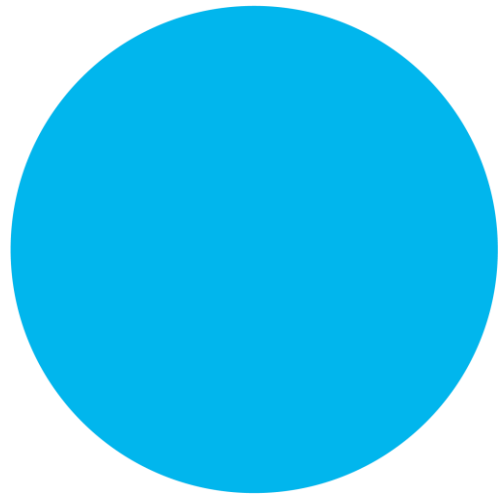


iXblue



Final Review of EDURAC project

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Main objectives of optical fibre technology development

iXblue task in the EDURAC project was to develop and deliver to MENLO with space-grade PM erbium doped fibres suited to provide high gain in amplifiers and laser cavities, to be integrated in space-grade frequency comb lasers.

4 main characteristics were mandatory to achieve this goal, as defined in the document *“Review on technical requirements for radiation hard fibers for optical frequencies combs”* :

- Finely tuned chromatic dispersion to generate short pulses in a ring configuration
- High erbium content to provide high gain in short lengths of active fibers
- Radiation resistance towards gain reduction in space radiation field
- Polarization maintaining fibres

iXblue based this development on its background related to radhard actives fibres, however further improvements were mandatory to obtain requested specifications, as compared to off-the-shelf products

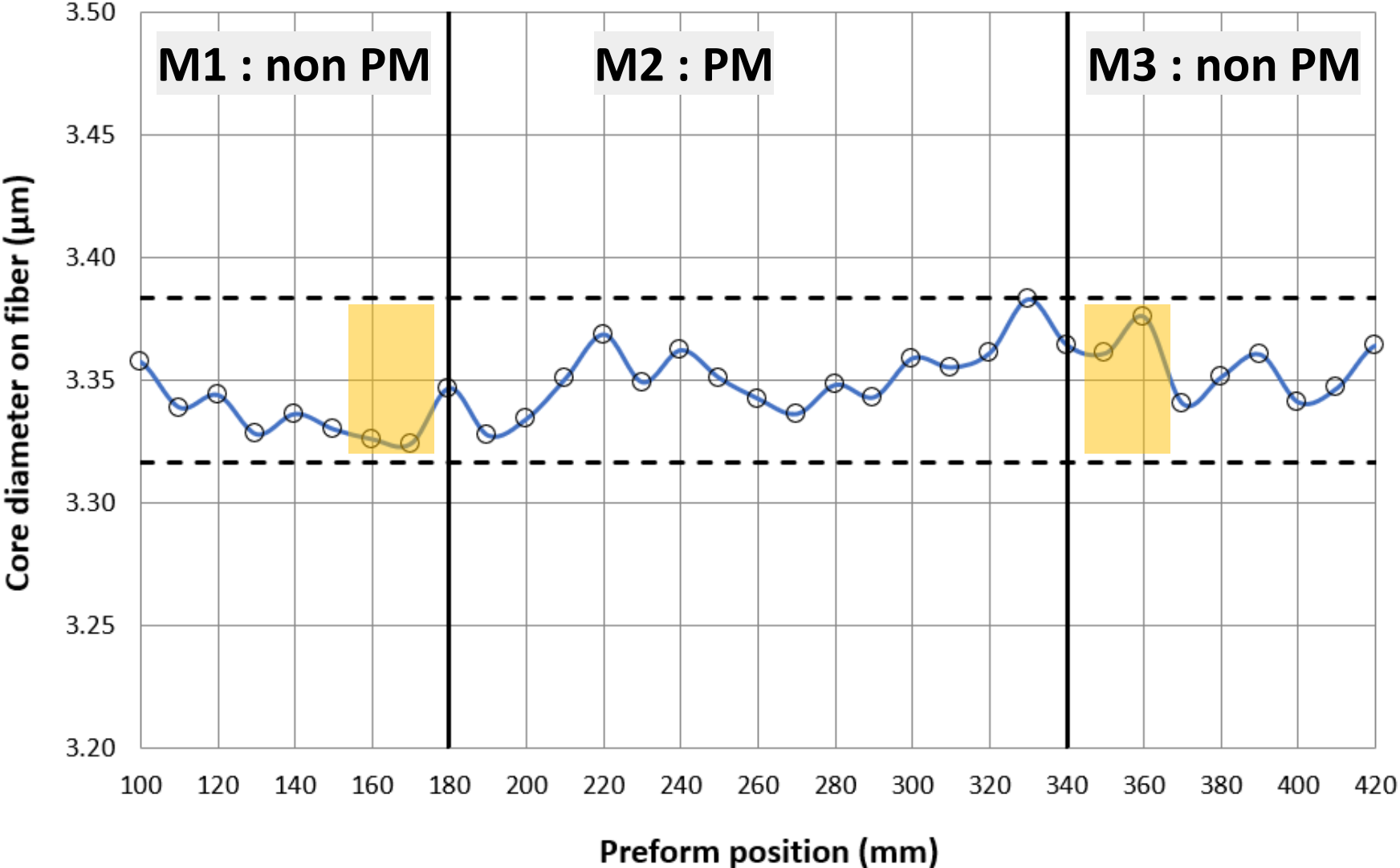
Chromatic dispersion

The specification on this parameter was $-10 \text{ ps/nm/km} \pm 1$, *a priori not* too much stringent. However, after some preliminary modelling runs, it appeared that this parameter (link to other constraints on the optical design) leads to a **very high sensitivity to fibre core diameter**.

In order to control this parameter, iXblue settled a specific and very accurate procedure to measure preform index profiles along their lengths (**400 measurements per preform**).

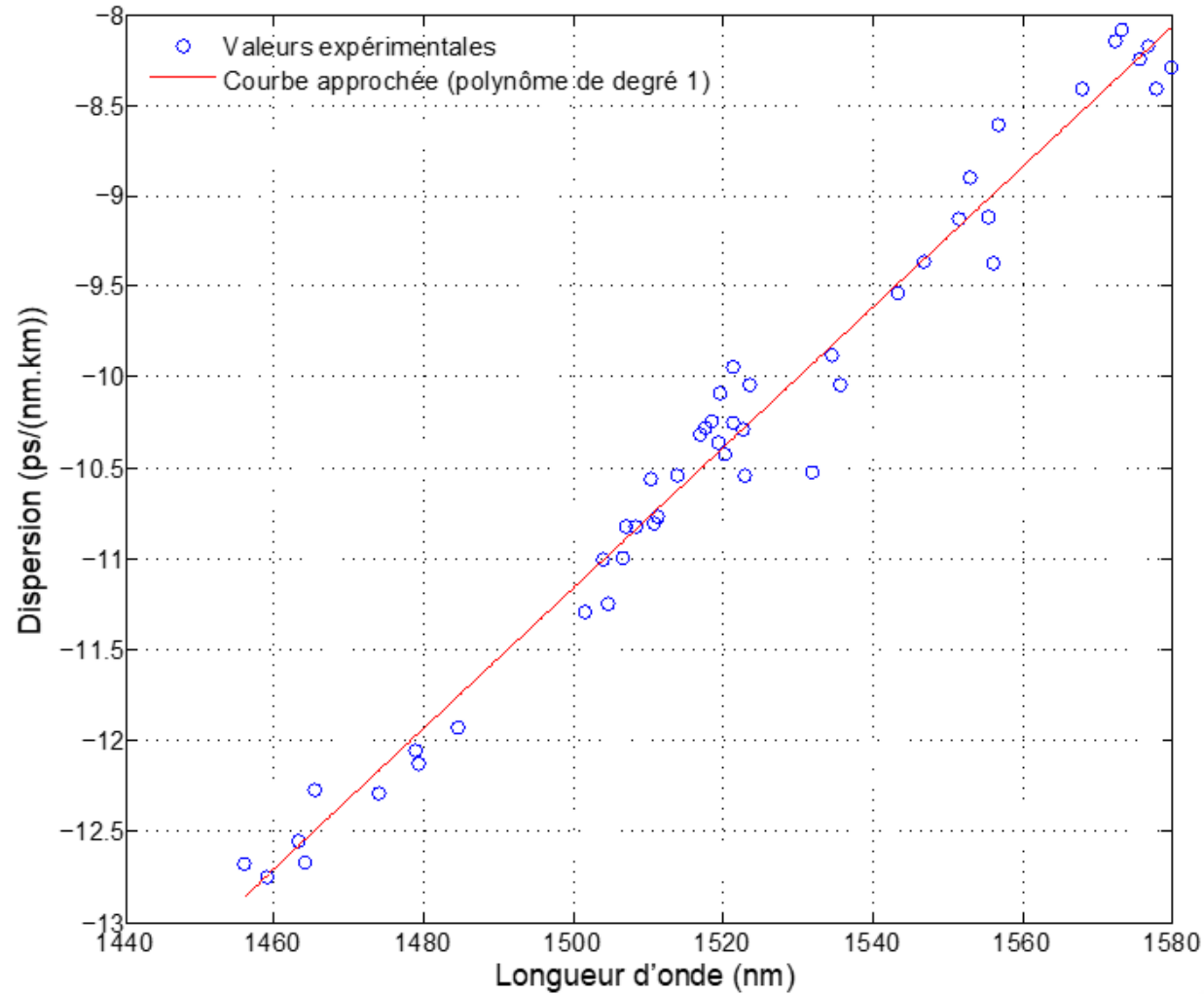
Only **the most stable part of the preforms** were selected for the process steps of overcladding and drawing. Prior to PM fibre assembly, non-drilled preforms sections were drawn to measure obtained chromatic dispersion, and final fibre diameter was eventually adapted to get the targeted chromatic dispersion.

Adjustment of chromatic dispersion (A2901)



Chromatic dispersion measurement

- ❑ Interferometric measurement performed by Photonics Bretagne (half a day for acquisition and treatment of the data)



Erbium content

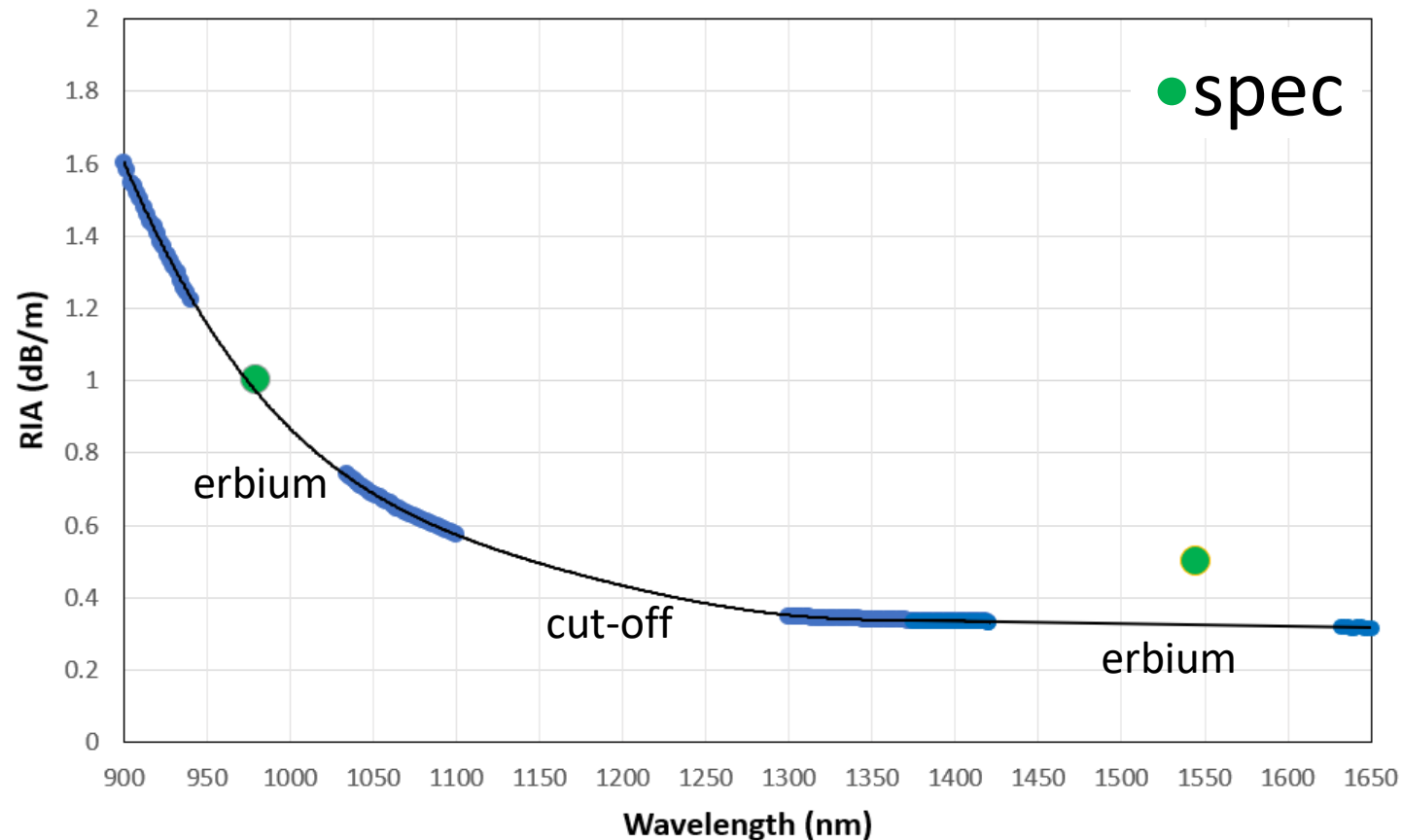
Targeted erbium content ($>35\text{dB/m@1530nm}$) is **significantly higher** than of-the-shelf space-grade iXblue fibres ($\sim 25\text{dB/m@1530nm}$) with a core diameter which is also higher.

Rare-earth doped elements are incorporated into an internal porous layer of silica **by soaking process**. After removing the liquid and drying, this soot layer is vitrified to embed erbium/aluminum ions into the glass : much more complicated as compared to the process of telecom fibres !

A few fabrication iterations were required to fix soaking solution and MCVD parameters to achieve this goal. As **erbium absorption is not measurable on a preform** (too low absorption), iXblue faced an unexpected low erbium content in the very first PM fibre iteration. This problem has been fixed afterward but leads to some delays in the project.

Radiation Inducted Attenuation

- ❑ Non PM fibers were irradiated up to 1 kGy at 0.001 Gy/s in 12 days
- ❑ OFF-LINE measurement, lower dose rate due to facility constrain, no bleaching through 980nm pumping



Full characterization of the two delivered PM fibers

Fiber 1st Gen

Product code: IXF-CUST-OPP-32096-HW1.1
 ERP PO: AR1200803
 Customer PO: BS45570-1

OF # IXF-CC200350 item 150 Prep Date: 7 April 2021
 Fiber serial number# A2901M2F1C020R02 Length: 100 m

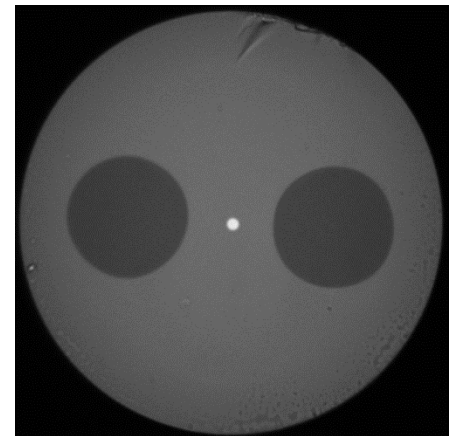
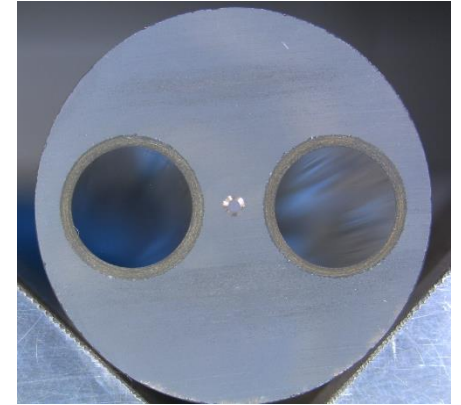
Fiber Parameter	Unit	Minimum required	targeted	Value	Compliance
Absorption at 980 nm	dB/m	> 17	> 20	18.0	Pass
Absorption at 1530 nm	dB/m	> 25	> 35	34.9	Pass
MFD @ 1550nm	μm	5.5	6.5	4.5	Fail (1)
Background losses	dB/km	< 20	< 15	6	Pass
Cladding Diameter	μm	125	125 ± 2	123.1	Pass
Coating Diameter	μm	245	245 ± 10	239	Pass
Proof Test Level	kpsi	> 100	> 100	100	Pass
Group Birefringence	-	> 2 · 10 ⁻⁴	> 4 · 10 ⁻⁴	3.1 · 10 ⁻⁴	Pass
Fiber Dispersion at 1550 nm	fs/nm/m	-10	-10 ± 1	-9.5	Pass
Splice Loss to PM1550 and PM980	dB	< 0.2	< 0.1	< 0.2	Pass (2)
RIA (@1545 nm)	dB/m/Gy	< 0.0015	< 0.0005	0.0003	Pass
RIA (@980 nm)	dB/m/Gy	< 0.0025	< 0.001	0.001	Pass
RIGV	dB/Gy	< 0.0025	< 0.001	-	TBM (3)

Fiber 2nd Gen

Product code: IXF-CUST-OPP-32096-HW1.2
 ERP PO: AR1200803
 Customer PO: BS45570-1

OF # IXF-CC200350 item 140 Prep Date: 20 Jul. 2021
 Fiber serial number# A2918M1F1C020R01 Length: 100 m

Fiber Parameter	Unit	Minimum required	targeted	Value	Compliance
Absorption at 980 nm	dB/m	> 17	> 20	18.6	Pass
Absorption at 1530 nm	dB/m	> 25	> 35	36.1	Pass
MFD @ 1550nm	μm	5.5	6.5	4.5	Fail (1)
Background losses	dB/km	< 20	< 15	6.6	Pass
Cladding Diameter	μm	125	125 ± 2	124.3	Pass
Coating Diameter	μm	245	245 ± 10	248	Pass
Proof Test Level	kpsi	> 100	> 100	100	Pass
Group Birefringence	-	> 2 · 10 ⁻⁴	> 4 · 10 ⁻⁴	3.5 · 10 ⁻⁴	Pass
Fiber Dispersion at 1550 nm	fs/nm/m	-10	-10 ± 1	-10.4	Pass
Splice Loss to PM1550 and PM980	dB	< 0.2	< 0.1	-	TBM (2)
RIA (@1545 nm)	dB/m/Gy	< 0.0015	< 0.0005	0.0003	Pass
RIA (@980 nm)	dB/m/Gy	< 0.0025	< 0.001	0.001	Pass
RIGV	dB/Gy	< 0.0025	< 0.001	-	TBM (3)



Conclusion

- ❑ Detailed overview of iXblue activities has been provided in the MS-1 version C report. iXblue pushed its actual technology closed to its limits *in the defined time frame* and finally managed to *deliver fibers as they were requested*.
- ❑ To summarize : a lot of preforms drawn (14) and a lot of different measurements (xxx)
- ❑ It might still have room for improvements, in particular by modifying targeted *erbium content and chromatic dispersion* to optimize final space-comb set-up design
- ❑ **iXblue warmly thank ESA** for the funding of this fiber development and is willing to support/collaborate with MENLO in the future steps of space-grade frequency combs development, for the best benefits of European Photonic Industries.