100GE 40km SMF Technology Limitation

IEEE 802.3ba Task Force

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40km SMF Outline

- Status
- Link Budget
- Overload Problem
- Overload Measurements
- Solution to Overload Problem
- Overload Solution Measurements
- Overload Solution Simulation
- Summary

40km SMF Status

- Consensus Approach to 40km SMF reach (cole_01_1106, cole_01_0407, traverso_01_0407, jiang_01_0507, gutierrez_01_0507, matsumoto_01_1107, nagarajan_01_1107)
  - TX: 4x25G MD-EML → Mux
  - RX: 4x25G PIN-TIA ← DeMux ← SOA
  - Grid: LAN WDM (2nm to 4nm)
- Key Issues analyzed
  - Min receiver sensitivity
  - Non-linear effects
- G.652 A&B SMF dispersion and fiber loss
  - λ = 1318nm (λ = 1306nm similar)
  - Max Dispersion (1319nm) = 72ps/nm
  - Max Loss (1319nm) = 17dB

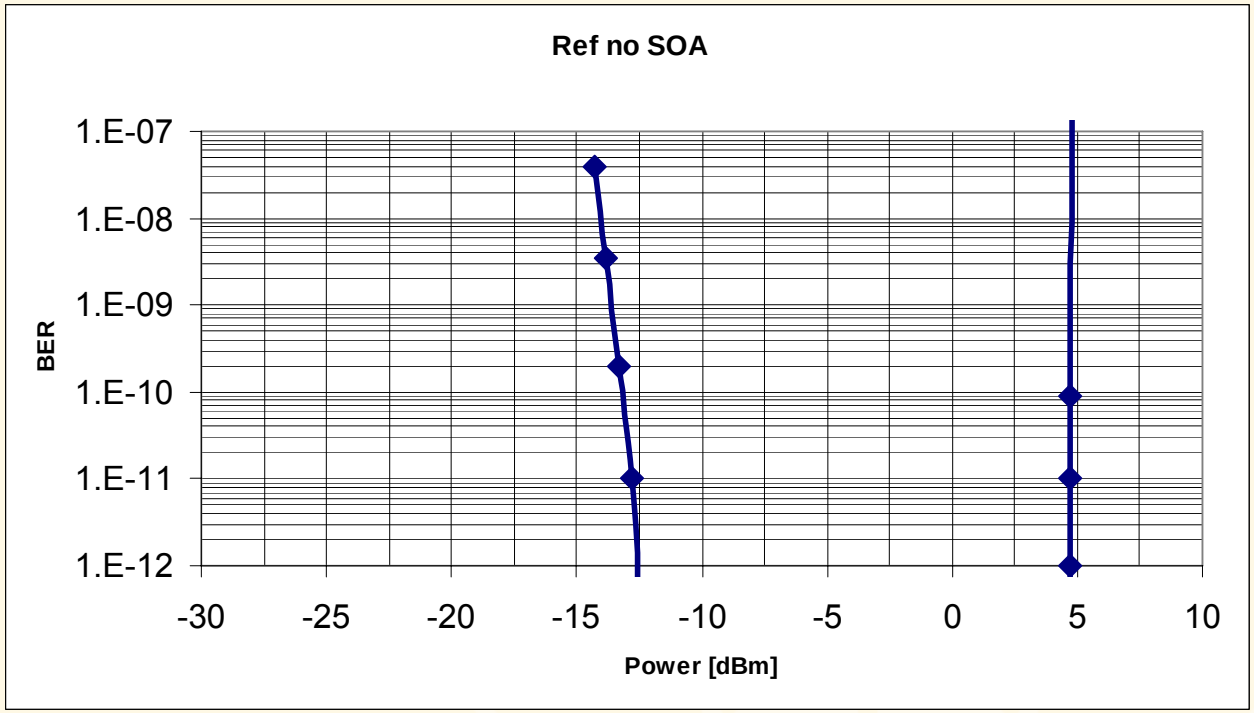
40km SMF Link Budget

40km SMF 25G	LAN WDM Cooled EML λ = 1318nm ER = 8dB
Fiber Loss (G.652 A&B)	17.0
ER penalty (versus ER=10dB)	0.6
CD	1.9
Connector & other losses (cross-talk)	3.0
Total budget	22.5

40km SMF Overload Problem

- 25G un-amplified PIN receiver properties:
  - Minimum sensitivity: -14dBm
  - Maximum input power (overload): +5dBm
- Example 40km SMF SOA receiver properties (cole_01_0507, p.8):
  - Minimum receiver Sensitivity: -22dBm
  - Extinction Ratio: 8dB
  - Target receiver sensitivity: -25dBm
  - Required effective SOA gain: 20dB
- Resulting maximum SOA receiver input power (overload): -15dBm
  (not accounting for SOA Gain decrease with input power)
- Additional G.652 A&B fiber loss property:
  - 40km minimum loss: ~13dB
- Problem is that any reach up to 40km can exceed the SOA receiver overload, requiring tuning of every link with a set of fixed optical attenuators to fit into the SOA receiver input dynamic range.

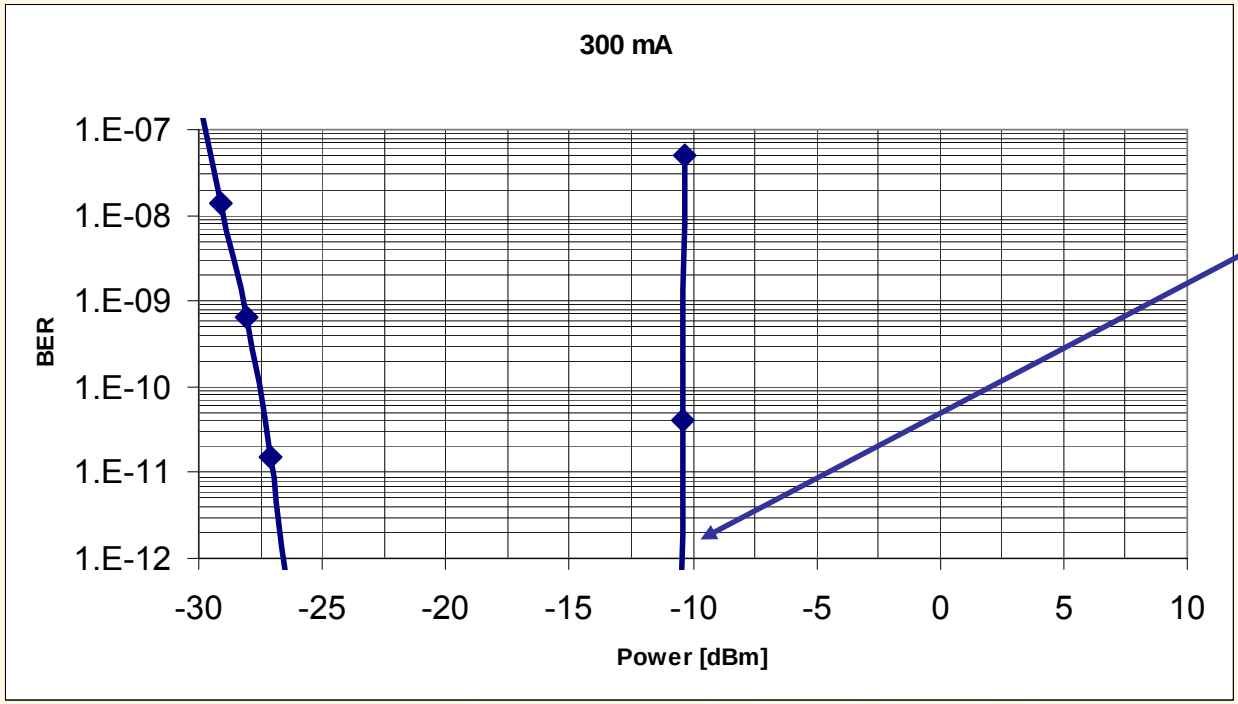
Un-amplified Receiver Sensitivity & Overload



Measurement Set-up

- Data: 20G PRBS 2^31-1
- TX: 40G 1544.1nm cooled EML (ER >10dB)
- Path: VOA → Polarization Rotator → ISO
- RX: 40G PIN/TIA → 40G CDR

SOA Receiver (Full Gain) Sensitivity & Overload



Overload Problem

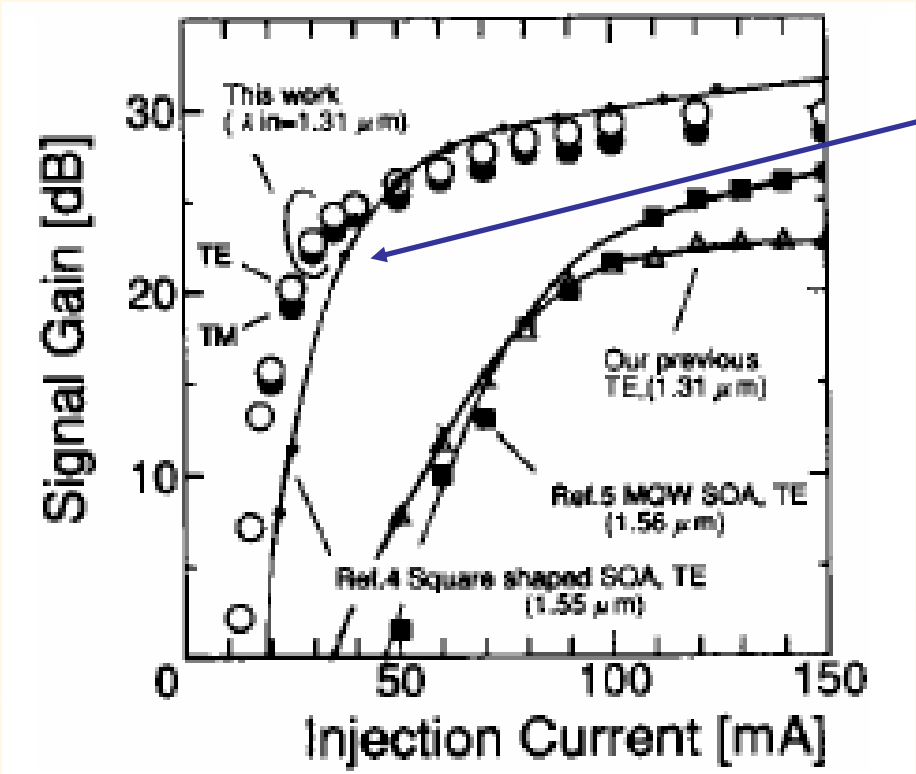
SOA Effective Gain at overload input power: 16dB

Measurement Set-up

- Data: 20G PRBS 2^31-1
- TX: 40G 1544.1nm cooled EML (ER >10dB)
- Path: VOA → Polarization Rotator → ISO
- RX: SOA (6.2dB NF) → ISO → BPF (1.3nm BW) → 40G PIN/TIA → 40G CDR
- SOA Effective Small Signal Gain: 19dB

Solution to 40km SMF Overload Problem

- SOA Signal Gain Bias Current dependence example



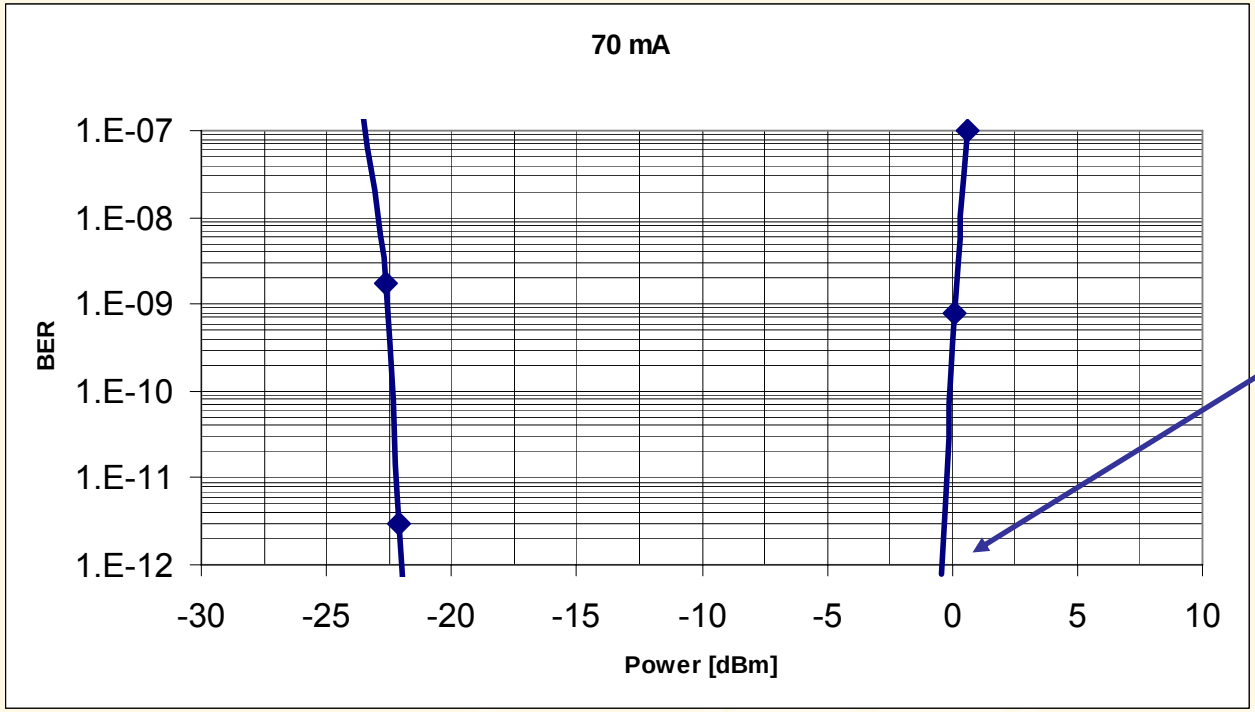
SOA Gain falls off with reduced Bias Current

S. Kitamura, Photon. Tech. Lett. vol. 7, page 147, 1995, cited in nagarajan_01_1107, p10

- Solution to Overload Problem:

  Reduce SOA Signal Gain for high receiver input power levels, by reducing SOA Bias Current.

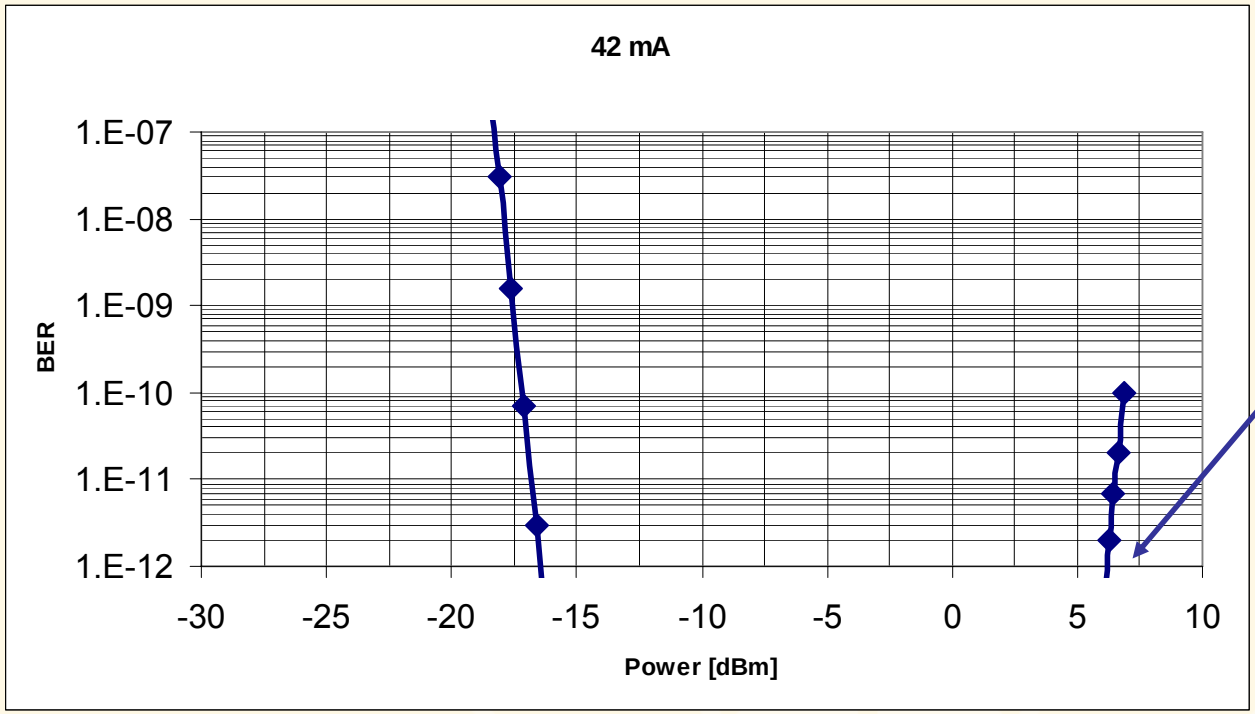
SOA Receiver (Low Gain) Sensitivity & Overload



SOA Effective Gain at overload input power: 5dB

- Measurement Set-up
- Data: 20G PRBS 2^31-1
- TX: 40G 1544.1nm cooled EML (ER >10dB)
- Path: VOA → Polarization Rotator → ISO
- RX: SOA (>>6dB NF) → ISO → BPF (1.3nm BW) → 40G PIN/TIA → 40G CDR
- SOA Effective Small Signal Gain: 10dB

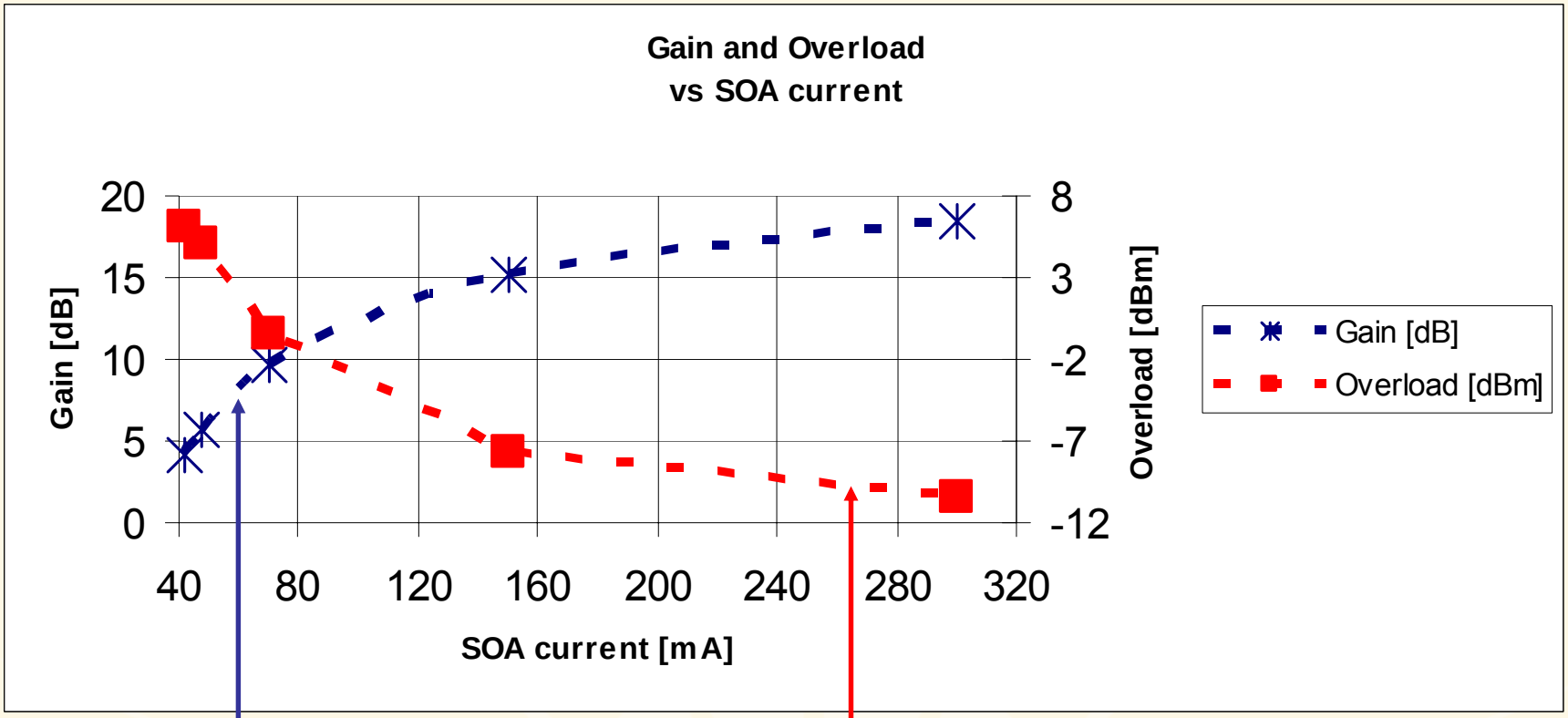
SOA Receiver (No Gain) Sensitivity & Overload



SOA Effective Gain at overload input power: -2dB

- Measurement Set-up
- Data: 20G PRBS 2^31-1
- TX: 40G 1544.1nm cooled EML (ER >10dB)
- Path: VOA → Polarization Rotator → ISO
- RX: SOA (>>6dB NF) → ISO → BPF (1.3nm BW) → 40G PIN/TIA → 40G CDR
- SOA Effective Small Signal Gain: 4dB

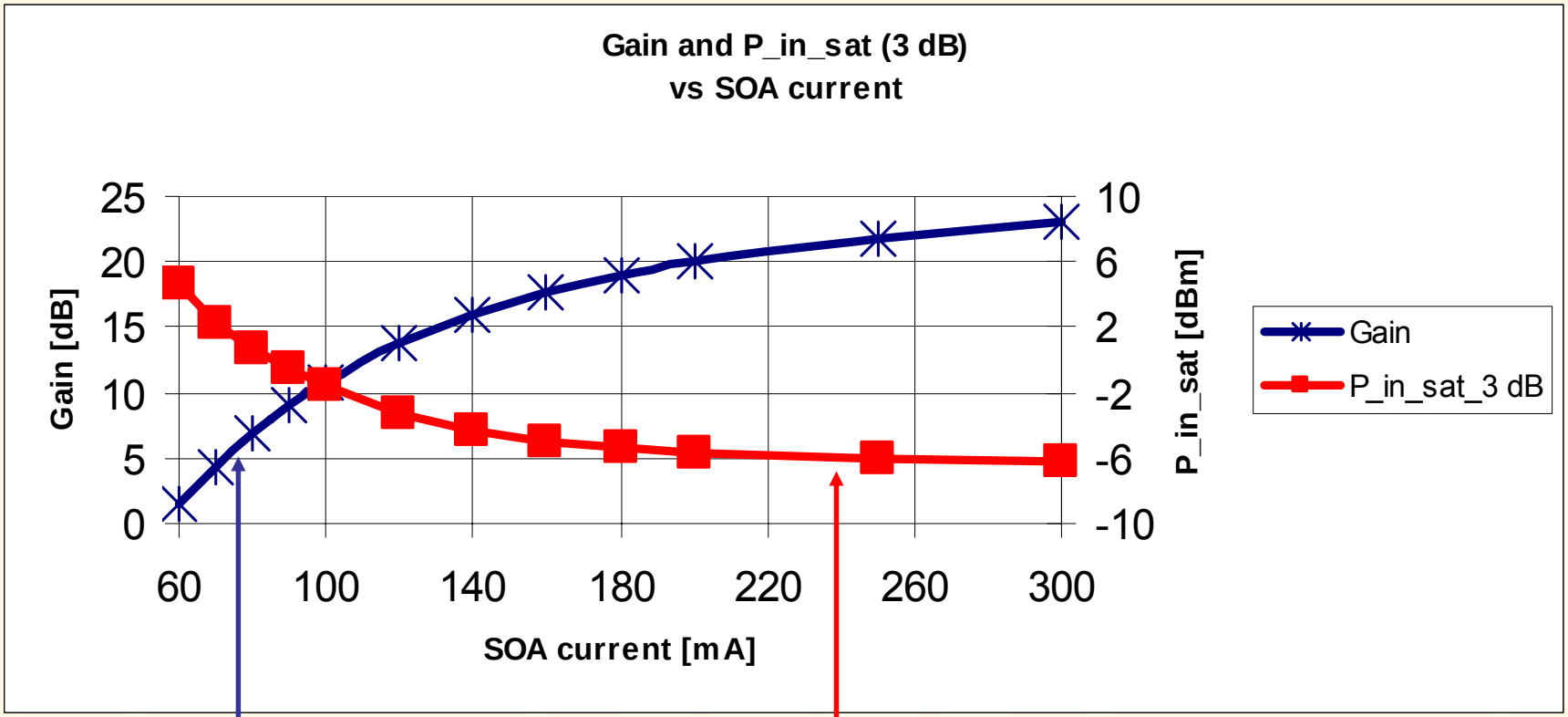
Sensitivity & Overload Measurement Summary



SOA Effective Small Signal Gain (dB)

Overload Input Power (dBm)

Gain & Input Saturation Power Simulation Summary



SOA Effective Small Signal Gain (dB)

3dB Input Saturation Power (dBm)

SOA3 data from “Gain Saturation vs. Injected Current in a Bulk SOA”, unpublished, 7 Dec. 2007, Ramón Gutiérrez-Castrejón (Institute de Ingenieria, Universidad Nacional Autonoma de Mexico-UNAM,) Marcus Duelk (Exalos)

Summary

- Reducing SOA Signal Gain by reducing SOA Injection Current when input power is high to increase the Dynamic Range of a 40km SOA Receiver appears promising.
- More investigation and measurements are required to characterize performance, in particular around the 0dB SOA Gain operating point, including with multiple wavelengths.
- Limitations of the approach need to be quantified for the 100GE 40km reach application, including effects of wavelength power differences.