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OFDR OPTIC FIBER MEASUREMENTS: PERFORMANCE LIMITATIONS

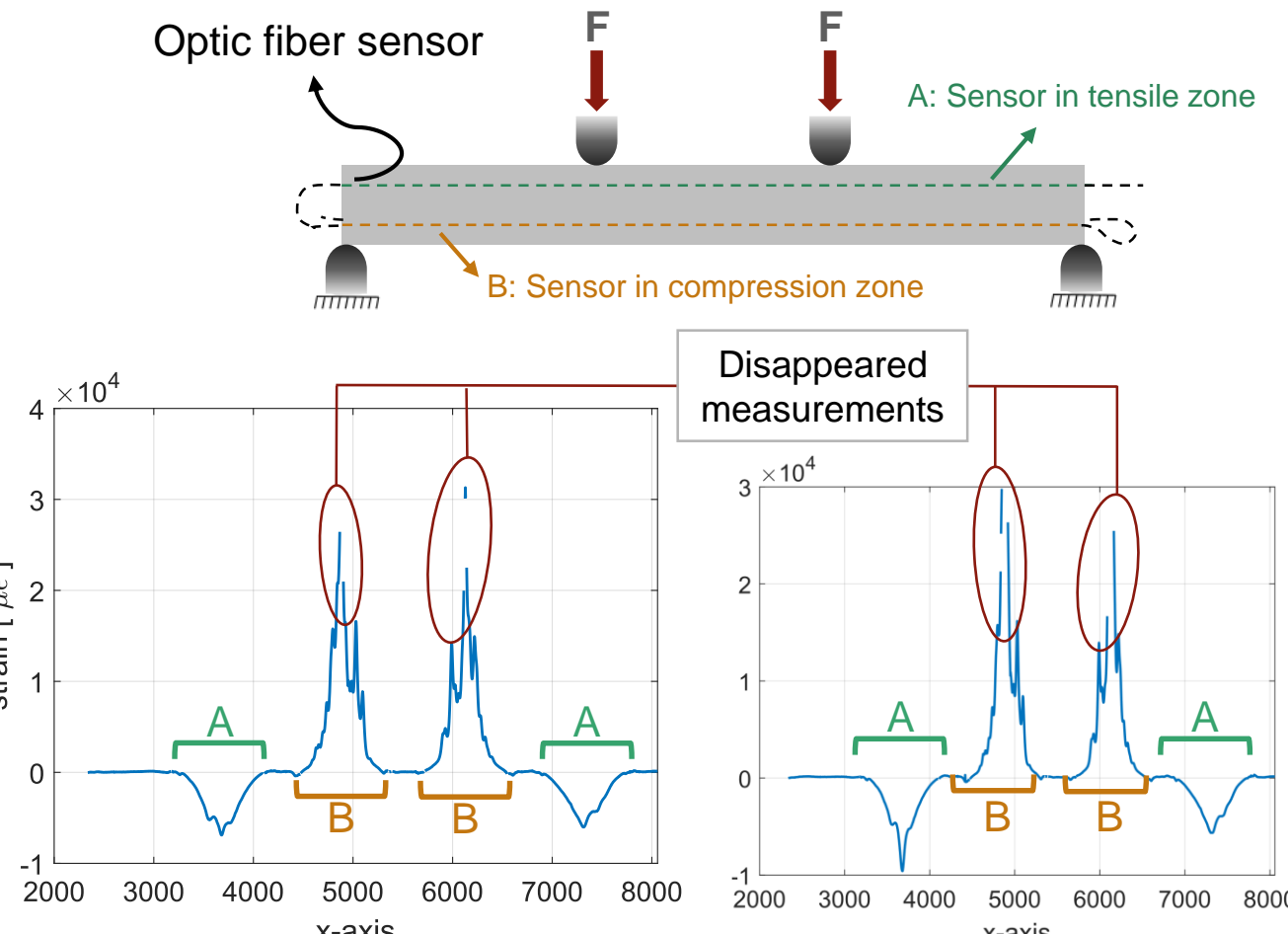
Sahar FARAHBAKSH^a, Martin PONCELET^a, Ludovic CHAMOIN^{a,b}

^a: Université Paris-Saclay, CentraleSupélec, ENS Paris-Saclay, CNRS, LMPS-Laboratoire de Mécanique Paris-Saclay, 91190 Gif-sur-Yvette, France

^b: Institut Universitaire de France (IUF), 1 rue Descartes, 75005 Paris, France

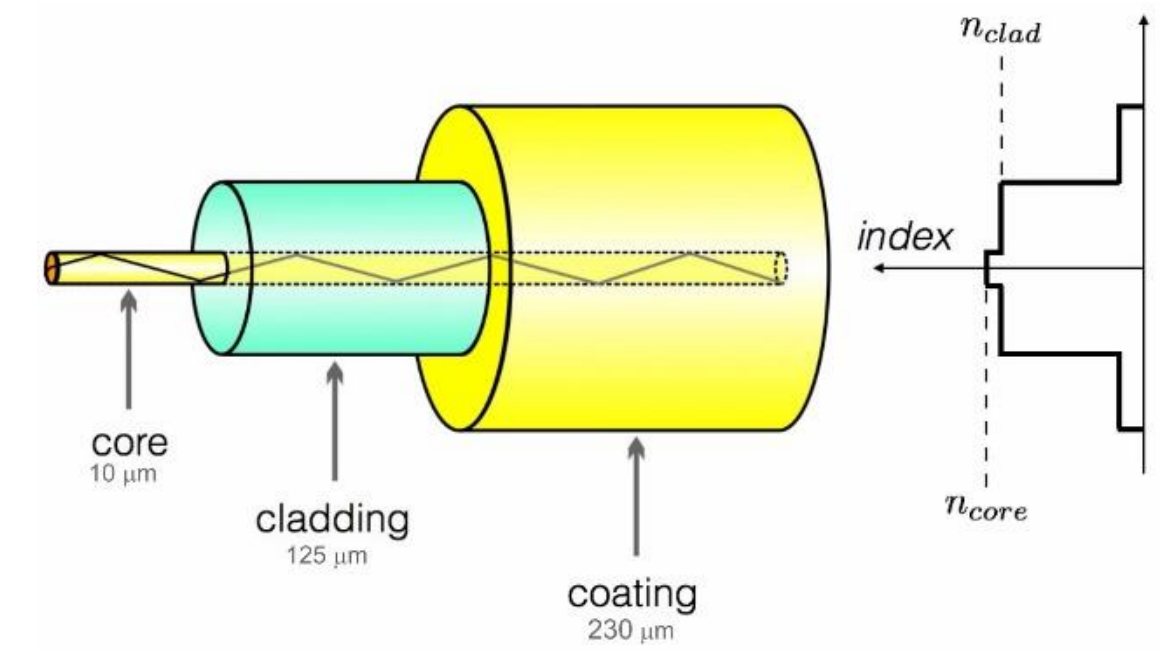
Context

As a part of the PhD research project, an OFDR Rayleigh-based optic fiber sensor is embedded as shown in a beam sample, passing through it 4 times to provide strain measurements along the axis of the fiber during a quasi-static 4-point bending test. Throughout the test, strain data in certain zones - generally where higher strains occur - disappeared and reappeared, without fiber breakage. This phenomenon happened both in loading and unloading phases, and could last minutes.

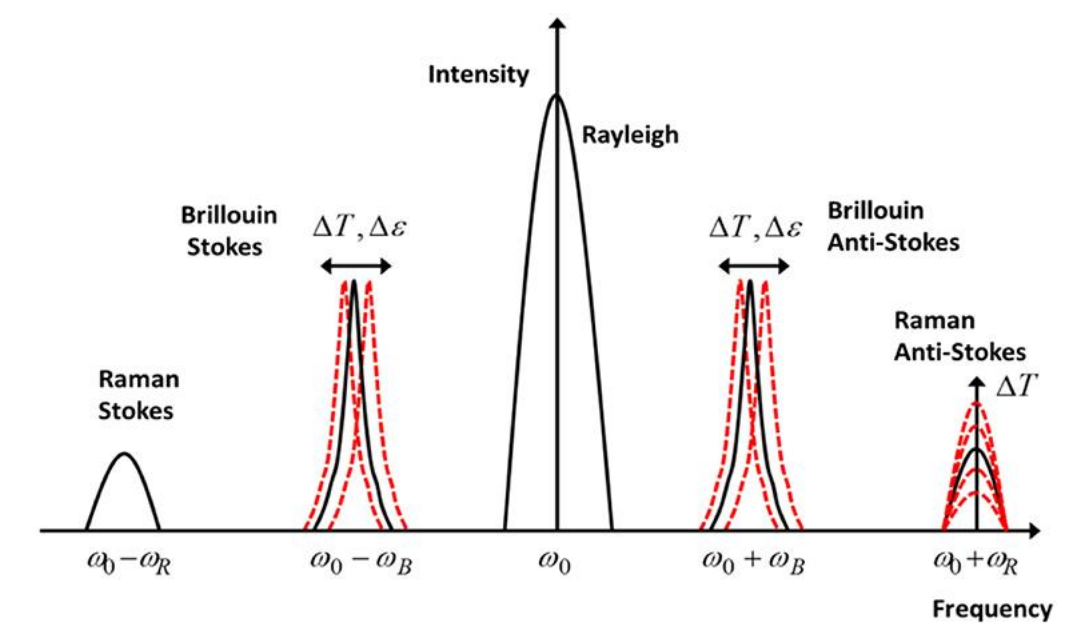


How optic fiber sensors work?

- Made of three main parts: Core, cladding and coating
- A small difference in the refractive index of core and cladding, leading to total internal reflection
- Three main scattering phenomena in optic fiber sensors: Raman, Brillouin and Rayleigh



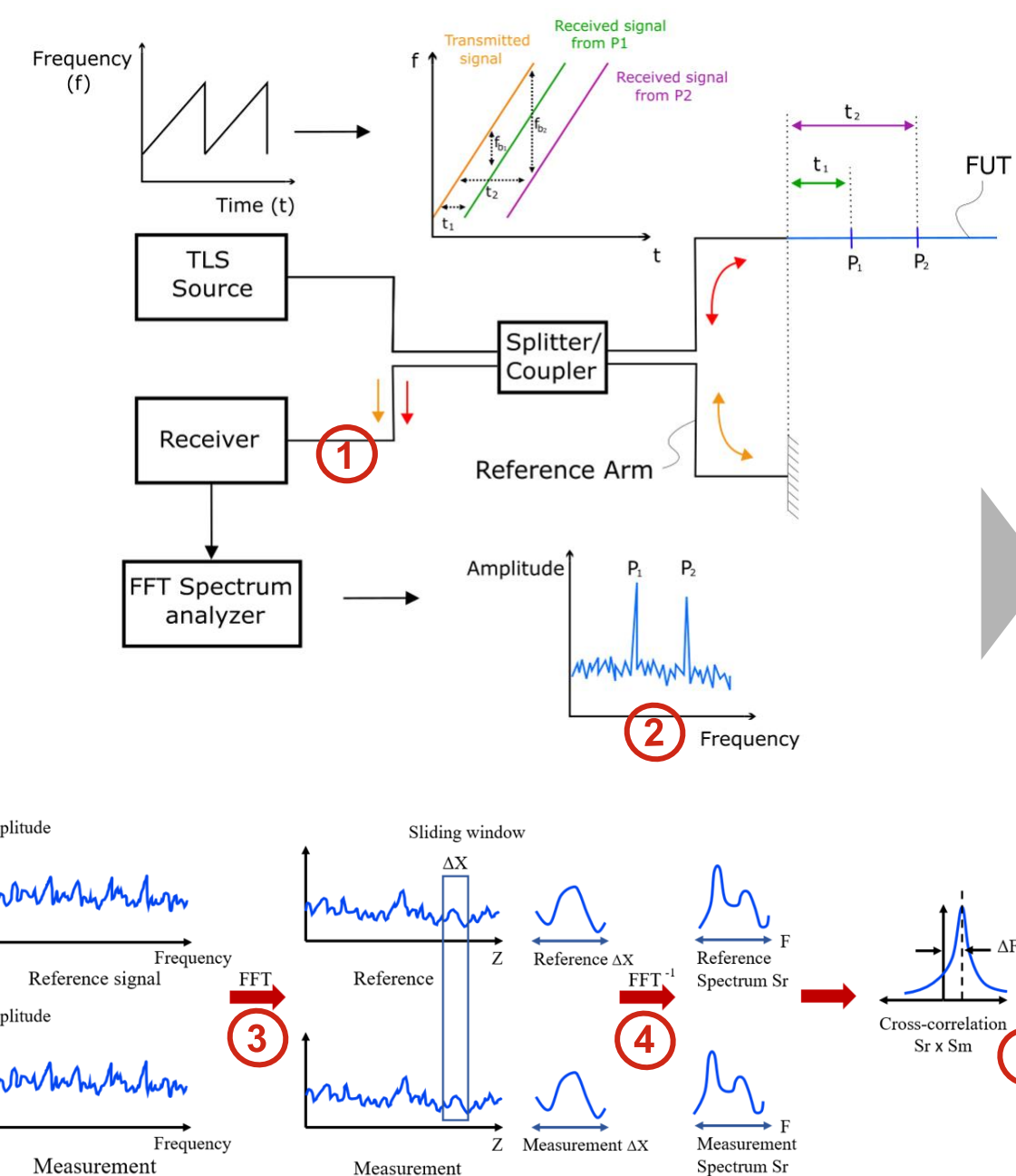
Type	Frequency change	Remark	Advantage
Raman	Yes	Only temperature	Up to 60 km
Brillouin	Slightly	Complex detection	Accurate and stable
Rayleigh	No	Light interference with core inhomogeneities	Constant frequency



OFDR technology

A Rayleigh-based method that uses interferometry and a frequency-modulated optical wave:

- Coupled backscattered light from 2 arms: beat frequency revealed by FFT
- Initial state gives Rayleigh backscattering signature (RBS) of fiber
- FFT on RBS and strained fiber: signals in spatial domain
- Inverse FFT applied on a sliding window on both signals
- Cross-correlation in each window: frequency shifts
- Frequency shifts linearly related to temperature and strain changes in fiber



Hypothesis

Why are the measurements disappearing in certain zones?

- Maximum strain threshold has passed
- Local pressure on the optic fiber causing local loss of data
- Strong local strain gradient causing local data loss

Protocol

A tensile test was designed on a notched sample resulting in a variable gradient of strain along the fiber axis. The material, shape and other details of this sample had to be chosen based on different criteria.

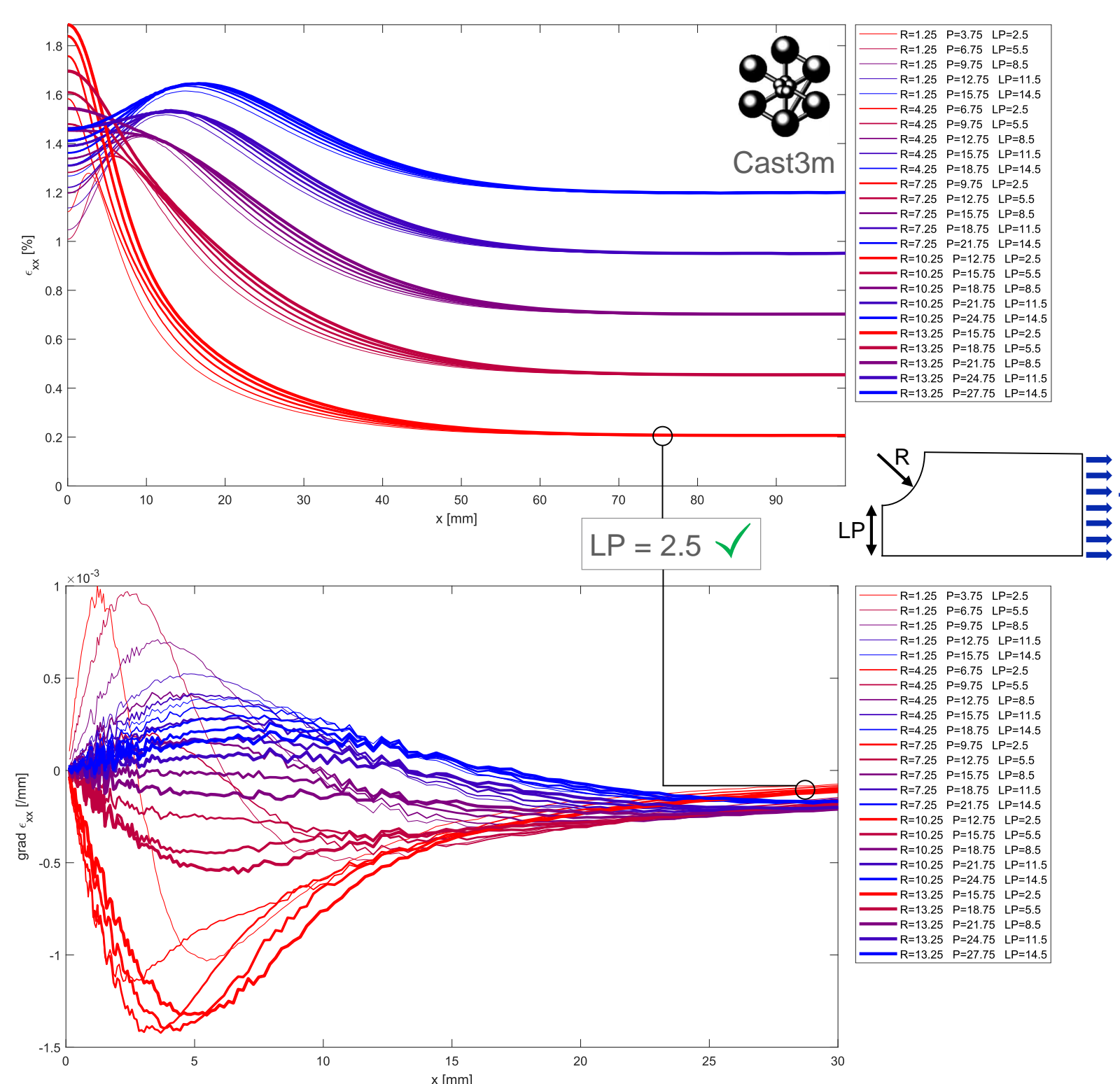
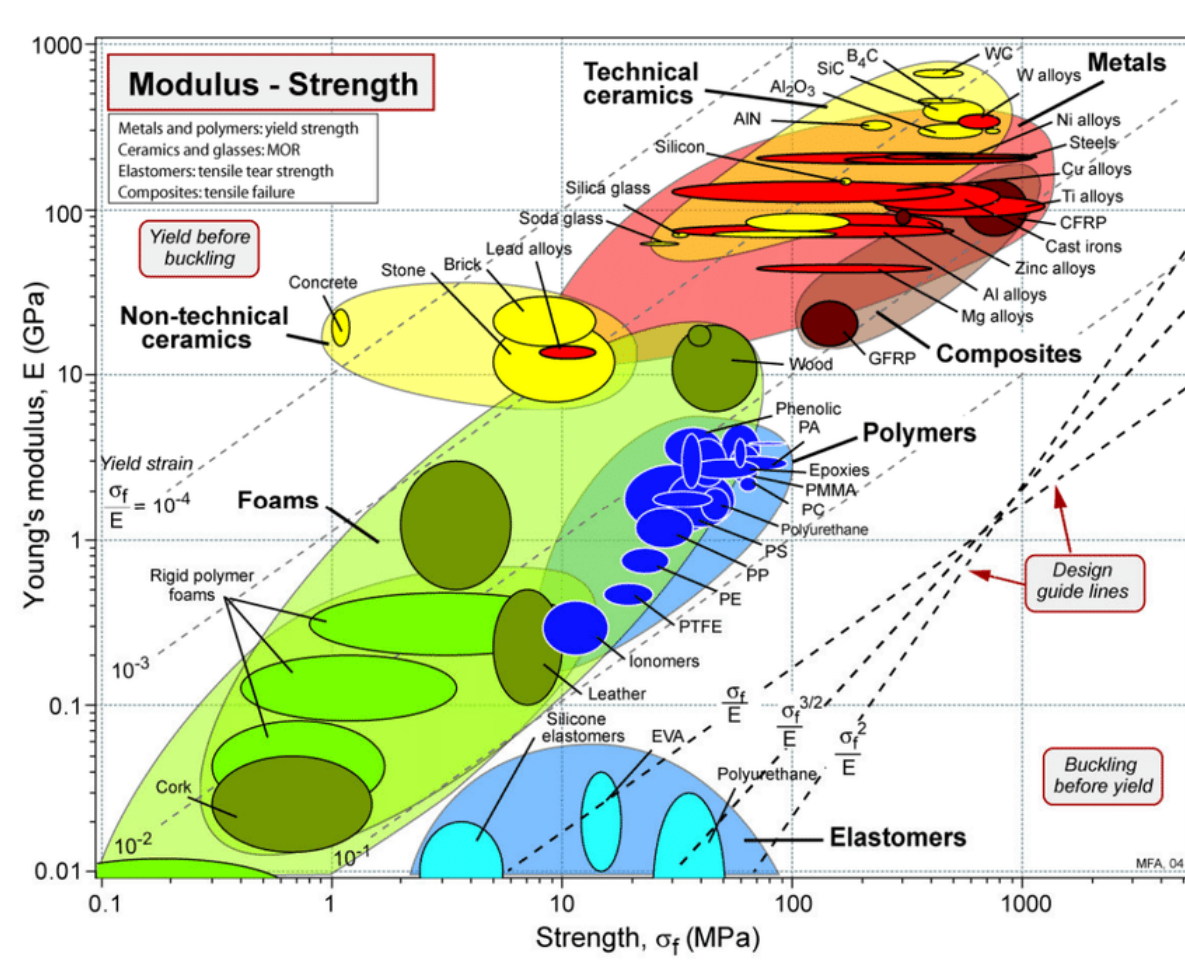
Shape

A parametric study on the influence of the notch shape on the strain and the strain gradient is done.

Material

Using the Ashby chart, the material was chosen based on the maximum elastic strain that is limited by the optic fiber sensor strain measurement threshold (1.5% strain).

Other criterion include the material being machinable, homogeneous and compatible with the adhesive used for gluing the optic fiber sensor on the sample. Finally, PMMA was chosen as the sample material.

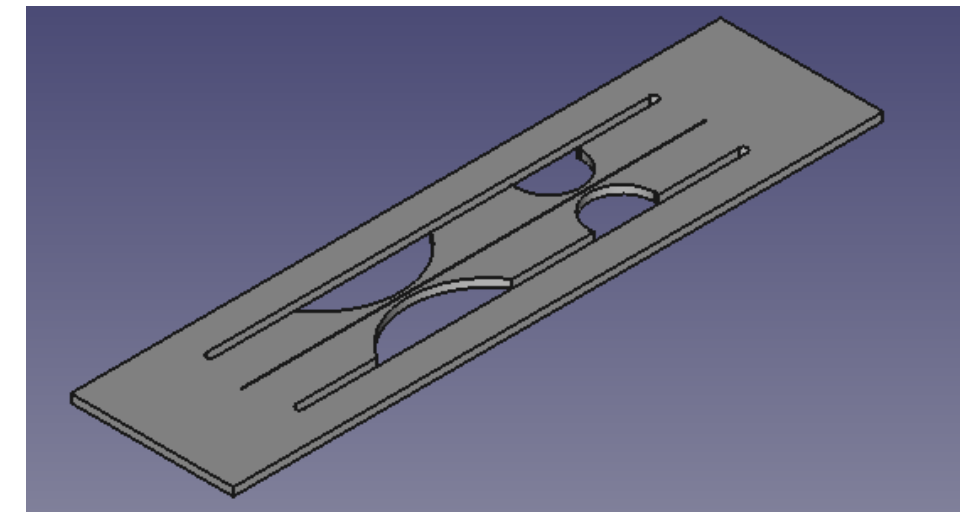


In a second step, the optimal notch shape (radius and ligament) is chosen:

- The idea is to have two notches with different dimensions, and ensure that their contributions don't superimpose.
- Notches must be small enough to induce high strain gradient, but large enough to enable several measurement point in the region of interest even with the largest gage pitch. The gage pitch of the employed optic fiber sensor can vary between 0.65mm, 1.3mm, 2.6 mm, 5.2 mm or 10.4 mm.

The optic fiber is located in a groove on each side of the sample, in reversed orientation. This might help to understand if a region of high strain or strain gradient has an influence downstream or upstream.

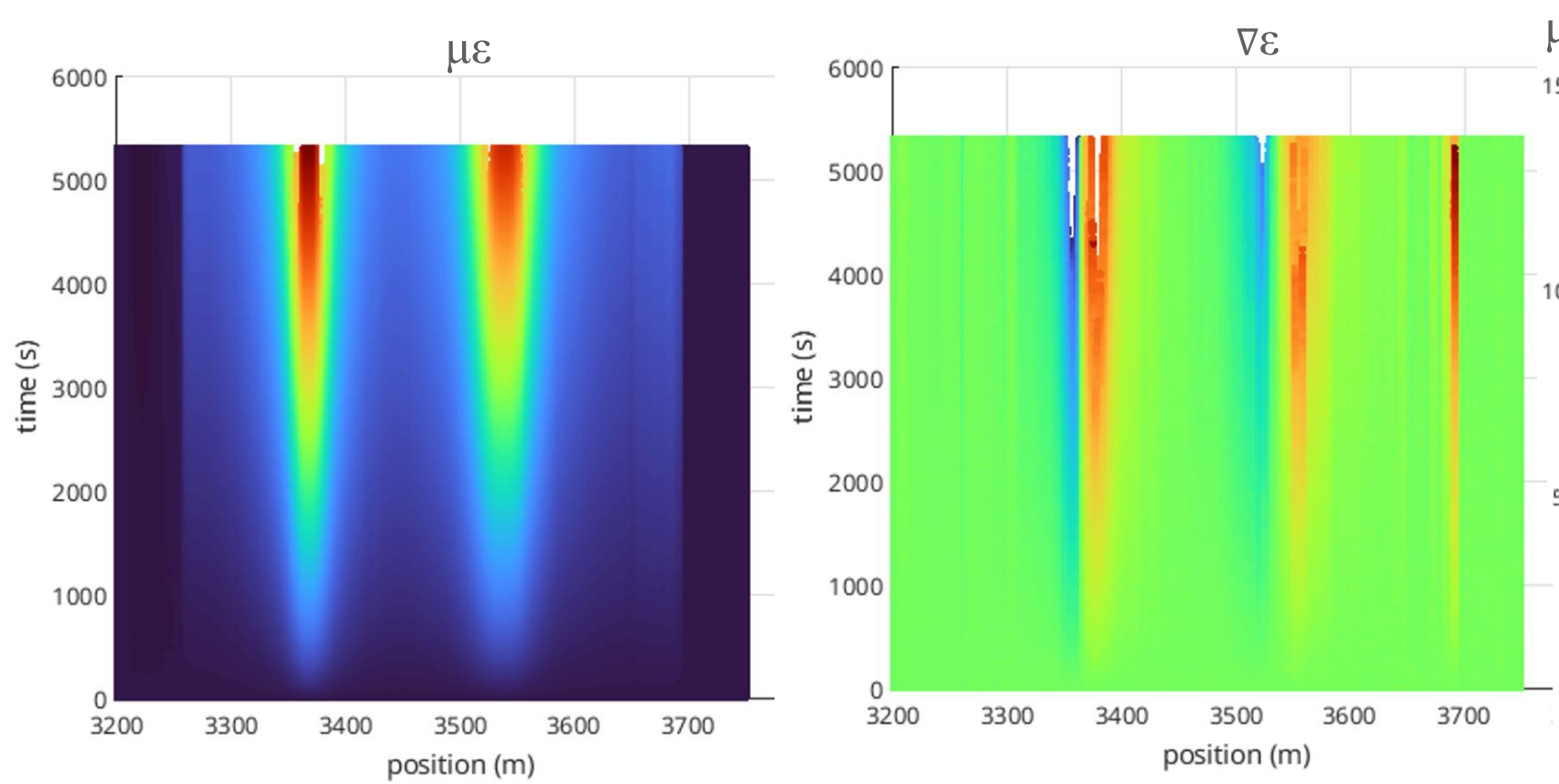
The additional side parts are added to the sample in order to ensure that the sample would not twist or bend prior and during the tensile test.



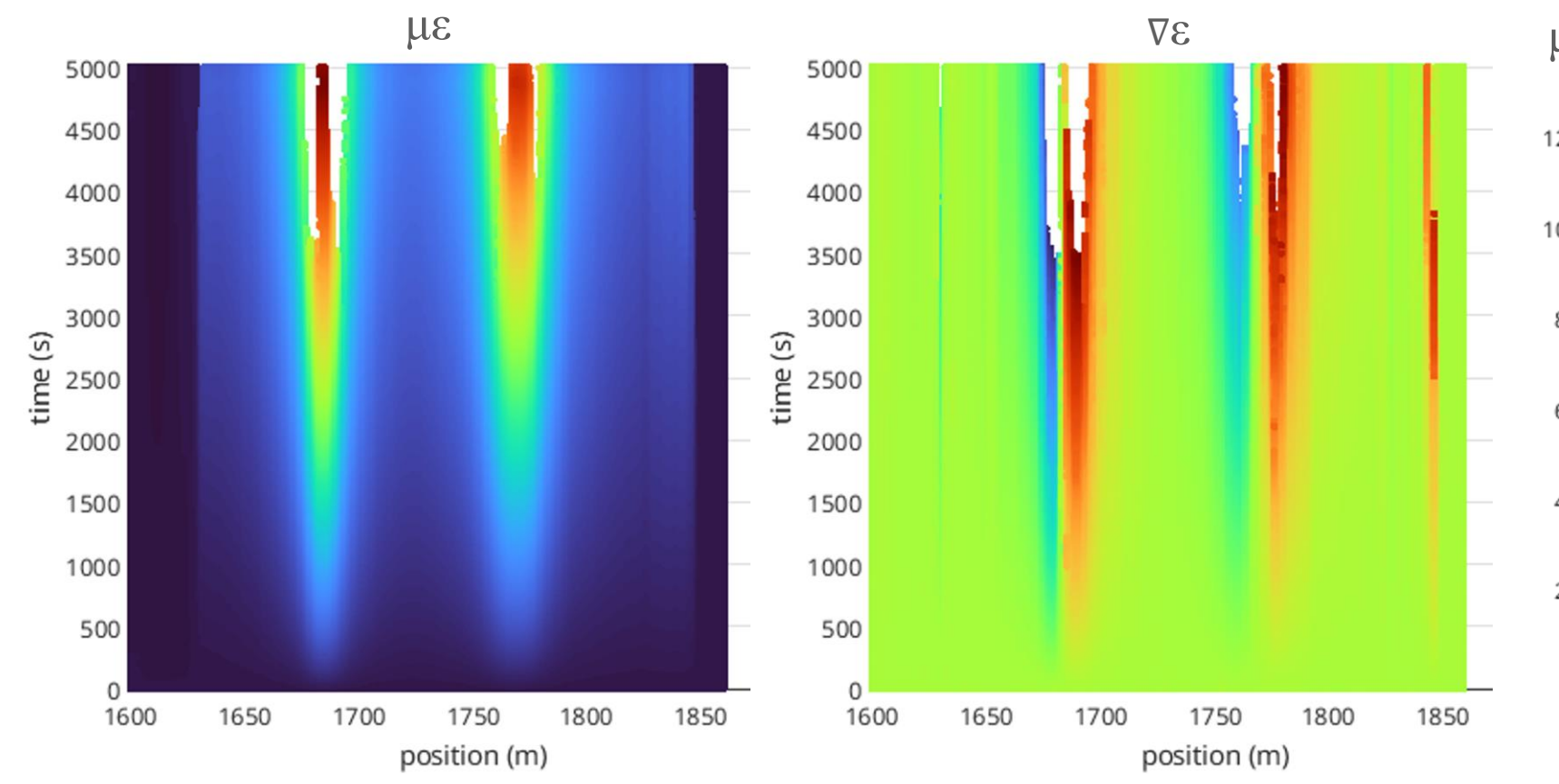
Results

The sample has undergone several tensile tests, all within the elastic limit of the sample and with the exact same conditions. The only difference between these tests was the gage pitch of the optic fiber sensor. The strain measurements of three of these tests as well as the corresponding strain gradients are presented.

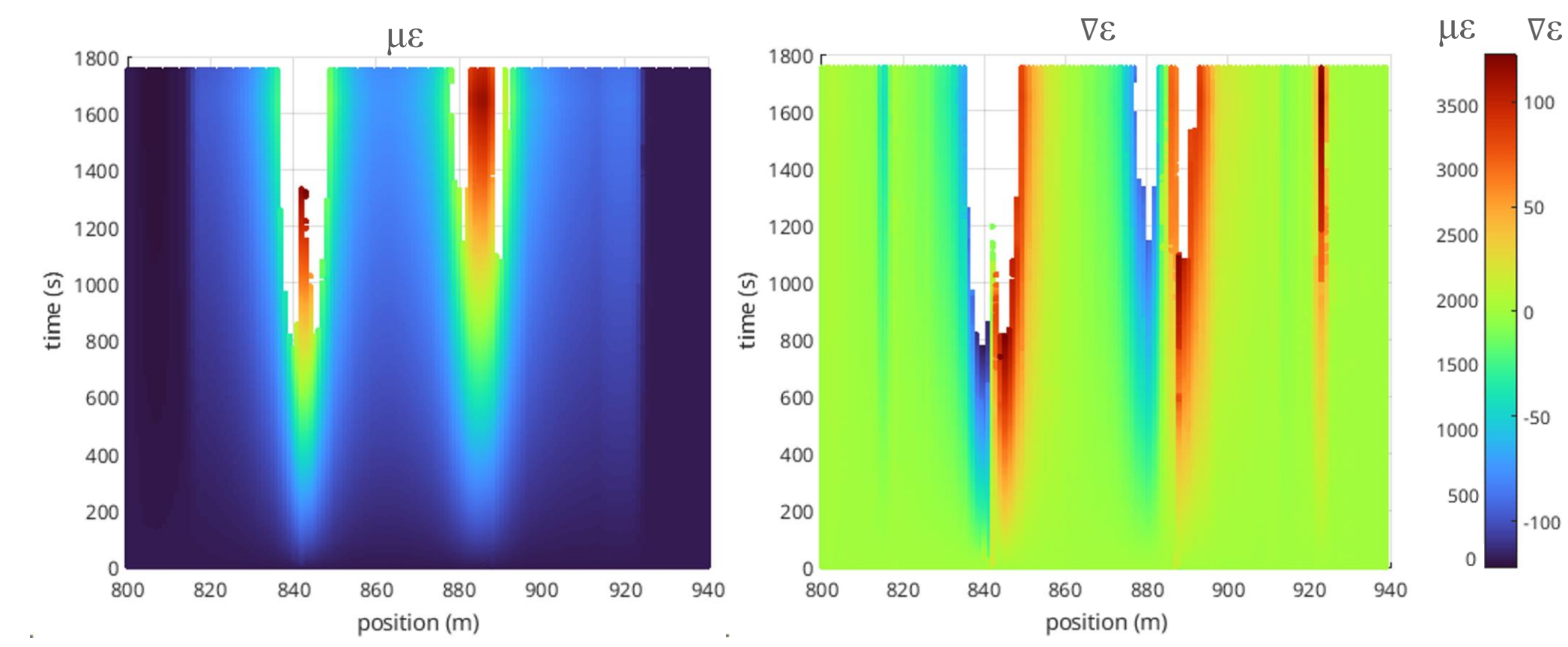
Gage pitch: 0.65 mm



Gage pitch: 1.3 mm

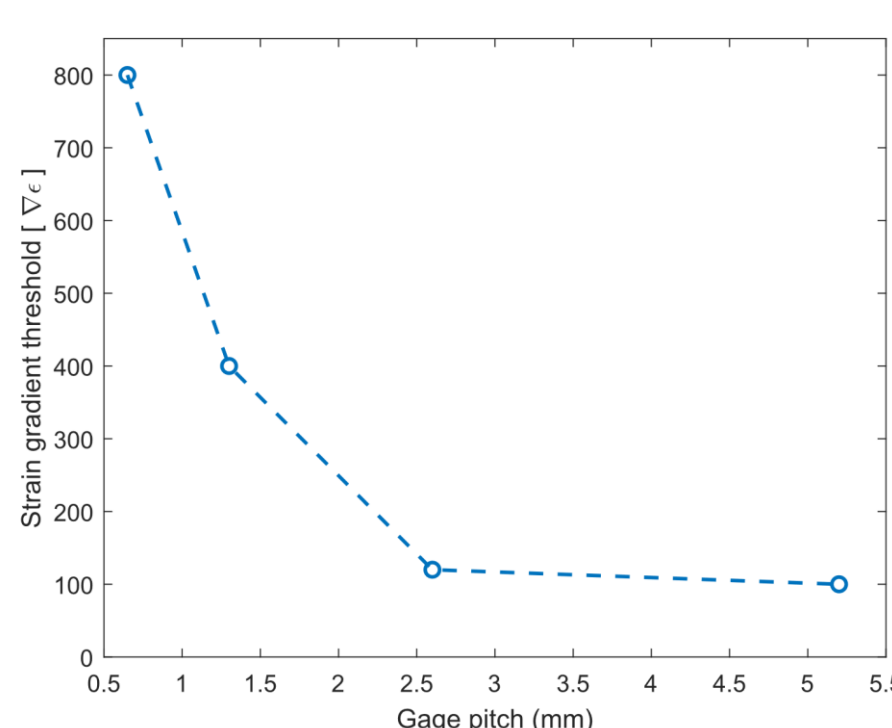


Gage pitch: 2.6 mm



Conclusion

- Local data loss in high strain gradient areas confirmed
- Maximum strain, sometimes higher than 1.5% (observed during previous tests, such as the aforementioned 4-point bending test) does not necessarily lead to data loss or fiber breakage
- Further research could elaborate on the effect of high strain gradient in the presence of other possible data loss sources such as high strain values, local pressure on sensor, considerable axis curve, etc.



References

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