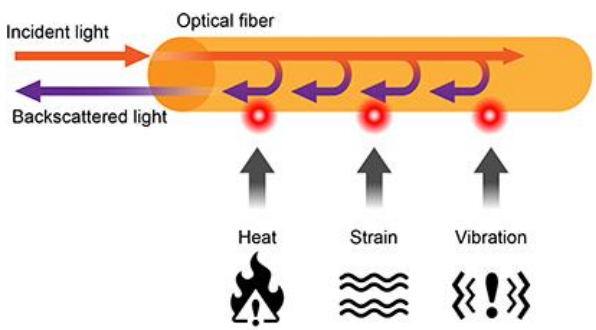
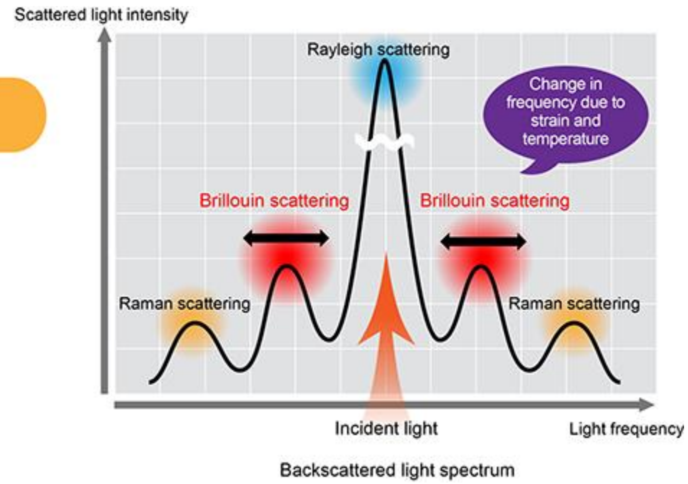
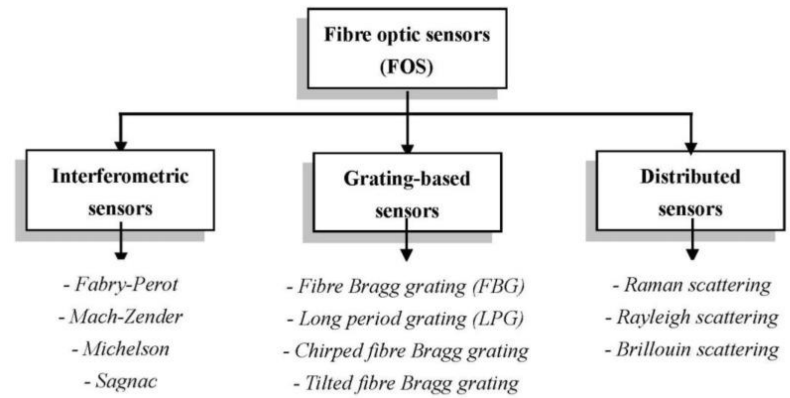
HANDS-ON SESSION
Static strain measurement based on optical fibres

MECHANICAL & MATERIALS ENGINEERING
FOR PARTICLE ACCELERATORS AND DETECTORS

Reminder (Optical strain sensing)

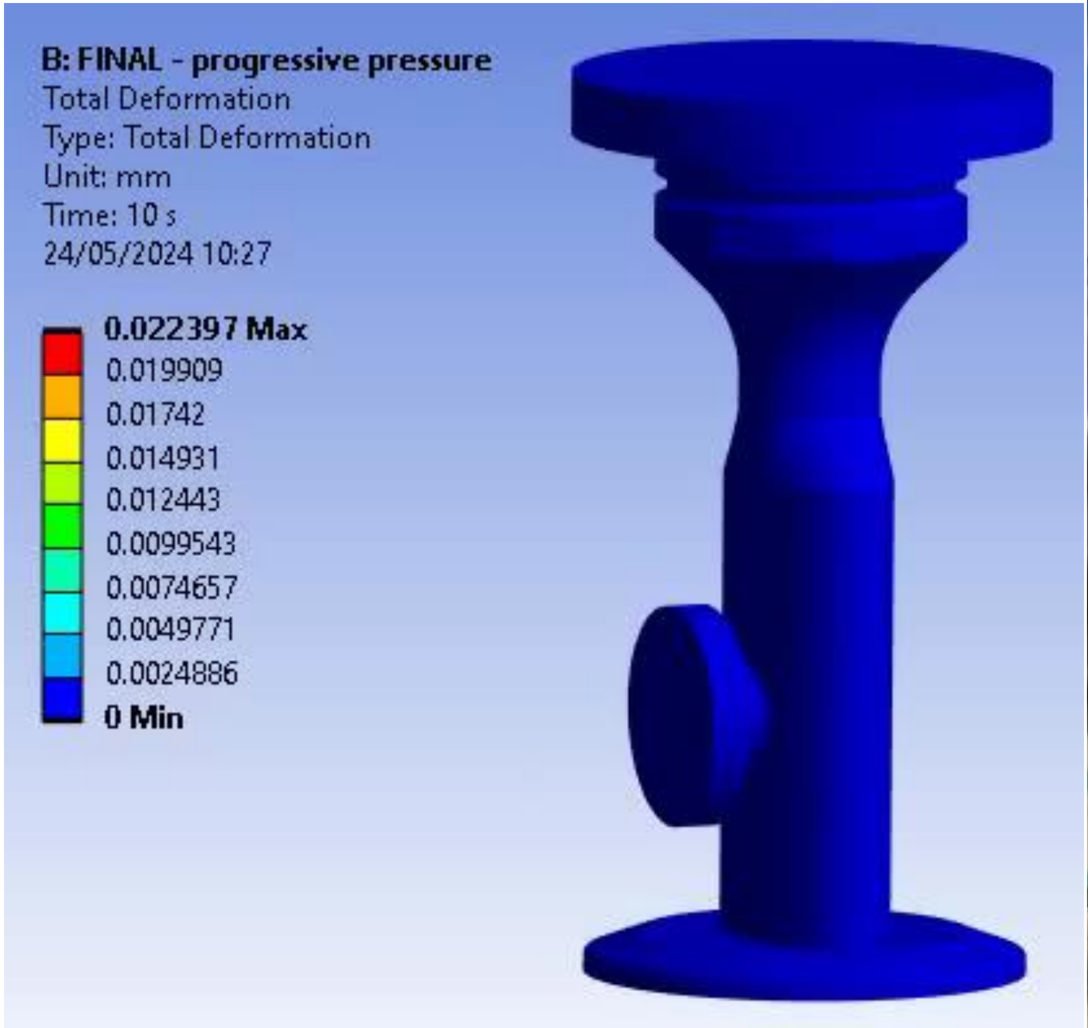


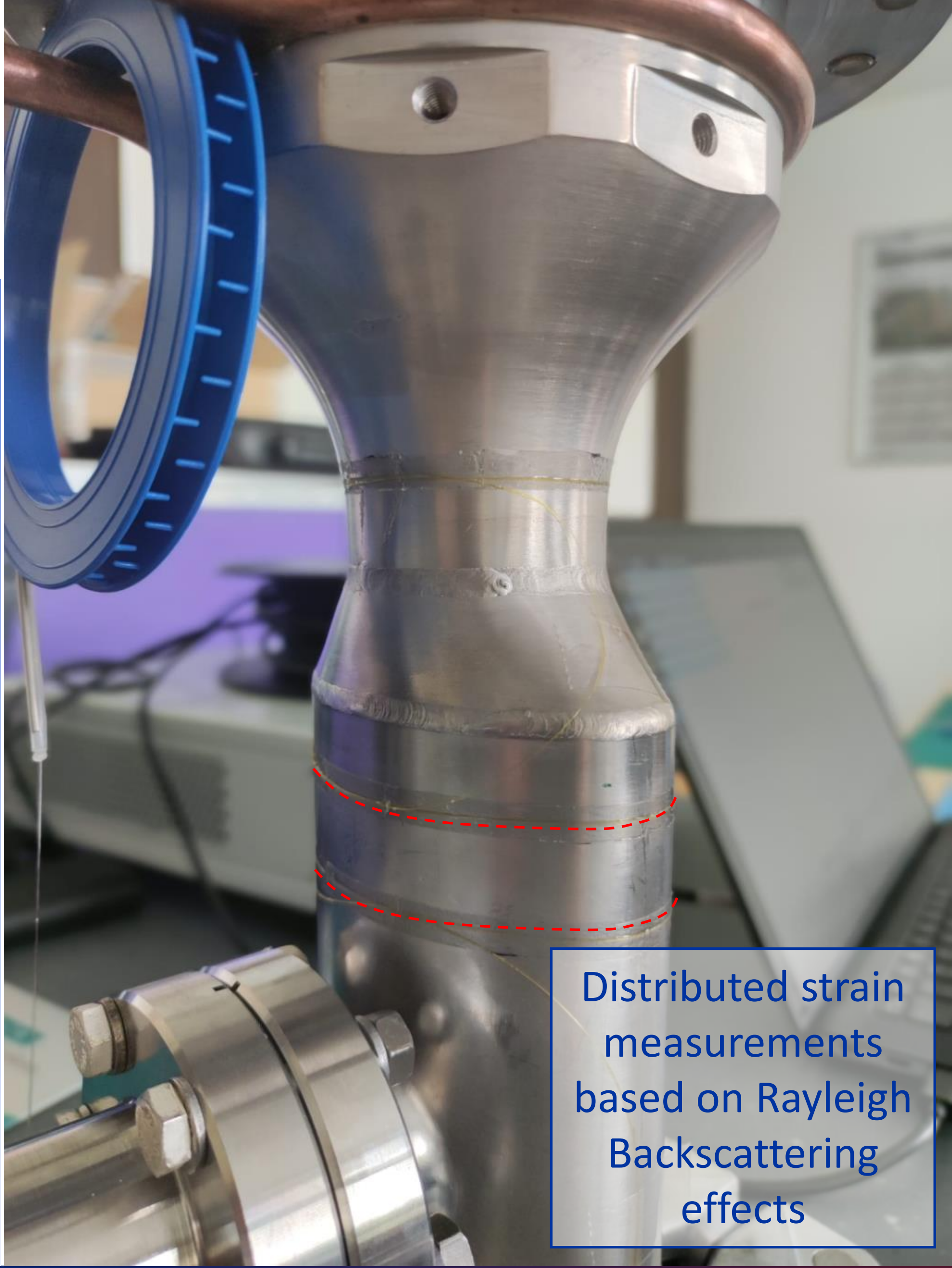




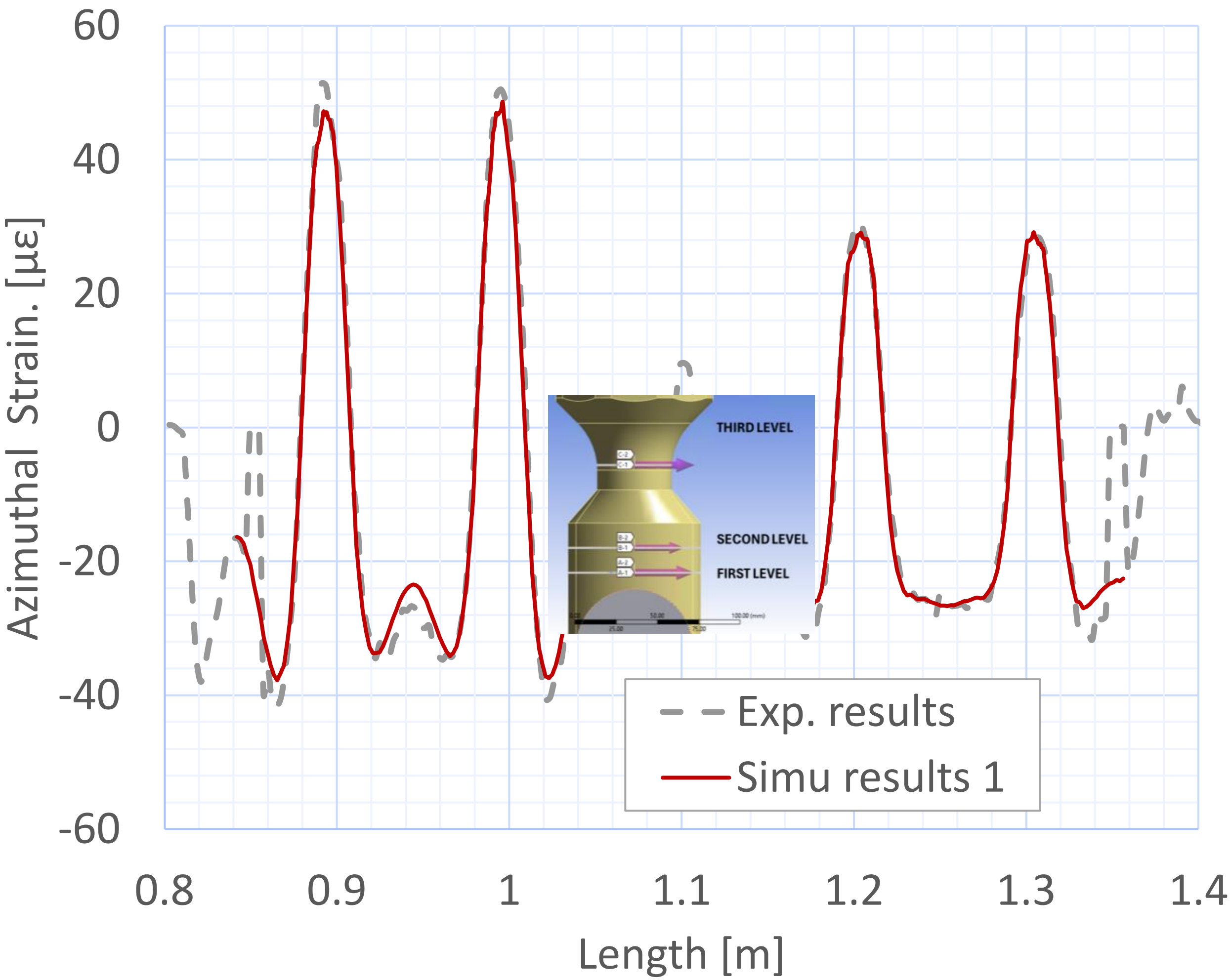
Sensing technology	Transducer Type	Sensing Length	Spatial Resolution	Physical Effects Measured
Raman	Distributed	1 to 37 km	1 cm to 17 m	Temperature
Brillouin OTDR (1)	Distributed	20 to 50 km	≈ 1 m	Temperature and Strain
Brillouin OTDA (2)	Distributed	150-200 km	2 cm to 2 m	Temperature and Strain
Rayleigh	Distributed	50-70 m	≈ 1 mm	Temperature and Strain
Bragg	Local	≈ 100 single points	2 mm (Bragg length)	Temperature and Strain

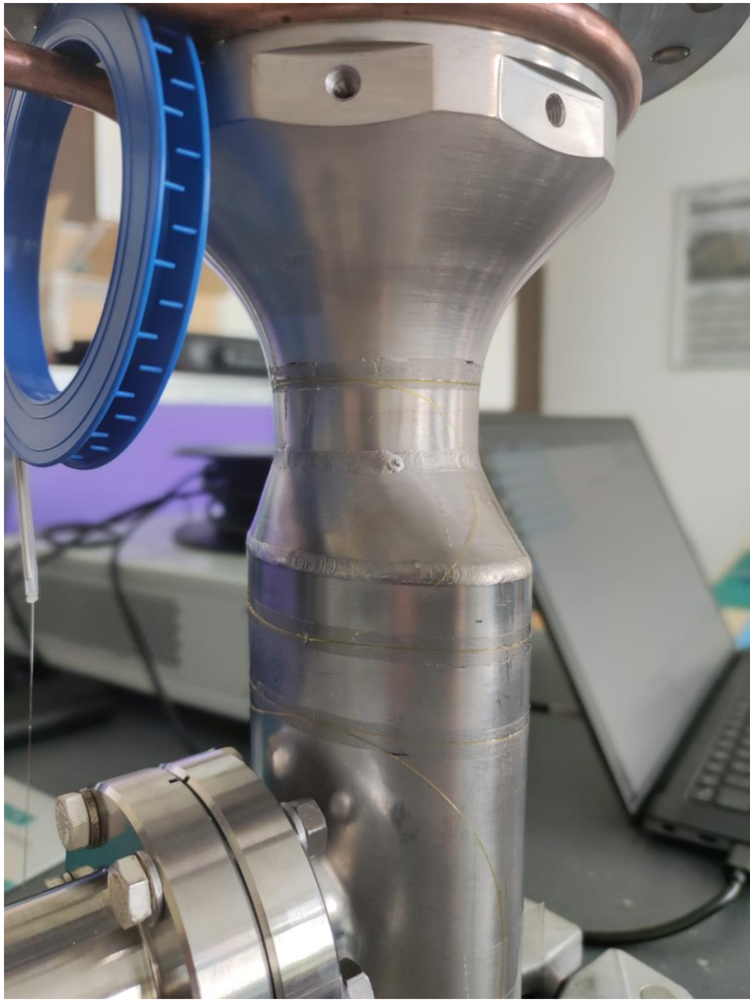
Rayleigh example





Rayleigh example





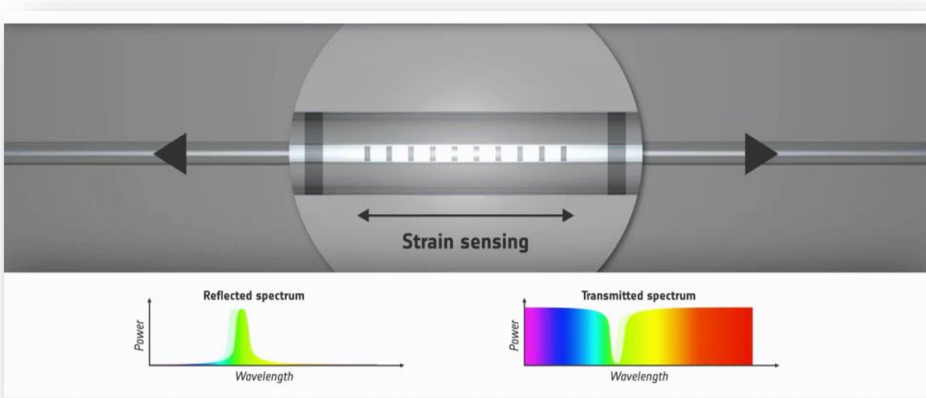
Reminder about Fiber Bragg Grating

Working principle

- Discrete strain measurements
- Integrated strain over the grating

$$\frac{\Delta\lambda_B}{\lambda_B} = (1 - p_e)\boldsymbol{\varepsilon_{ax}} + (\alpha_s + \zeta_s)\boldsymbol{\Delta T}$$

$p_e = 0.22$ photo sensitivity of germanosilicate fiber
ε_{ax} = axial strain
α_s = Thermal expansion coefficient of fiber
ζ_s = Thermo-optic coefficient of fiber



- Multiple sensors on a single array
- Immune to magnetic fields
- No k factor variation

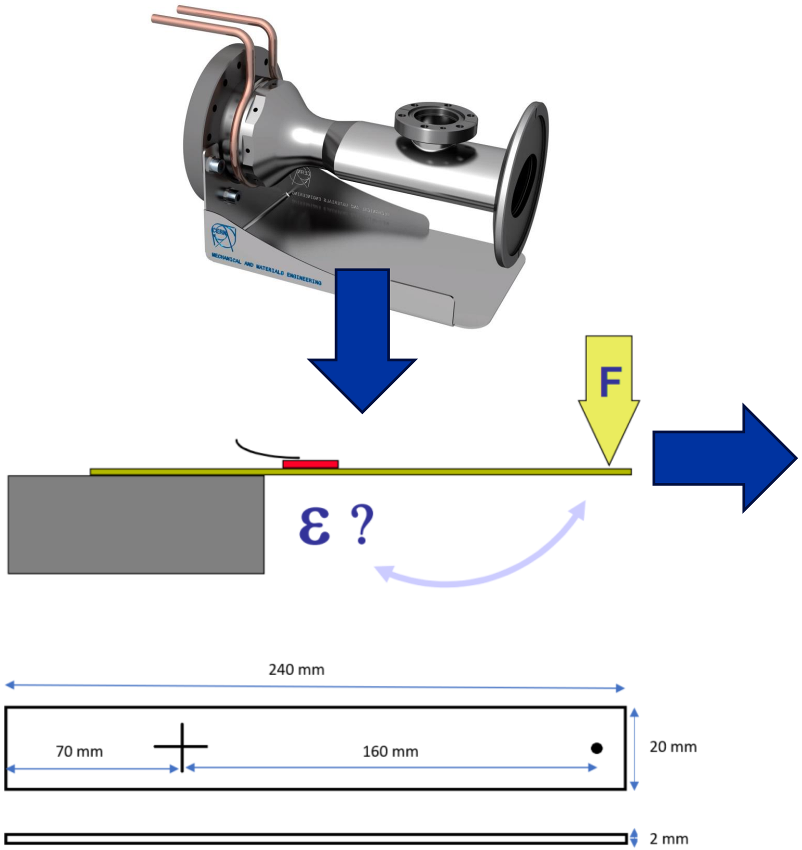
- Curvature limitations
- Delicate compared to accelerator structures
- Apparent strain with temperature

Context of the hands-on session

Strain measurements on the beam pipe during pumping operation at room temperature to assess FEA model

Reminder (FEA model)

What is the expected strain to be measured for a known force applied ?



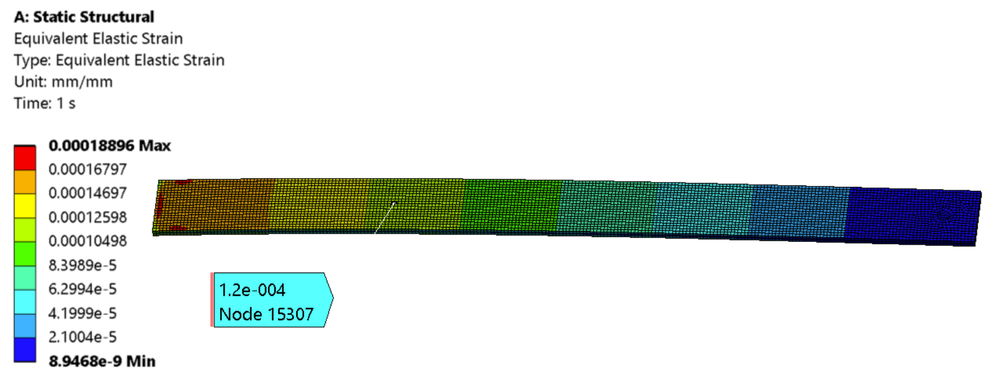
Analytical calculations

$$F = m \times g \qquad M_b = F \times l \qquad W_b = \frac{b \times h^2}{6}$$

$$\sigma = \frac{M_b}{W_b} = \varepsilon \times E \qquad \boldsymbol{\varepsilon = \frac{6 \times m \times g \times l}{b \times h^2 \times E}}$$

$$\boldsymbol{If\ F = 2\,N \qquad \varepsilon = 124\ \mu m/m}$$

FEA simulations



Let’s work with your hands to measure it !!!!

DISCLAIMER

This procedure was developed only for education purpose…

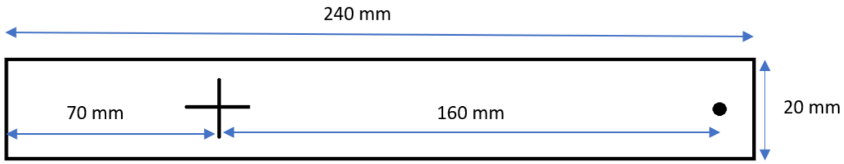
Bonding process is not applicable for cryogenic application.

For specific application, do not hesitate to contact us

mme.mechlab@CERN.CH

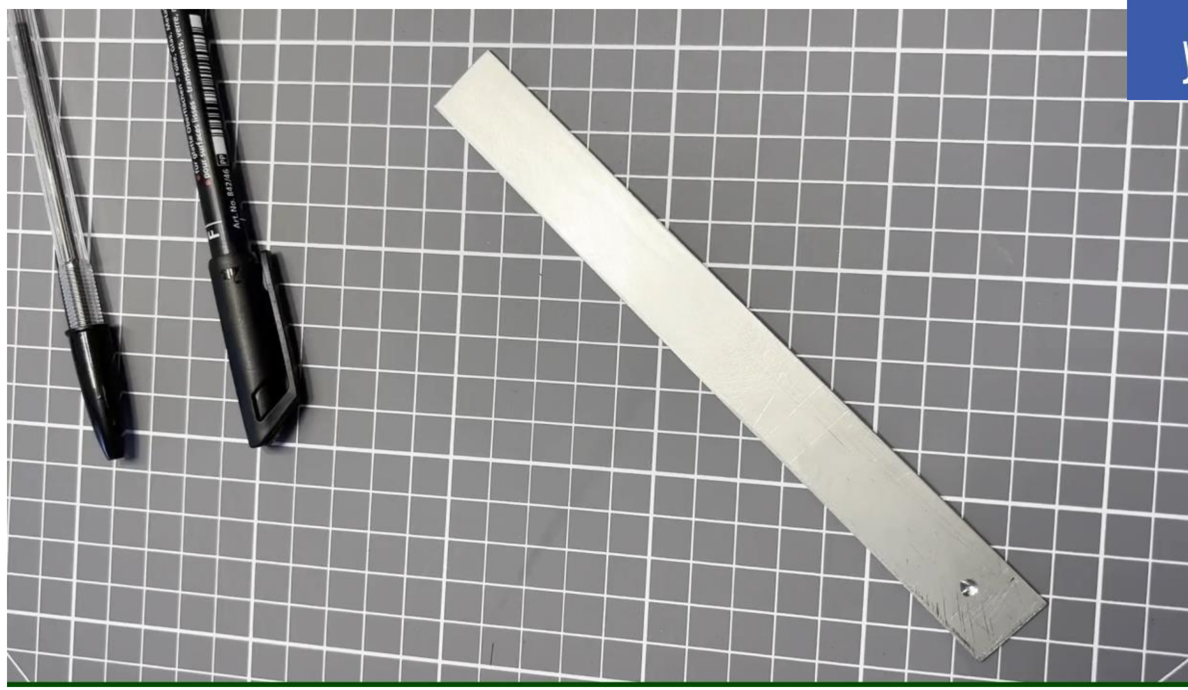
Optical fiber bonding process

Sample preparation → Sample cleaning → Grating identification → Fiber installation → Fiber bonding → Fiber protection → Optical connections



Determine the final position of the grating with a marker first and with a pen in a second time.

Tools requested



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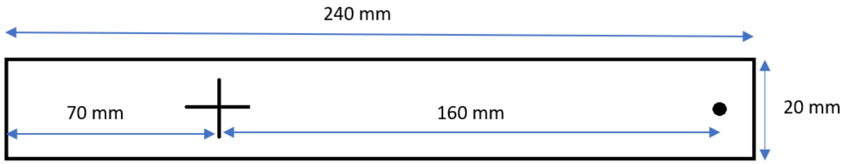
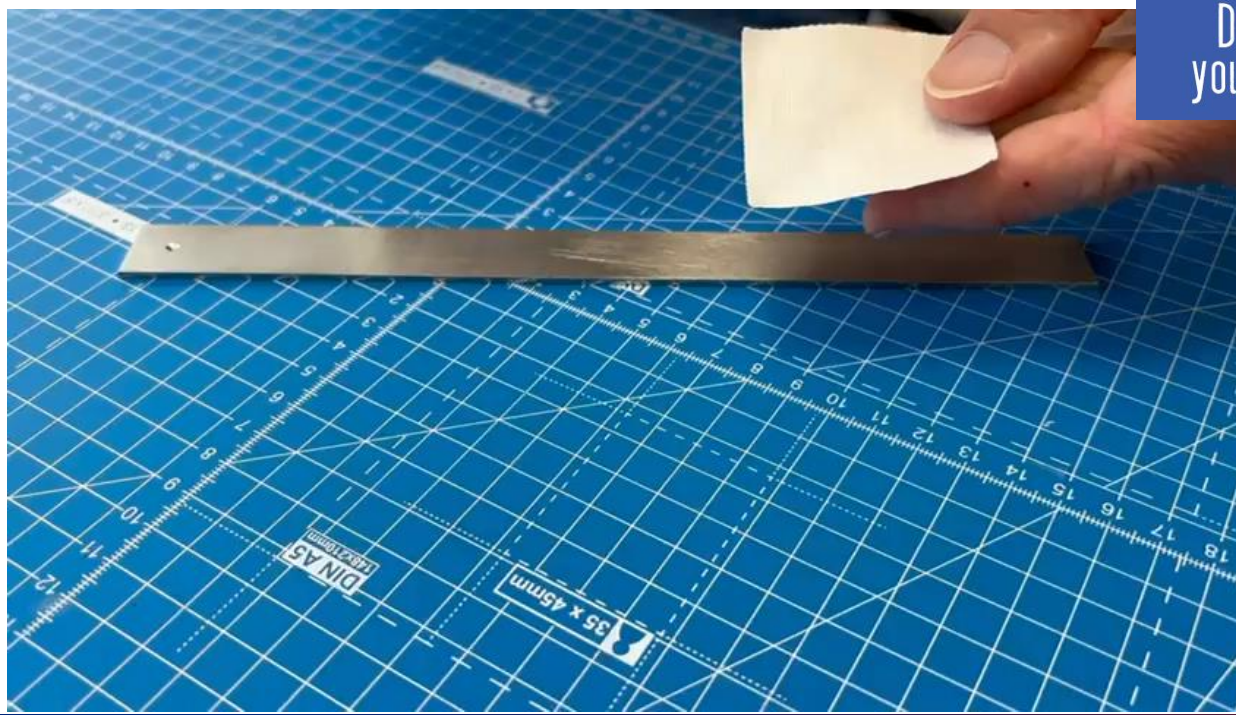


Clean the surface with the chemical agent to remove all the pen traces. Do it from the cross to outside.

Do it yourself

Tools requested



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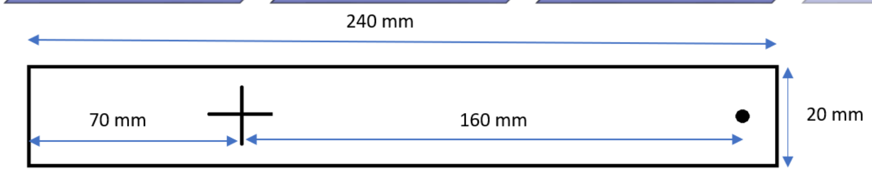

Unpackage the fiber and identify the grating position on the fiber.

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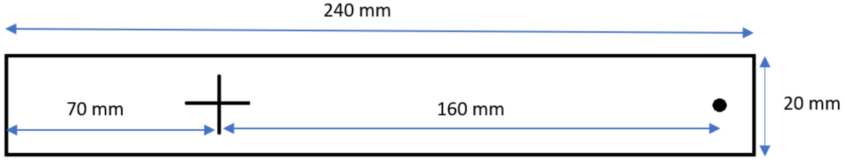
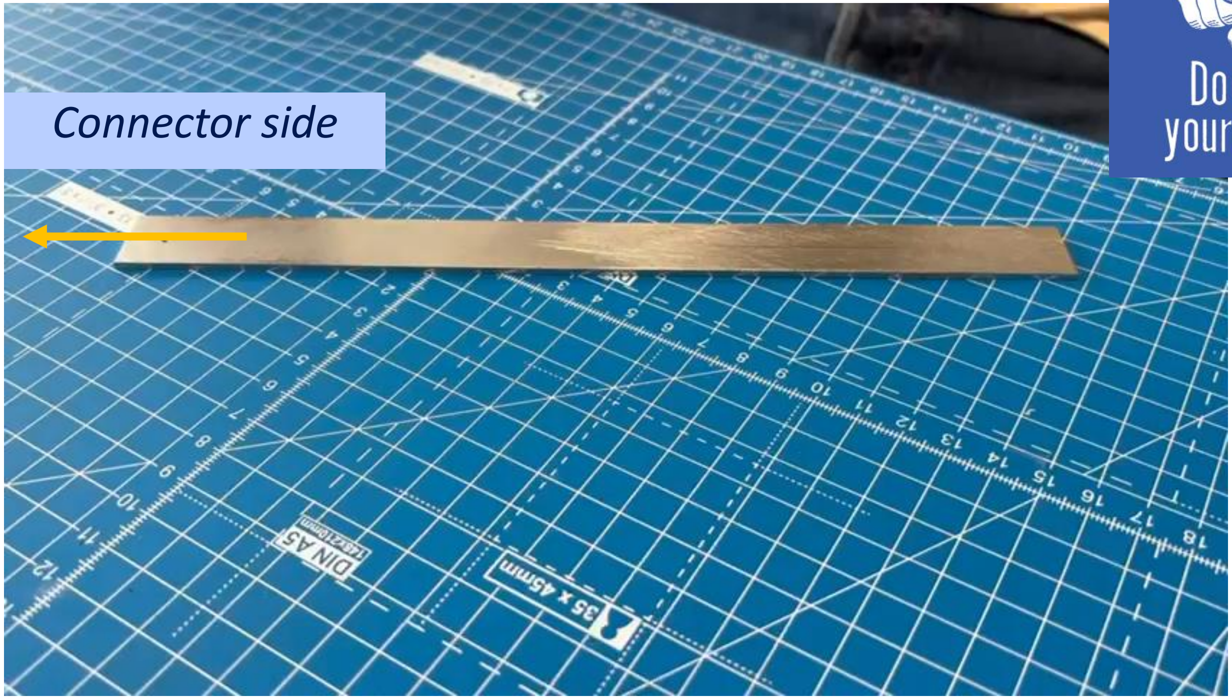


Place the fiber and the grating on top of the cross and go down slowly. Ask to you colleague to install a fix point with Kapton tape on the long side!

Tools requested

Connector side



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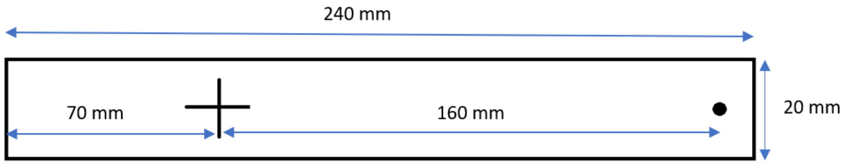
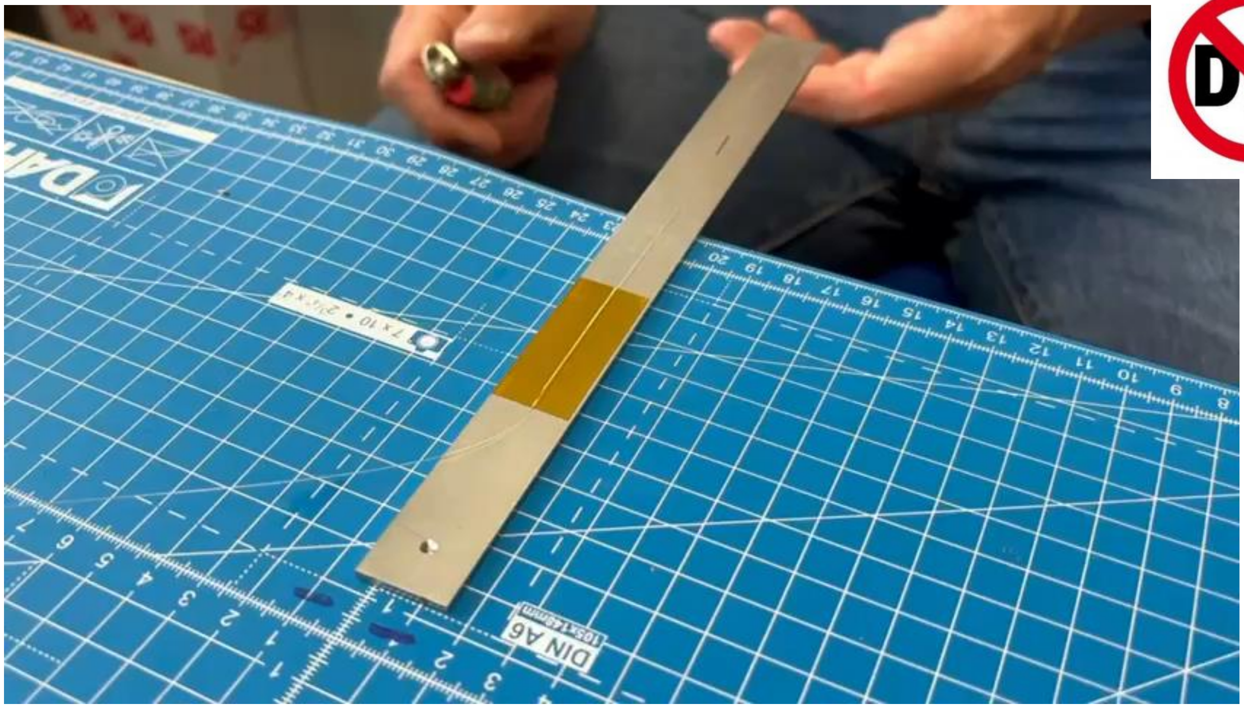


Coating removal operation.

This operation will be done by the helpers !



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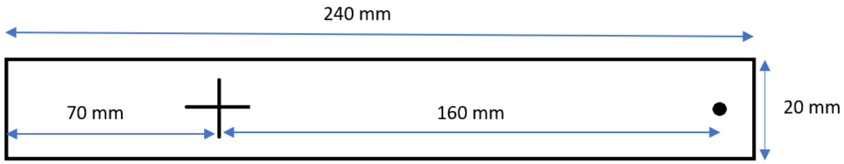
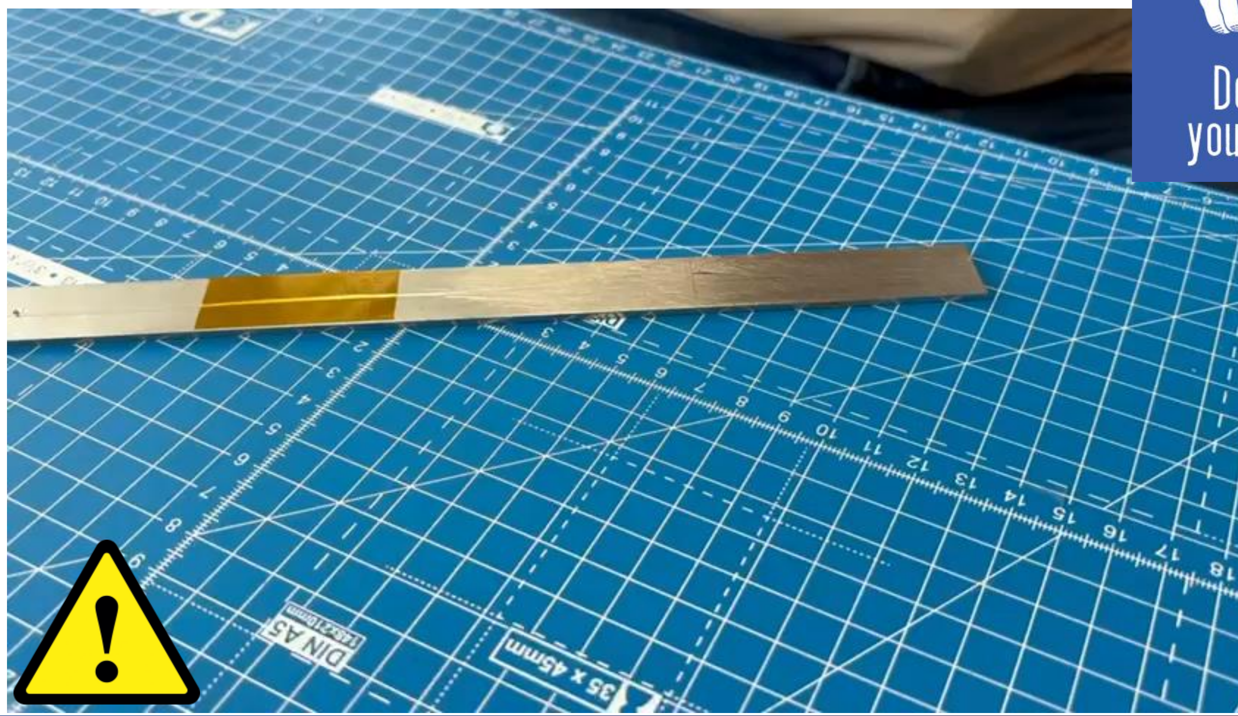


Clean the fiber to remove burned dusts and clean again the specimen.

Tools requested



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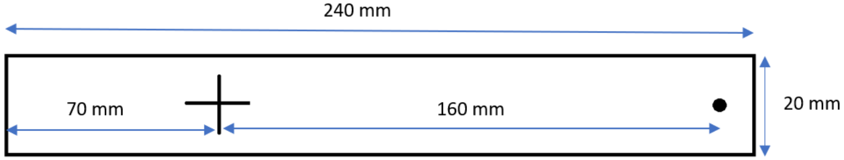

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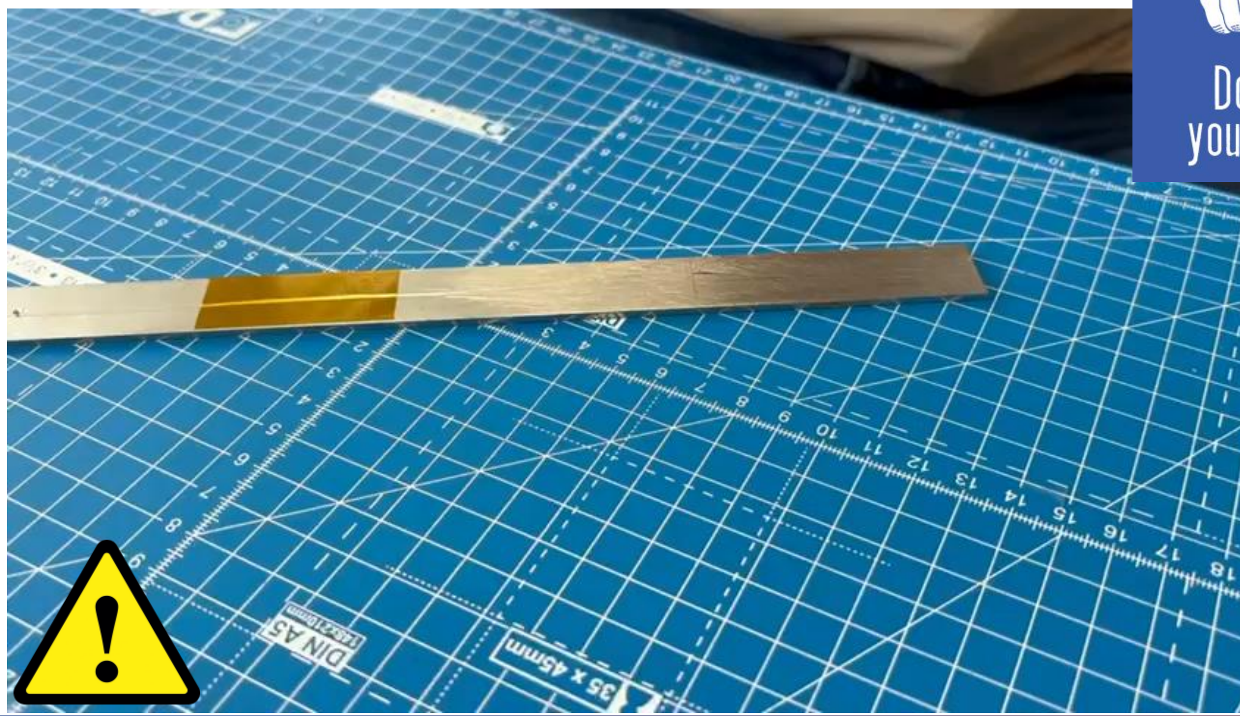


Optical fiber bonding process

Sample preparation → **Sample cleaning** → **Grating identification** → **Fiber installation** → **Fiber bonding** → Fiber protection → Optical connections

1) *Lift-up the fiber to place, place the Loctite activator and* ***<u>one drop of glue on the cross</u>****.*
2) *Place back the fiber in the glue with a small tension with your hand.*
3) *Ask again to you colleague to install the second Kapton tape to keep the tension on the fiber.*
4) *Apply a pressure during 2 minutes on the glue and the grating with your finger* ***<u>and the Teflon layer</u>***

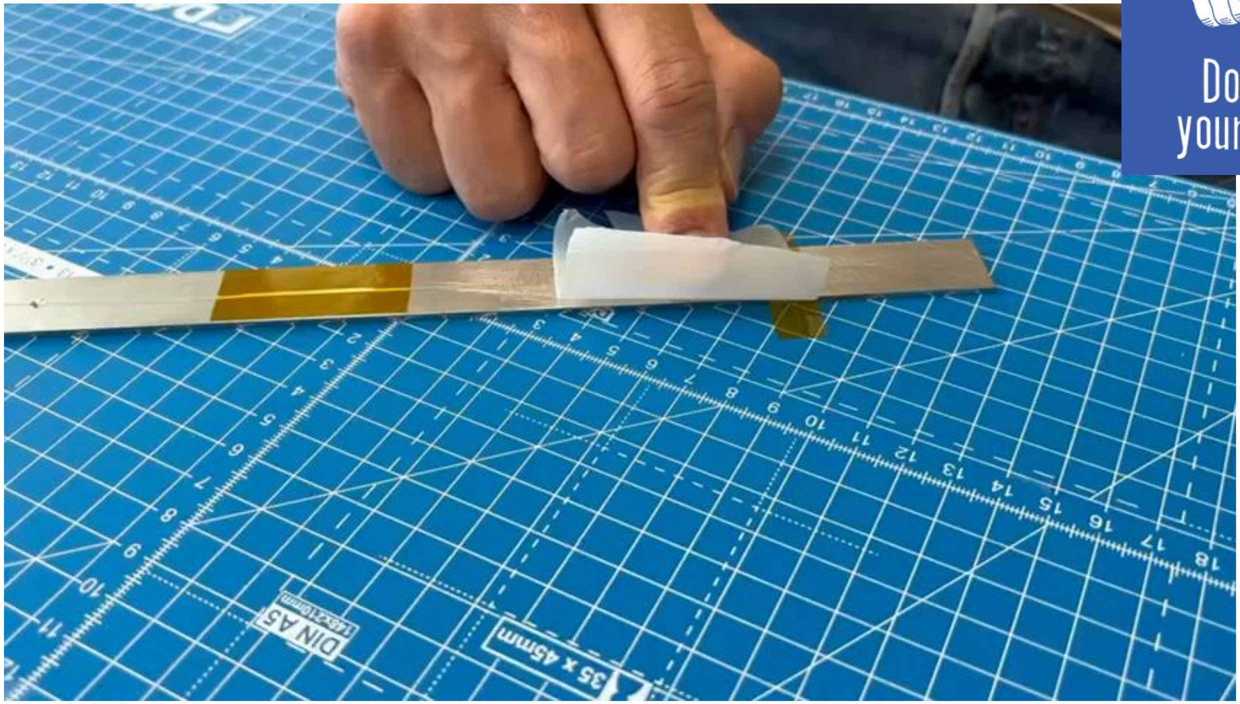
Tools requested

Optical fiber bonding process

Sample preparation → Sample cleaning → Grating identification → Fiber installation → Fiber bonding → Fiber protection → Optical connections

Add Kapton tape to keep the fiber in a safe position, take care to the extremity of the specimen (sharp angles are very dangerous for fibers)

Tools requested



Optical fiber bonding process

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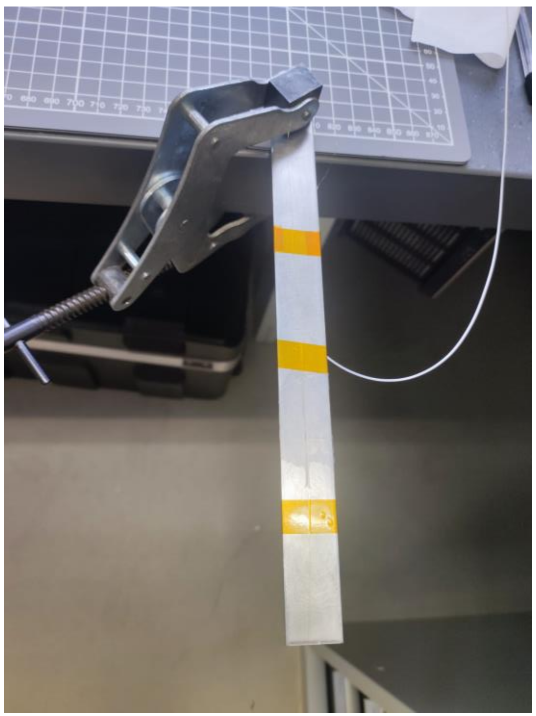
1) *Clamp your specimen on the table*
2) *Connect the FC-APC connectors to one channel of the interrogator (Take care to the orientation of the connector)*



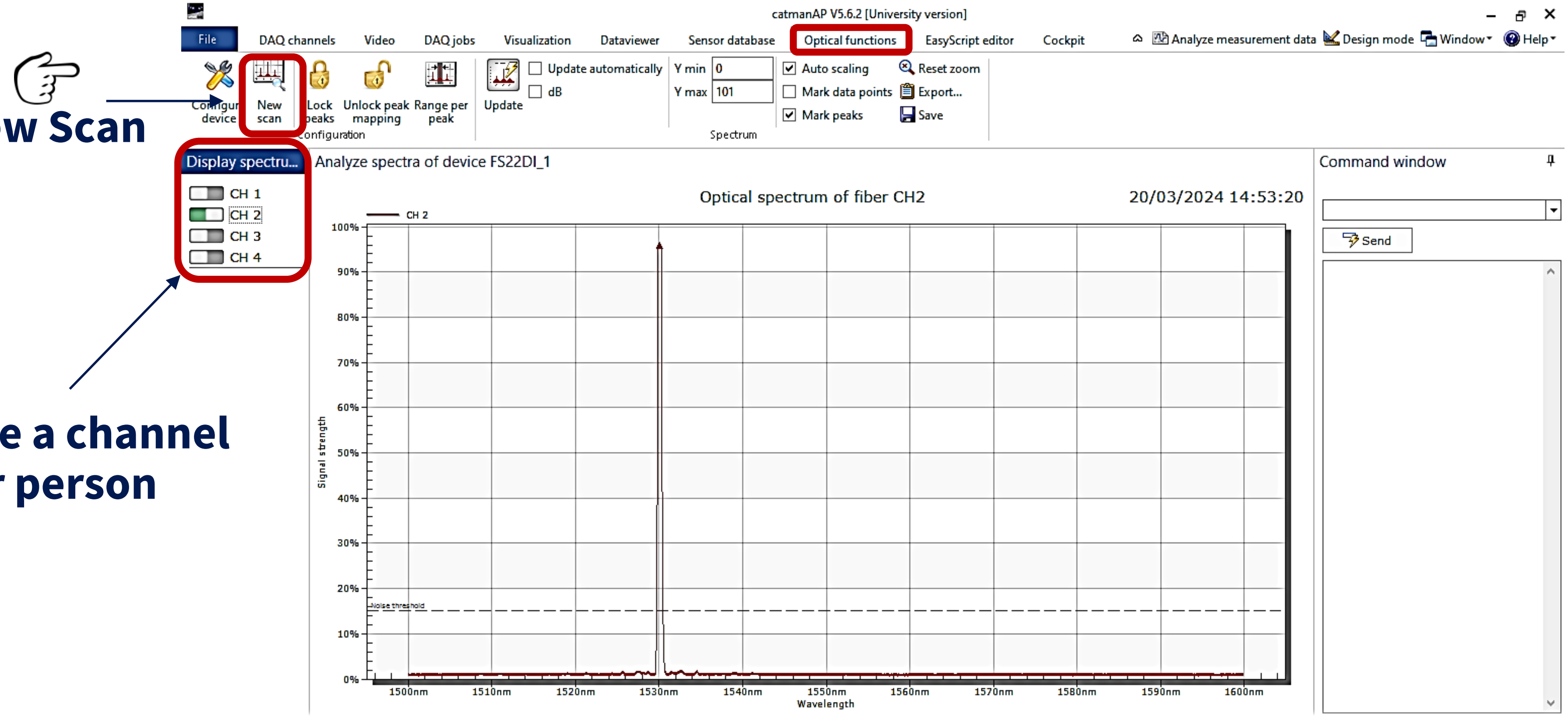
Take a deep breath
and enjoy your measurement now !

Software settings

- *In the software, click on the “Optical Functions” and launch a new scan when all the fibers are connected.*

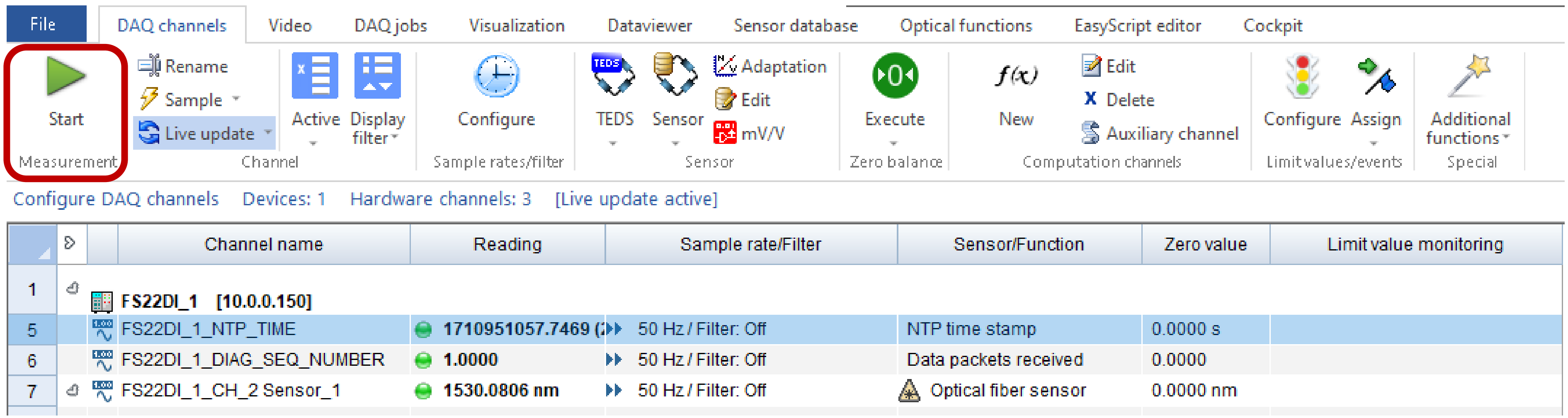
New Scan

Choose a channel per person

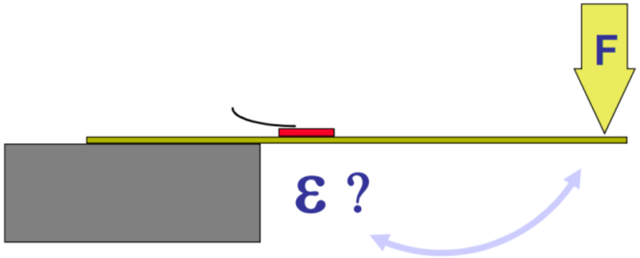


Software settings

- *In the software, back to "DAQ Channels" and start the measurements*



Measurements



1) *Add the mass support and measure the initial wavelength of your grating after the bonding process in free-free conditions :*

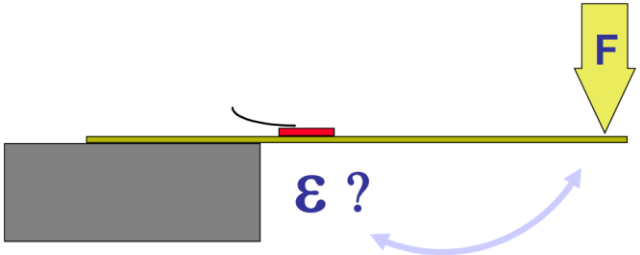
λ_0 =	nm

2) *Please to measure the wavelength of your grating with a different mass centered on the central point of the specimen :*

λ_{50g} = nm	λ_{100g} = nm	λ_{200g} = nm
λ_{300g} = nm	λ_{400g} = nm	λ_{500g} = nm

HINT : Do not hesitate to build an Excel spreadsheet with all your values, calculations and answer to the questions !

Measurements



3) *Assuming no temperature fluctuation during the measurement, please to calculate the strain measured by the Bragg grating with masses applied at the extremity ?*

4) *Calculate the sensitivity of the sensor.*

5) *Please to share your results with your colleagues in your group. Compare your results with the analytical calculations and the FEA simulations.*

6) *Change slightly the supporting conditions of your specimen and repeat the measurement at 200 g, what we should conclude ?*

HINT : Do not hesitate to build an Excel spreadsheet with all your values, calculations and answer to the questions !

Additional questions…

7) *A colleague from the Vacuum group ask me to perform the same measurements at 1.9 K and inside a strong magnetic field (12 T), could you confirm that our measurement system is applicable for a correct measurement ?*

	Applicable	Not Applicable
1.9 K temperature		
12 T Magnetic field		

8) *If this system is not compensated for temperature, could you propose some solutions ? (assuming the request to perform only a bending strain characterization)*

Additional questions…

9) *Please to repeat 5 times the 200g measurement and note the values.*

10) *Please to calculate the average strain value for 200 g mass with the repeatability associated according to ISO5725.*

11) *Please to share your results with your colleagues in your group. From all your measurements and the measurements of your colleagues, please to calculate the reproducibility of the measurement technique according to ISO5725.*

We hope you enjoyed the practical session

Thank you for your attention and work done

CERN

ENGINEERING DEPARTMENT

MECHANICAL & MATERIALS ENGINEERING
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Optical Fiber (Acrylate Coating)

Corning® SMF-28® Ultra 200 Optical Fiber

Product Information

Corning's SMF-28® Ultra 200 optical fiber is a single-mode fiber with a reduced coating diameter that leverages the latest technology of Corning® SMF-28® Ultra optical fiber. SMF-28 Ultra 200 shares the same advanced optical performance as SMF-28 Ultra fiber and is designed for use in applications where space is at a premium. SMF-28 Ultra 200 fiber enables maximized fiber count per cable and minimized cable outer diameter while maintaining superior optical and mechanical performance. It has bend performance that exceeds Recommendation ITU-T G.657.A1, and is compatible and fully compliant with Recommendation ITU-T G.652.D.