Advances in optical amplifier technologies

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Outline

- Past
- Present
- Future

... of optical amplifiers for long distance networks
A build example

Düsseldorf

Paris
A build example
A build example

The 1980’s

PDH/SDH regenerator

PDH/SDH terminal

PAR
LIL
BRU
ROT
AMS
DÜS

300km
150km
200km
100km
250km
A build example

The 1980’s

PDH/SDH regenerator

PDH/SDH terminal

The 1990’s

EDFA

SDH/WDM terminal
A build example

The 1980’s

PDH/SDH regenerator

PDH/SDH terminal

The 1990’s

EDFA

SDH/WDM terminal

Early 2000’s

EDFA/Raman

OADM

SDH/WDM/XC terminal
Performance
- Reach: Several 100 km’s to several 1000 km’s
- Capacity: 4x2.5G λ’s to 160x10G λ’s
- (R)OADM support

Cost
- EDFA: > €5000/λ to < €1000/λ (1996-present)
- Raman: > €5000/λ to < €1000/λ (1999-present)

Interworking
- Coloured LR optics on SDH ADM’s and XC’s
Next steps in performance

- All Optical Networks
- Hut Skipped Networks

OADM only

No inline amplifiers
Next steps in performance

- **All Optical Networks**
  - Amplifier requirements
    - Very low noise (~0dB)
    - Moderate gain (~15dB)
    - Moderate dynamic range (~5dB)
    - Raman only
  - Network requirements
    - Very high capacity (>100 Gb/s per route)
    - Long circuits (>2000km)

- **Hut Skipped Networks**
  - Amplifier requirements
    - Low noise (<3dB)
    - High gain (>30dB)
    - Large dynamic range (>10dB)
    - Hybrid EDFA/Raman
  - Network requirements
    - Moderate capacity (<100 Gb/s per route)
    - Shorter circuits (<1000km)
Hut Skipping « Rule of thumb »

Typical inline amplifier site reduction (%)

Hybrid vs. Raman only

Hybrid vs. EDFA only (Traditional)
Economics of Hut Skipping (~650km link)

<table>
<thead>
<tr>
<th></th>
<th>Traditional</th>
<th>HSA</th>
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<tbody>
<tr>
<td>Opex (4 yrs)</td>
<td>244,800 €</td>
<td>168,960 €</td>
</tr>
<tr>
<td>Capex</td>
<td>432,000 €</td>
<td>360,000 €</td>
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Traditional WDM system engineering

- EMS interface
- Element Management System
- Single vendor domain
- Mux Demux
- Amplifiers
- Client (e.g. Router)

Slide 13 Proprietary
Open WDM system engineering

Example: Strategy pursued by 40G transponder vendors for upgrading existing links
Open WDM system engineering

Umbrella Element Management System

EMS interface

Multiple vendor domains

Amplifiers

TxRx

Mux

Demux

Client (e.g. Router)

Example: Strategy pursued by Optovia

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Proprietary
Open WDM system engineering

Umbrella Element Management System

Multiple vendor domains

Early examples in the SDH world
Next logical step in the IP/WDM world!?
How can an amplifier support Open WDM systems?

- Flexible link engineering
  - Compatibility with broad range of TxRx settings
  - Transparency to modulation formats (NRZ, RZ, xPSK, …)
  - Compatibility with any kind of DCM
  - Easy to use link engineering tool

- Optical Supervisory Channel interworking
  - Compatibility with OSC of client system

- EMS integration
  - Integrability into 3rd party NMS
  - Integrability into EMS of client system (WDM, XC, …)
  - Autonomous EMS
The road ahead

- The basic amplifier technology is available.
- Innovation will come from...
  - Integration of components (the « secret sauce »)
  - Standardization of ancillary functions
  - Open WDM systems
- … and advances in enabling technologies
  - New fibre types
  - New modulation formats
  - « Super-Turbo » FEC chipsets
Questions?