Foreign Ingress

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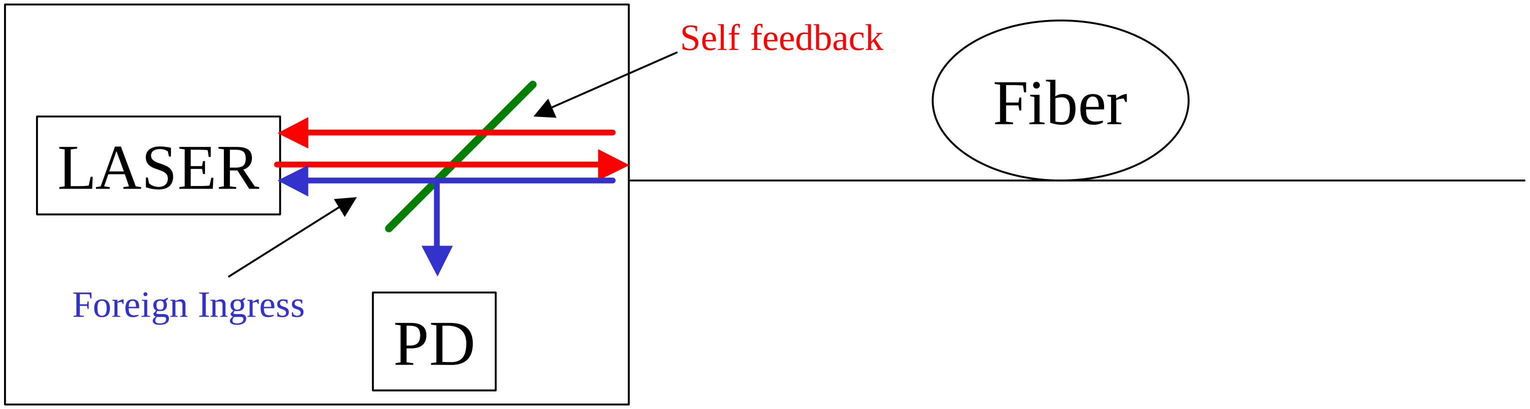
Background

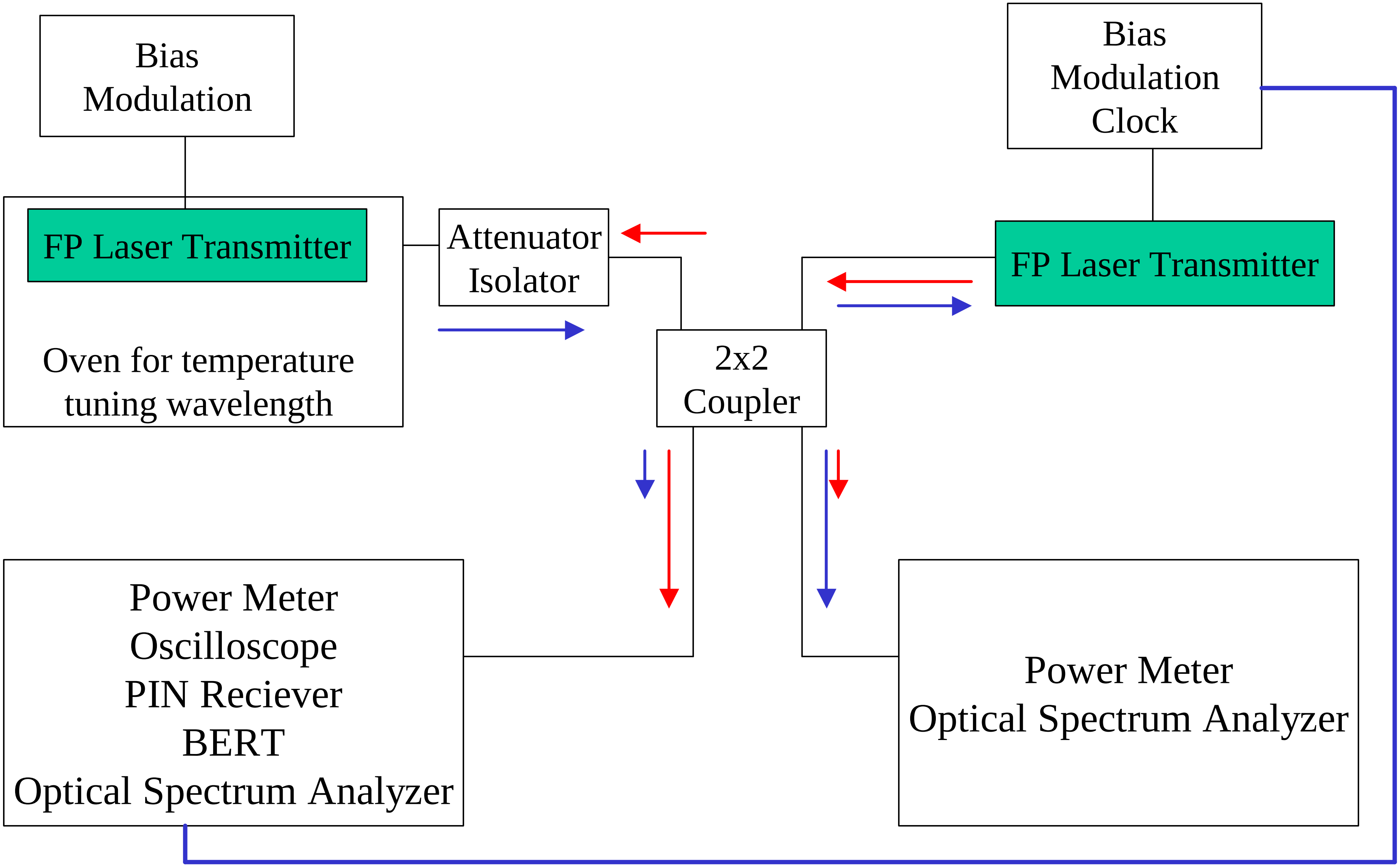


- Traditional feedback from a laser to itself include:
  - Reflection from near end fiber tip/fiber stub
  - Reflection from far end fiber tip
  - Reflection from splices/connector
  - Reflection from far end laser/pd/optics
- Foreign ingress is light from the other laser in a bidirectional link being injected into the first laser
  - Generally some form of isolator is needed to prevent noise problems
  - Foreign ingress is the most problematic source of noise in a bidirectional link

Research

- Injection of signals from once laser source into another has been exhaustively studied in the technical literature. Some of the other common names are injection locking, intensity noise, etc.
  - Literature has proven that chaotic behavior of the laser is possible
  - Strong intensity fluctuations are found when the laser wavelengths overlap
  - Tuning of the wavelength can be easily accomplished using temperature and/or current.
  - Polarization can enhance the effects

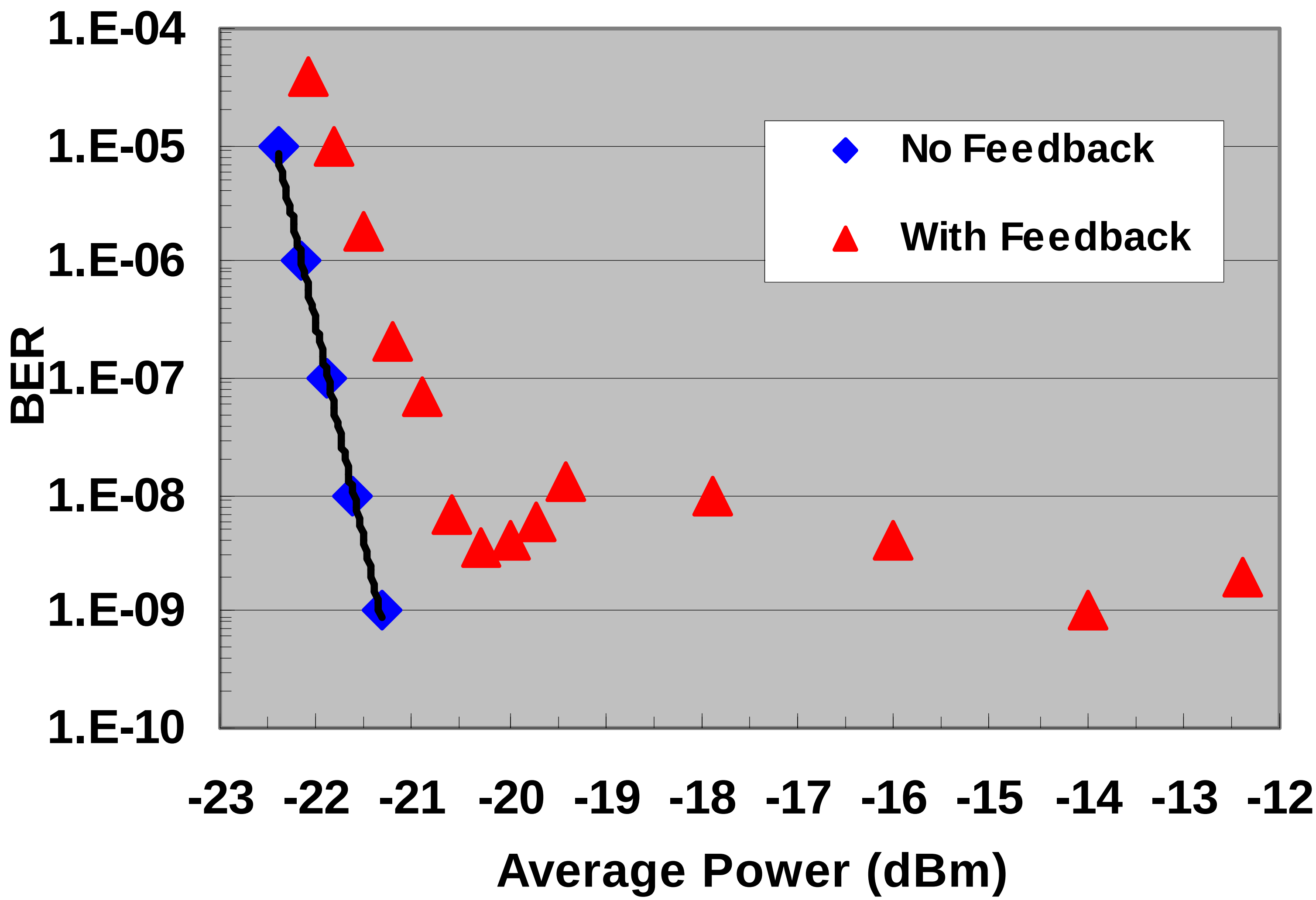
Experimental Verification



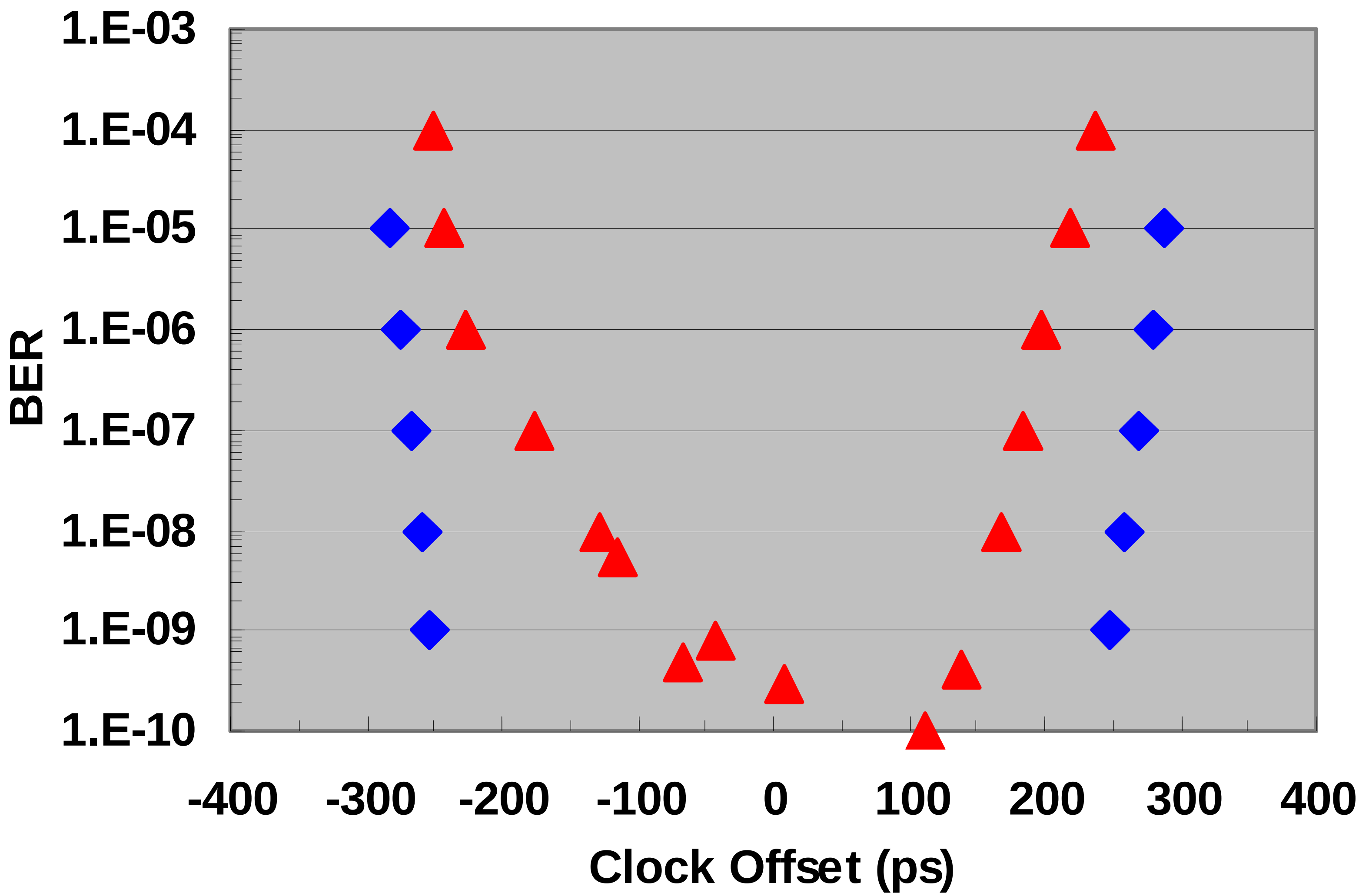
Measurements

- Measurements at Honeywell have indicated…
  - Burst noise as the laser wavelengths are tuned
  - Up to 7dB of noise penalty observed to maintain BER < 1e-12. In some cases a true noise floor is found.
  - Jitter budget is compromised
    - Random jitter is effected by RIN increase
    - Deterministic jitter is increased due to fluctuation in the laser output bias points
  - It is difficult to quantify the noise measurements because the effect may or may not be transient
  - Only a problem when the lasers are at the same wavelength
  - Polarization may enhance the effects, but is not necessary to produce the effects

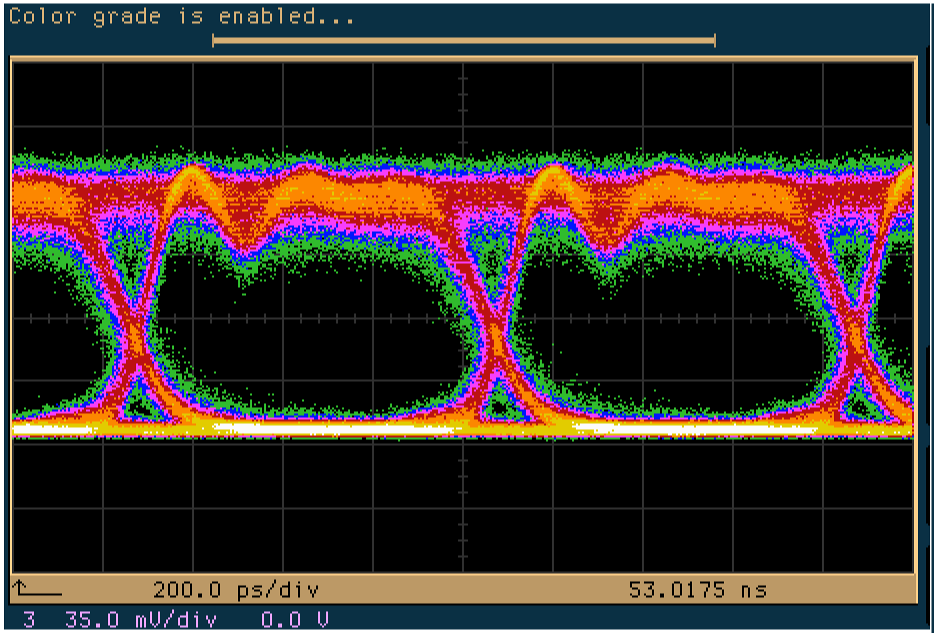
BER Measurements



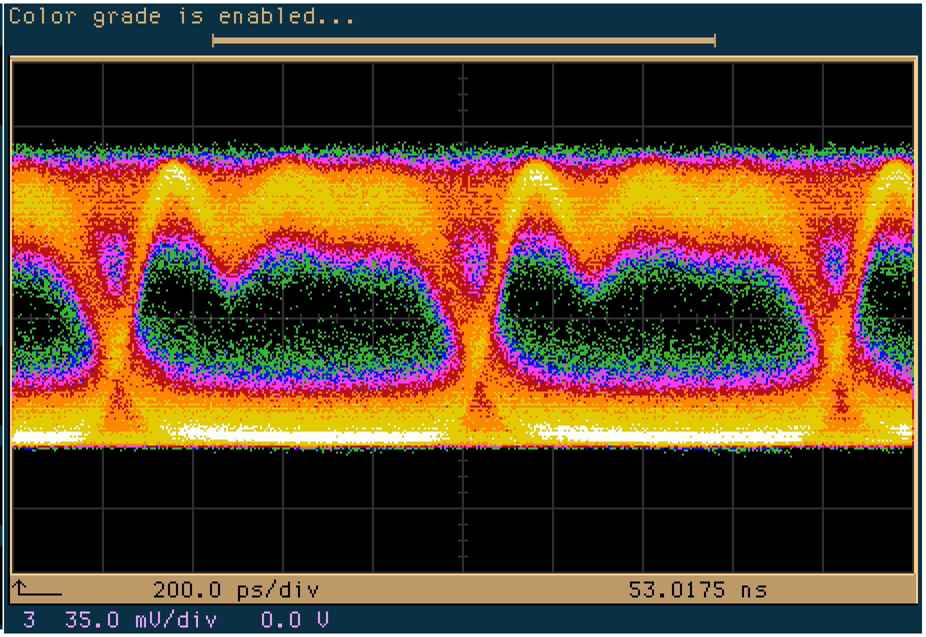
Bathtub plot



Time Domain

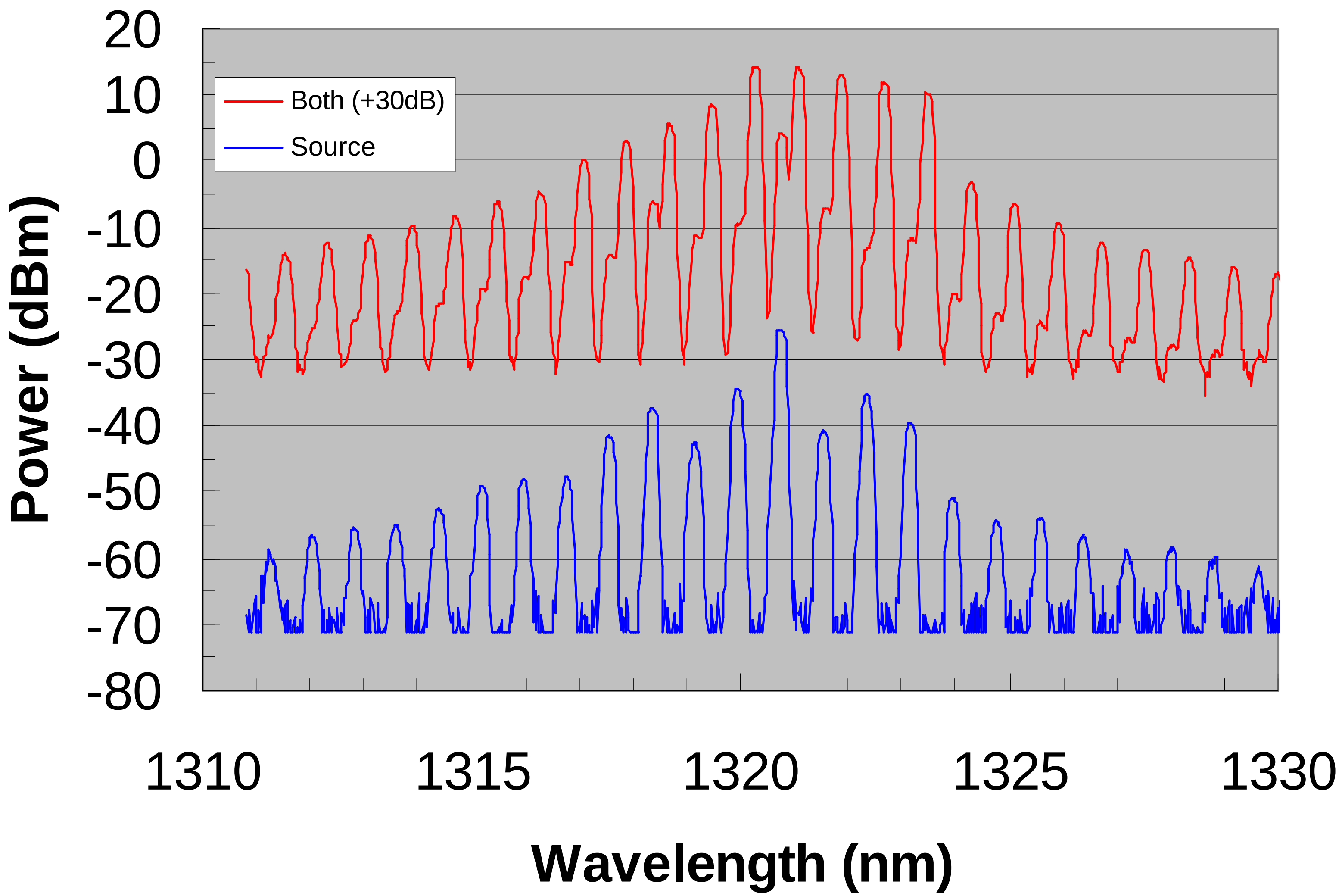


No Feedback



With Feedback

Optical Spectrum



Link Budget Calculations

- Current link budget models do not take foreign laser ingress into account
  - Effects may be transient and difficult to effectively quantify
  - Effect on BER and link budget from multiple areas
    - Spectral width
    - RIN
    - K factor
    - Output power
- New link models must be developed to account for these noise sources, or an isolator must be assumed in the transmitter
  - Any new model must be experimentally verified which will be both costly and time consuming
  - Most likely will take model out of the spreadsheet domain

Cost Analysis –1310/1550nm

- Common components ignored (Laser drivers, etc)
- 1310/1550nm Materials
  - 1310nm laser, minimum launch power of $P_{min,\ 1310nm}$
  - 1550nm laser, minimum launch power of $P_{min,1550nm}$
  - 2 PIN photodiodes, Sensitivity P_{sens}
  - Dichroic beam splitter
  - Coupling optics
- 1310/1310nm Materials
  - 2 1310nm laser, minimum launch power of $P_{min,\ 1310nm}$ + 3dBm
  - 2 photodiodes, Sensitivity P_{sens} – 3dBm (*e.g*. APD, etc.)
  - Beam splitter
  - Coupling optics
  - Potentially a fiber isolator
- Small, if any, differential in overall cost
  - 1550nm laser can be a low cost DFB or VCSEL
    - DFB does not have to be low chirp, etc.

Recommendation

- IEEE adopt a multi-wavelength point to point solution for EFM applications
  - Ensures robust link performance
  - Well known manufacturing infrastructure
  - VCSELs will drive the cost of 1550nm solutions
  - Total cost is similar
    - Assumes 3dB more sensitivity for the receiver
    - Assumed 3dB more power from the laser
    - Isolator requirements could control BOM costs
- Honeywell will make a technical presentation at the EFM interim meeting, and invites others to participate. Contact Jim Tatum