

The Operation and Power Budget of Amplified Optical Networks for Aerospace Applications

BAE SYSTEMS



FOHEC Conference

May 2010

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CWDM Aerospace Networks

- Increase network bandwidth
 - Dense Wavelength Division Multiplexing (DWDM)
 - **Coarse Wavelength Division Multiplexing (CWDM)**
- 20 nm spacing
- Less susceptible to wavelength drift
- Use of uncooled devices (where possible!)
- Extended aerospace temperatures and harsh environments

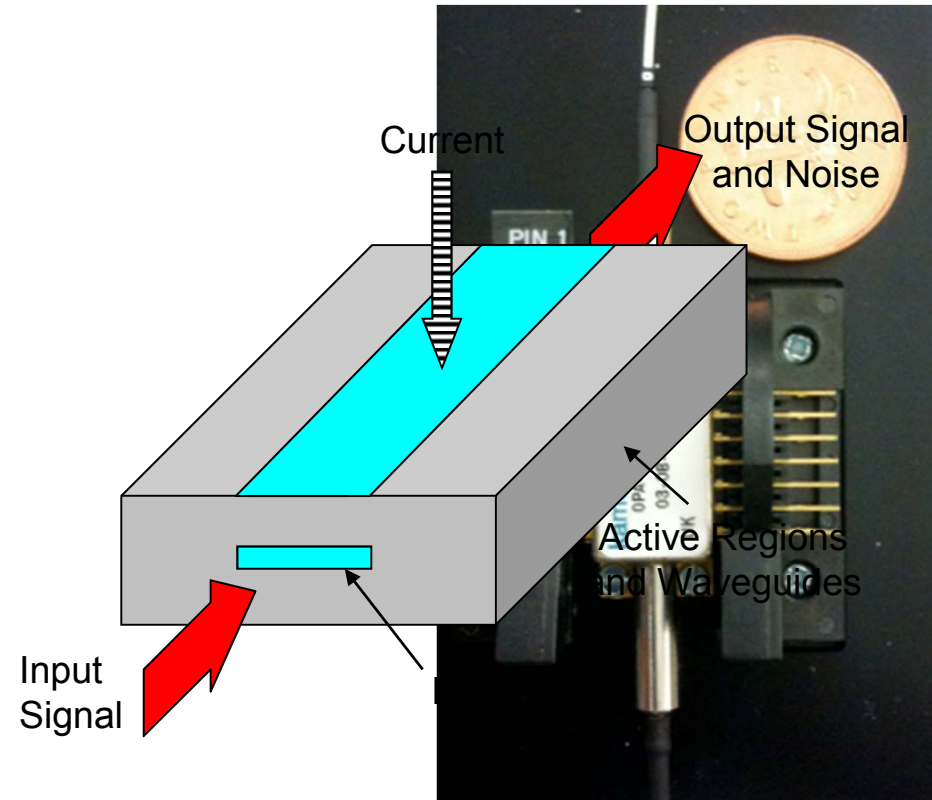
Optical Amplified Network



- Booster Amplifier
- In-Line Amplifier
- Pre-Amplifier
- Location of Amplifier depends on overall system margin
- Trade-off between split loss and trunk loss
- Amplifier not always in optimum position due to installation considerations
- In-Line most likely situation

Optical Amplifier

- Many versions of optical amplifiers
 - Erbium-Doped Fibre Amplifier (EDFA)
 - **Semiconductor Optical Amplifier (SOA)**
- Fabry-Perot laser diode
- Gain up to 30 dB
- Data rate transparent
- Small form factor
- Less expensive
- COTS device used



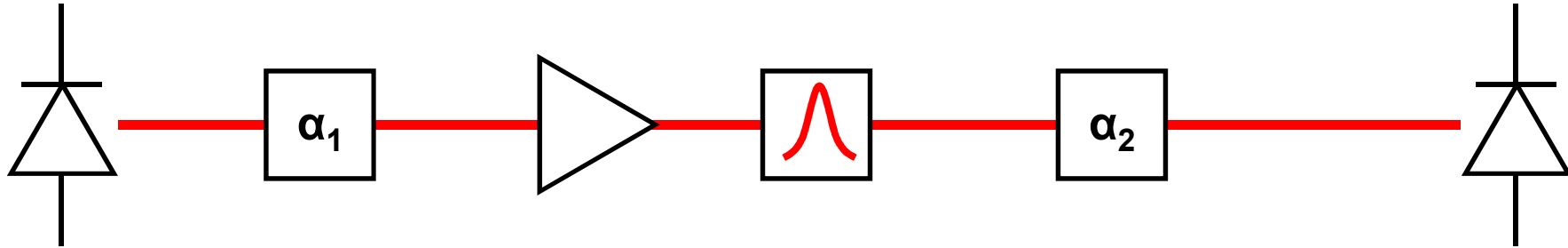
Optical Amplifier

- Suitability for CWDM systems
- ITU CWDM standard of 1260 to 1620 nm (low loss fibre transmission window)

- EDFA:
 - C-Band (1530 – 1562 nm)
 - L-Band (1570 – 1610 nm)
- SOA:
 - 1260 – 1620 nm

SOA	
Advantages	Disadvantages
High Gain	Noisy
Wide Transmission Window	Low Temperature Range
Inexpensive	Polarisation dependent
Compact	
Data Transparent	
Easier Integration	

Simulated Network



The following setup was used for the analysis:

- The transmitter – extinction ratio and power
- The loss before the amplifier (splitter / connector / trunk loss)
- Amplifier gain, saturation power and noise figure
- Post amplification filtering – restrict wavelength
- Post amplification loss (splitter / connector / trunk loss)
- Receiver performance, including noise sources

Noise Sources

- System performance
 - Signal-to-Noise Ratio

$$SNR = \frac{\text{Average_Signal_Power}}{\text{Noise_Power}} = \frac{I_p^2}{\sigma_{tot}^2}$$

- Total Noise

$$\sigma_{Tot}^2 = 2\sigma_T^2 + \sigma_S^2 + 2\sigma_{ASE}^2 + \sigma_{S-ASE}^2 + 2\sigma_{ASE-ASE}^2$$

- Combines contributions from:

Thermal Noise

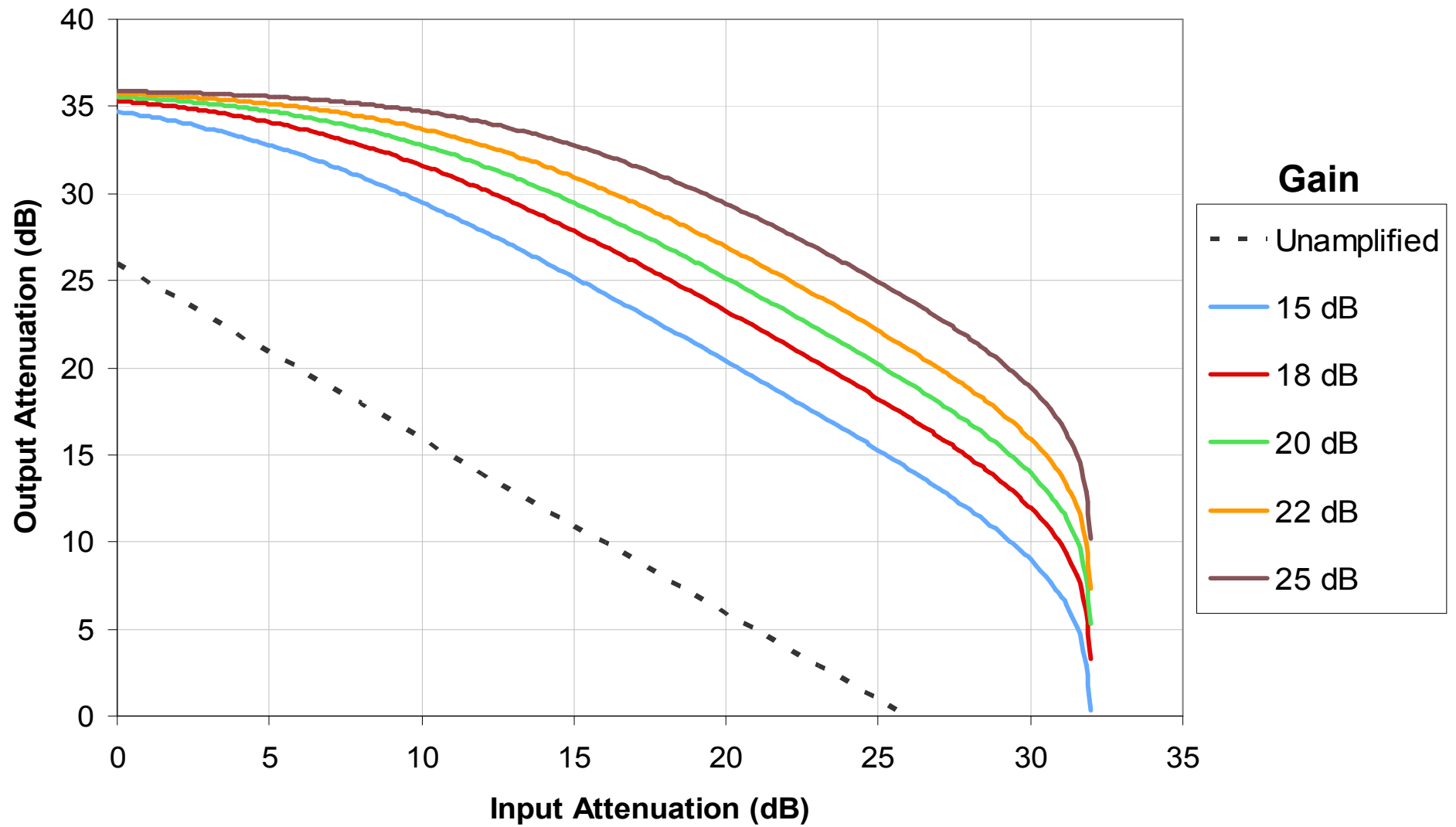
ASE- Shot Noise

Shot Noise

ASE-ASE Beat Noise

Signal-ASE Beat Noise

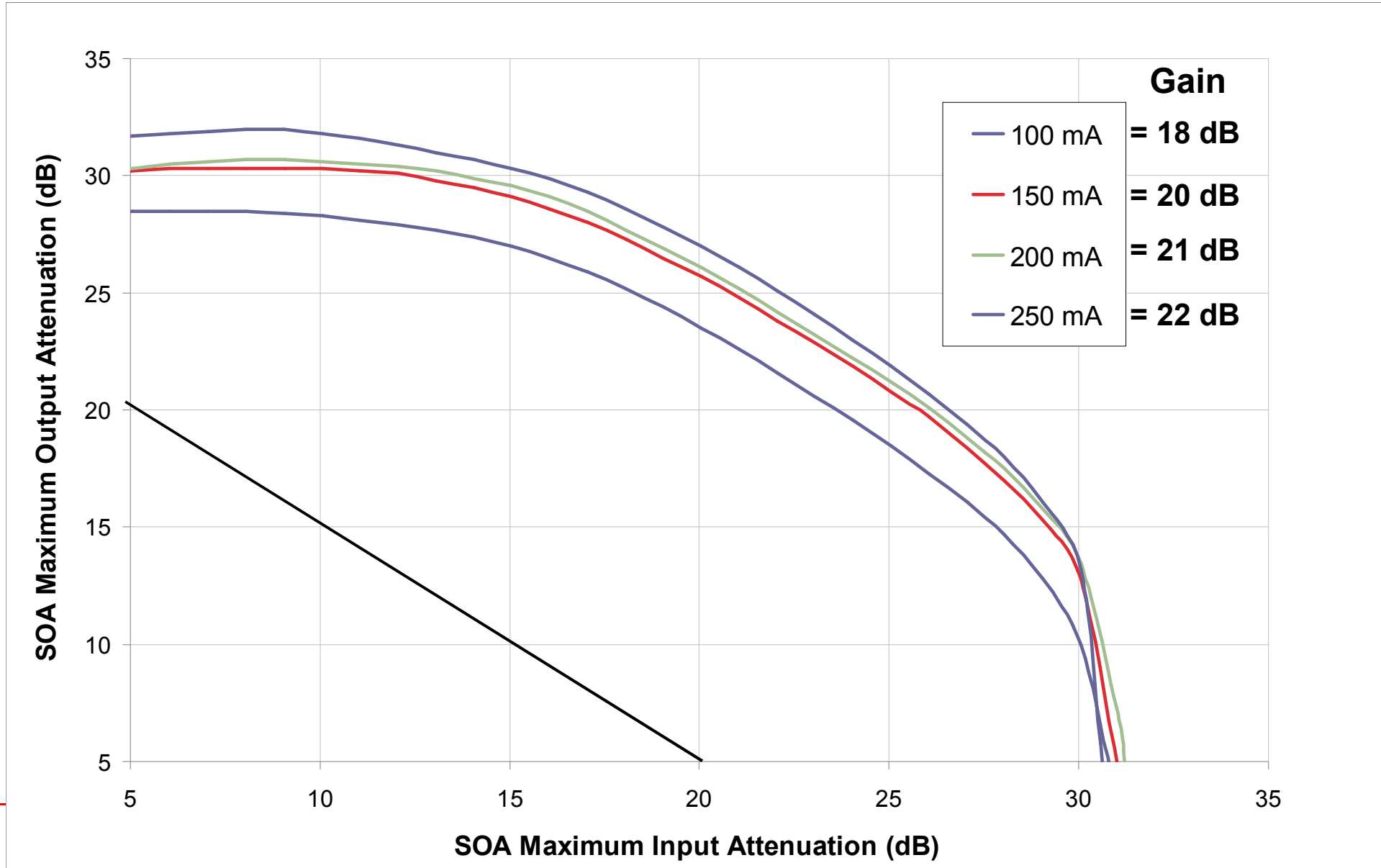
Modelled Results



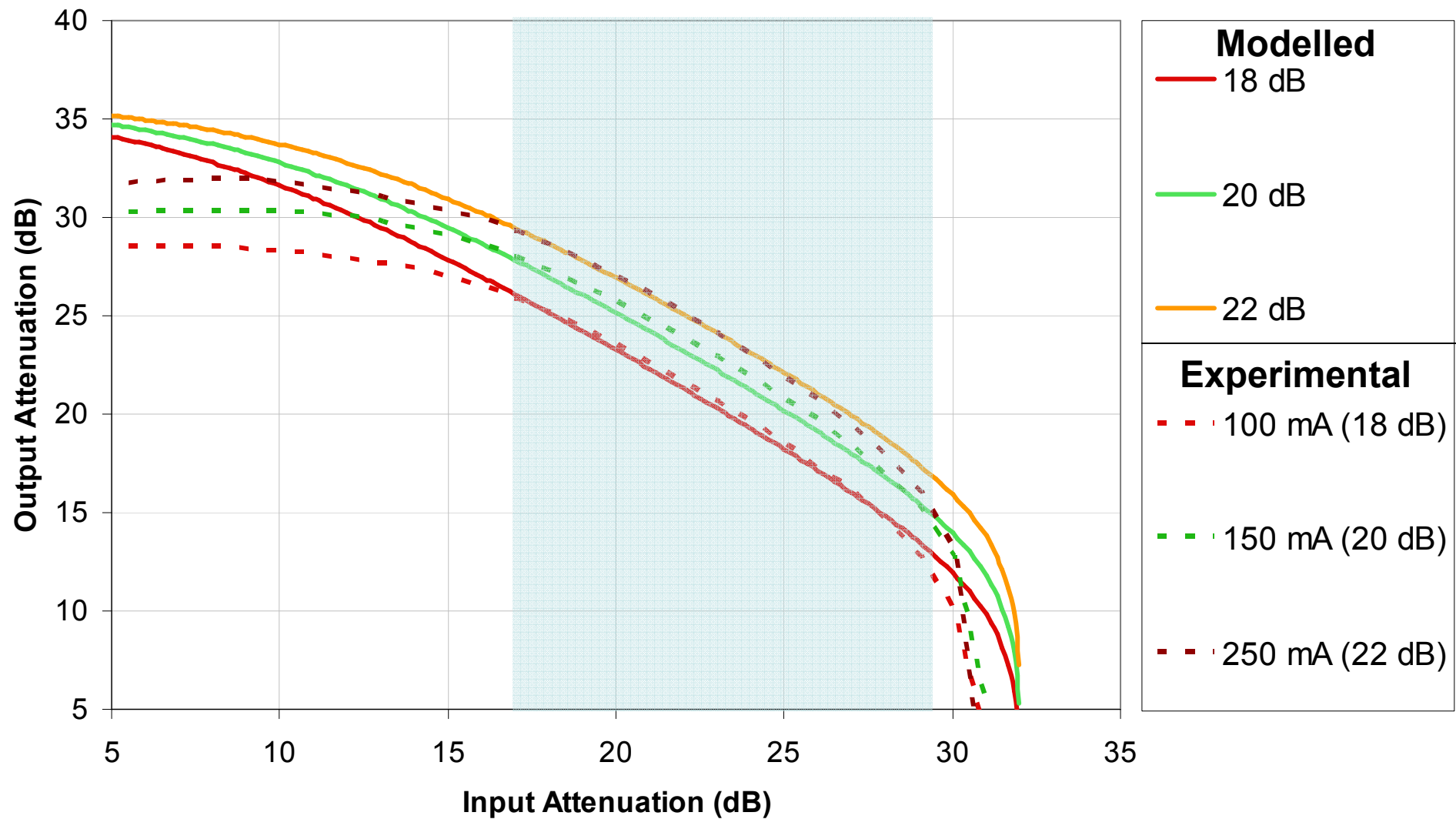
Experimental Setup



Experimental Results

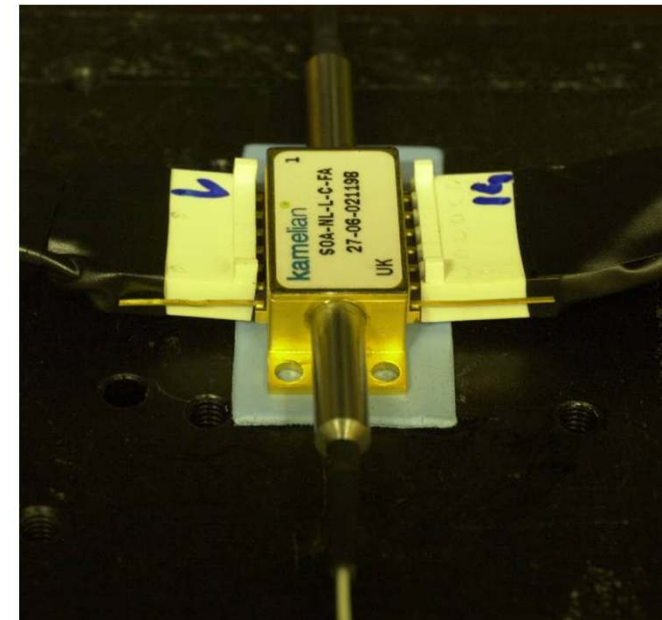
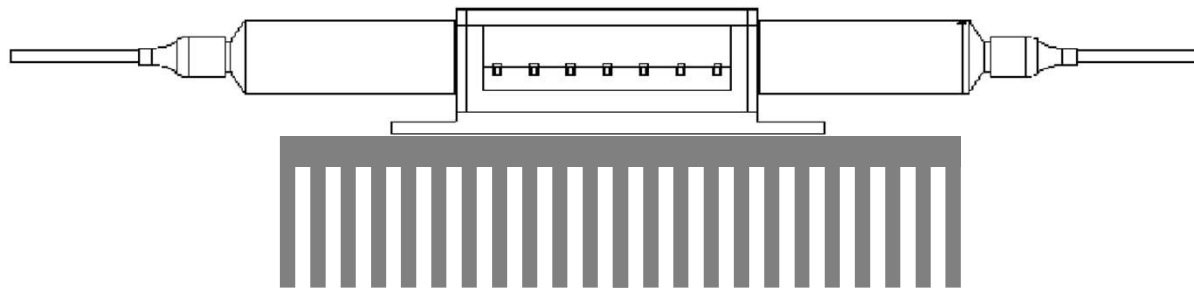


Comparison of Model to Experimental Results



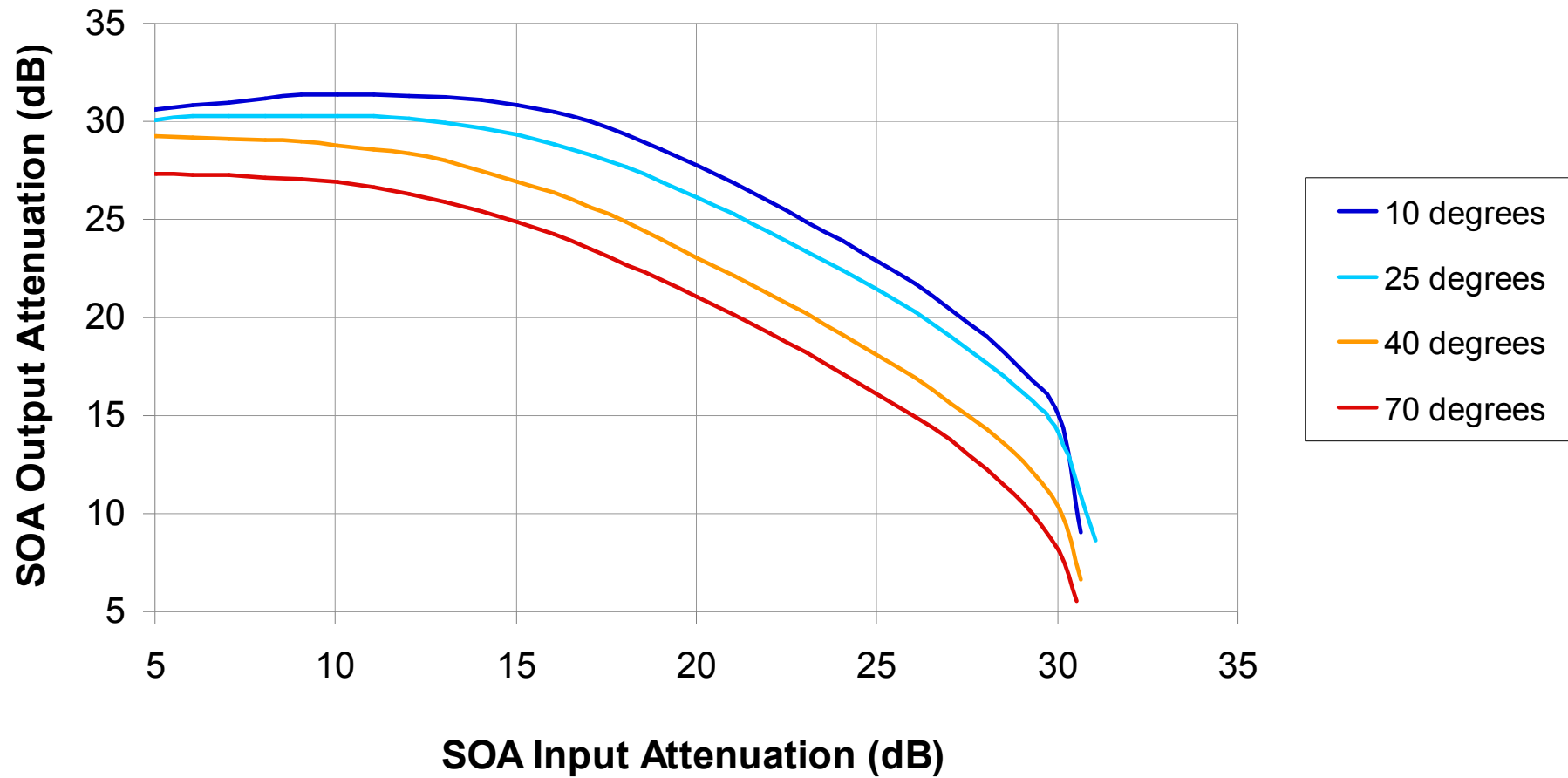
TEC Control

- SOA mounted on Thermoelectric Cooler (TEC)
- Operational range of SOA: 10 ° C to 70 ° C
- Want extended temperature range
 - -40 ° C to 120 ° C
- Maximum TEC power: 3.5 W
- Gain dependent on temperature

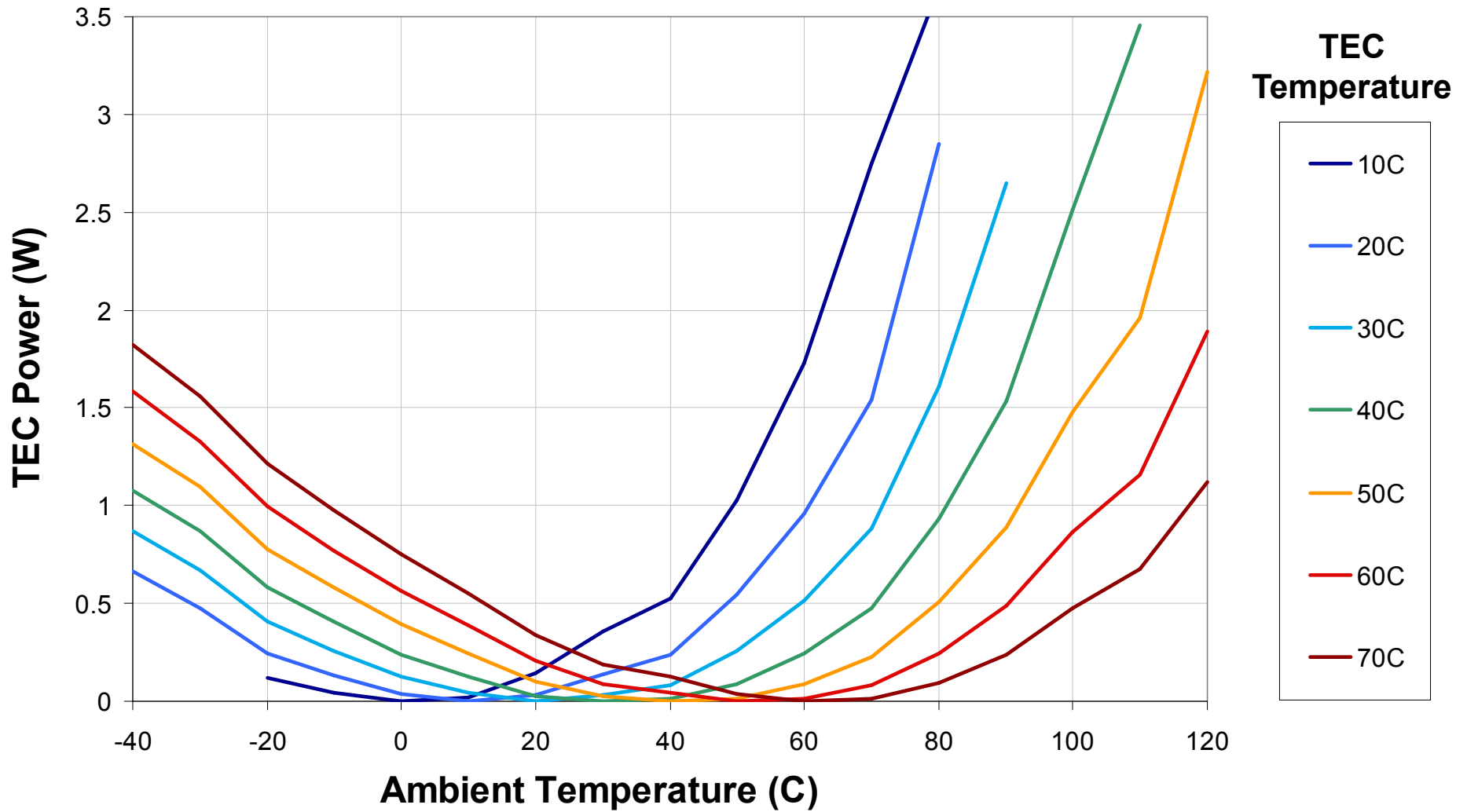


Temperature Dependency

Dynamic Range of SOA at 150 mA



Power Budgets



Conclusion

- Suitability of amplified optical networks for aircraft assessed
- Modelling optically amplified network
 - Network layout
 - Position of SOA
- Experimental Verification
 - Amplified dynamic range
 - Dependency on temperature
 - SOA operational temperature range
 - Extended operation with TEC
 - Power consumption implications
- Model can be used to determine
 - Operation in aerospace conditions
 - System Implications