Experimental Studies of VCSEL-MMF Transmission Impairments at 850nm

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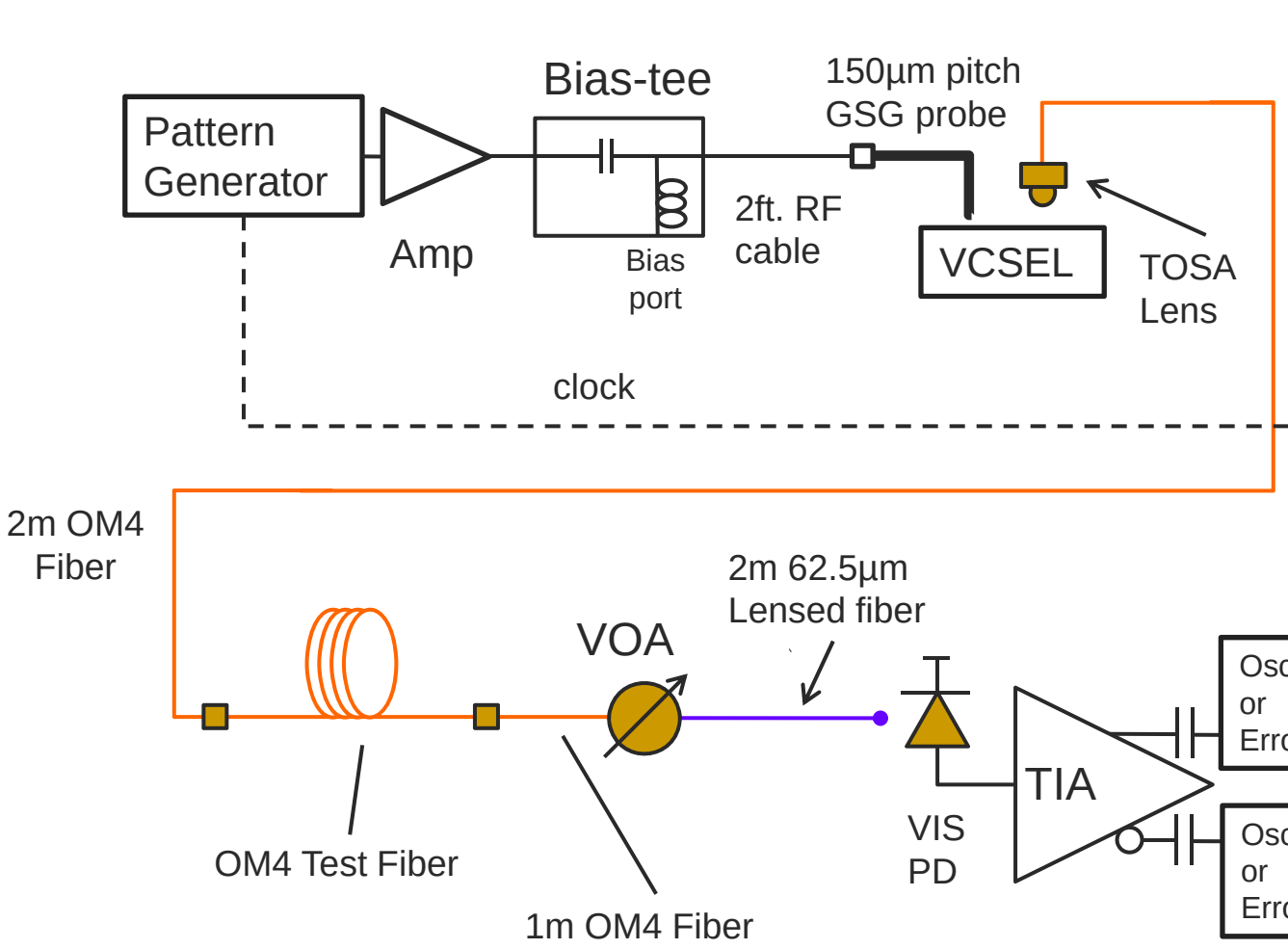
Motivation

- In the CFI, several papers showing 25G over MMF with PRBS7 were referenced. There has been a dearth of published studies at PRBS31 in the literature and a paucity of experimental studies in the study group in general.
- Simulations capture sources of ISI effectively; mode-partition and modal noise are more difficult.
  - Several versions of the IEEE spreadsheet models adapted to 25G yield unreasonably pessimistic mode partition noise (MPN) contributions
- It is also difficult to vary systematically one parameter at a time in VCSEL-MMF studies
  - Varying bias current changes both resonance frequency and σ_{rms}
  - Varying fiber length changes both modal and chromatic dispersion, which changes two forms of ISI plus mode-partition noise
  - Thoughtful fiber selection, systematically varying DMD and length, comparing with simulation, holds chromatic dispersion constant, allowing isolation of ISI from signal-borne noise penalties

Link Setup



Prototype VCSEL dies provided by Emcore

VCSEL biased at high current to explore high σ_{RMS} limits

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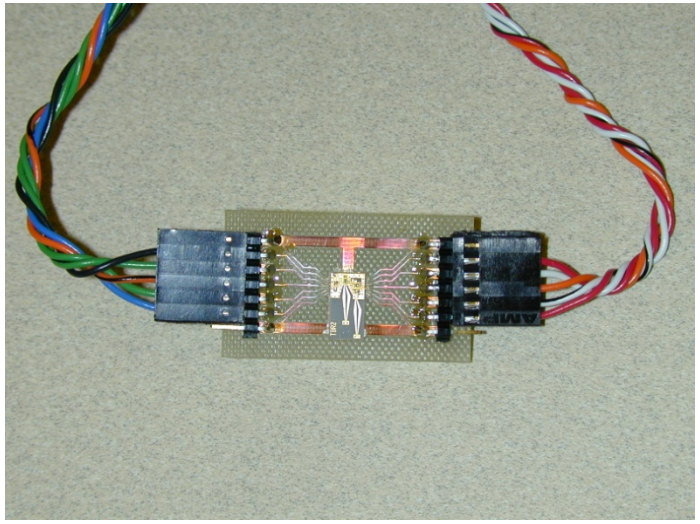
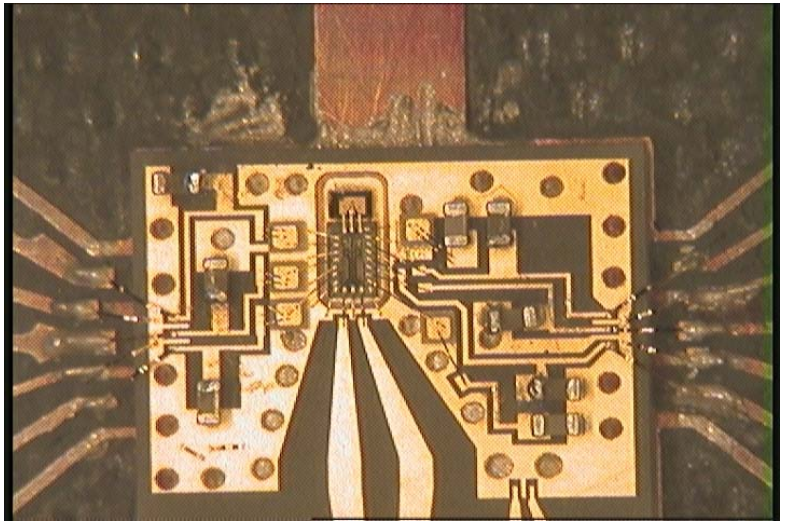
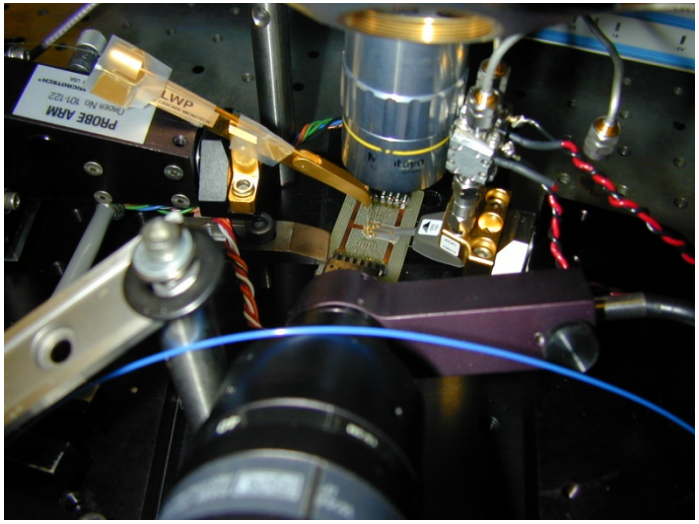
VIS Receiver

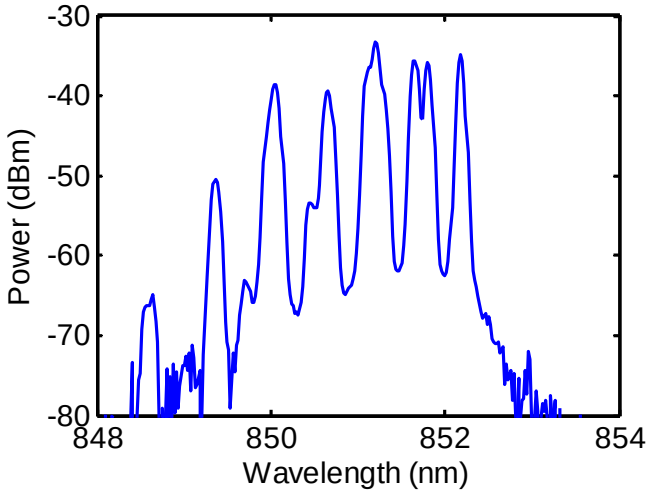


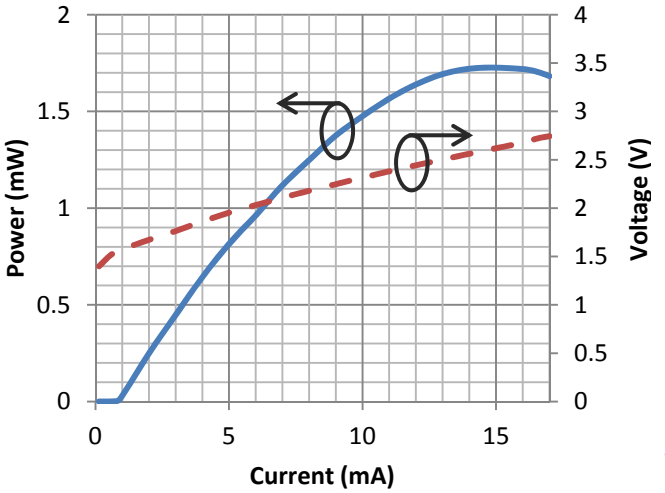


- Wire bonded VIS 40G receiver module to breakout PCB
  - ~30GHz PD
  - High speed TIA



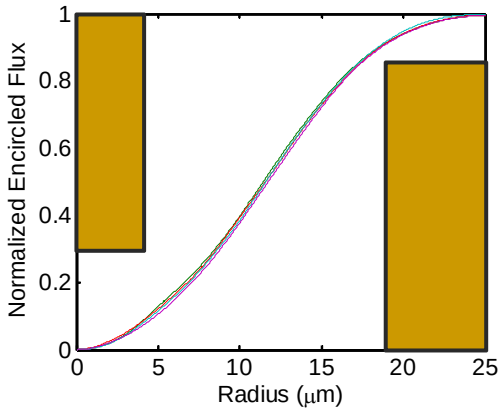
VCSEL Characterization



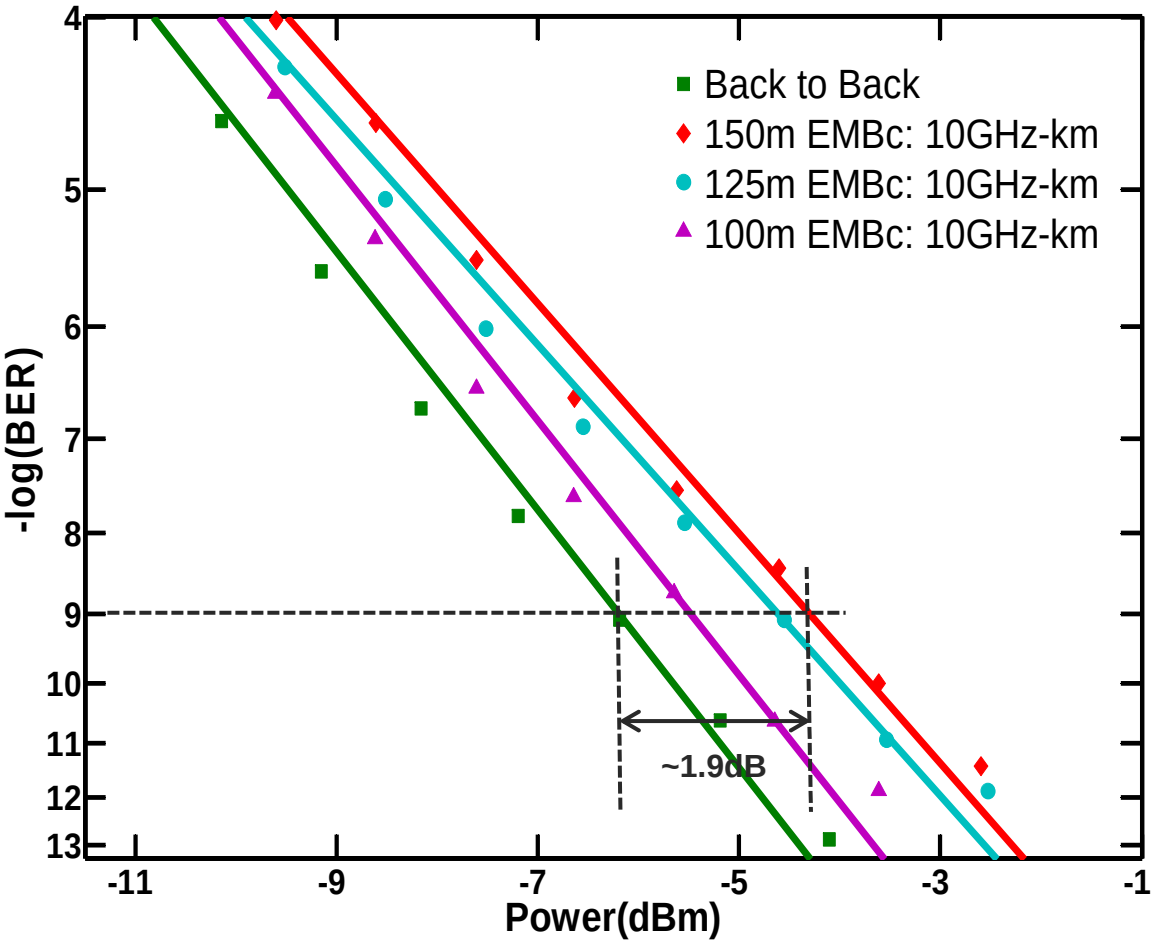


- Center wavelength: 851.3nm
- RMS spectrum: 0.627nm
- Launch power @8mA: 1.2dBm

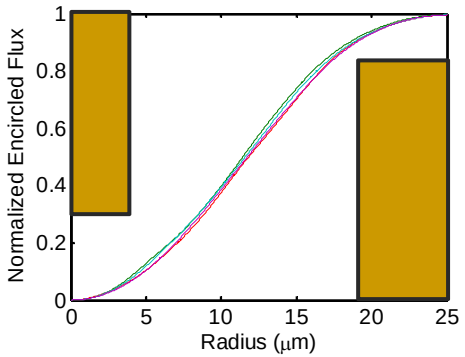
- Launch power @8mA: ~1.2dBm



Length Dependence 10 GHz-km



- OM4 MMF, modal bandwidth (EMBc) of 10GHz-km
- 2^{31}-1 PRBS
- 1.9dB penalty at 10^{-9} BER, for 150m fiber length
- Penalty at 10^{-12} BER is only a few tenths higher.
- Penalty is not accelerating from 100 to 125 to 150m



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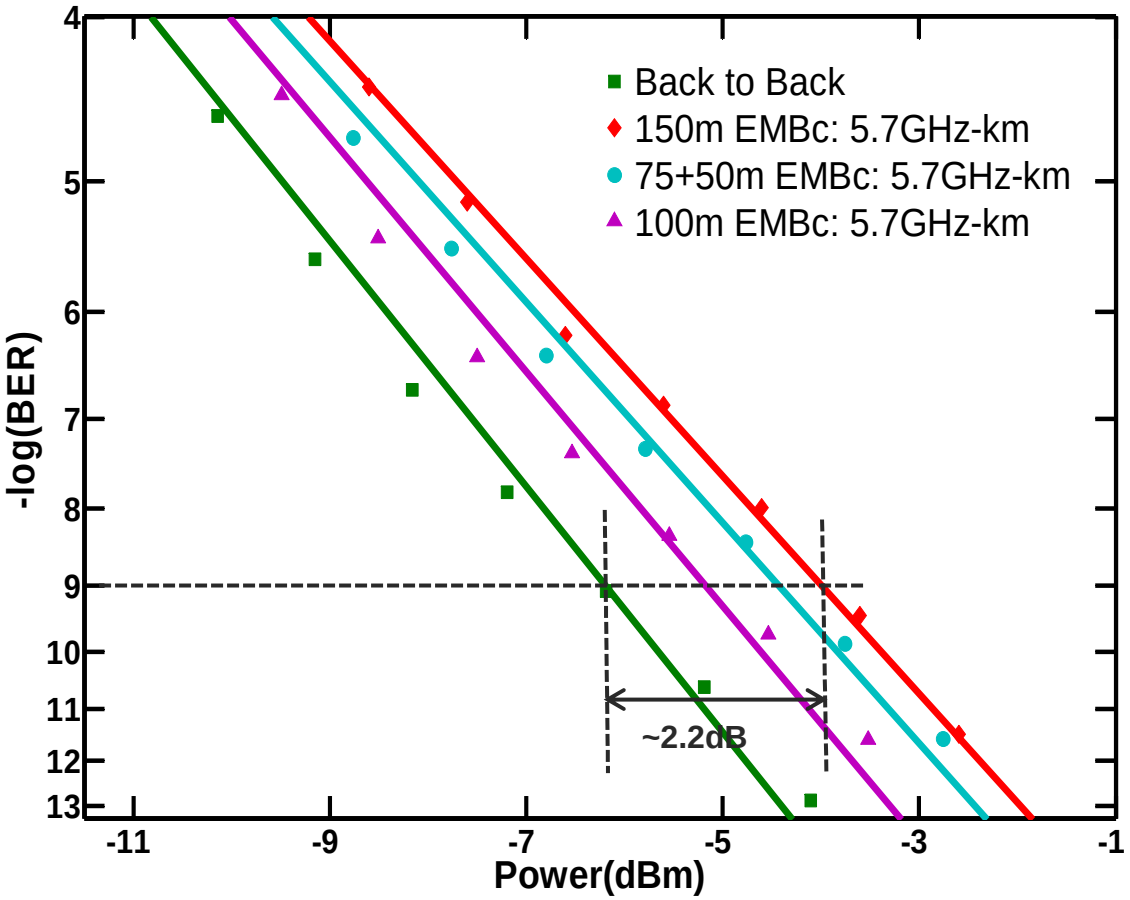
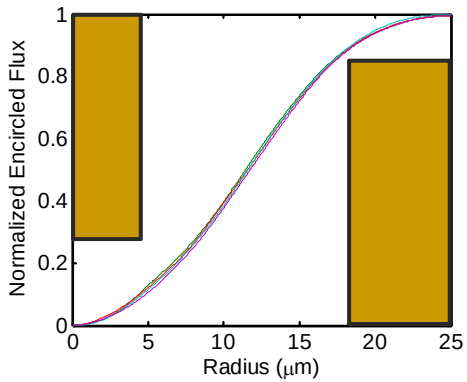
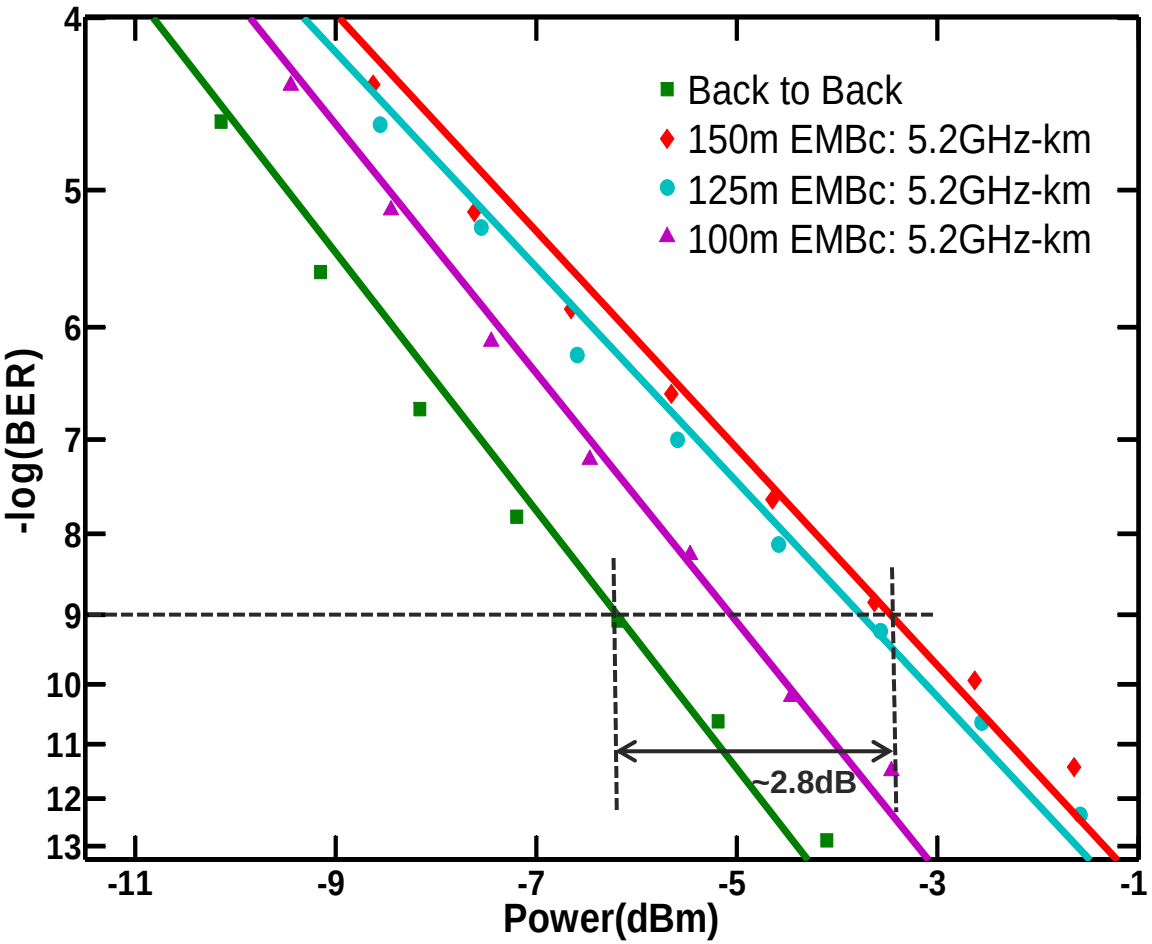
Length Dependence 5.7GHz-km



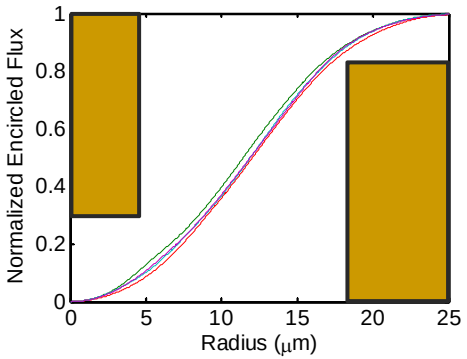
- OM4 MMF, modal bandwidth (EMBc) of 5.7GHz-km
- 2^{31}-1 PRBS
- 2.2dB penalty at 10^{-9} BER, for 150m fiber length
- Penalty at 10^{-12} BER is only a few tenths higher.
- Penalty is not accelerating from 100 to 125 to 150m



Length Dependence 5.2GHz-km



- OM4 MMF, modal bandwidth (EMBc) of 5.2GHz-km
- 2^{31}-1 PRBS
- 2.8dB penalty at 10^{-9} BER, for 150m fiber length
- Penalty at 10^{-12} BER is only a few tenths higher
- Penalty is not accelerating from 100 to 125 to 150m



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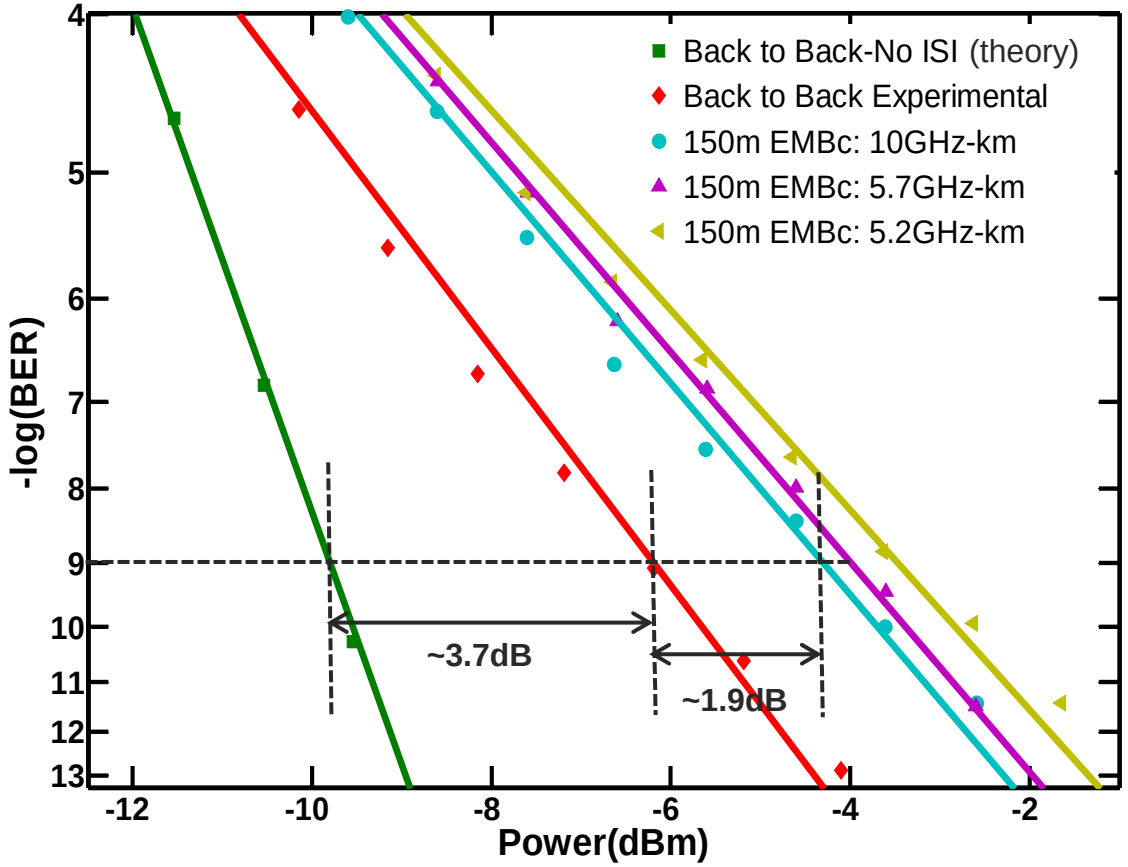
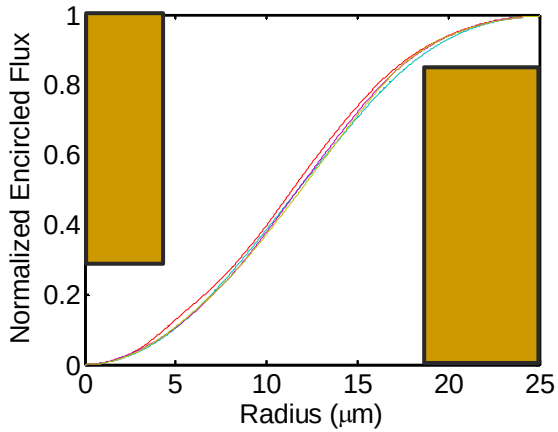
Fiber Comparison at 150m

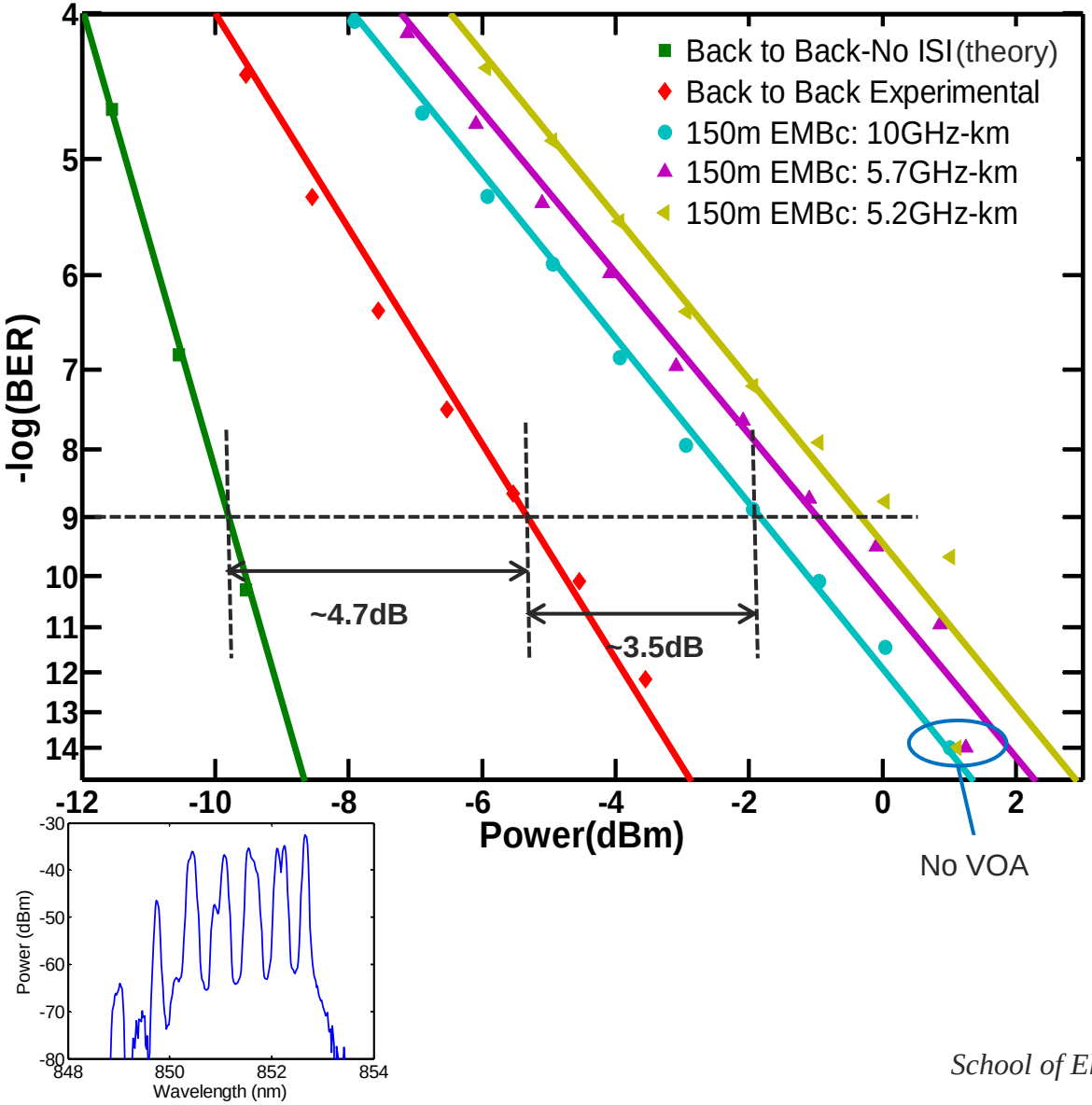


150m OM4 fiber, Bias current: 8.01mA

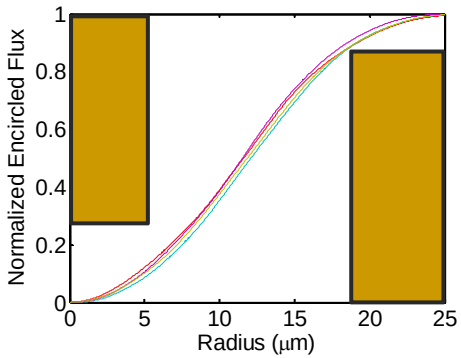
- 2^{31}-1 PRBS
- VCSEL biased at 8.01mA



Fiber Comparison at 150m



- 2^{31}-1 PRBS
- VCSEL biased at 9.52mA
  - RF modulation amplitude not changed
  - RMS spectral width increased to 0.793nm
  - Encircled flux approaching outer limit
- Penalties at 10^{-9} BER range from 3.5 to 5 dB
- Penalties at 10^{-12} BER range from 4 to 5.5 dB



Conclusions

- Focus in this study is on experimental fiber path penalties
- Penalties for 150m on OM4 with σ_{RMS} ~ 0.6nm range from 1.9-3 dB
  - Simulation indicates pure ISI should range from 0.6 to 1.7 dB (lingle_02_0112_NG100GOPTX.pdf)
  - On the order of 1.5 dB should be due to signal-born noise penalties such as RIN and MPN *in the presence of vertical eye closure*.
  - The spreadsheet overestimates MPN, even after accounting for the 28 to 30 GHz receiver BW.
- Transmission at 150m over OM4 in the presence of relatively high RMS spectral width does not seem to be in the range of runaway penalties
- Many effects are not accounted for in this study. However it argues against applying excessive caution based on pessimistic models.
  - Equalized links with reasonable eye closure may not be limited by MPN at 150m.
- More and careful experiments should be shared as part of setting objectives for MMF reach.