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Technical Bulletin

Bi-EDF

November, 2002

Introduction of high performance EDF based on bismuth oxide host glass

Asahi Glass Co., Ltd.

Agenda

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- Advanced features
- Merits for amplifiers
- Fusion splicing
- Applications
- Specifications of Bi-EDFs
- Measurement data
- Reliability
- Summary

Advanced features of Bi-EDF

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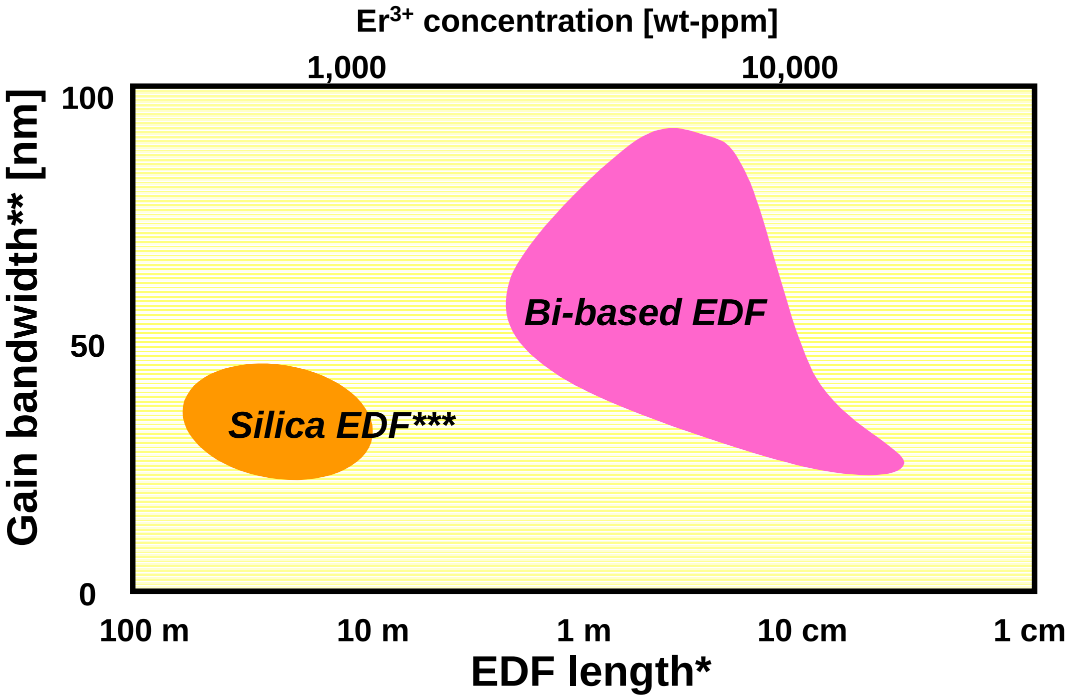
■ Inherently differentiated performance

- Broad gain profile covering 1530 to 1620 nm
- High Er^{3+} concentration up to 13,000 wt-ppm
- Fusion-spliceable to silica fibers

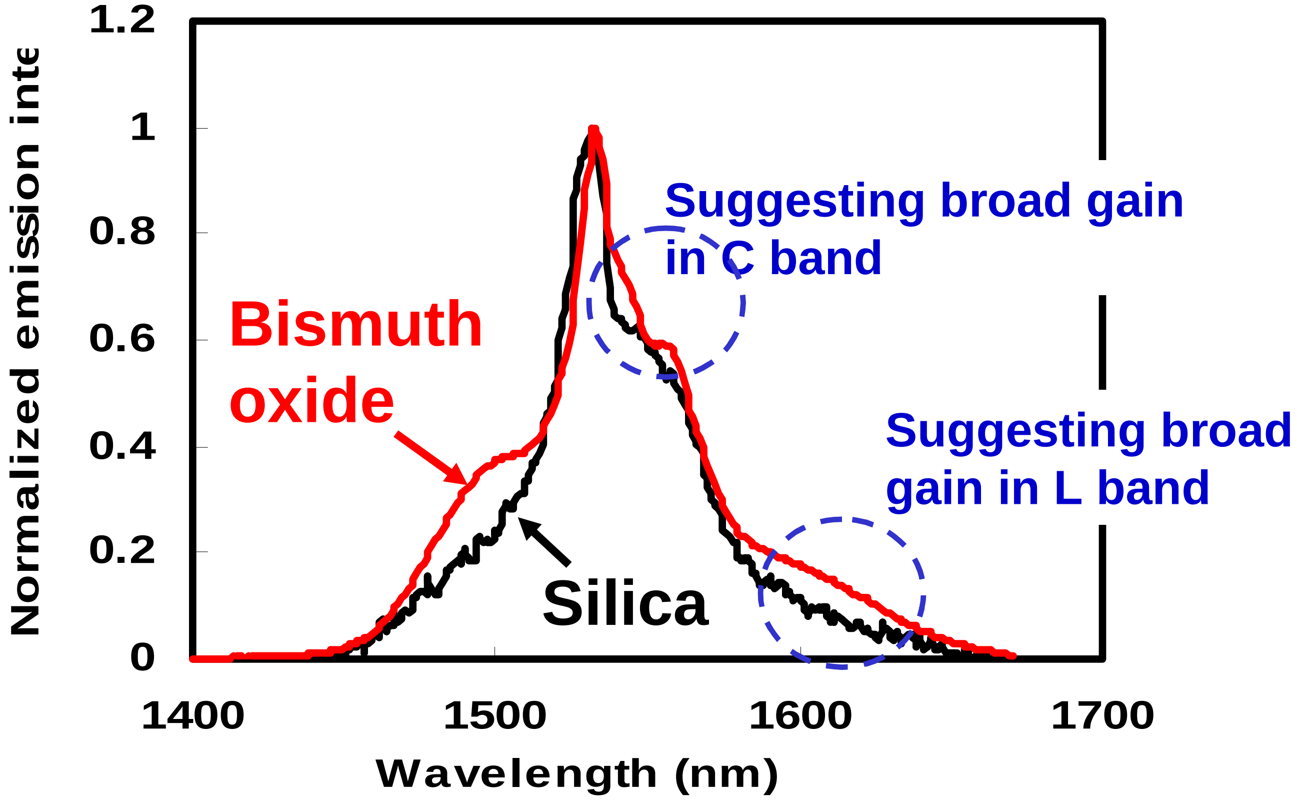
Relation between EDF length and gain bandwidth



* Gives 10 dBm output
** 3 dB bandwidth
*** Typical value

Advanced features - Broad emission spectrum

■ **Bismuth oxide glass can bring out broad emission from Er^{3+}**



Merits for amplifiers – Broadband

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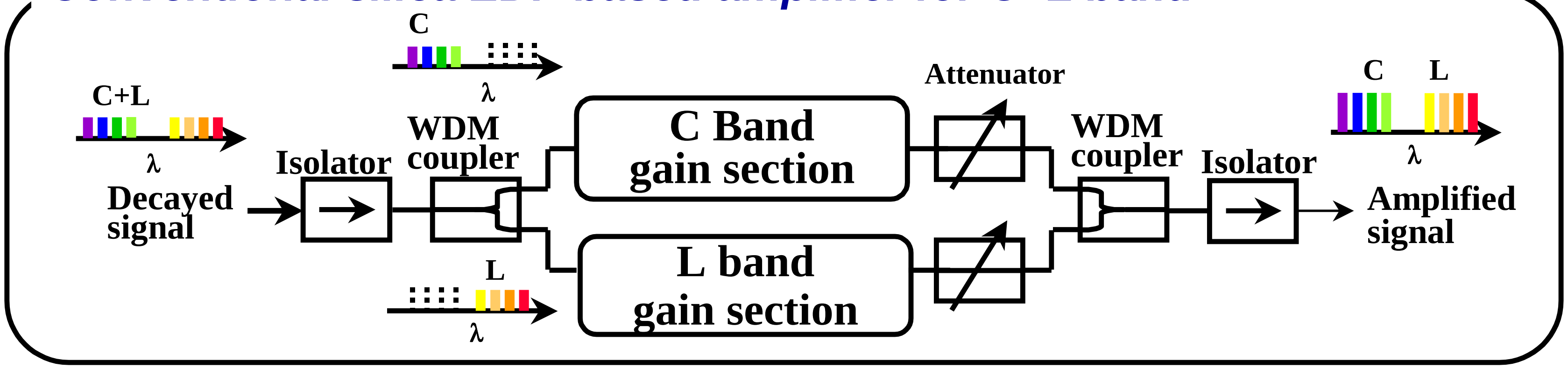
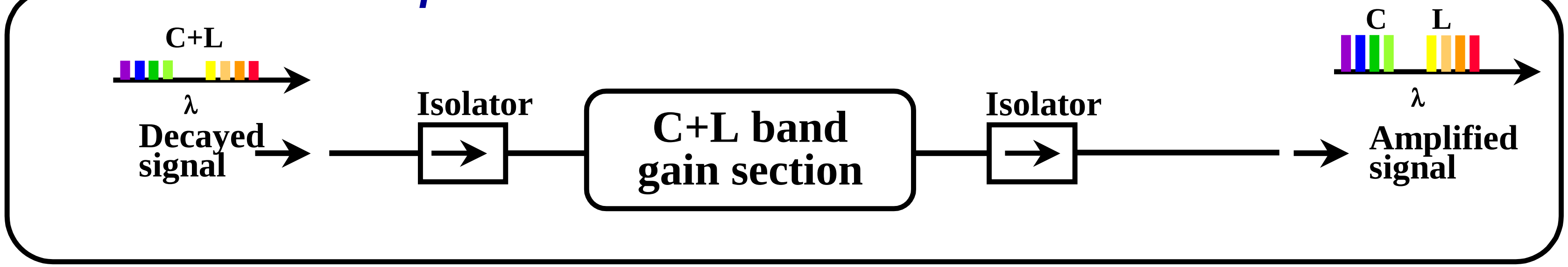
Bi-EDF realizes simple and low cost broadband amplifiers

Conventional silica EDF-based amplifier for C+L band



Bi-EDF-based amplifier for C+L band / Extended L-band



Merits for amplifiers - High Er^{3+} concentration

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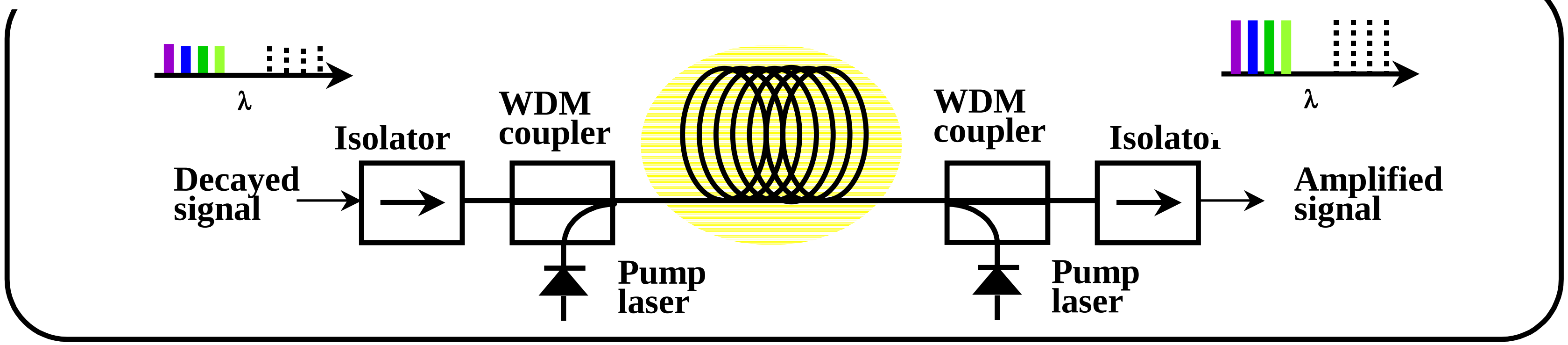
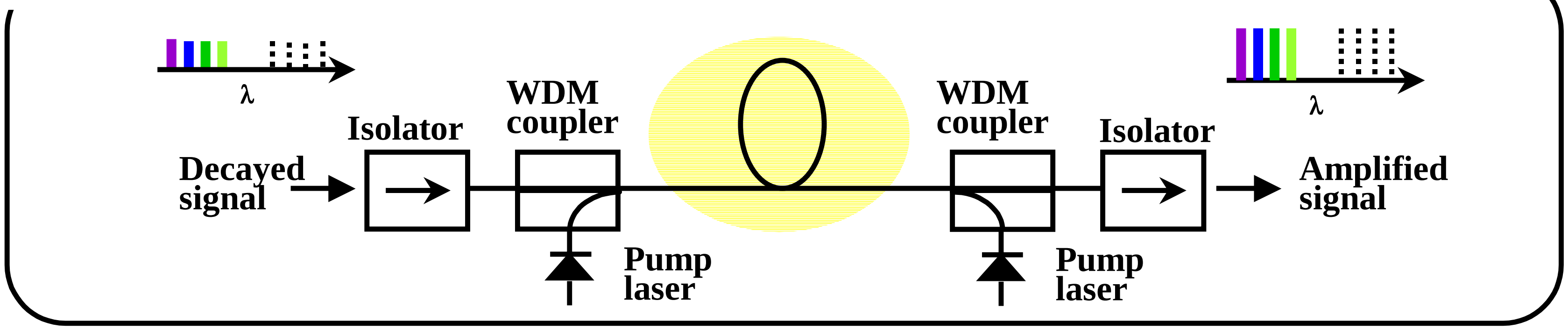
■ Bi-EDF realizes ultra-compact amplifiers

Silica EDF (Several 10s to 100s m)



Bi-EDF (5 cm to several 10s cm)



Fusion splicing - Technique

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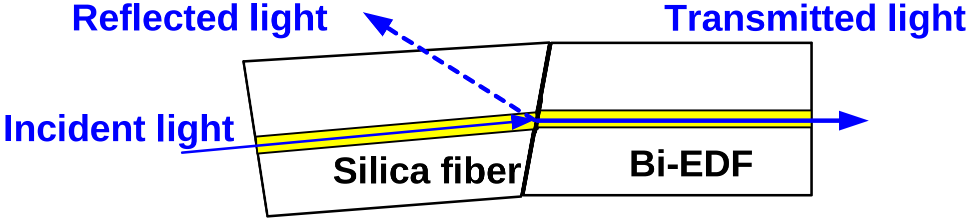
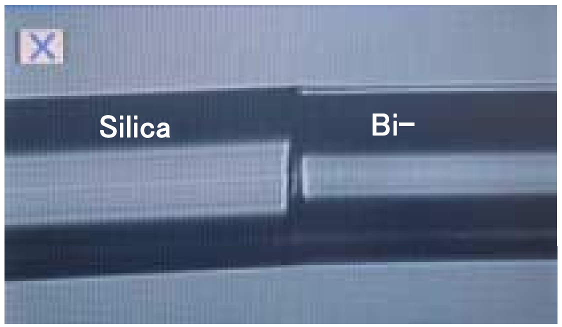
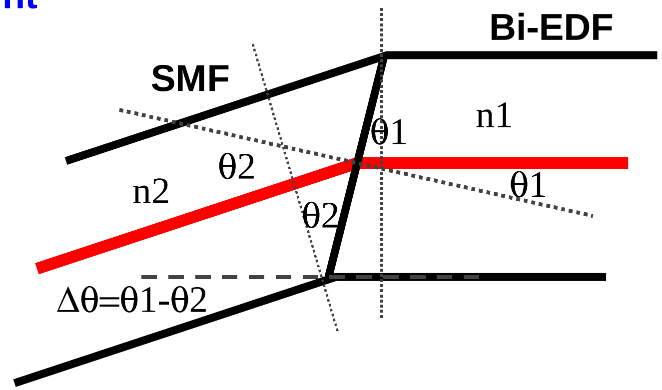
■ Intensively worked out splicing technique now enables satisfactory high return loss and low splice loss

- **Angled (6 °) splice to obtain return loss > 55 dB**
- **Mixed angle splice to reduce the splice loss < 0.5 dB (per each splice point)**







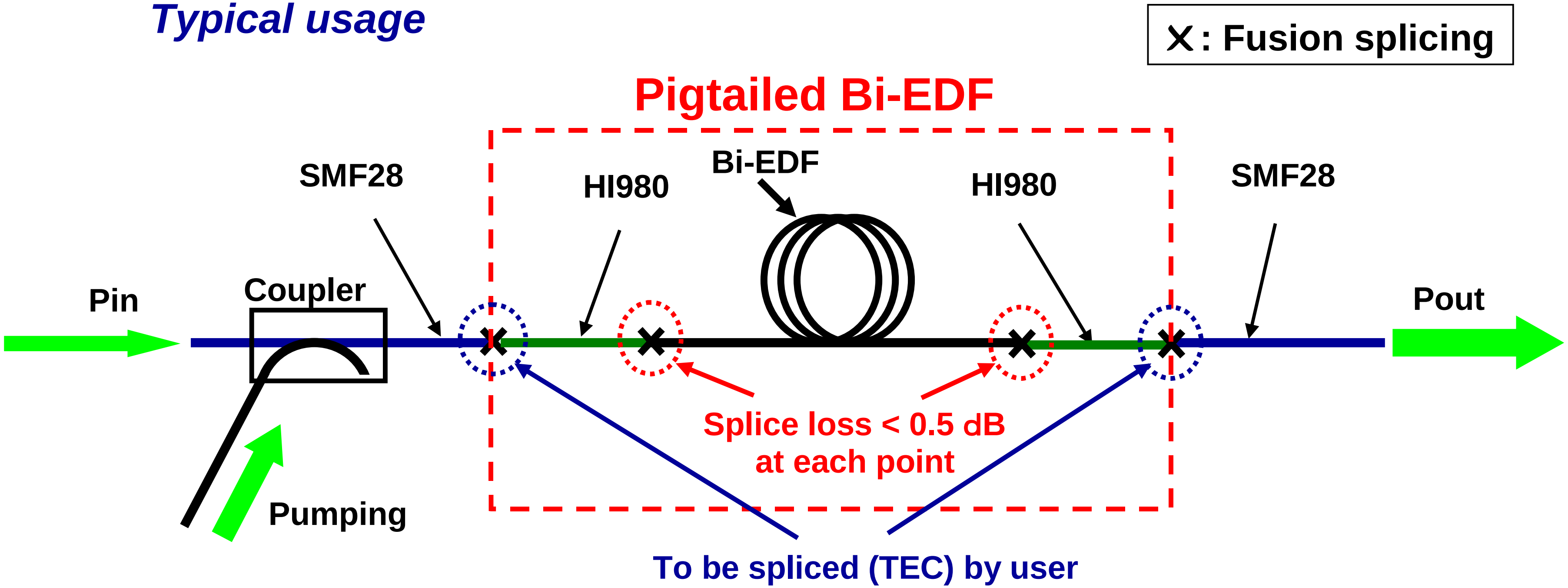
θ1=6.0 °, θ2=8.2 ° is the optimum

Note: Modification service to fit the technique for commercial splicers will soon be available by splicer manufacturers.

Fusion splicing - Typical usage in silica fiber-based system

■ Bi-EDF is fusion-spliceable to ordinary silica fibers

Typical usage



Note: We either supply Bi-EDFs as cut or as pigtailed.

Applications

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■ Bi-EDF exhibits advanced performances

- Broad gain profile covering 1530 to 1620 nm
- High Er^{3+} concentration up to 13,000 wt-ppm

  →Short length EDF (1/100 to 1/10 of silica EDF)

■ Hence following applications will be proposed

- L band/ extended L band amplifiers
- Broad - C+L band amplifiers
- Ultra-compact amplifiers
- Short pulse/ high speed signal amplification
- Broad ASE sources

Applications – A couple of examples

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Extended L band amplifiers

- Broadband: Additional 30 % band coverage with one gain medium in L band with no or modest cost impact
- Compactness: Very short length will ease amplifier design and assembly

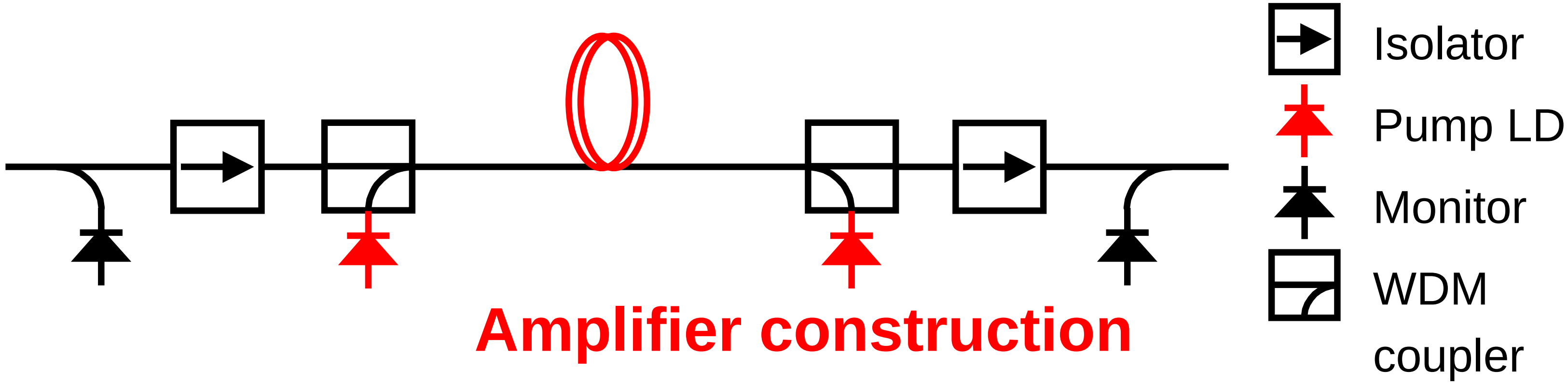
Single channel and narrow band amplifiers

- Broadband: Inventory cost reduction by dual band - C+L band coverage with the same design amplifier
- Compactness: Built-in or arrayed usage on cards/ shelves, namely small footprints of systems

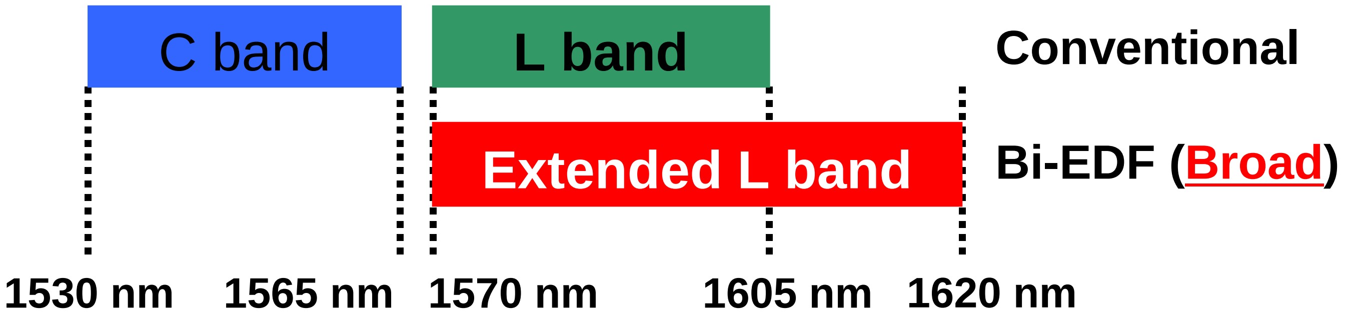
Applications - Extended L band amplifiers

■ Additional 30 % band coverage beyond 1605 nm

Bi-EDF (Compact – several meters)



Amplifier construction



Amplifier bandwidth

Applications - Single channel and narrow band amplifiers

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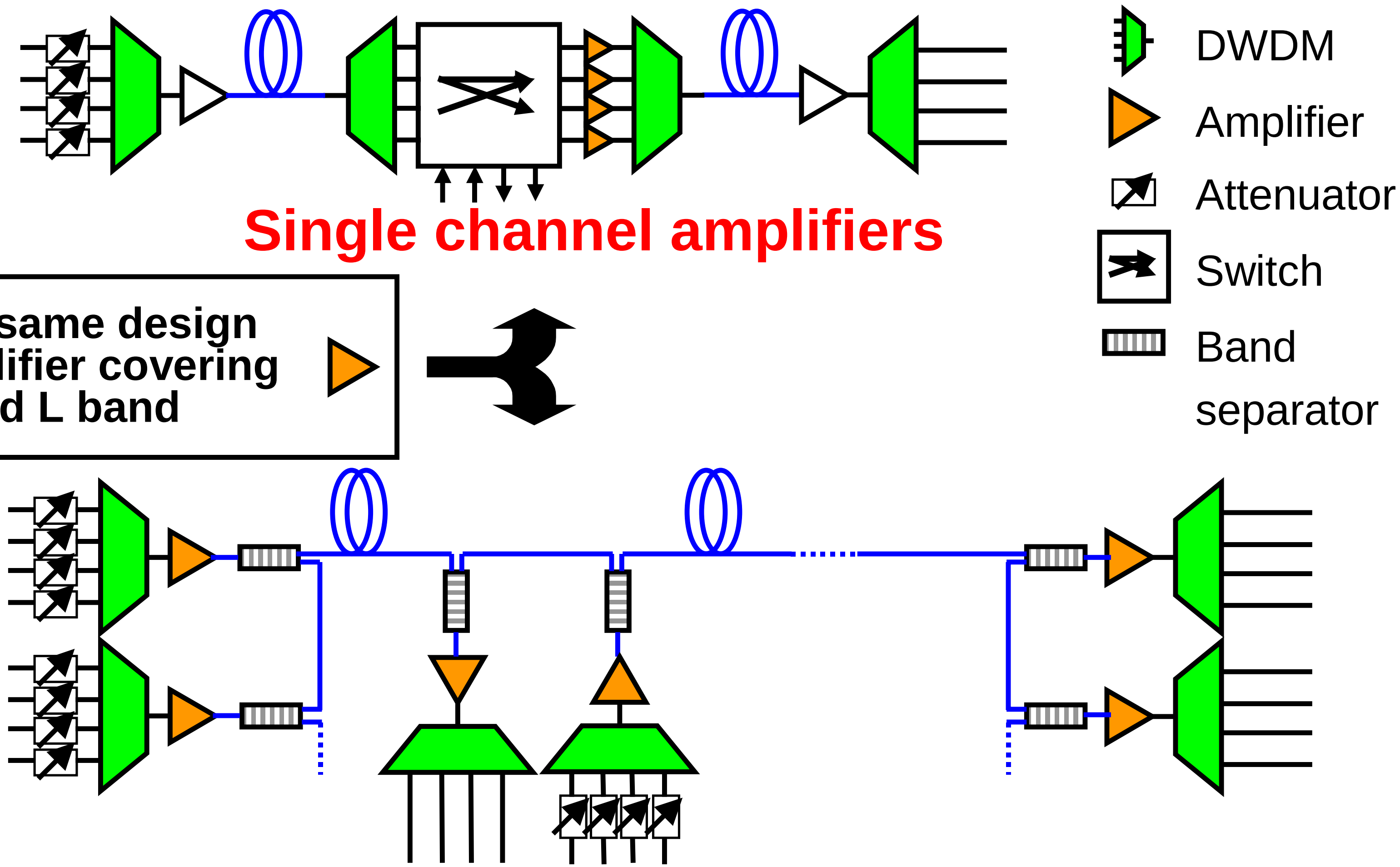
■ Dual band - C+L band coverage



Narrow band amplifiers for sub-band system

Specifications of Bi-EDFs

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Parameters	Types				
	T1L	T1M	T2M	T2H	T3L
Erbium ions concentration [wt. Ppm]	3,250	6,500	6,500	13,000	3,250
Co-dopants	La		La, B		None
Peak absorption around 980 nm [dB/m]	73	145	127	246	74
Peak absorption around 1480 nm [dB/m]	83	167	141	278	84
Peak absorption around 1530 nm [dB/m]	133	267	219	429	134
Maximum background loss at 1300 nm [dB/m]	< 1		< 1		< 1
Maximum splicing loss per splice point [dB]	< 1		< 1		< 1
Return loss at splice point [dB]	> 55		> 55		> 55
Numerical aperture	0.20		0.20		0.20
Mode-field diameter at 1550 nm [μm]	6.2		6.0		6.0
Cutoff wavelength [nm]	<1450		<1450		<1450
Cladding diameter [μm]	125		125		125
Coating diameter [μm]	250		250		250
Core/cladding concentricity [μm]	< 1		< 1		< 1
Core/cladding refractive index at 1550 nm	2.03 / 2.02		2.03/ 2.02		2.02 / 2.01

Measurement data – Measurement setup

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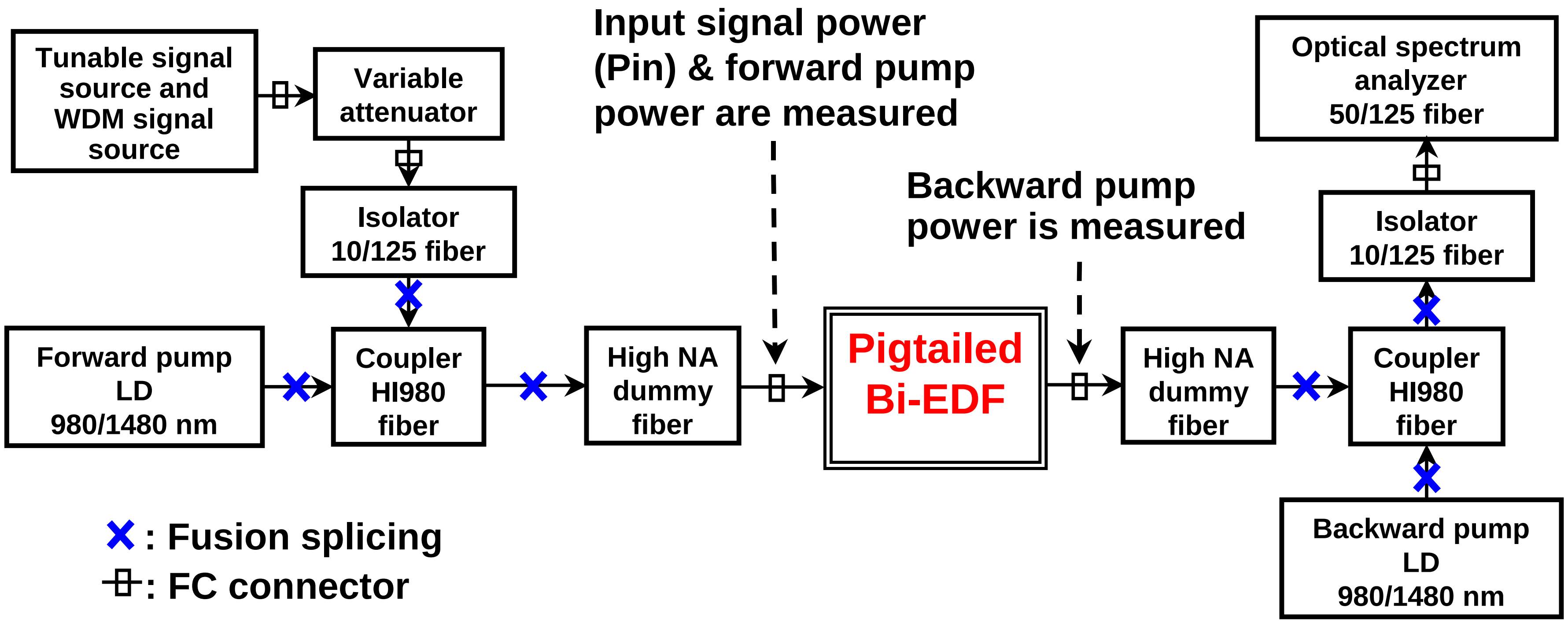
■ Block diagram of measurement system for characterization



Definition: Gain (dB) = { Pout (dBm) – Pin (dBm) } – System Loss (dB)

Measurement data - T1L Bi-EDF for extended L band amplification (1)

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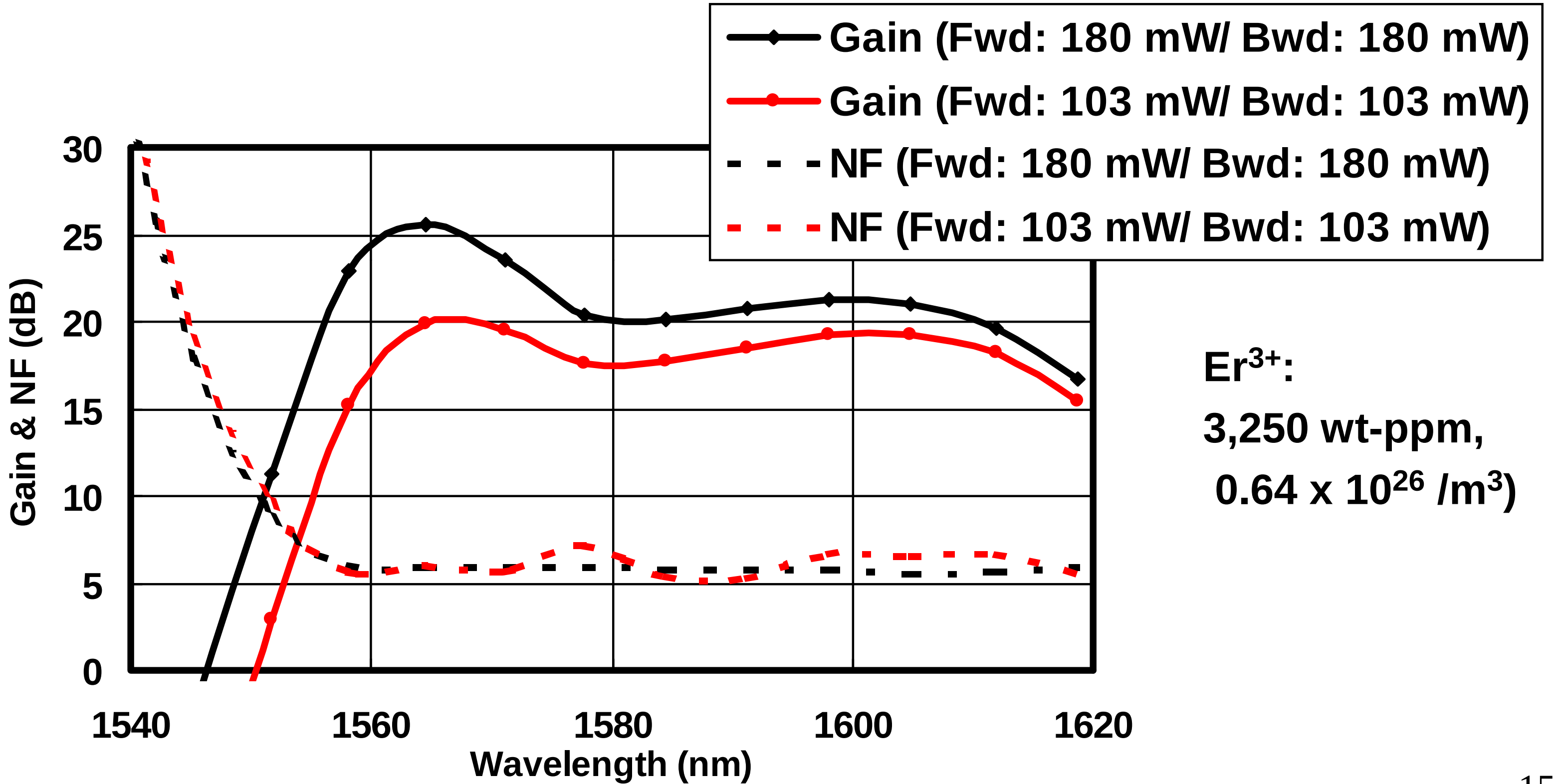
■ Over 15 dB gain is sustained up to 1620 nm

Gain profiles for 254 cm length of T1L Bi-EDF with 1480 nm pumping

● **16 ch WDM signal source/ Total input power: 0 dBm**



Er^{3+}: 3,250 wt-ppm, 0.64 x 10^{26} /m^3)

Measurement data - T1L Bi-EDF for extended L band amplification (2)

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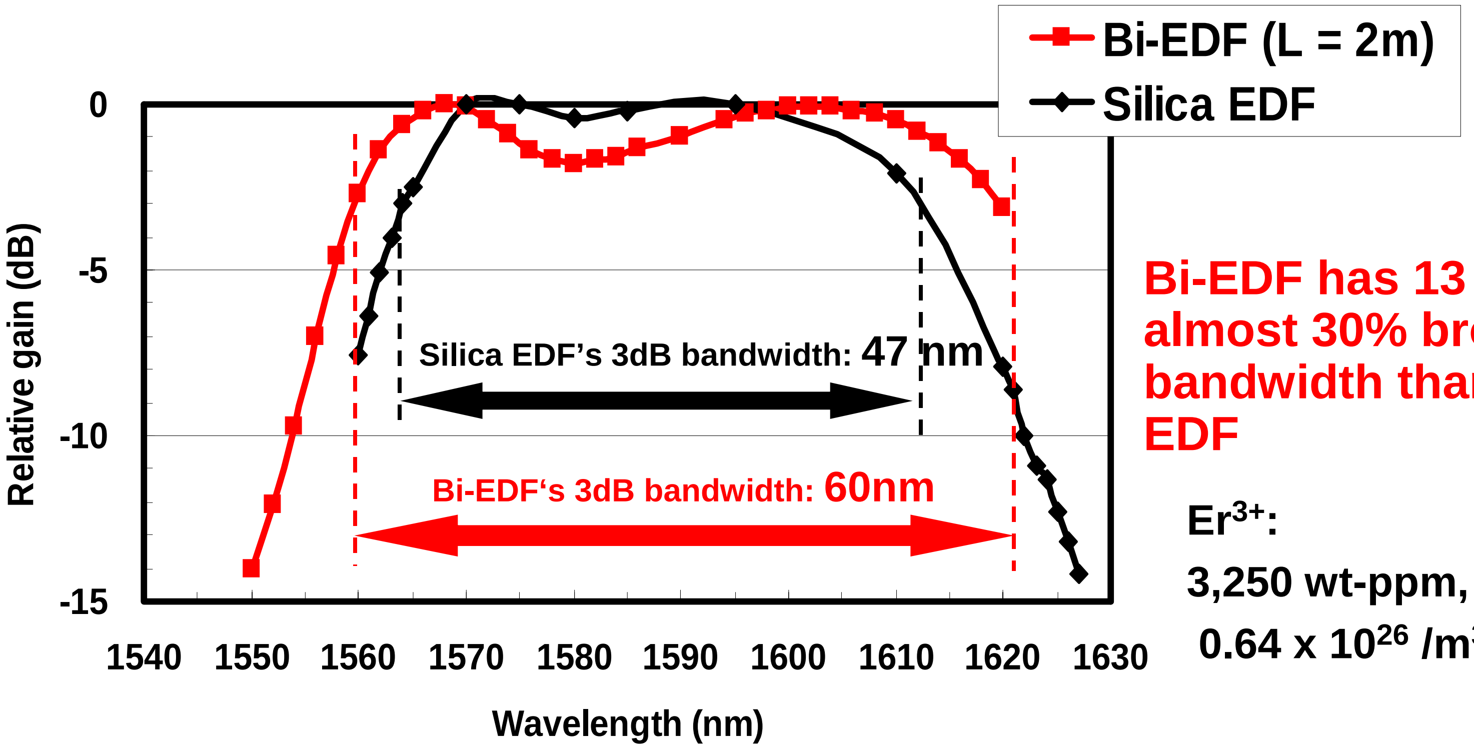
■ Almost 30% broader bandwidth than silica EDF

Gain profiles for T1L Bi-EDF & silica EDF with 1480 nm pumping

● **Probe method/ Pumping: Optimized to obtain broadest gain profile for each sample.**



Bi-EDF has 13 nm - almost 30% broader bandwidth than silica EDF

Er^{3+}:
3,250 wt-ppm,
0.64 x 10^{26} /m^3)

Measurement data - T1L Bi-EDF for extended L band amplification (3)

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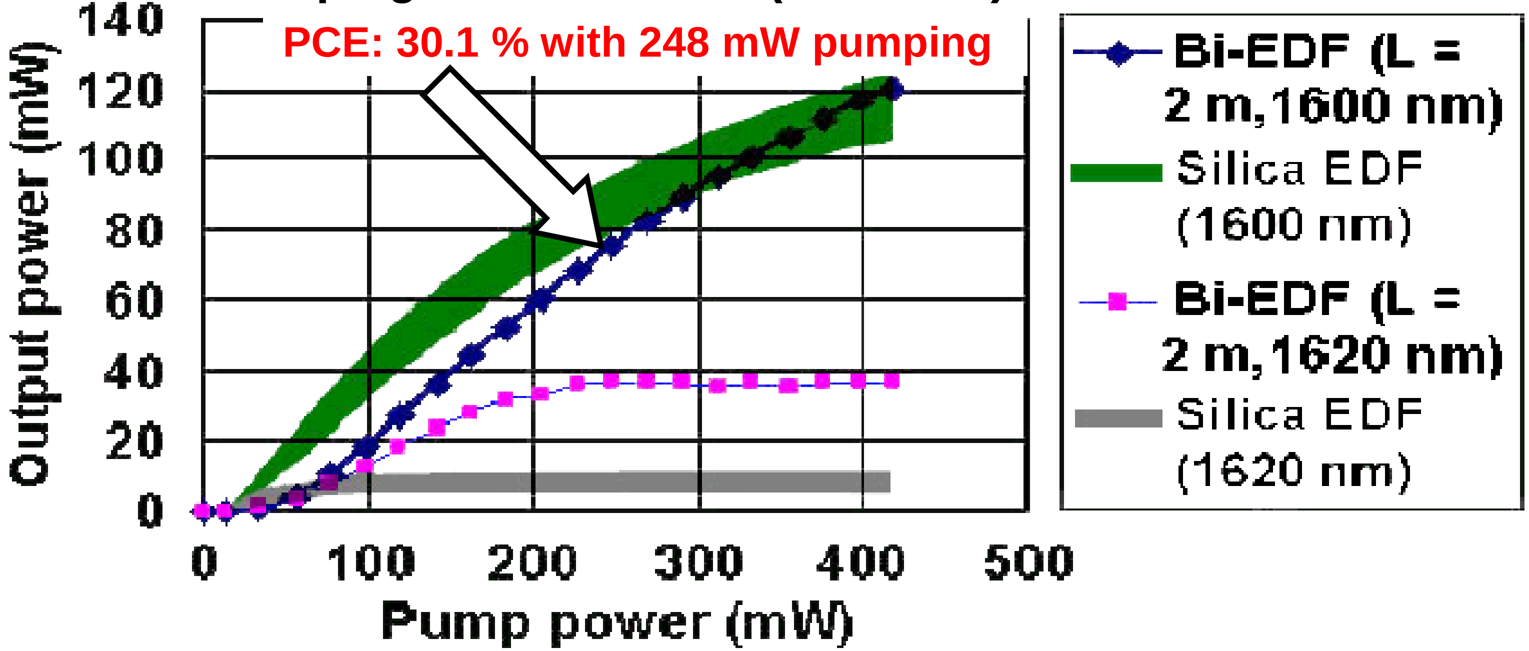
■ **Bi-EDF still sustains substantial output power at 1620 nm, where silica EDF loses it**

Pump power vs. output power for T1L Bi-EDF and silica EDF

- **Input power: 0 dBm at 1600 nm and 1620 nm**
- **Pumping: Bi-directional (balanced) at 1480 nm**



Note: We have selected relevant samples and conditions for the benchmarks.

Measurement data - T2M Bi-EDF for C+L band amplification (1)

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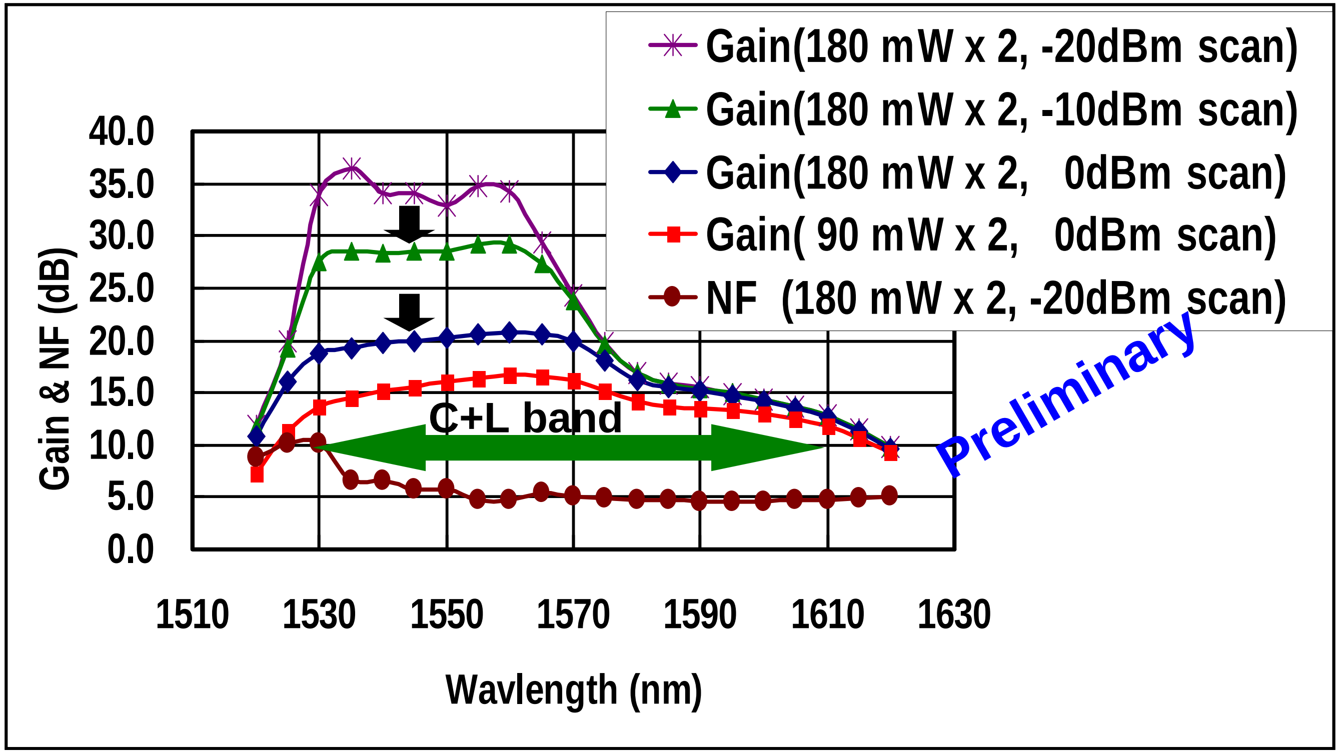
■ 47 cm-long Bi-EDF covers both C band and L band if used in saturation mode

Gain profile for 47 cm-long T2M Bi-EDF with 1480 nm pumping

● **Scan method/ Pumping: 1480 nm, 180 mW × 2 or 90 mW × 2**



Er^{3+}:
6,470 wt-ppm,
1.27 x 10^{26} /m^3

Measurement data - T2M Bi-EDF for C+L band amplification (2)

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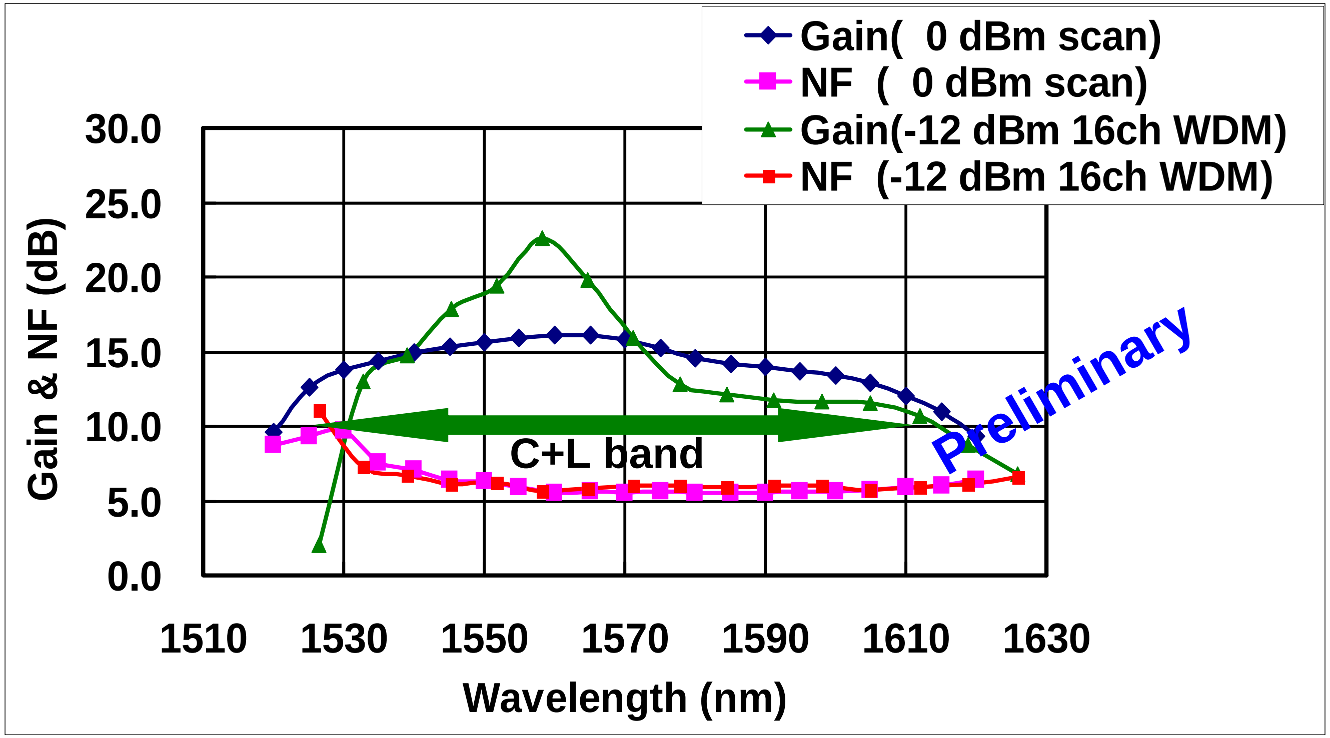
T2M Bi-EDF can be pumped at 980 nm as well

Gain profile for 47 cm-long T2M Bi-EDF with 980 nm pumping

● 16 ch WDM & Scan/ Pumping: 980 nm, 140 mW × 2



Er^{3+}:
6,470 wt-ppm,
1.27×10^{26} /m^3

Measurement data - T2H Bi-EDF for compact amplifiers

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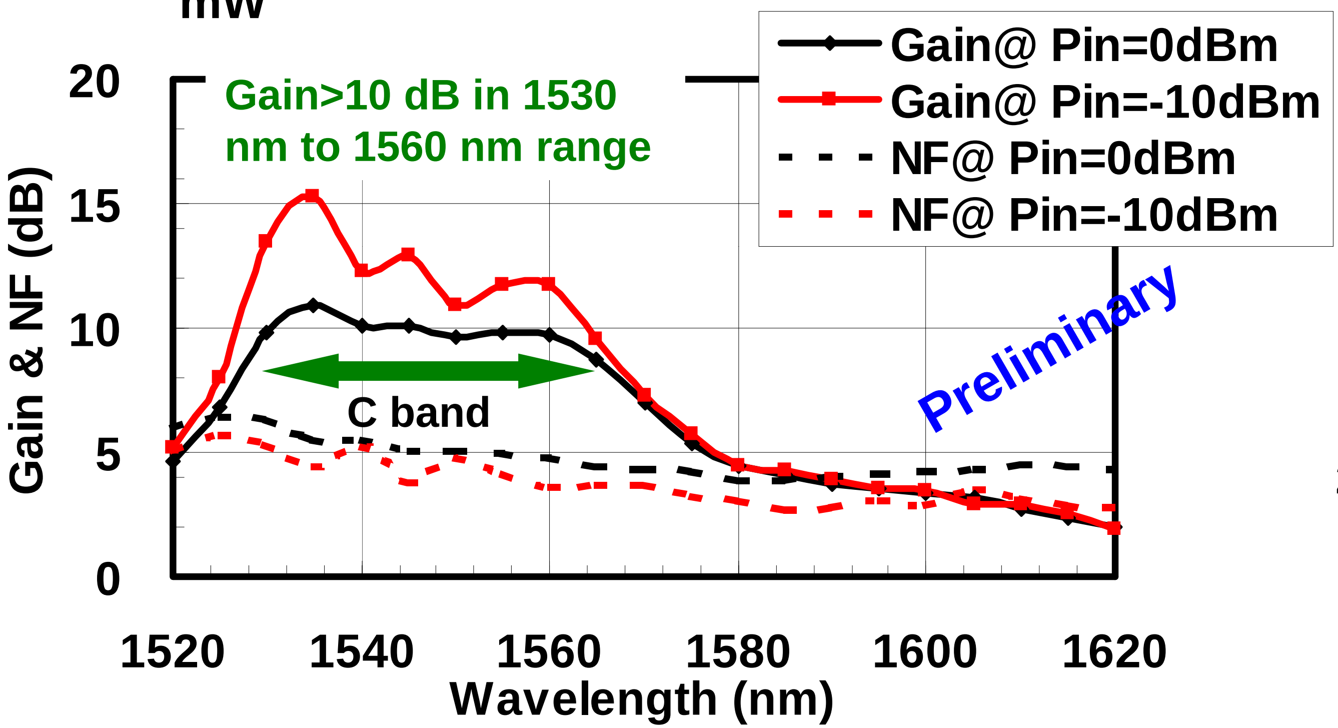
■ **Almost 10 dB gain is obtained in C band with only 5 cm-long EDF**

Gain profile for 5 cm-long T2H Bi-EDF with 980 nm pumping

● **Scan method/ Pumping: Forward 121 mW + backward 108 mW**



Er^{3+}:
13,000 wt-ppm,
2.55 x 10^{26} /m^3

Reliability (results of Telcordia GR-1221-CORE test)

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■ Pigtailed Bi-EDF meets Telcordia GR-1221-CORE

Items (Results are qualified by gain measurement test)

- ◆**Thermal shock test**
  ΔT = 100 °C, Dwell time 30 min, Transfer time 2 min, 20 cycles : passed
- ◆**High temperature storage test**
  (Humid) 75 °C, 95 %, 2500 / 5000 h : passed
  (Dry) 85 °C, <40 %, 2500 / 5000 h : passed
- ◆**Low temperature storage test** - 40 °C, 5000 h : passed
- ◆**Temperature cycling test** - 40 to 75 °C, 1000 cycles : passed

Summary

- **Excellent performances - broadband, compactness are introduced with measurement data**
- **Potential applications are extended L band amplifiers, C+L band amplifiers, ultra-compact amplifiers and so on**

Note: Bi-EDFs are ready for your evaluation. Please try it.

"Look Beyond"