

A Long-Span Repeater for Regional Submarine Systems

Equipment & Component Technologies



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Submerged Equipment Development - Alcatel-Lucent Submarine Networks

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Outline

1. Introduction
2. Choice of the dual-stage EDFA topology
3. Dual-stage amplifier-pair design
4. Repeater optical performances
5. Summary - Conclusion

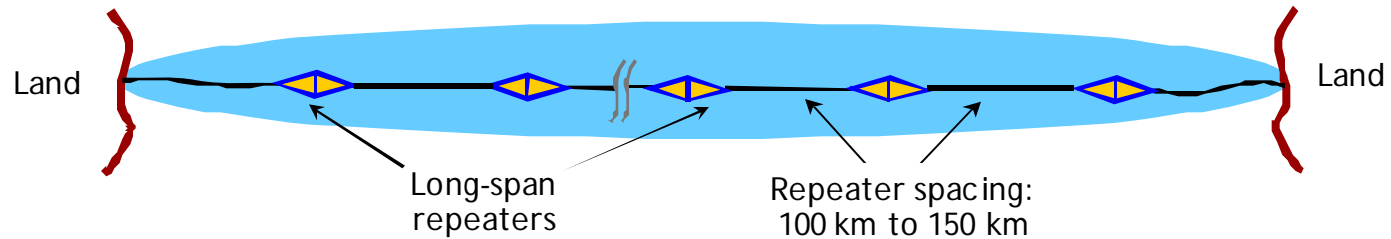
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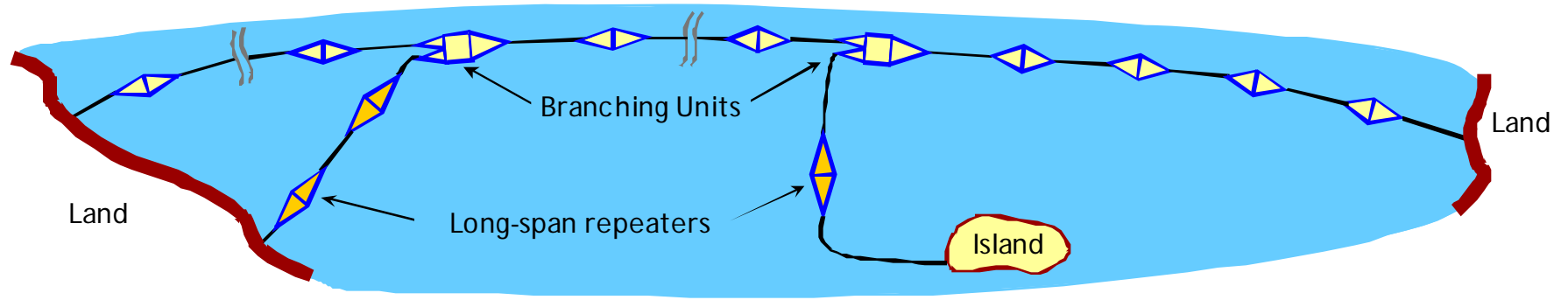
Introduction

- Increase of span reach allows to reduce the cost of submarine telecommunication cable systems,
- New long-span submarine repeaters enabling repeater spacing in the range 100-150 km is presented. Example of applications :

Regional cable systems (main application) :



Branches of long-haul or ultra long-haul cable systems :



Introduction

Which technology for long-span repeaters ?

Various amplification methods investigated (lab demonstrations) :

Distributed Raman amplification / Raman-assisted Erbium-Doped Fibre Amplifier (EDFA):

- + Low Noise Figure \equiv OSNR improvement compared to EDFAs
- Low pump efficiency. Large pump power consumption required
 \Rightarrow high line current requirement (impact the cable cost and/or PFE),
- System performances may suffer from pump power & wavelength unstabilities and significant impact of cable repair all along the system lifetime.

Erbium-Doped Fibre Amplifier:

- + High pump efficiency,
- + Robust and reliable technology for use on submarine cable systems,
 - BUT, long-span repeater (\equiv "high-gain" $>$ 20 dB) implies the use of dual-stage EDFA to achieve stable line amplification.

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Submarine Long-Span Repeater Topology

Design Requirements

Submarine repeater key drivers:

- **Reliability :**

Must be qualified for use on undersea operation over a lifetime of twenty-five years.

- **Robustness :**

The design shall take into account a wide range of operational conditions that the repeater could experience :

- The systems shall remain operational in the event of a repeater input level drop reaching 10 dB below its nominal input level,
- Shall not be altered in case of any faulty conditions (cable break / cable loop incident).

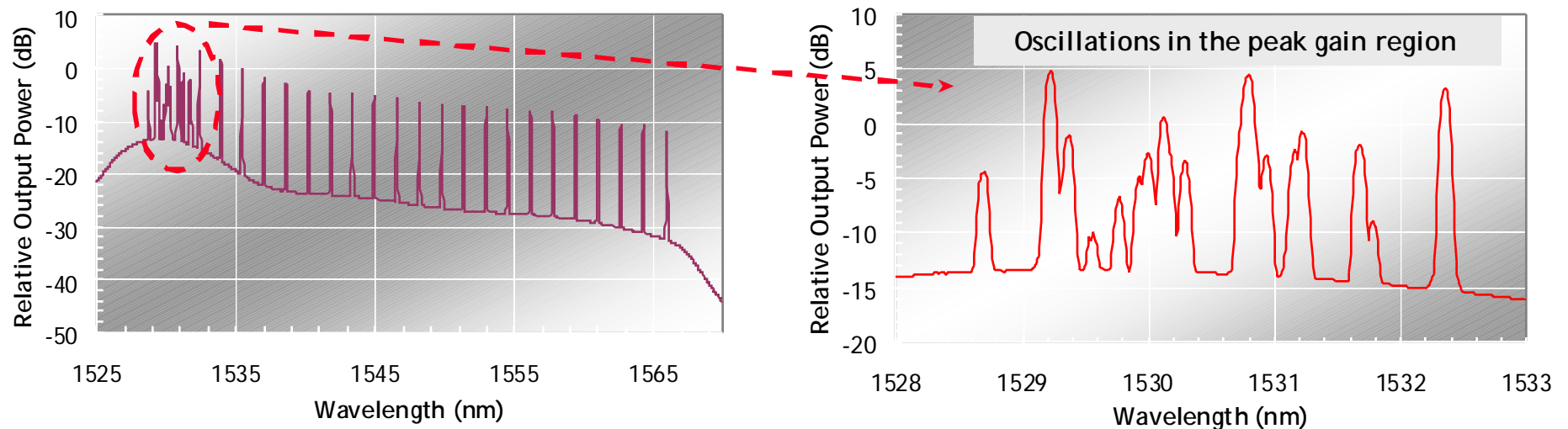
Submarine Long-Span Repeater Topology

Single-stage Erbium-Doped Fibre Amplifier Operational Limitation

- Output spectrum oscillations phenomenon

Example of lasing effect observed on a 22 dB gain single-stage EDFA when input light level is dropped by 16 dB (\equiv 38 dB operating gain),

\Rightarrow strong transient amplification instability that may damage the amplifier !



Single-stage EDFA topology well suited for long-haul cable systems

- Repeater gain lower than 20 dB (repeater spacing shorter than 100-km)

Double-stage EDFA topology required for long-span repeater (gain higher than 20 dB)

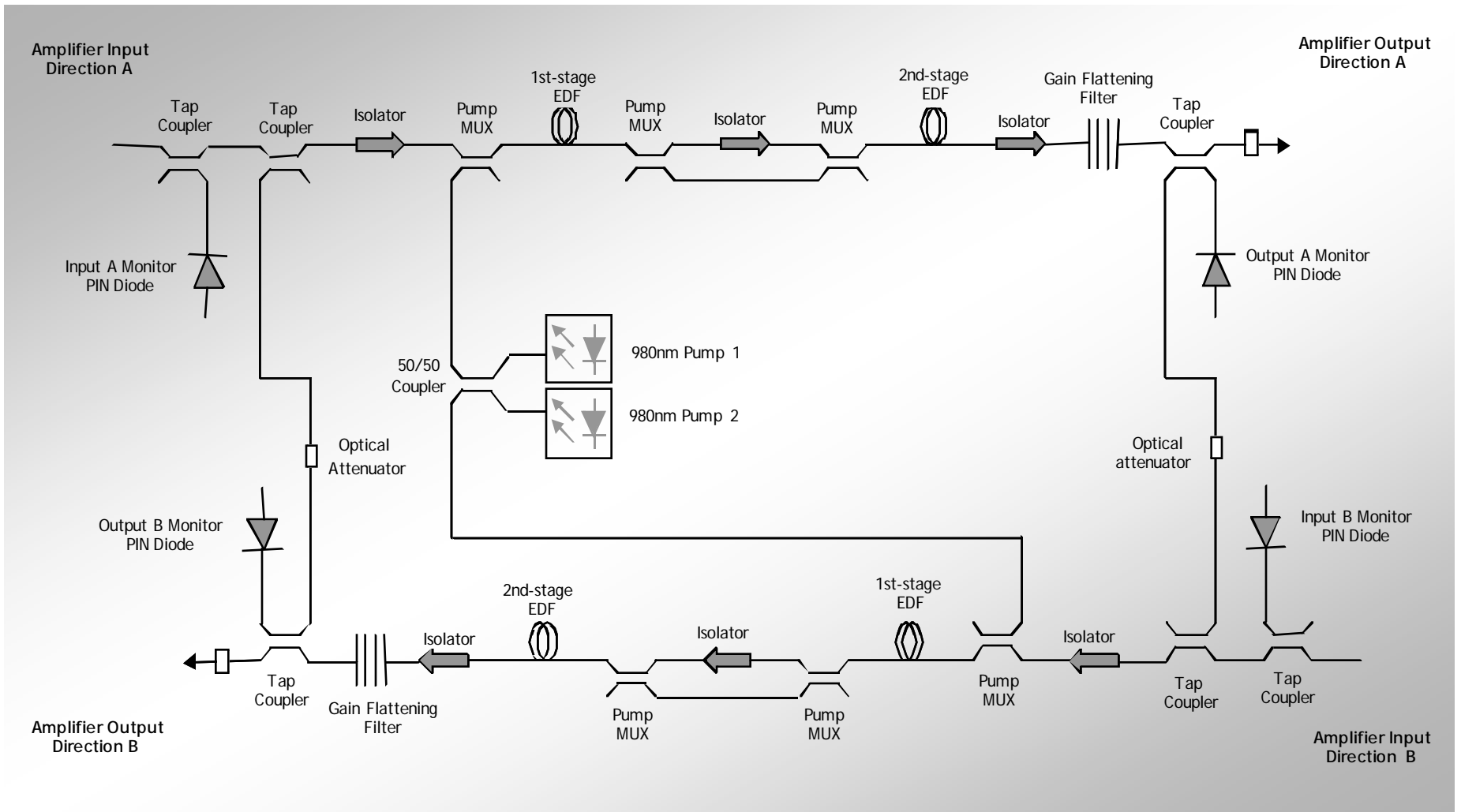
- Allows to distribute the internal gain between both amplification stages

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Submarine Long-Span Repeater

Double-Stage Erbium-Doped Fibre Amplifier-pair Description



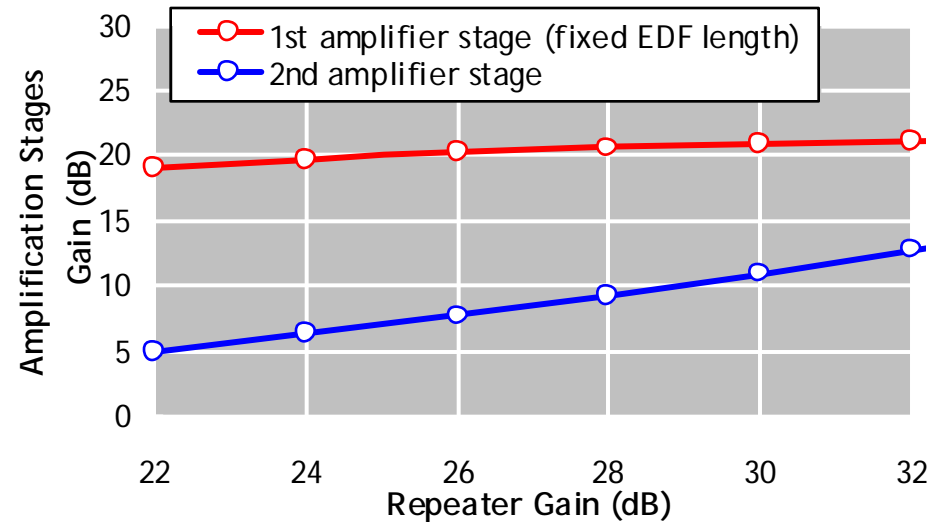
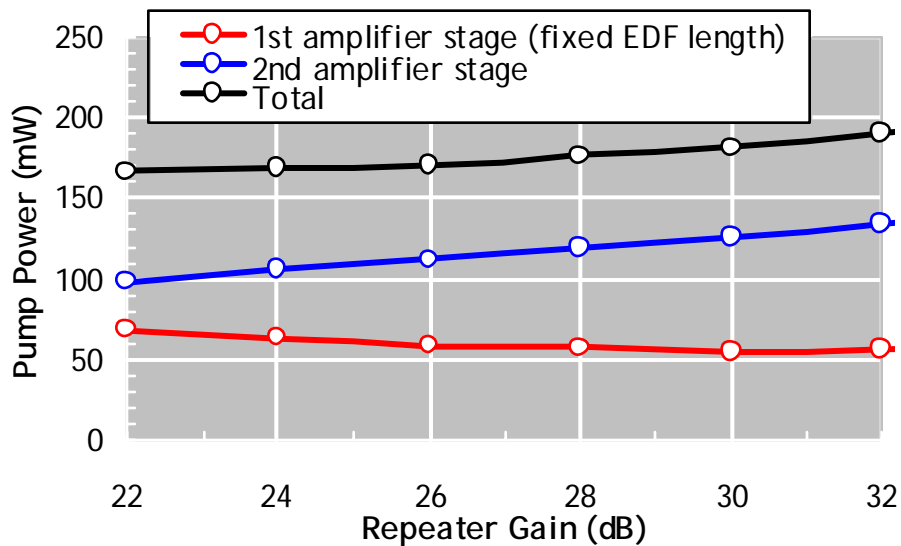
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Optical Performances

- Repeater optical performances (gain, output power, ...) are optimized to match specific requirements of each cable system.
- Generic design of the first amplification stage successfully achieved :
 - 1st amplifier provides about 20 dB gain whatever the total repeater gain is.
 - Allows to ease the manufacturing process. Only the 2nd amplification stage is finely adjusted during manufacturing.



13 nm bandwidth repeater / 15 dBm output power (2 x 200 mW 980nm pumps topology)

Submarine Long-Span Repeater

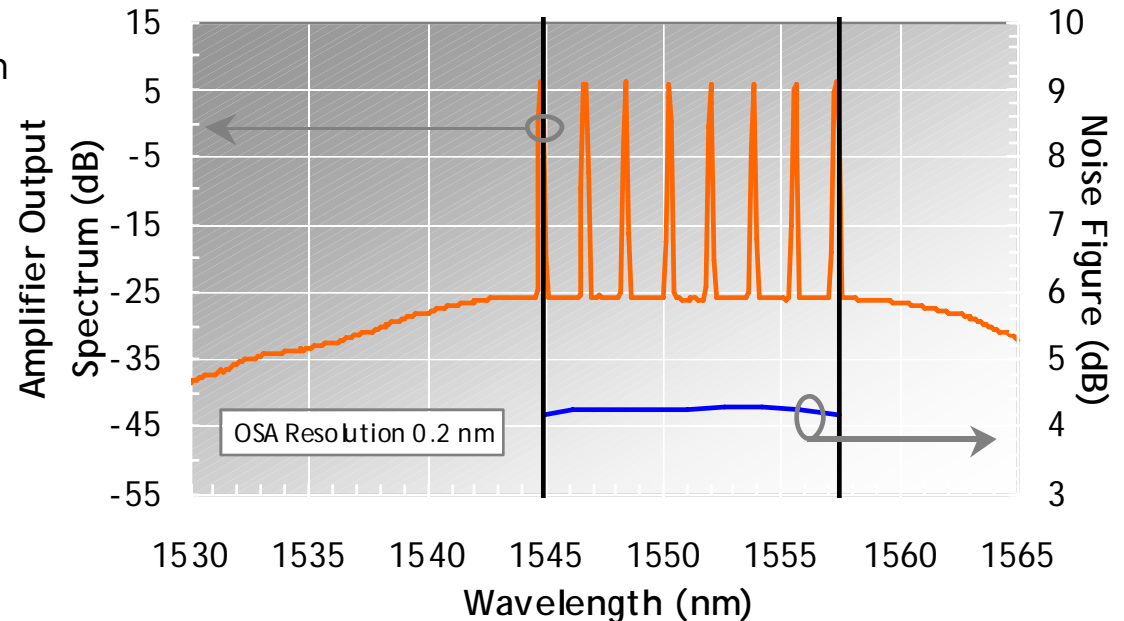
Optical Performances

- Amplifier parameters :

Transmission BW: 1544.92-1557.36nm

Output power : 15 dBm

Repeater gain : 25 dB



- Noise Figure :

Noise figure lower than 5 dB are achieved

NF similar to those of single-stage EDFAs

- “High-gain” adjustment of the 1st stage ensures good NF performances and masks significantly inter-stage losses.

- Gain flatness :

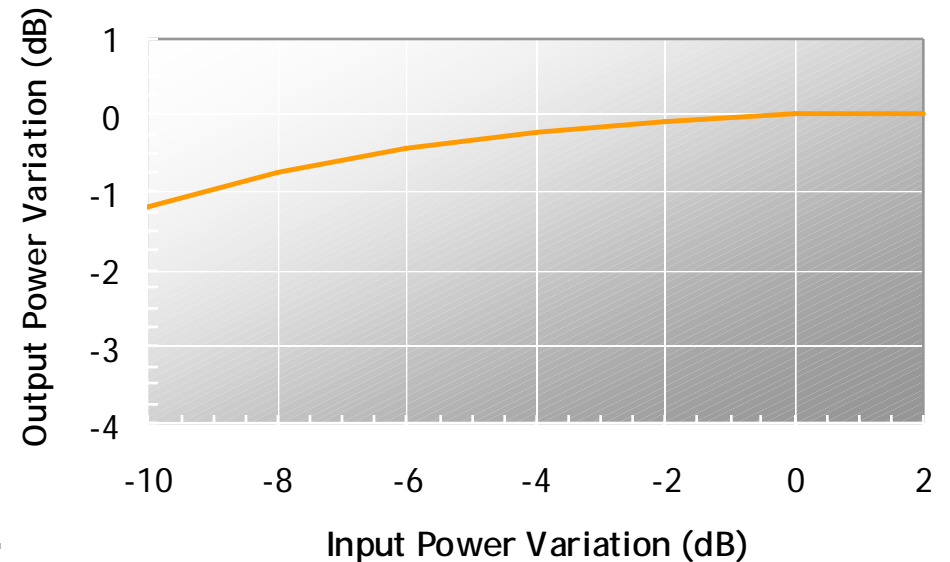
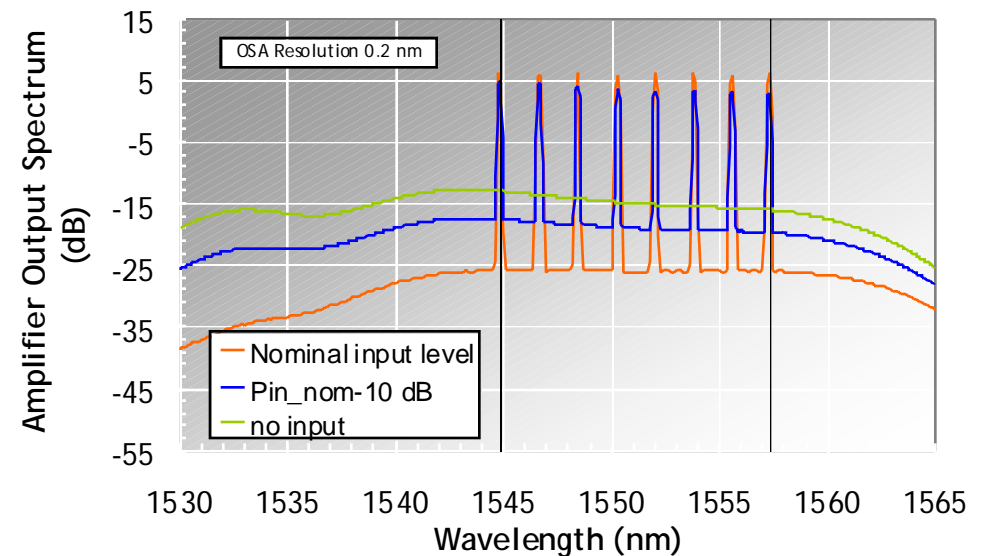
Typical gain unflatness lower than 0.15 dB

Efficient noise rejection (1532nm ASE peak) thanks to the gain flattening filter design

Double-Stage Erbium-Doped Fibre Amplifier

Optical Performances vs Input Level

- Robust dual-stage EDFA design :
 - No oscillation on the output spectrum when input light level is switched off.
- Repeater output power tolerant to input light level drop :
 - Amplifier saturation regime,
 - Pump control \Rightarrow automatic output level control
 - ▶ Less than 0.6 dB output power drop when the input light level is reduced by 5 dB.



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Summary - Conclusion

New long-span repeater dedicated to regional systems :

- Design based on dual-stage erbium-doped fibre amplification,
- Robust and reliable operation are achieved for gain ranging from 20 dB to 30 dB (100-150 km repeater spacing),
- Repeater output power of 17 dBm can be achieved using high power submarine pumps delivering more than 300mW,
- Repeater fully compliant with standard requirements of submarine repeaters,
 - Line fault localization by means of COTDR test equipment and repeater supervision via the system management facility.
- New repeater qualified for undersea operation over a lifetime of 25 years.
 - Already deployed on several regional telecommunication cable systems.



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