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# Multimode Fiber Bandwidth Issues - Impact on 1394b Specification

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# Outline

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- Multimode fiber
- Lasers and multimode fiber
- Bandwidth issues
- Gigabit Ethernet solution
- Effect on 1394b specification

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# Multimode Fiber

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- MMF was designed to be used with LEDs
- Bandwidth is limited by modal dispersion
- Bandwidth is specified using an overfilled launch (OFL)
- OFL launches equal power into every mode - this is a good approximation to LEDs

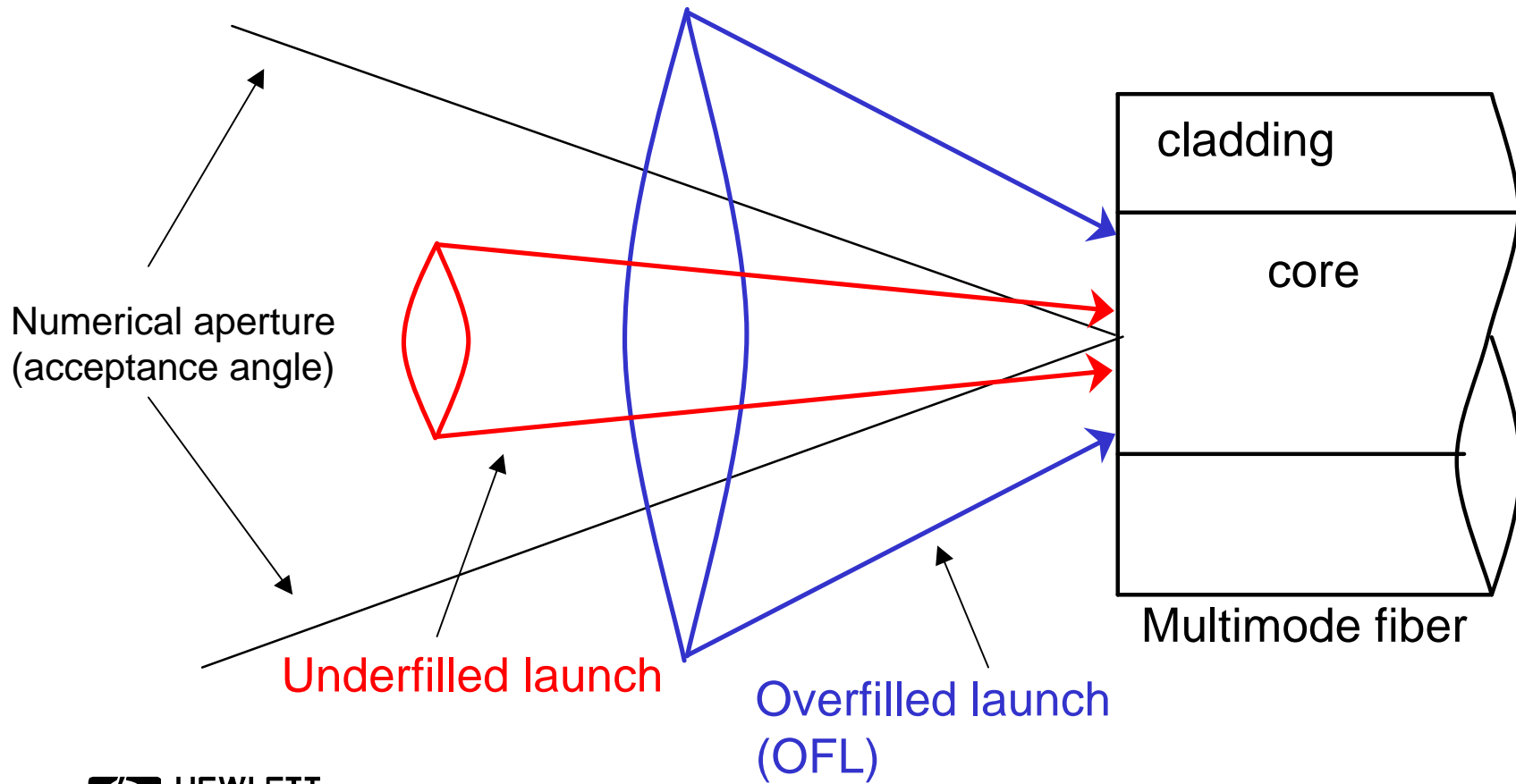
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# Lasers and MMF

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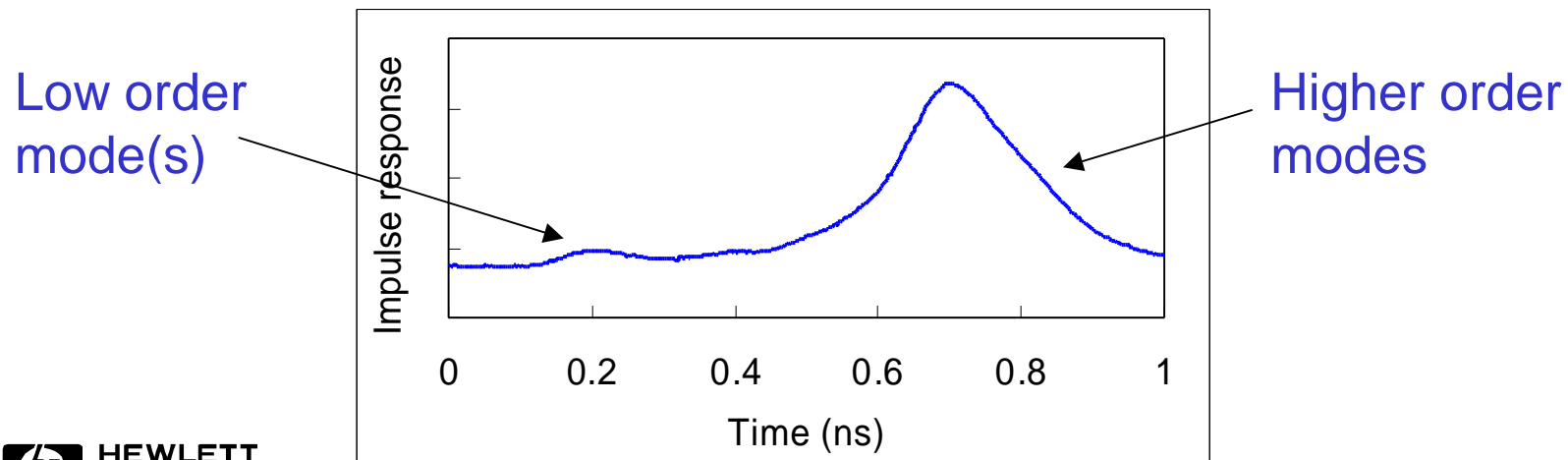
- Lasers underfill the MMF core (launches fewer modes)
  - Lower numerical aperture
  - Smaller spot size
- Assumption was that since fewer modes are excited the modal dispersion will be less and therefore higher modal bandwidth
  - Unfortunately this is not always true

# MMF Launches

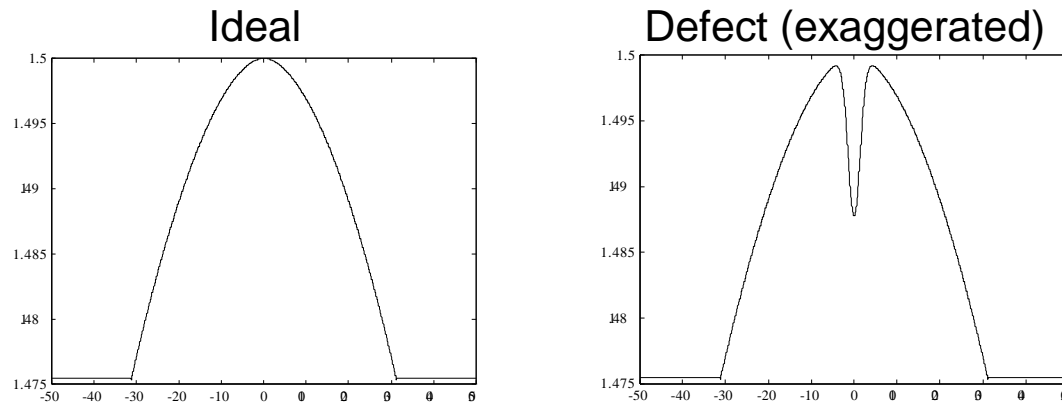


# Modal Dispersion

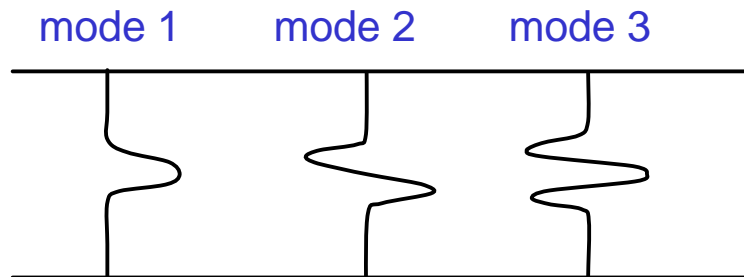
- OFL - many modes excited so that no individual modes dominate
- With an underfilled launches, relative differences between individual modes can have a greater impact



# Refractive Index Profile



MMF has a parabolic index of refraction but some defects can occur in production. These defects often have no effect on OFL bandwidth.

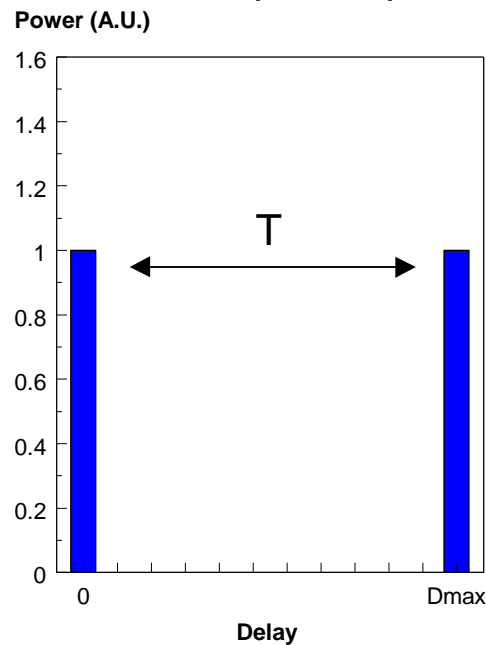


Modes 1 & 2 experience very different refractive indices if there is a dip - different delays

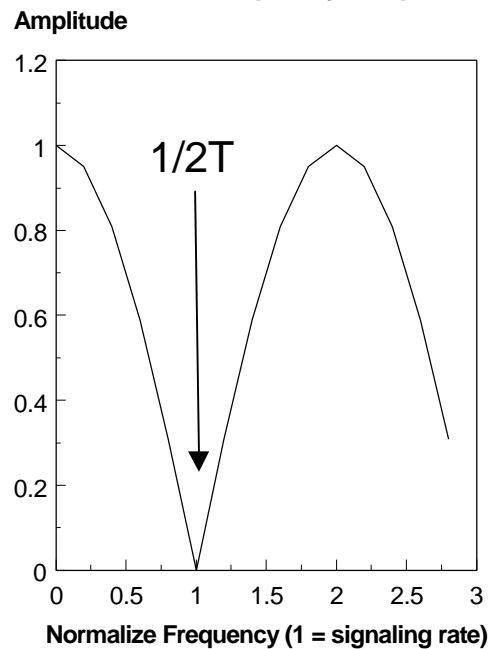
# Worst Case Launch

In the worst case, only two modes are excited which have significant delay difference.

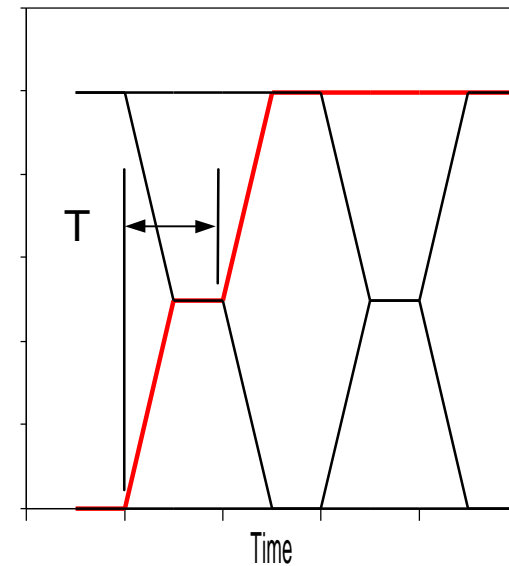
Worst Case Impulse Response



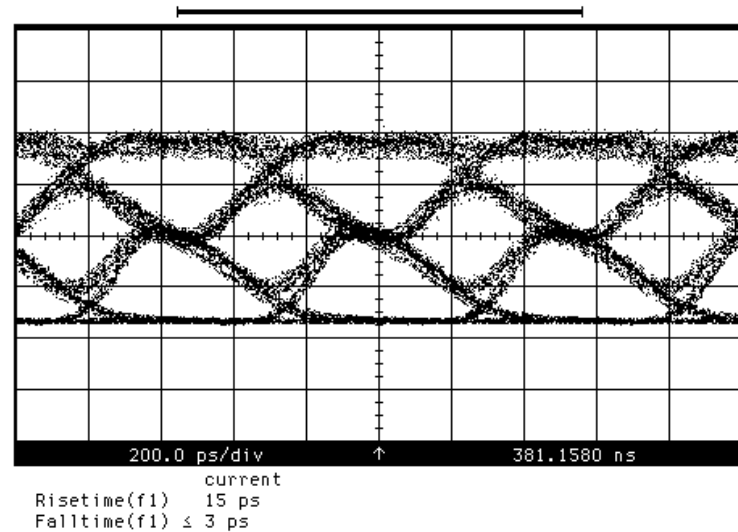
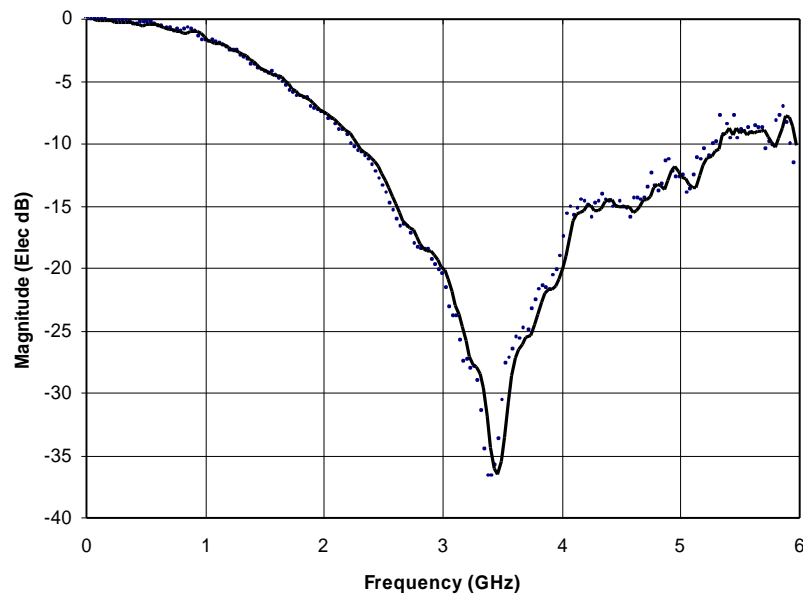
Worst Case Frequency Response



Schematic eye diagram



# Examples



Frequency response and eye diagram of 50MMF when excited with 'worst case' launch

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# Gigabit Ethernet Solution

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- Conditioned launch
  - Offset launch for 1300nm
  - Coupled power ration (CPR) specification for SW
- Adjust jitter specification to account for fiber induced 'jitter'
- Limit receiver bandwidth
- Stressed receiver testing to ensure interoperability

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# 1394b vs. GbE

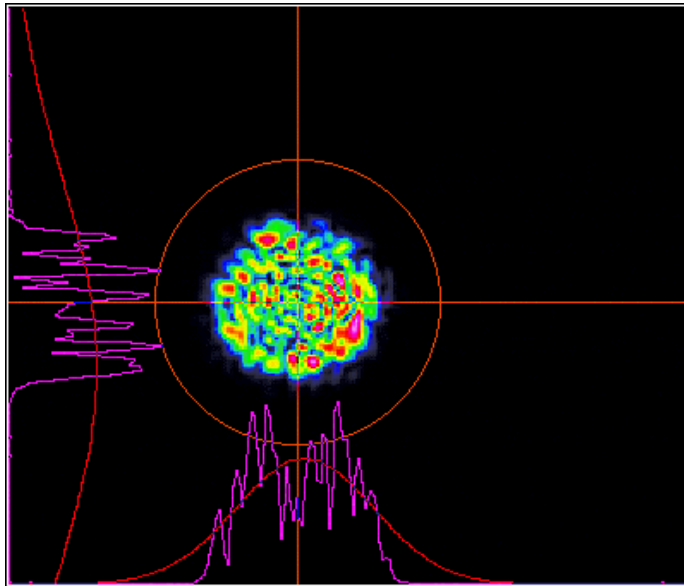
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- Problems are not as dramatic
  - Specification is 850nm only
    - VCSELs statistically give a better launch
  - Specification is 50MMF only
    - Effect is less likely to occur in 50MMF due to better control of fiber defects
  - Distance is only 100m
  - Do not have to support installed base
    - GbE field testing identified problems with older fiber

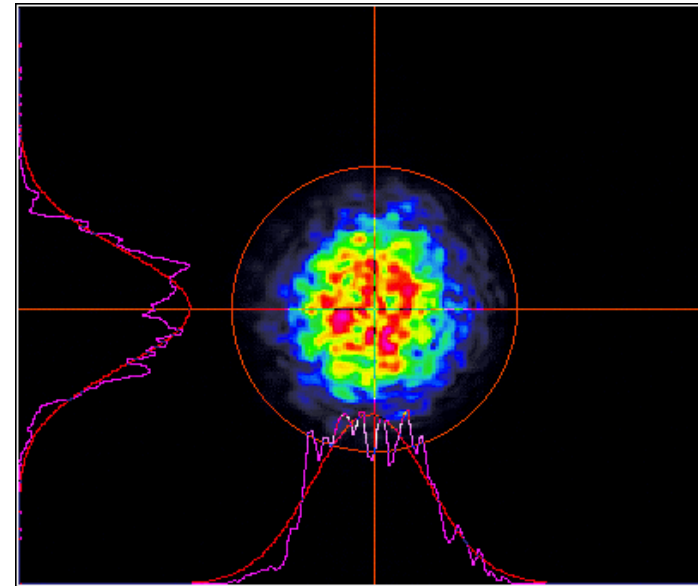
# VCSEL Launch

VCSELs are spatially multimoded. This excites many modes in the MMF.

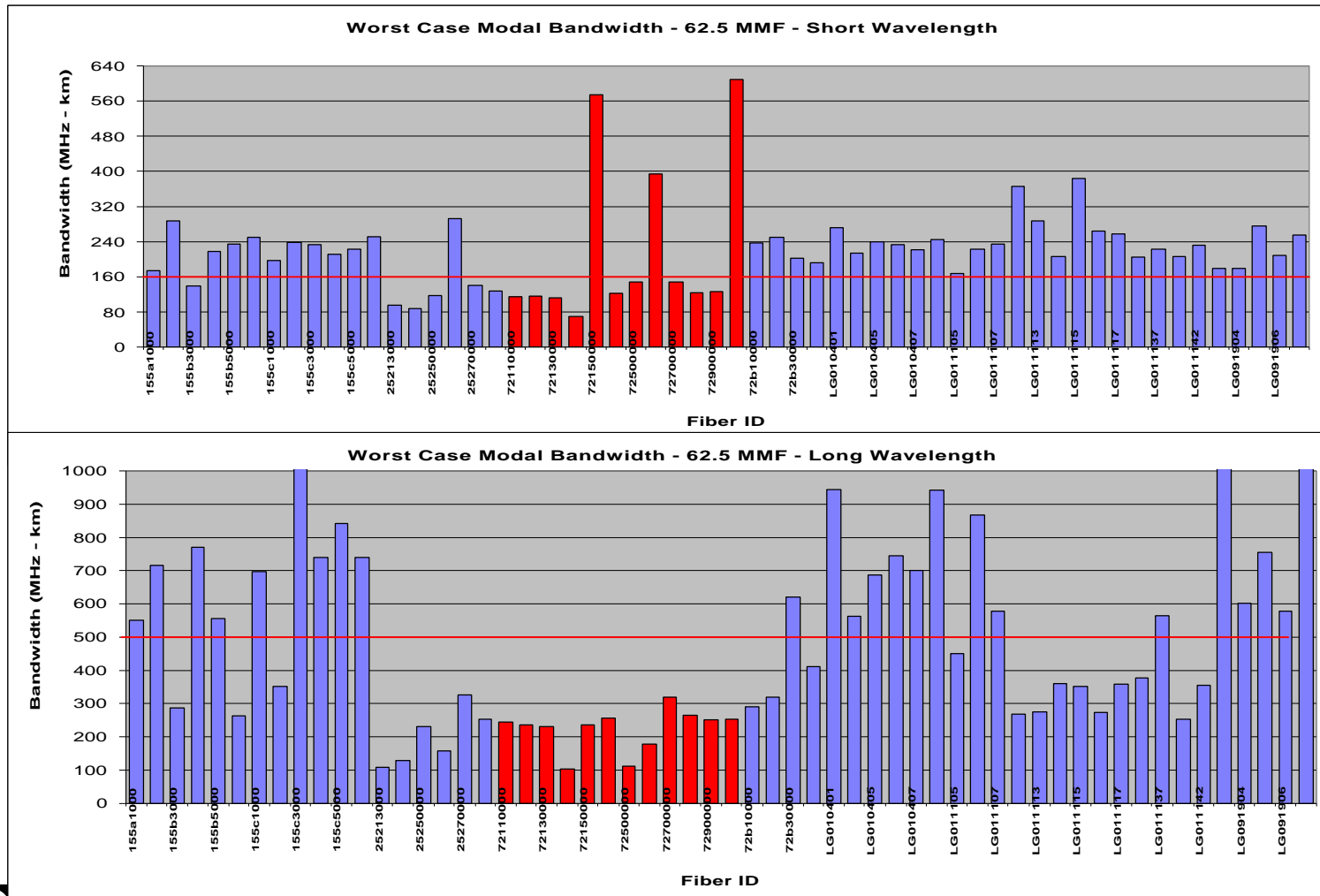
GbE offset patchcord (1300nm)



Typical VCSEL



# Gigabit Ethernet Field Testing



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# What Is Being Done...

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- TIA FO2.2 currently has a project whose goal is to:
  - Define a conditioned launch and measurement technique
  - Define a fiber characterisation method which will result in ‘laser certified’ MMF
- Contact: Mike Hackert - Corning Incorporated  
Tel: 607-974-3063  
hackertmj@corning.Com

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# Specifying DMD?

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- DMD actually has two meanings:
  - The actual effect of differential mode delay
  - A measurement technique
- All fibers have DMD
- The measurement technique is:
  - Not standardised
  - Does not tell you what you need to know anyway
  - Costly to implement in production

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# Updated 1394b GOF specification

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- Developed using Gigabit Ethernet model
- Updated jitter tables
- Gigabit Ethernet products meet S800 specification