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4x25-Gb/s 40-km 1310-nm PMD with SOA Pre-Amplifier: Impact of Channel Spacing

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(collaboration with Marcus Duelk, Bell Labs / Alcatel-Lucent)

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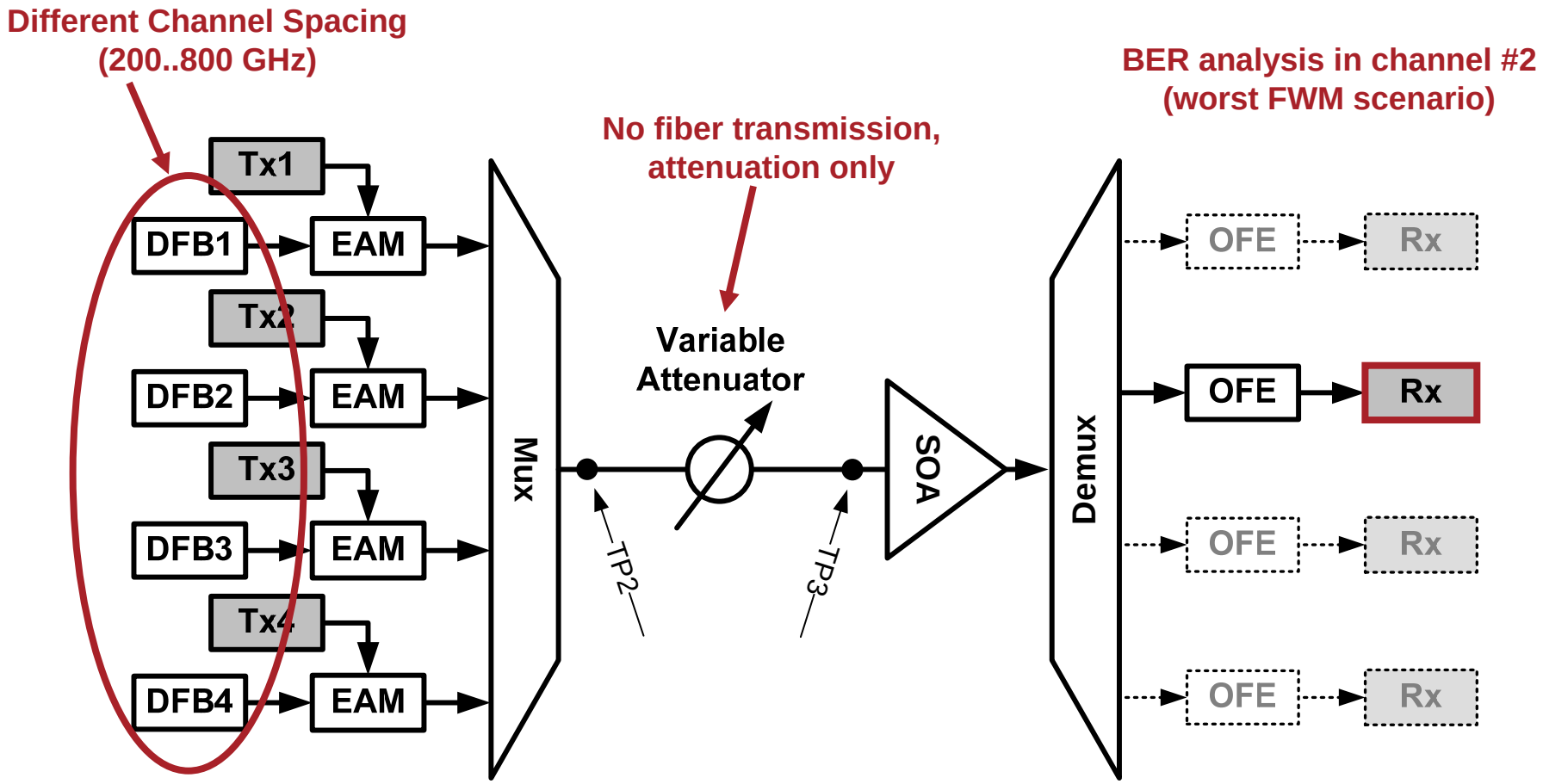
Link Configuration



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Other Details for This Analysis

- Fiber substituted by attenuator to suppress fiber dispersion and nonlinearities
- EML characteristics:
  - 10 dB extinction ratio (ER)
  - +4 dBm output power
- SOA characteristics:
  - small-signal gain = 23 dB
  - 3-dB compression point P_{sat} = +8 dBm,
  - noise figure = 9 dB
- Channel plan built around Tx2, which is spectrally located at the SOA gain peak (1310 nm)
- Numerical analysis carried out by varying the channel spacing from 200 to 800 GHz
- Spectral shifting of the transmitters due to age and temperature has also been considered

BER Results

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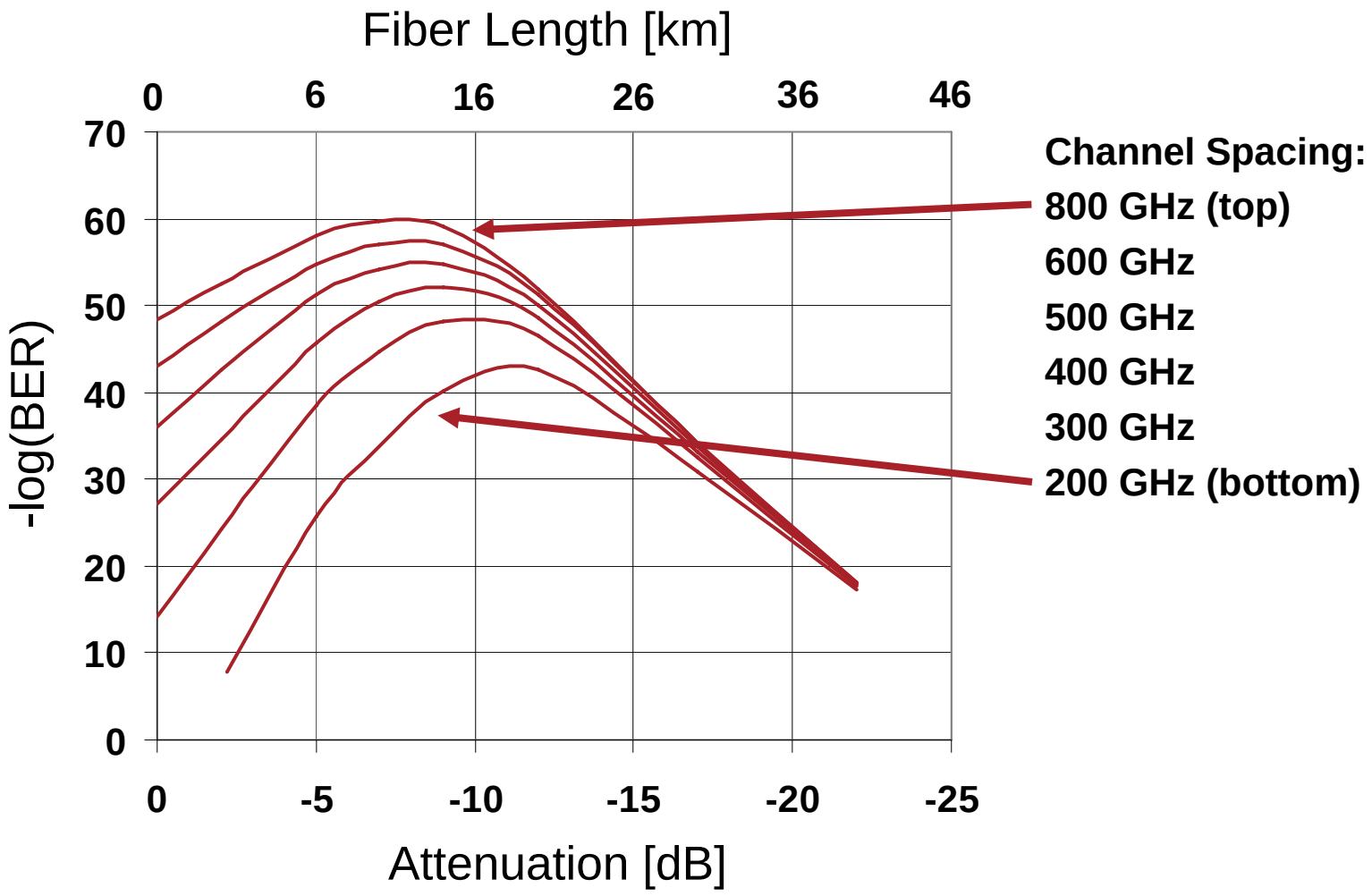
BER vs Attenuation for Different Channel Spacings



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BER vs Attenuation …cont'd

- For high attenuation (long fiber length) the BER becomes practically independent of channel spacing
- For low attenuation (short to medium fiber length) the link performance is impaired by SOA nonlinear effects, which become stronger for shorter fiber lengths
- A tighter channel spacing induces stronger SOA nonlinearities, thus reducing the system performance
- Apparently, the main SOA nonlinear effect is four-wave mixing
- Preliminary studies identify a strong contribution from the carrier heating effect in the SOA

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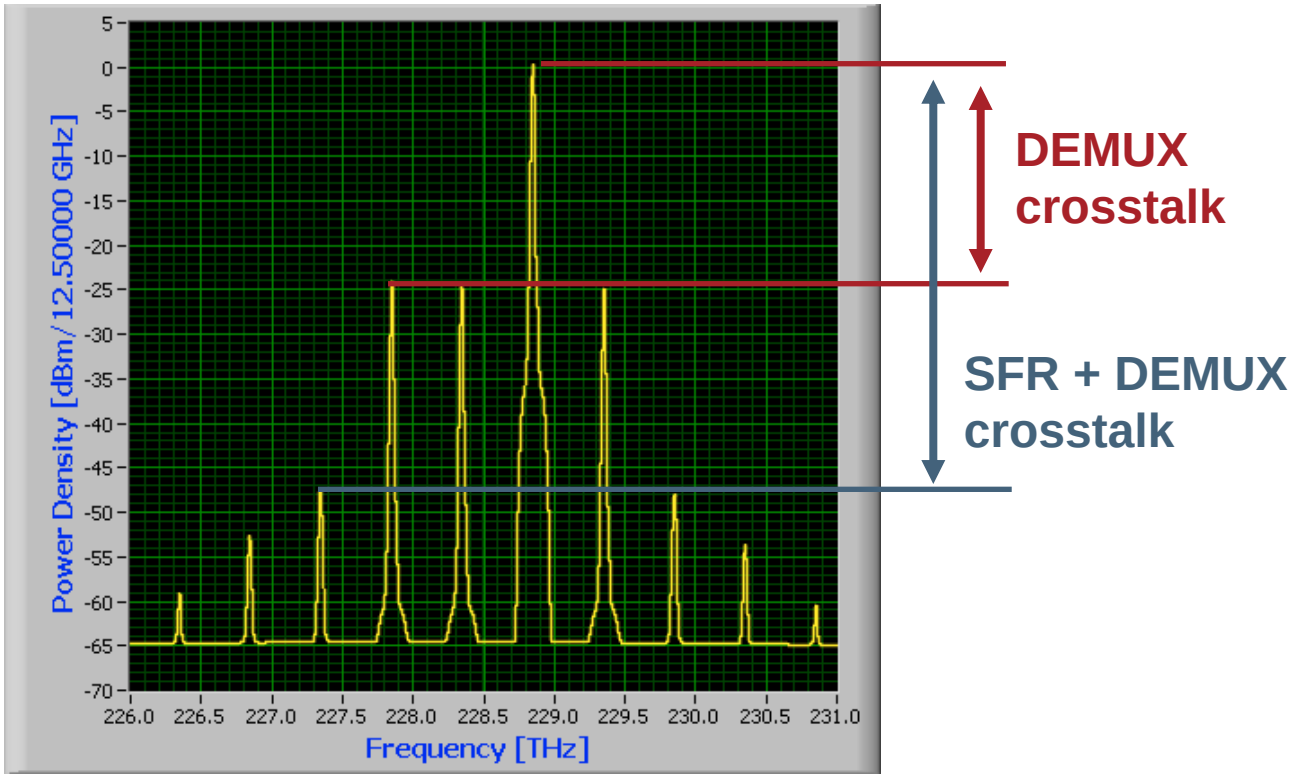
Example of Received Optical Spectrum (after DEMUX)



- "SFR" = Signal-to-FWM power Ratio
- Example for 10-km link (7 dB span loss), 500-GHz channel spacing
- Satellite products generated by Four-Wave Mixing (FWM)

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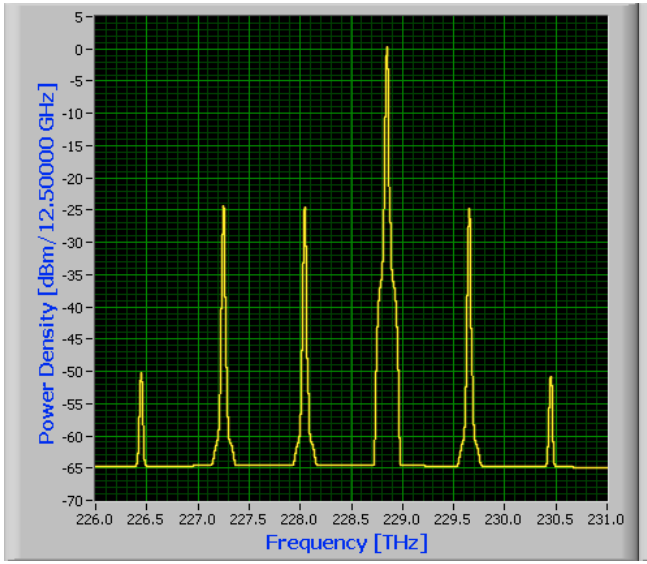
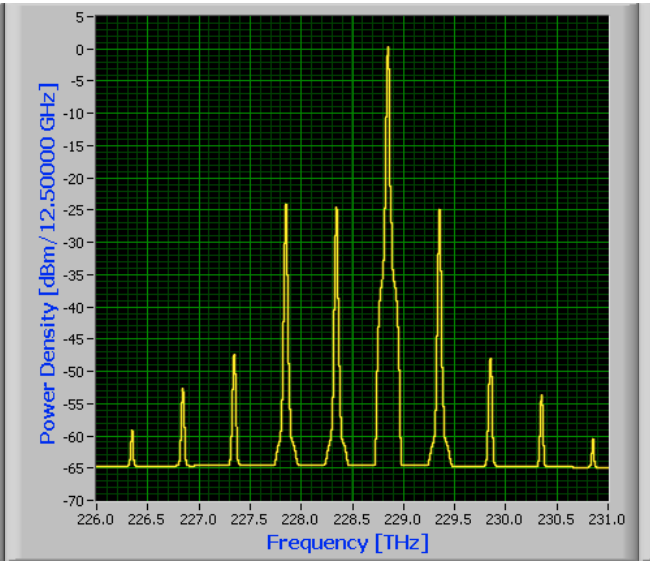
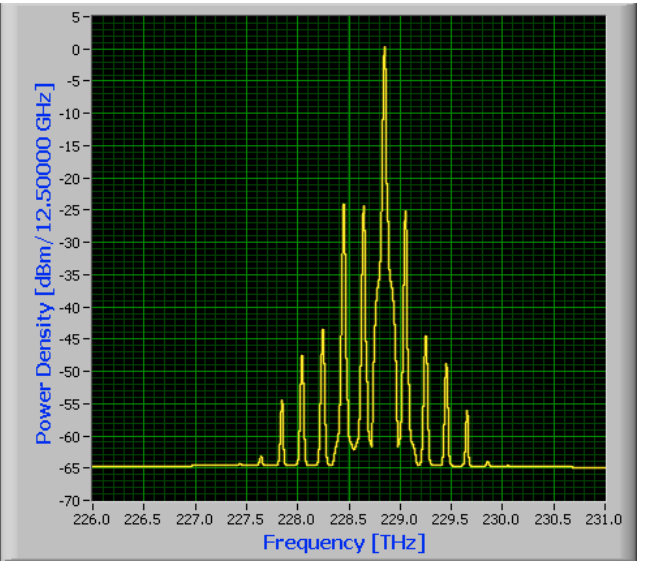
Simulated Spectra for an Attenuation of -7 dB (10 km)



800 GHz



500 GHz



200 GHz

- Spectra exhibit satellite products due to four-wave mixing
- FWM satellites become stronger for tighter channel spacing

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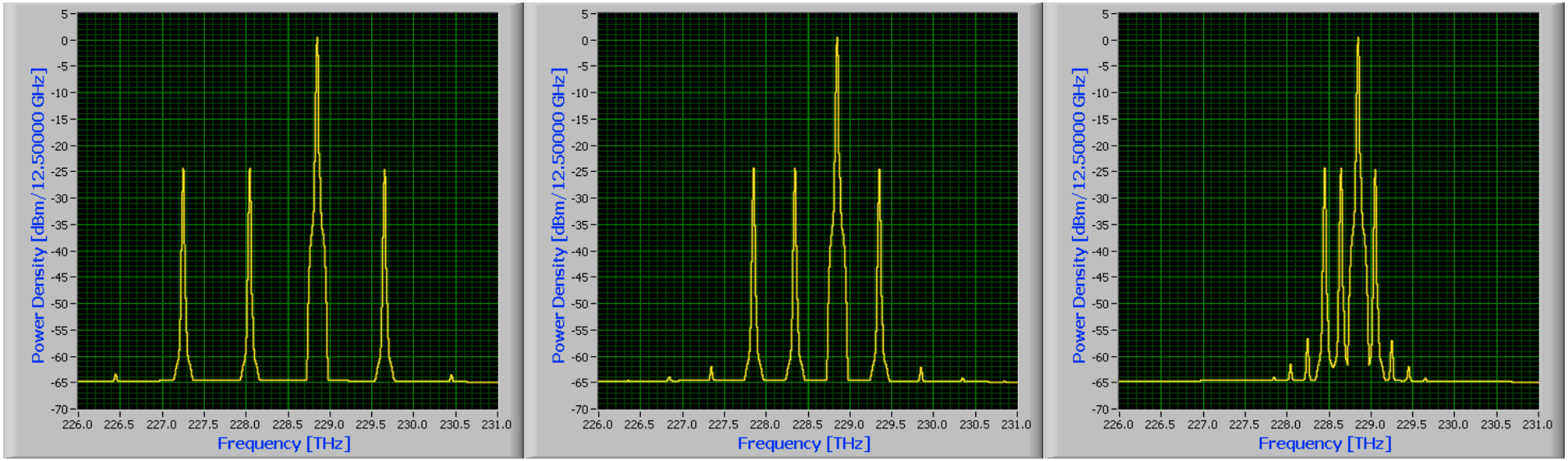
Same Spectra Without Carrier Heating Effect



800 GHz **500 GHz** **200 GHz**

- When the carrier heating effect is artificially turned off a reduction in the FWM products power is observed for every channel spacing
- Further research in explaining and quantifying how carrier heating affects the system performance is necessary

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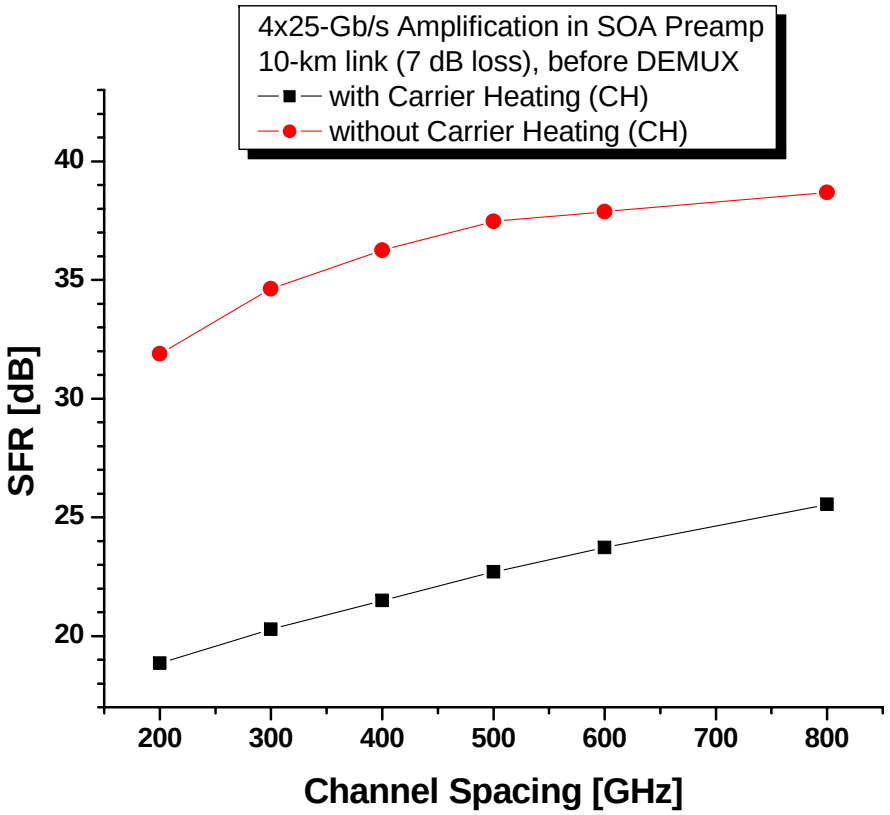
Impact of FWM as a Function of Channel Spacing



- "SFR" = Signal-to-FWM power Ratio
- SFR measured before optical DEMUX, i.e. FWM satellites are additionally suppressed by filter function of DEMUX (depending on specified Xtalk)
- Carrier Heating in SOA preamp reduces SFR by 10-15 dB, seems to impact BER performance for short fiber links

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Conclusions

- The impact of the channel spacing on the BER performance becomes negligible for attenuations larger than about -17 dB, corresponding to a 30-km link
- For smaller attenuations the BER performance varies with the channel spacing, i.e. smaller spacing yields worse BER
  - Example with -7 dB attenuation (10-km link), EML 10 dB ER, + 4dBm → The –log(BER) varies from 33.7 to 59.8 for a channel spacing variation from 200 to 800 GHz
- Apparently, the most relevant SOA nonlinearity is FWM
- Carrier heating plays a significant role in system degradation at short distances and tight channel spacings

Backup Material

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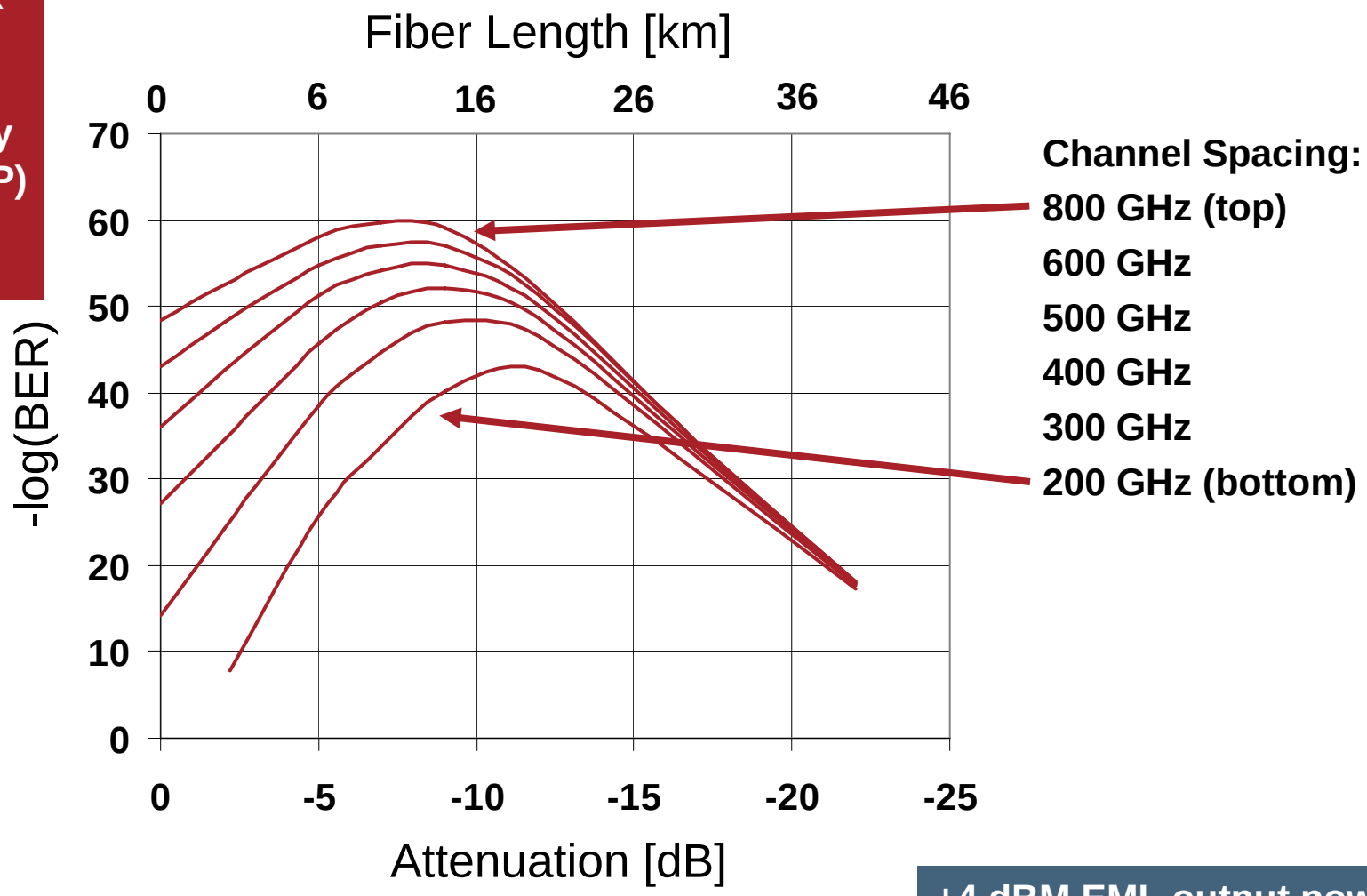
BER vs Attenuation (with Carrier Heating in SOA)

Spread in BER due to FWM caused by Carrier Density Pulsation (CDP) and Carrier Heating (CH)



+4 dBM EML output power

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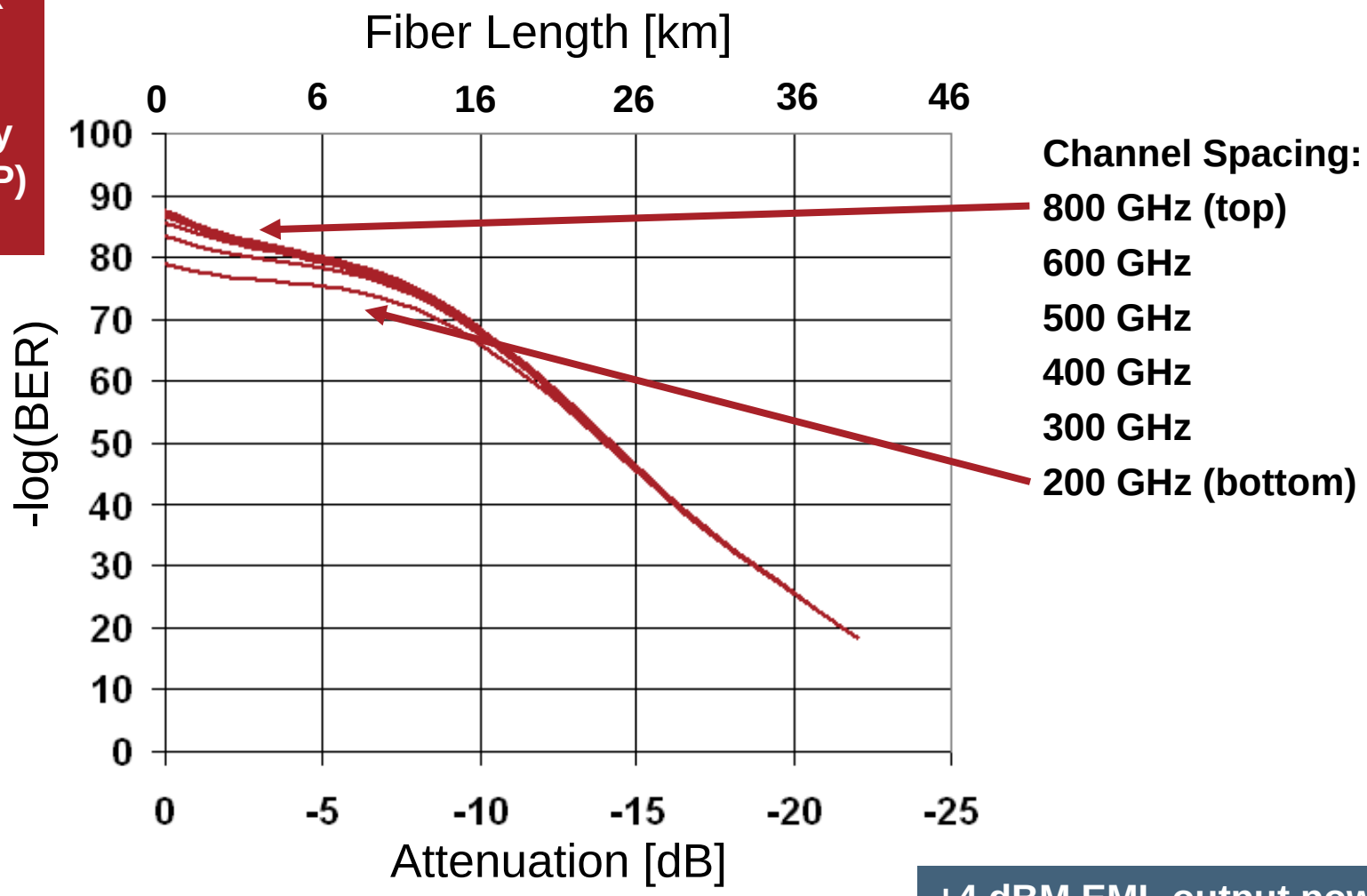
BER vs Attenuation (without Carrier Heating in SOA)

Spread in BER due to FWM caused by Carrier Density Pulsation (CDP) only, no CH !



+4 dBM EML output power