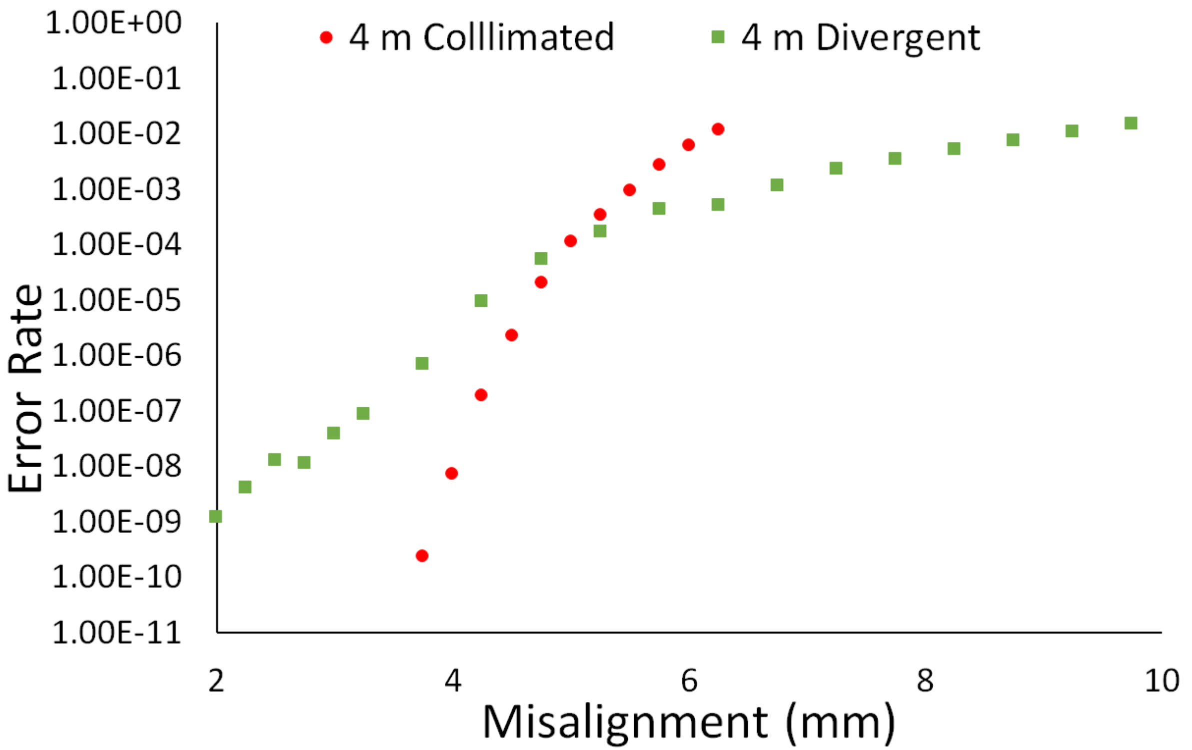
For a given error rate the shorter cable achieves greater misalignment tolerance

BER vs Misalignment for various Launch Conditions

BER vs Misalignment for different launch conditions using a 1 m MMF cable

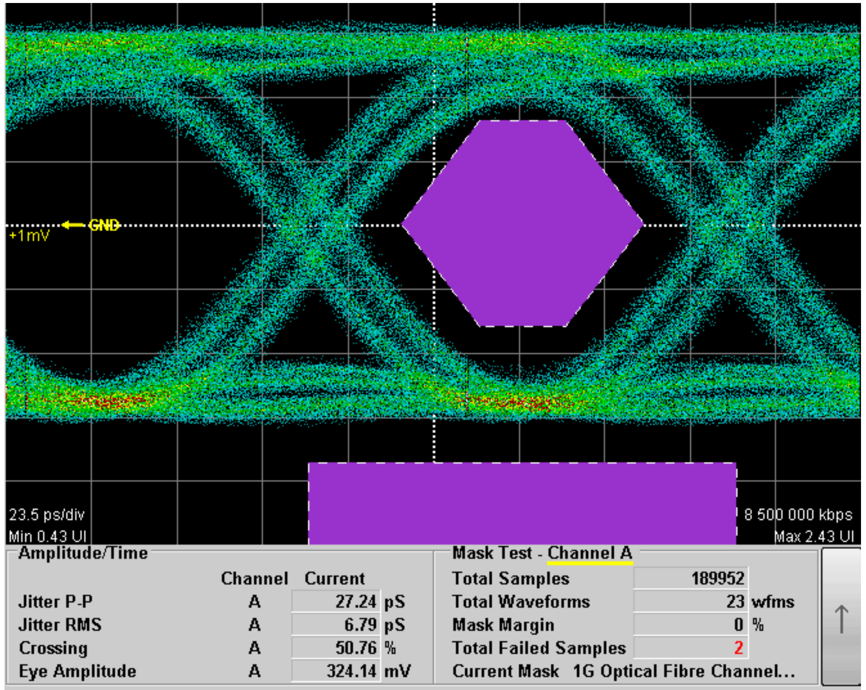


BER vs Misalignment for different launch conditions using a 4 m MMF cable



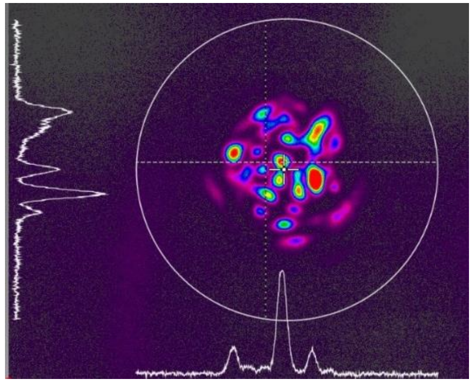
For a given length of cable length there is a error rate at which a divergent beam becomes better then the collimated beam, this crossing point tell us that there is an optimal divergence for a given error rate.

Summary/Future Work



Summary

- The automated FSO BERT system was presented
- Results were presented on BER performance of a 20 meter FSO using various lengths of a 105 µm MMF to which differential mode delay was observed
- The 105 µm MMF and optimal launch condition show potential for an Intra ISS FSO system



Future Work

- Investigate efficient power coupling between the 105 µm MMF and SMF ROSA (receive optical sub assembly)
- Further investigate modal dispersion using an eye diagram and its quantifiable metrics (Jitter and Amplitude)
- Investigate launch condition and mode excitation of the MMF given a divergent beam collected in free space