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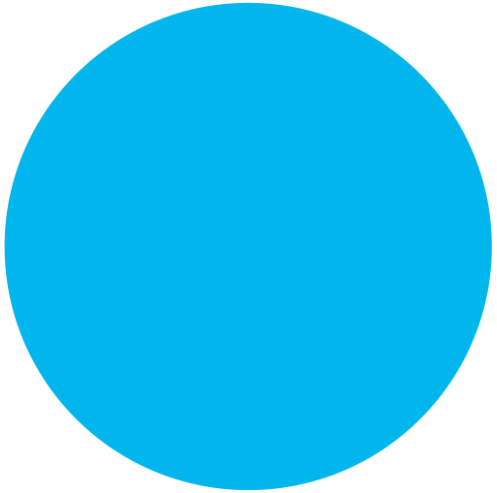

Multicore Fibers

Doped and passive Fibers
Multicore components

For lasers, amplifiers and sensing

01/06/2022 nicephore.nicolas@ixblue.com

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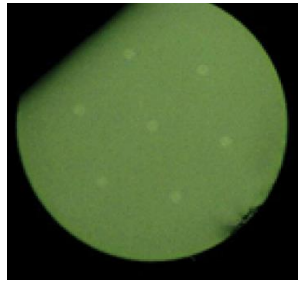
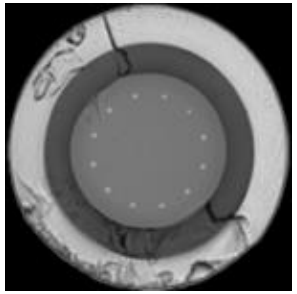
Overview

20 years experience in Multicore Fibers!





Product Overview

iXblue has 20+ years experience in custom multicore fiber design with first realization back in 2000 with twincore fibers during the telecom boom for add/drop multiplexers.

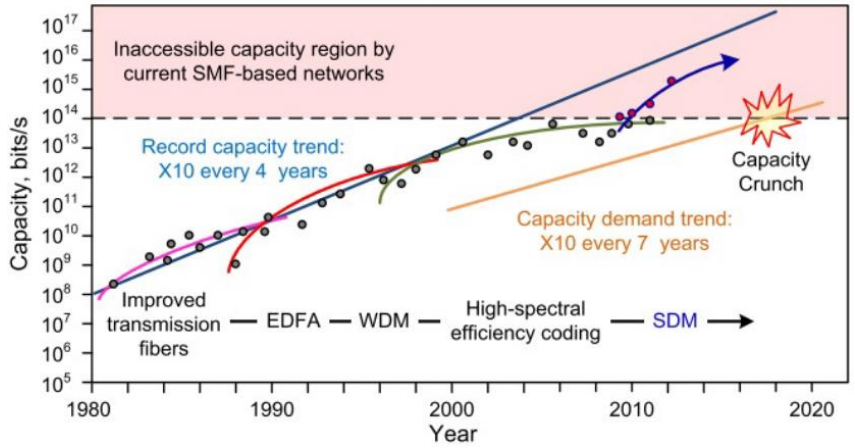
- Fibers
  - Passive multicore fibers
  - Doped multicore fibers (single or double Clad)

- Components
  - Gain Flattening Fibers

No limitation in core numbers

Applications

- Space Division Multiplexing (SDM)
  - Increased capacity, total bandwidth proportional to the number of cores



From "*Emerging DSP techniques for multi-core fiber transmission systems*"

- Next-gen optical amplifiers
  - multiple amplifiers in a single fiber

Power efficient all-fiberized 12-core erbium/ytterbium doped optical amplifier

G. MÉLIN, T. ROBIN (IXBLUE); R. KERAMPRAN, S. BORDAIS (LUMIBIRD); A. MONTEVILLE, D. LANDAIS, T. TAUNAY (PHOTONICS BRETAGNE); A. LEBRETON, Y. JAOUËN (TELECOM PARIS)

Optical Fiber Communication Conference and Exhibition (OFC) – March 2020

- Temperature, strain or shape sensing
  - Structural Health Monitoring (SHM)

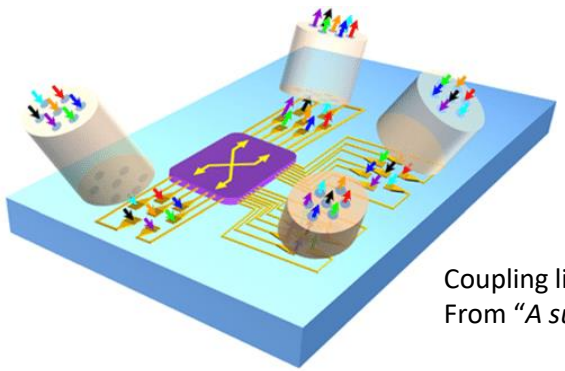
Shape sensing using multi-core fiber optic cable and parametric curve solutions

Jason P. Moore* and Matthew D. Rogge

NASA Langley Research Center, Hampton, Virginia 23681, USA

**jason.p.moore@nasa.gov*

- Photonic Integrated Circuits (PICs)
  - Alternative to fiber arrays for coupling



Coupling light in and out of a photonic integrated circuit (PIC) using multicore fibers.
From "*A survey on role of photonic technologies in 5G communication systems*"

- Multi-beam phase coherent combining, for high power applications

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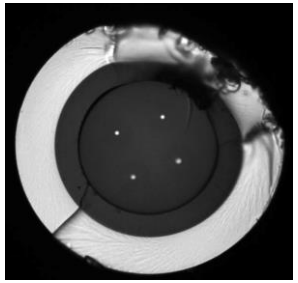
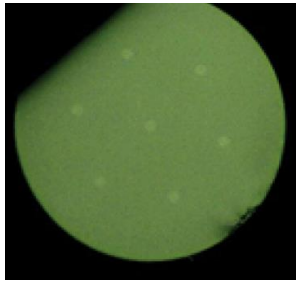
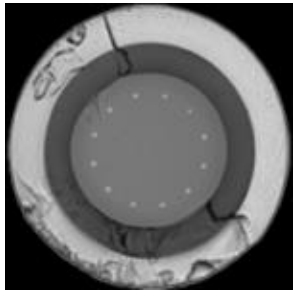
iXblue Key expertise in multicore fibers

- In-house mastering of the entire doped and passive fiber core manufacturing: form fiber preform deposition to fiber draw
  - 2 to ~7 cores
  - Germanium, Phosphorous but also Erbium, erbium/Ytterbium, Ytterbium, Neodynium, Holmium, Thulium
  - All specs could be customized
- For higher number of core : stack and draw process

- Available from stock:
  - 4 cores:
    - Single Clad Passive, SMF : ok from 980 to 1.5nm
    - Active Erbium doped version
  - 7 cores:
    - Single clad Passive, SMF for 1550 nm
  - 12 cores:
    - Active Double Clad Erbium/Ytterbium fibers
    - Double clad passive fiber
    - Single Clad passive fiber

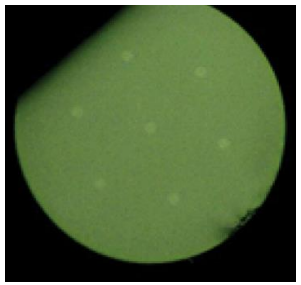






Multicore Fibers for Sensing & Transmission

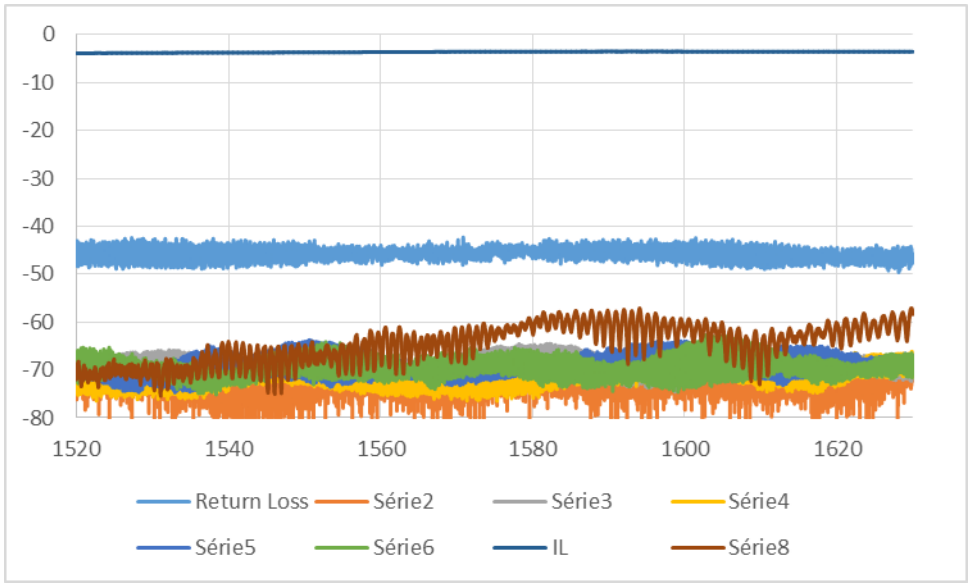
1550 nm, High NA



- Germanium core for easy FBG inscription
- 0.21 NA for robustness to bending.
- Low crosstalk between cores & low loss
- Complimentary fan-in / fan-out available

Product code: Multicore Fiber IXF-MC-7-SM-1550

	Parameter	Value	Unit
1	operating wavelength	1500-1650	nm
2	cutoff wavelength	1300-1520	nm
3	Numerical Aperture	0.21 +/- 0.02	/
4	Mode Field Diameter	6 +/- 0.5	µm
5	Proof Test	100	kpsi
6	cladding diameter	125+/-1	µm
7	core spacing	35+/-0.5	µm
8	core position shape	Hexagon & center	
9	Coating diameter	245 +/-15	µm
10	Number of cores	7	
11	Proof test level	100	kpsi



Measurment over a 100 m pachcord with FAN-IN/FAN-OUT at both extemity

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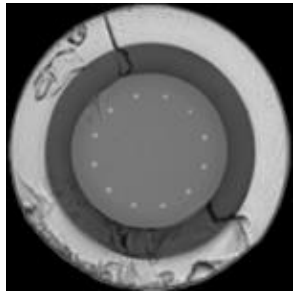
Multicore Fibers for Telecom application

Reduce power consumption



- EFFLAM project : unique 12 core Erbium-Ytterbium co-doped fiber.
  - Clad pumping over 12 cores
  - Both core composition and number of core have been selected in order to provide the best efficiency and lower electrical power consumption versus standard single core pumping scheme.

Product code: IXF-2CF-MC12-EY-6

	Parameter	Specification	Units
1	Core Number	12	
2	Core diameter	6±0.5	µm
3	Mode field Diameter @ 1550nm	6.5+/-0.5	µm
4	Core Spacing	35±0.5	µm
5	Clad diameter	187.5±2.5	µm
6	Coating diameter	355 ± 15	µm
7	Core NA	0.19 ±0.02	
8	Cladding NA	≥0.46	
9	Clad absorption @915nm*	3.5+/-0.5	dB/m
10	Clad absorption @976nm (estimated)	11.5+/-2	dB/m
11	Core absorption @1536nm**	40+/-10	dB/m
12	Multimode background losses	<50	dB/km
13	Proof test level	50	kpsi

Product code: IXF-2CF-MC12-PAS-6

	Parameter	Specification	Units
1	Core Number	12	
2	Core diameter	6±0.5	µm
3	Mode field Diameter @ 1550nm	6.5+/-0.5	µm
4	Core Spacing	35±0.5	µm
5	Clad diameter	187.5±2.5	µm
6	Coating diameter	355 ± 15	µm
7	Core NA	0.19 ±0.02	
8	Cladding NA	≥0.46	
12	Multimode background losses	<25	dB/km
13	Proof test level	50	kpsi

Passive available in double Clad and single Clad fibers

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Multicore Fibers for Telecom application

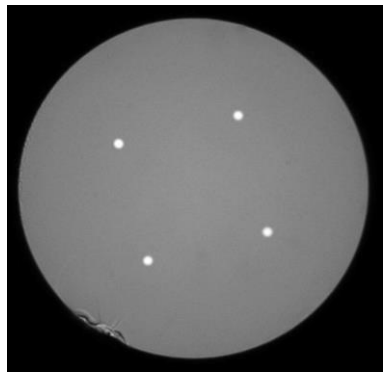
Space Division Multiplexing: 4 cores in standard 125 µm cladding

- Goal: increasing the data-rate by adding a new dimension to a standard outer diameter fiber (125 µm) keeps compatibility with conventional cabling equipment, low attenuation loss and frees up issues related to mechanical strength. By combining space division multiplexing with the wavelength division multiplexing of a 4-core optical fiber, it opens the way to an increase of transmission capacity with a higher information density.

- IXF-MC4-EDF-FGC-980: 4 Core Erbium Fibers for core pumping
  - Compatible with ultra low loss silica core multicore fibers developed by Japanese manufacturer for submarine tranmsision
  - 44 µm core spacing
  - 125 µm cladding
  - C band
- IXF-MC4-SM-1060: associated 4 germanium core passive fibers, equivalent to Hi 1060, for multicore component manufacturing

	Parameter	Specification	Units
1	Core Number	4	µm
2	Core diameter	3.2 ± 0.5	µm
3	Mode field Diameter @ 1550nm	6.5+/-0.5	µm
4	Core Spacing	44±1	µm
5	Clad diameter (flat/flat)	125±1.5	µm
6	Coating diameter	245 ± 15	µm
7	Core NA	0.21 ±0.02	
8	Cutoff Wavelength	< 970	nm
9	Absorption @ 1530 nm	5.3 – 6.6	dB/m
10	Absorption @ 1480 nm	2.0 – 2.5	dB/m
12	Background losses	< 8	dB/km
13	Proof test level	100	kpsi

Fiber Parameter	Specification
Core spacing *	44.2 ± 0.6
Core NA	0.21 ± 0.01
Core diameter	3.4 ± 0.2
Cladding diameter	125 ± 3
Coating diameter	245 ± 15
Attenuation@980nm **	< 2.5
Attenuation@1550nm ***	< 1.0
Cut-off wavelength ****	< 970
Mode field diameter@980nm	4.0 ± 0.3
Mode field diameter@1550nm	6.5 ± 0.5



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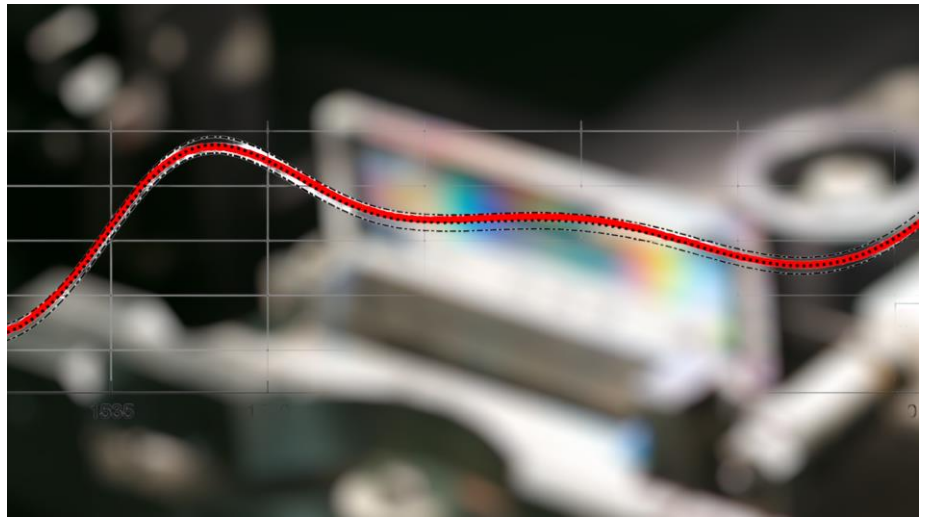
Multicore GFF

Product Overview

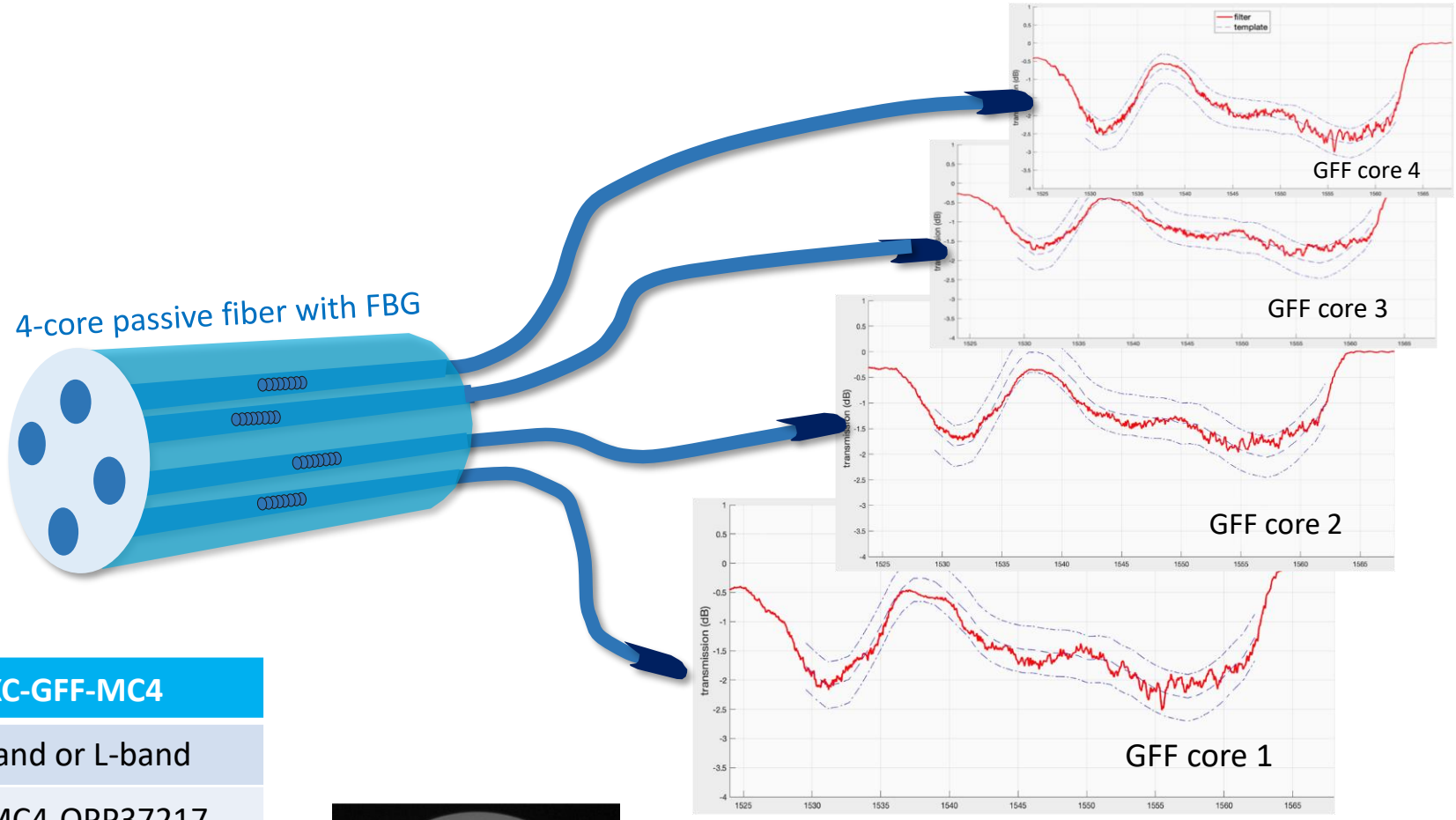
- GFF based on 4-core Fiber Bragg Gratings is an easy and effective solution to flatten the gain of Multicore amplifier in WDM/SDM systems.

- Fast prototyping made possible by our highly flexible production lines with the advantage of FBG technology for achieving low systematic error, low ripple and good core-to-core uniformity.

- Keys features:
  - Customized filter profile in C or L band
  - Low excess loss
  - Weak PDL and PMD
  - Compliant with Telcordia GR-1209 & GR-1221
  - Athermal or recoat component

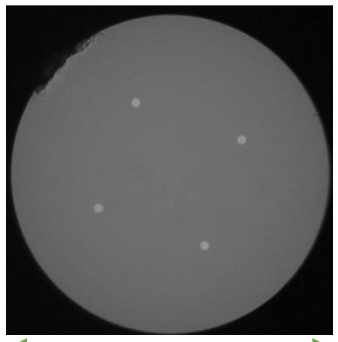


Multicore GFF
Optical characteristics



Typical characteristics

Specifications	IXC-GFF-MC4
Wavelength range	C-band or L-band
Fiber	IXF-MC4-OPP37217
Transmission depth	up to 4 dB
Typical error function	< 1 dB
Excess Loss	< 1 dB
Core to core IL variation	< 1 dB



Cross-section view of the passive 4-core fiber

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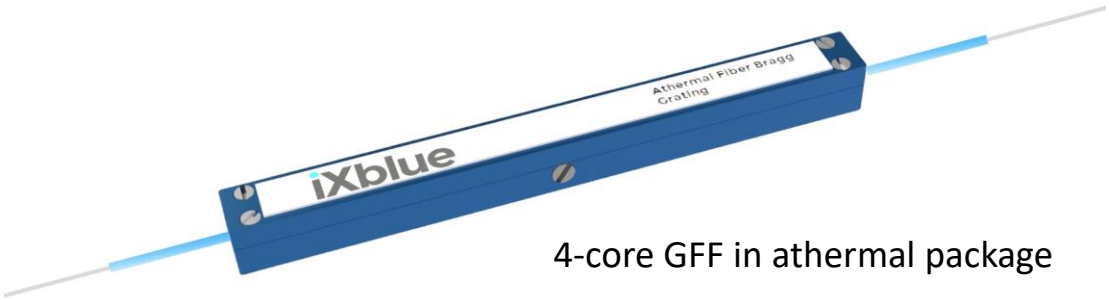
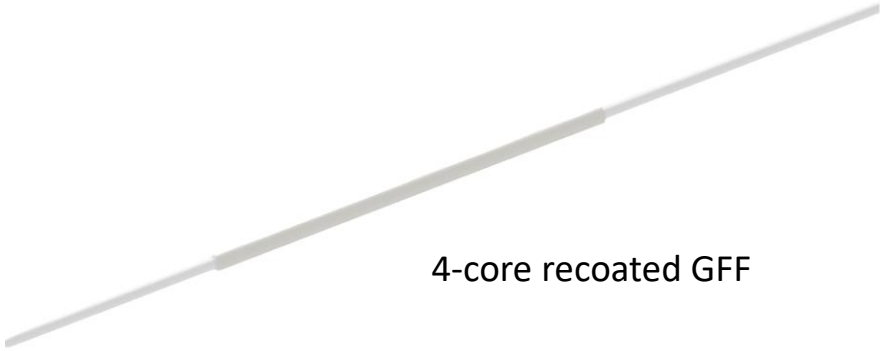
Multicore GFF
Packaging

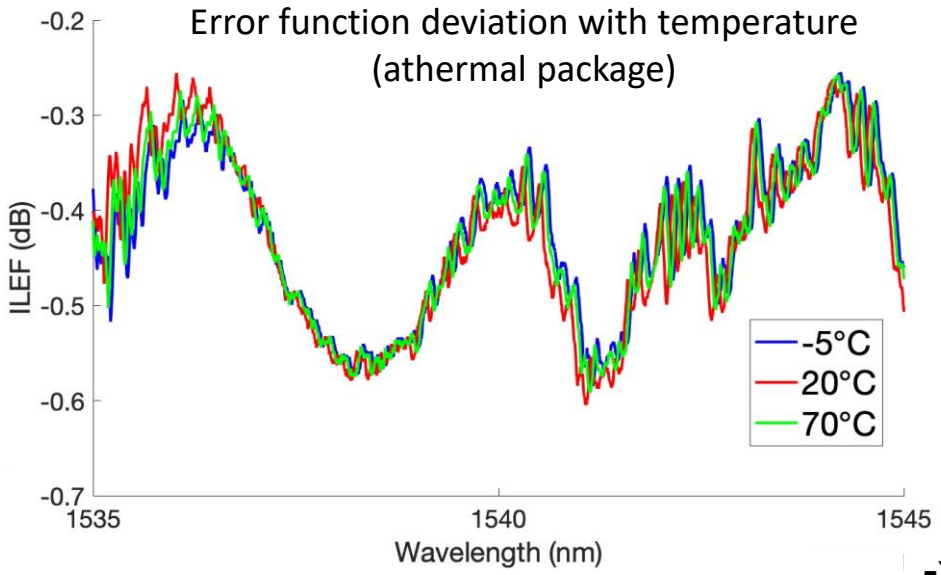


4-core GFF in athermal package



4-core recoated GFF

Specifications	IXC-GFF-MC4 (athermal package)	IXC-GFF-MC4 (recoat)
Storage temperature	-40 to 80°C	-40 to 80°C
Operating temperature	-5 to 70°C	-40 to 80°C
Wavelength shift in the operating temp. range	< 0.15 nm	≈ 1.3 nm
Thermal stabilization in [20;70]°C	< 2 pm/°C	11 pm/°C



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