# A thin solid hydrogen target for ion acceleration at high repetition rate


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GRENOBLE **FRANCE**

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- Acceleration schemes
- Target development
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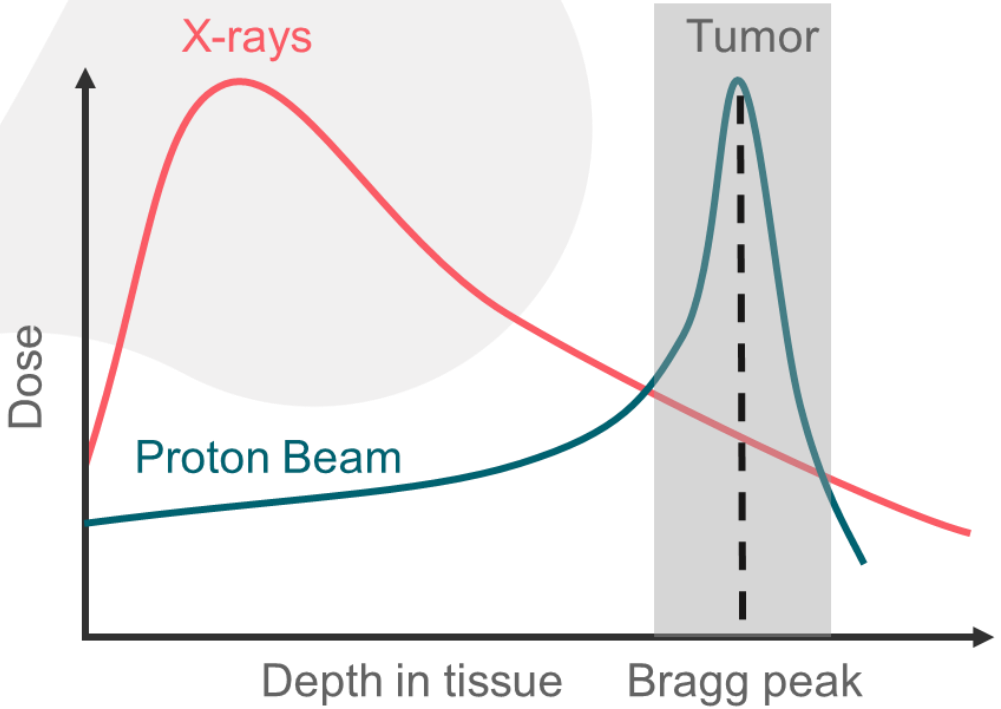
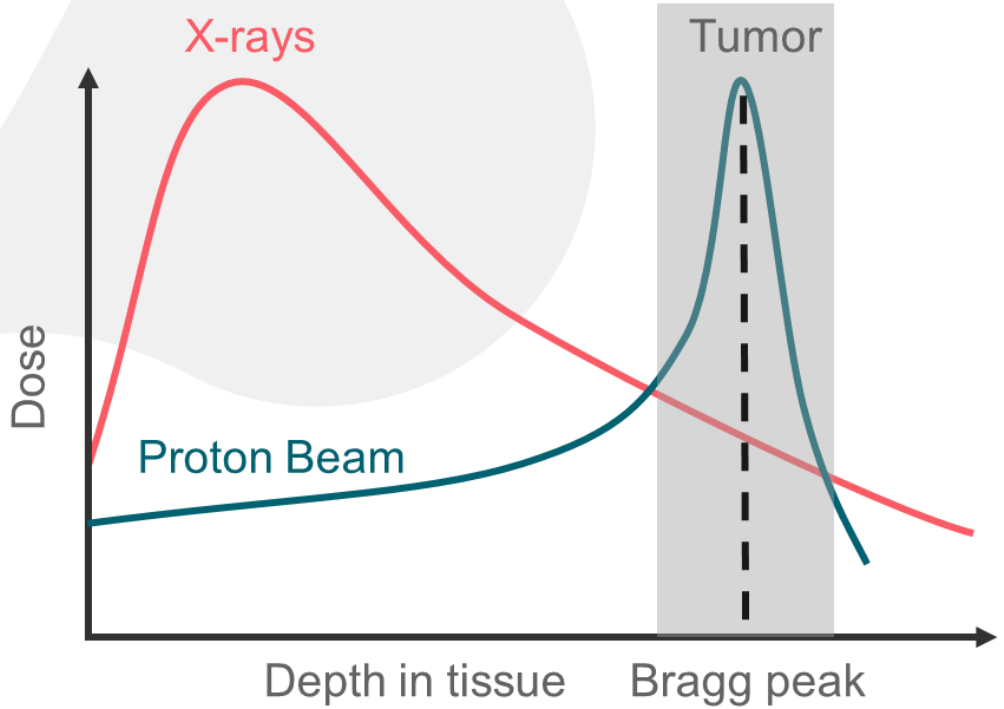
# Context

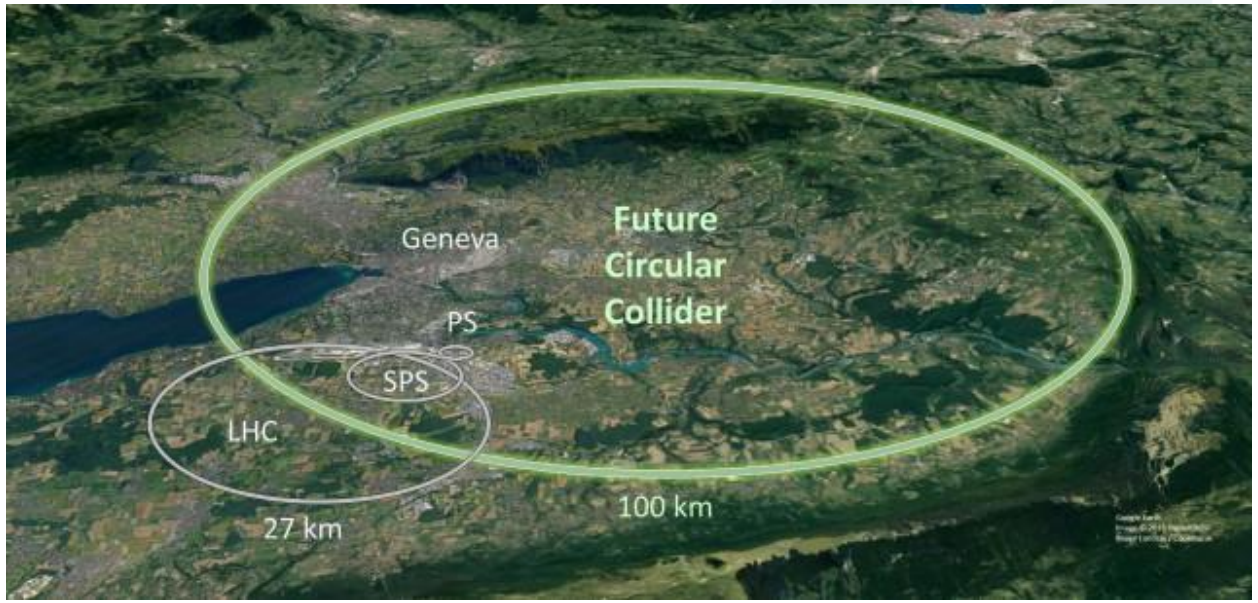



Difference between X-rays and a proton beam for medical use

# Context




Difference between X-rays and a proton beam for medical use



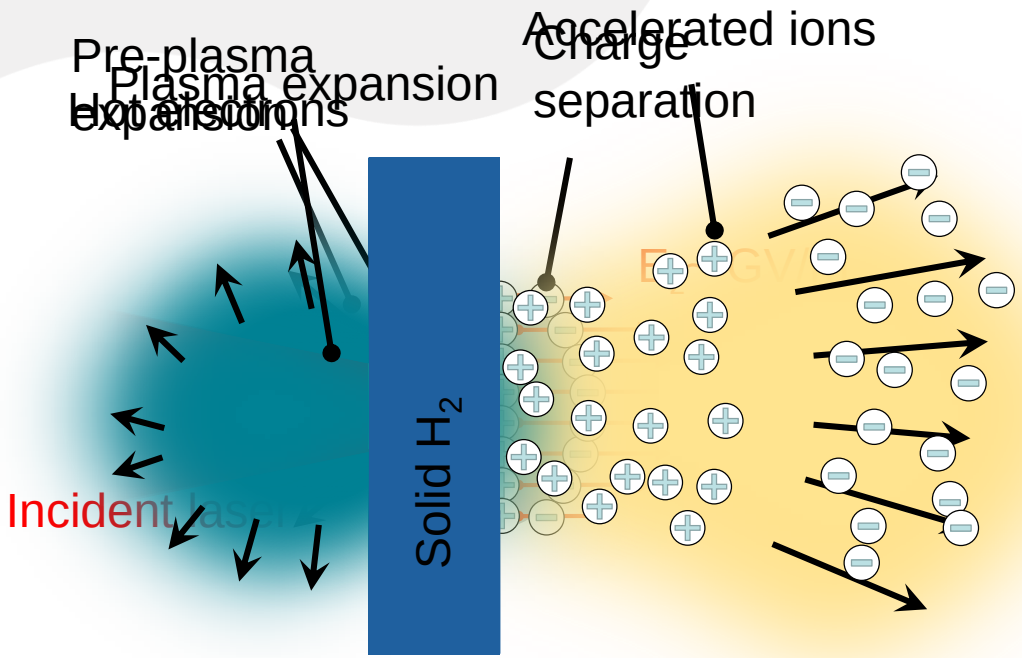

Source: Cern

Large facility using radiofrequency cavities to accelerate particles

**RF accelerators ~100 MV/m | Laser plasma ~100 GV/m**
**→ Compact accelerators with laser plasma acceleration**

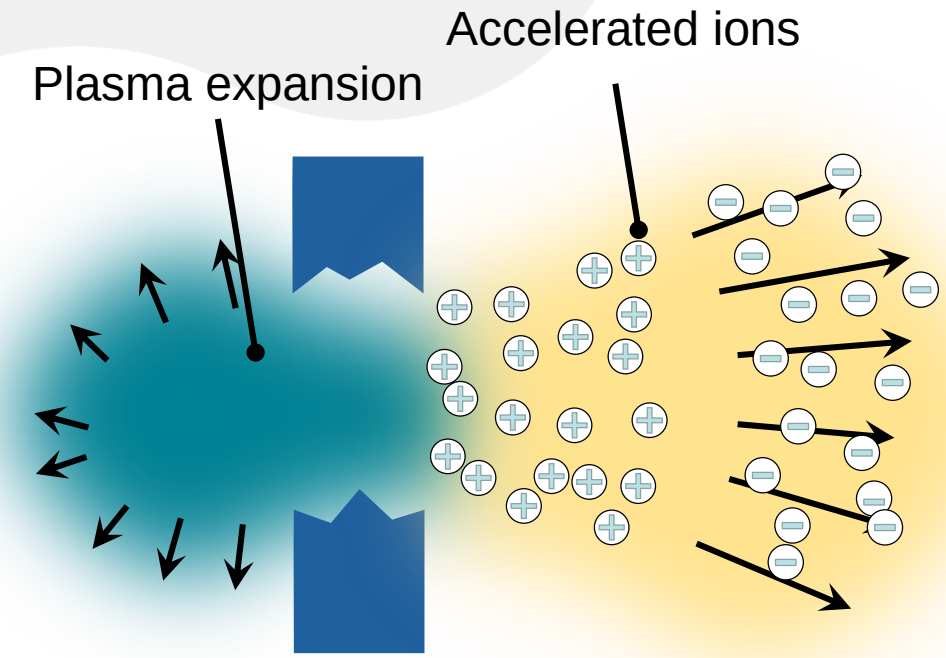
# Acceleration schemes

## Target Normal Sheath Acceleration

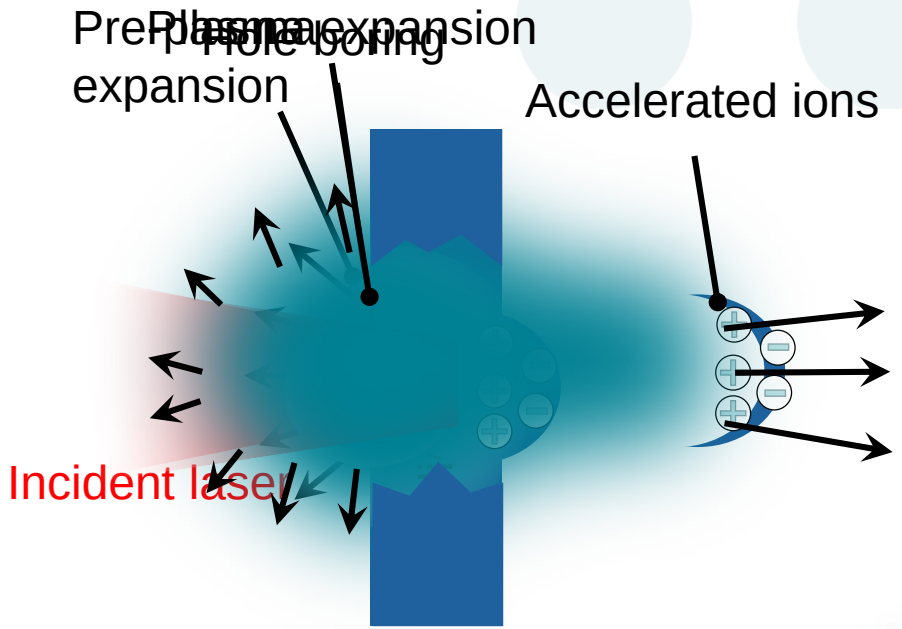


# Acceleration schemes

## Target Normal Sheath Acceleration

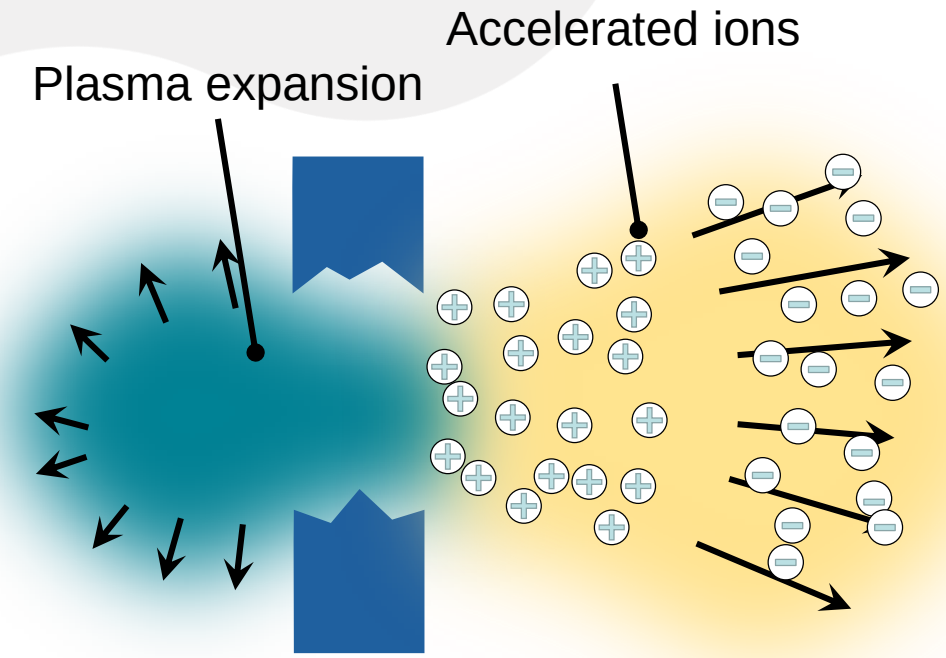



## Radiative Pressure Acceleration

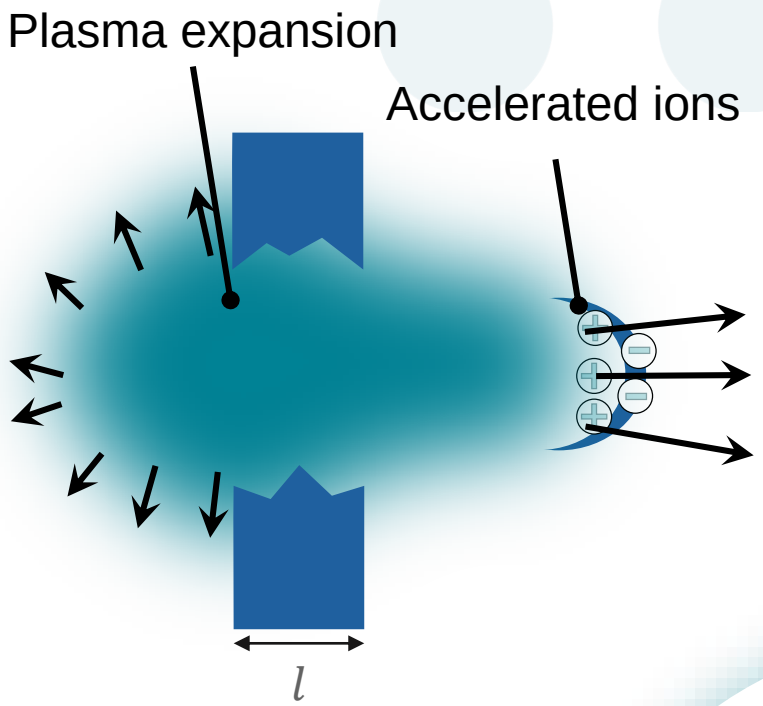


# Acceleration schemes

## Target Normal Sheath Acceleration




## Radiative Pressure Acceleration




$$E \propto \frac{I}{\rho l}$$

$I \rightarrow$ Laser intensity

$\rho l \rightarrow$ Area density

# Laser innovation

- **New PW laser facility at high repetition rate**

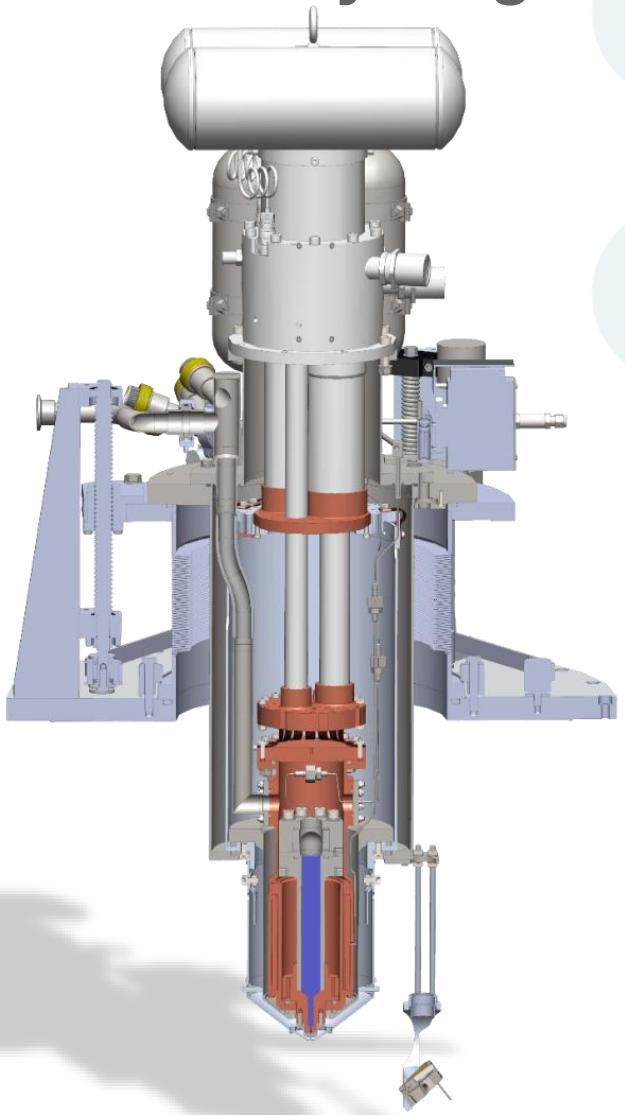
  **→ Apollon, ELI**

- **Ideal characteristics of a target to optimize the experiment on the new laser facility:**

  - High repetition
  - Low thickness

# ELISE

- Experiment on Laser Interaction with Solid hydrogEn



## ELISE I

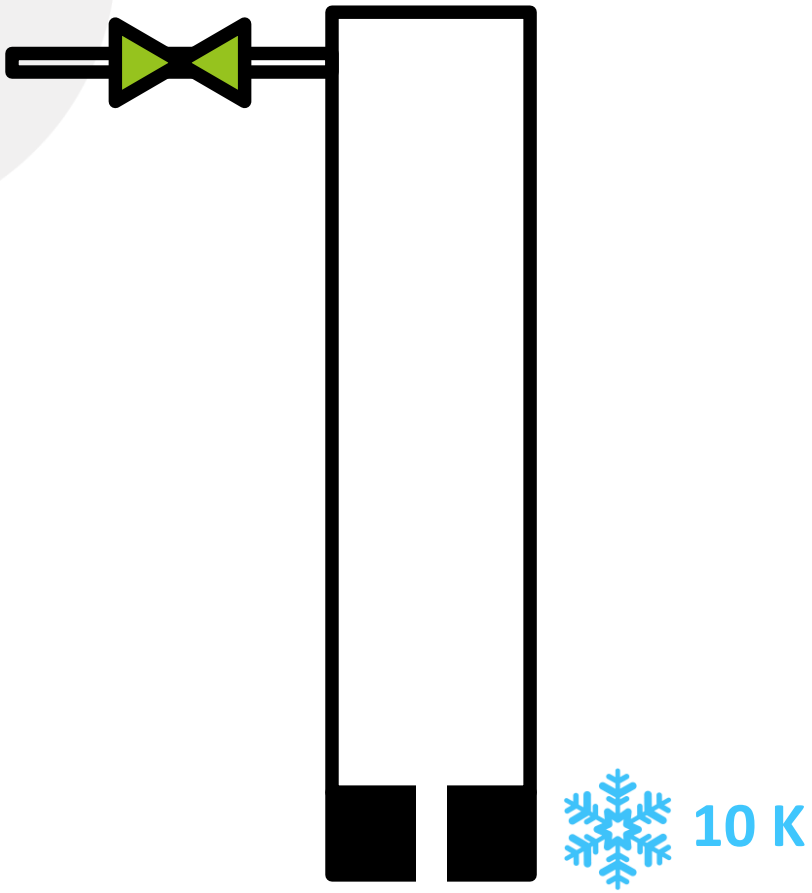
- Uses liquid helium

## ELISE II

- Uses a pulse tube cooler

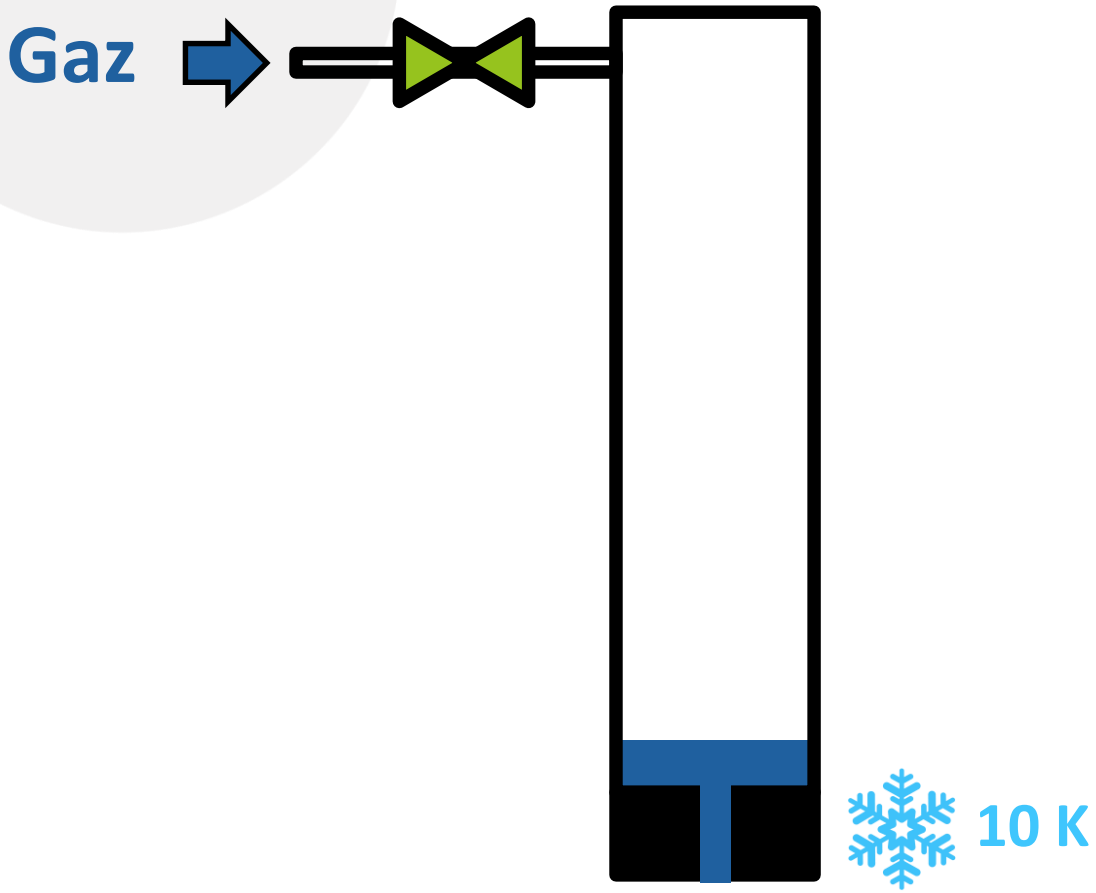
# Target productions

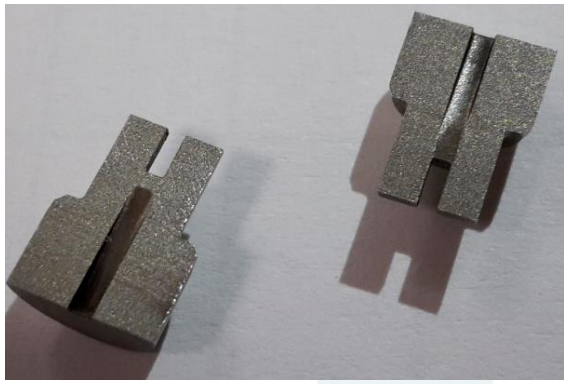
**Empty cell**

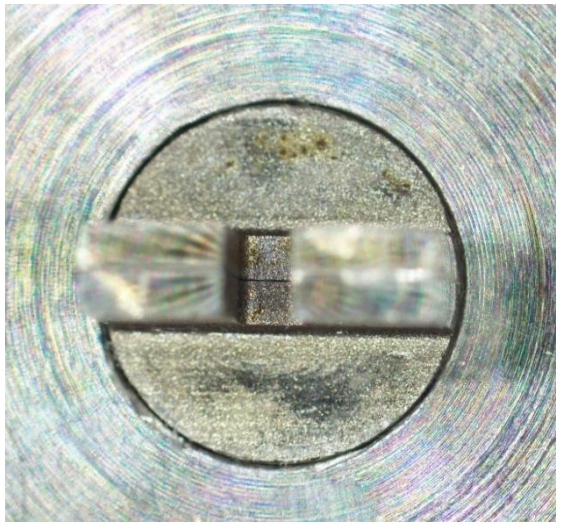


# Target productions

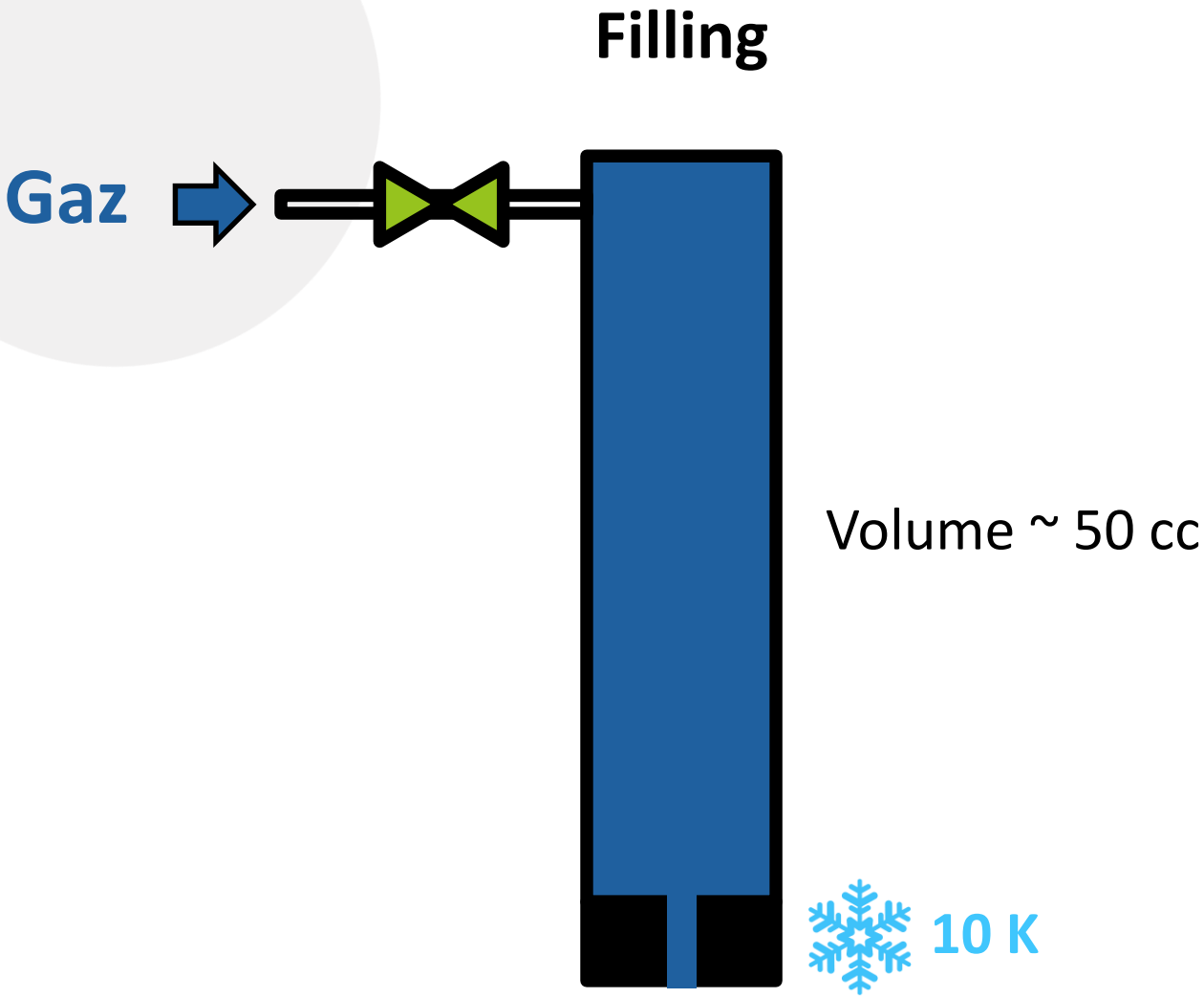
## Plugging the extrusion nozzle



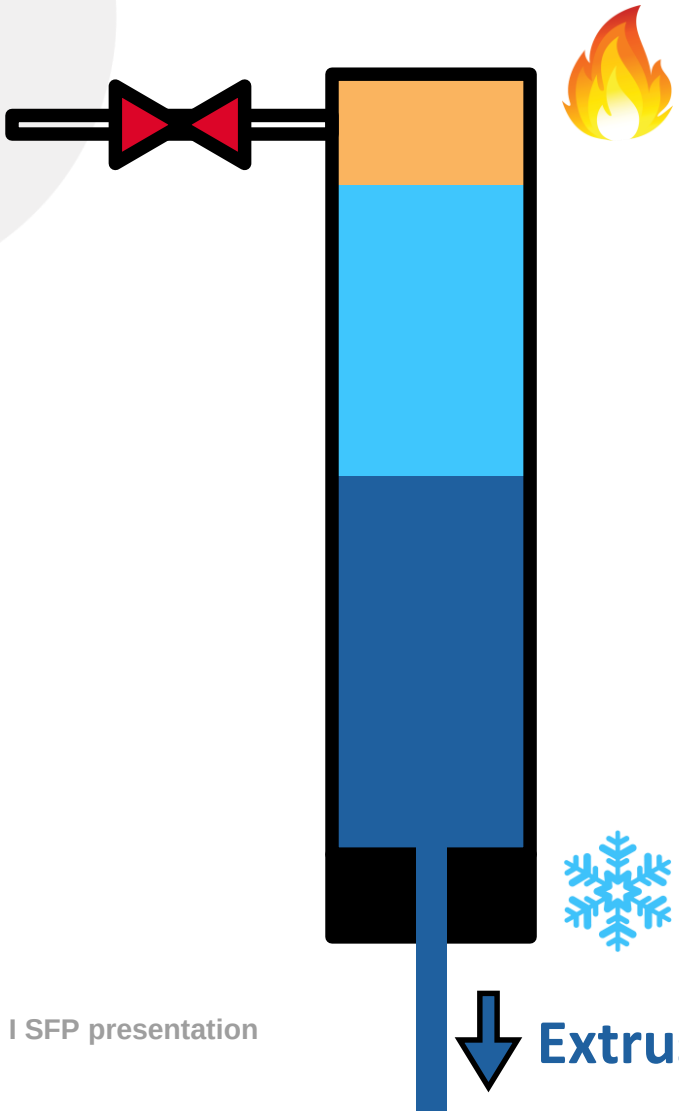


# Target productions



# Target productions

## Heating and Extrusion

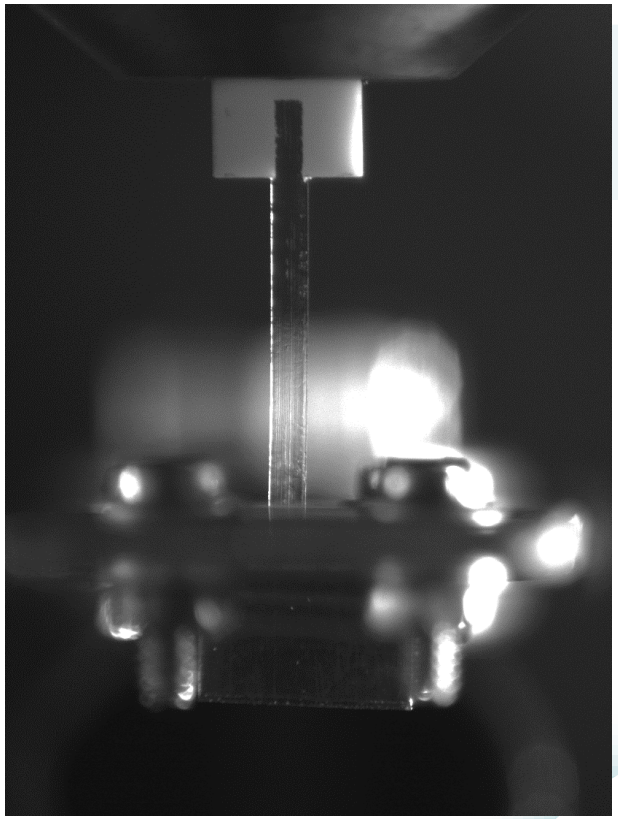


~ 30 K

100 – 200 bar

10 K

Extrusion (mm/s – cm/s)

# ELISE

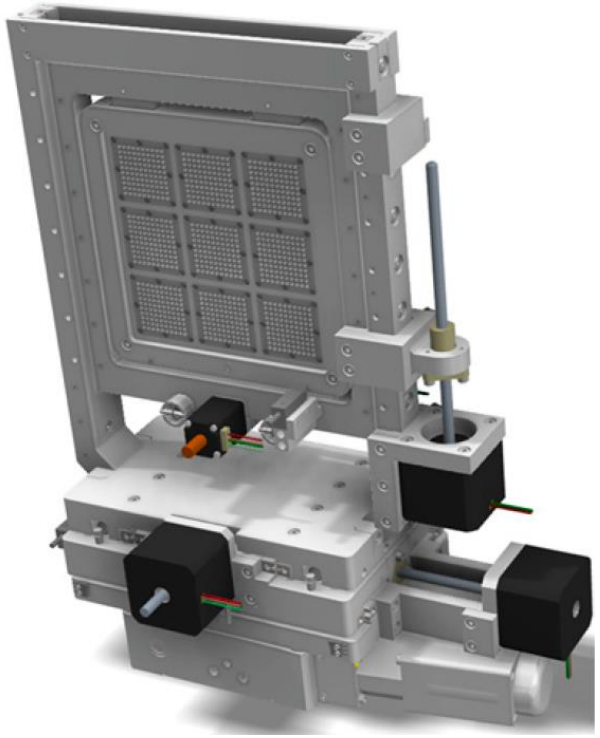
## Advantage compare to other target :

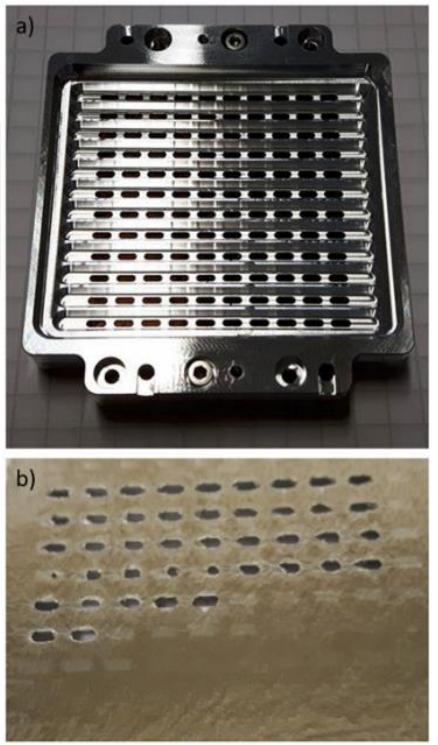
- High repetition rate
- No debris that damages optics
- High purity and a source of pure protons
- Other gases can be used ($D_2$, $CH_4$, Ar … )

## Limitation :

- Thickness ( 50 – 100 µm )

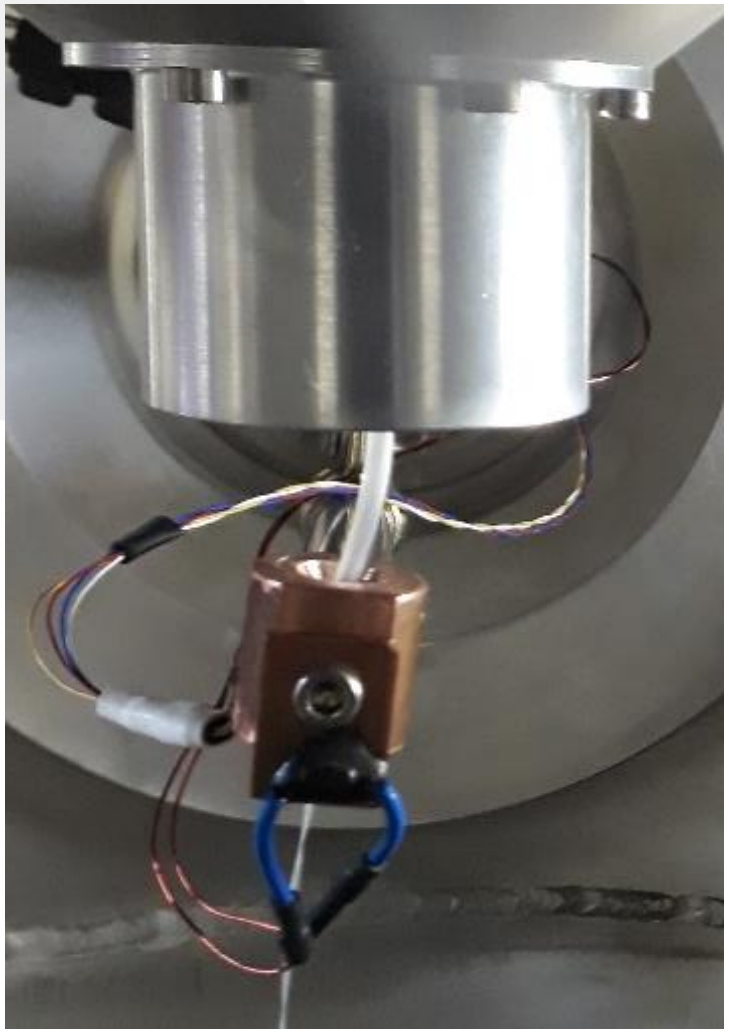
*I. Prencipe et al., High Power Laser Science and Engineering **5** (2017)*

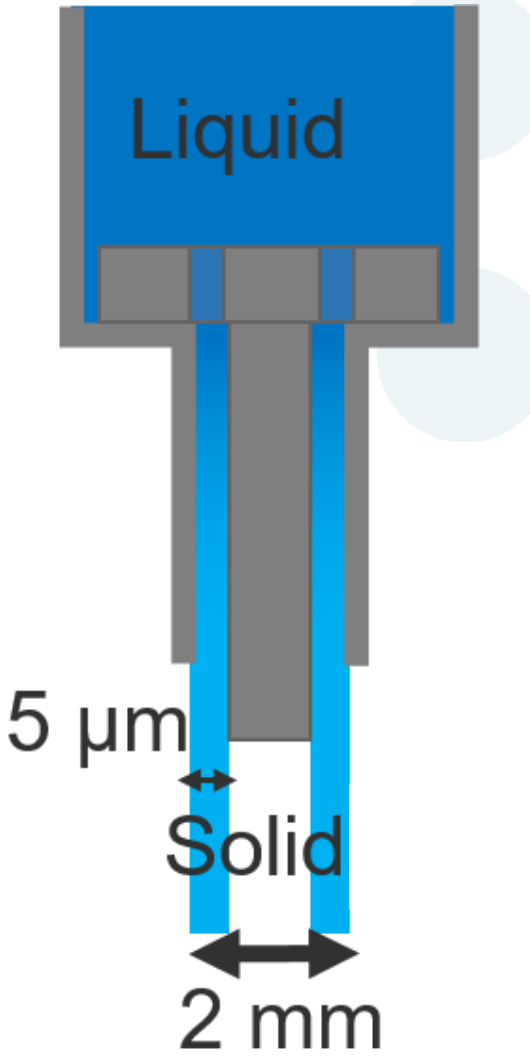





*D. Margarone et al., Quantum Beam Sci. **2** (2018)*

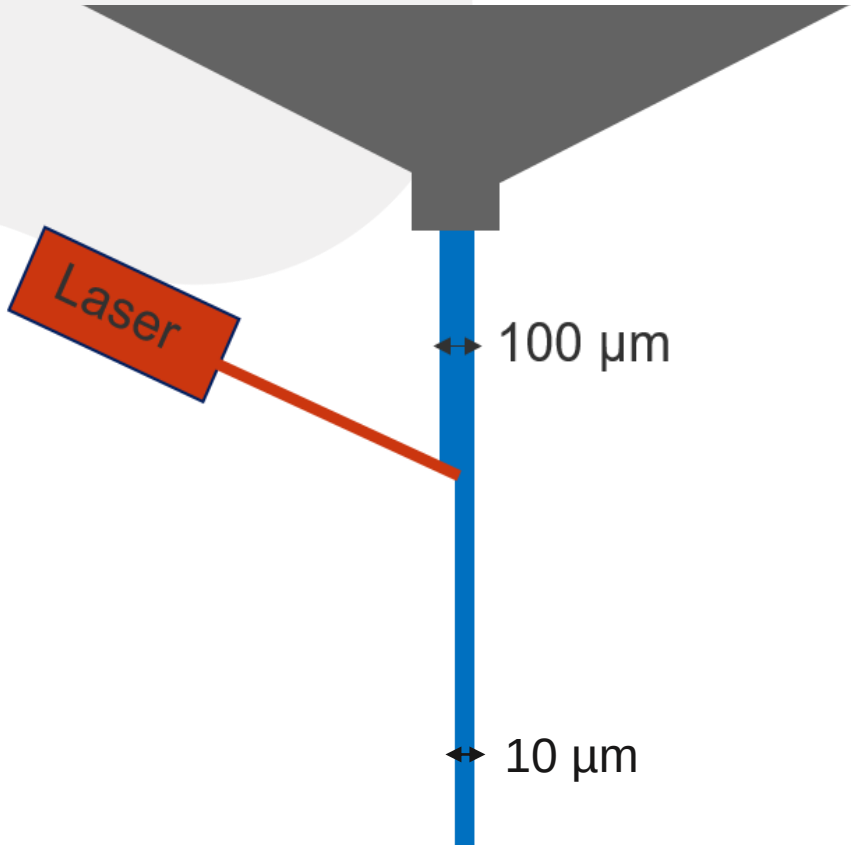
# Methane target

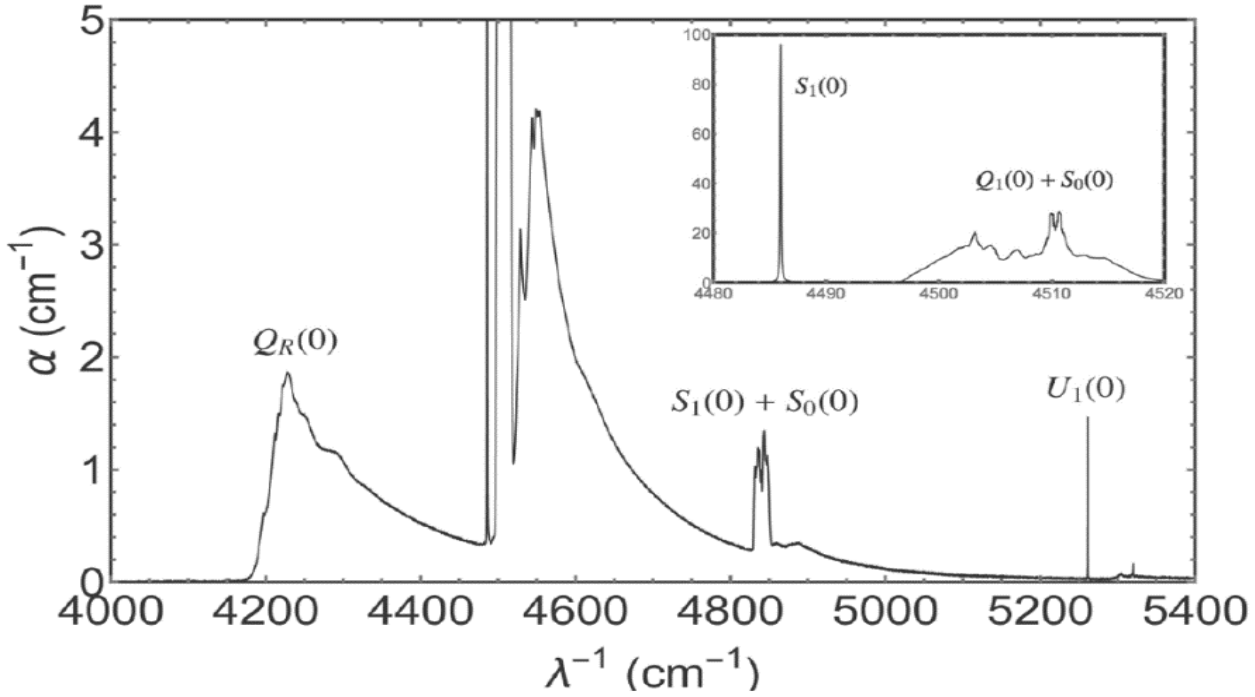





Solid methane target  with an adiabatic expansion process

# Laser ablation

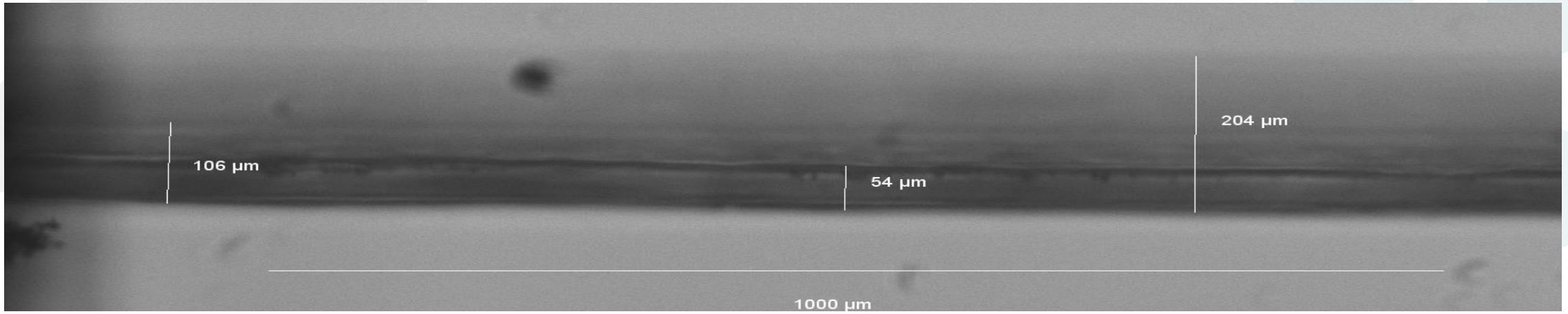



Absorption spectrum of solid hydrogen in infrared range. Peak of absorption at 2.23 µm

Source :S.C.Kettwich et al., 2015, Royal astronomical society, 1032-1041

# Thickness measurement

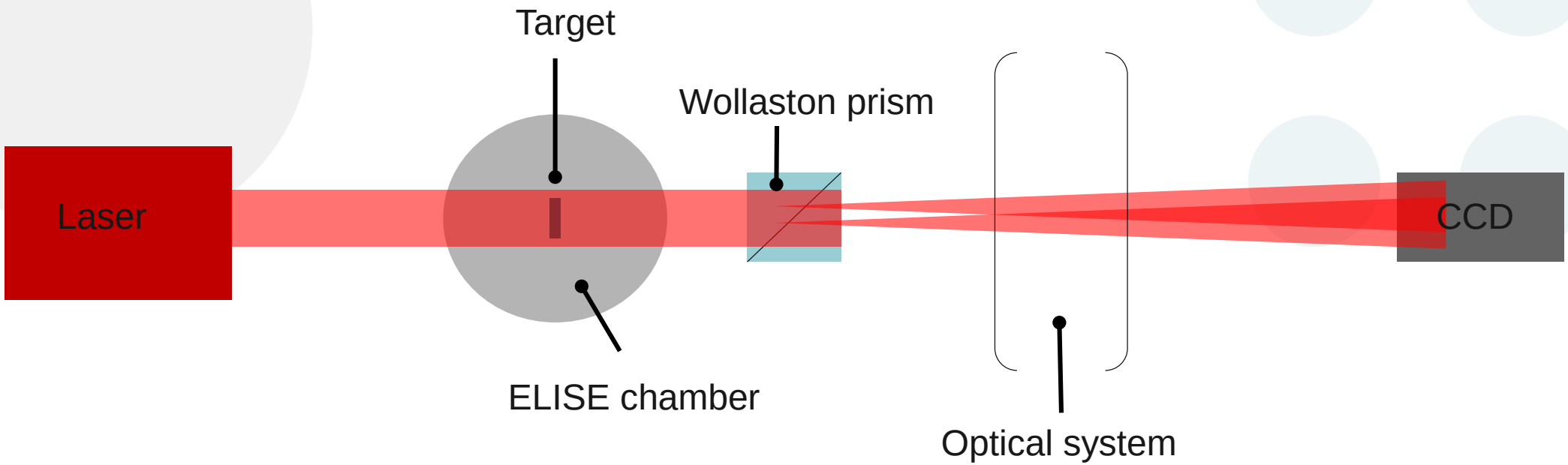



Target thickness observation with long distance microscope Questar QM100

## Limits :

- On the right axis
- Resolution is limited at long distance

# Thickness measurement




$$\Delta\phi = \frac{2\pi}{\lambda} nl$$

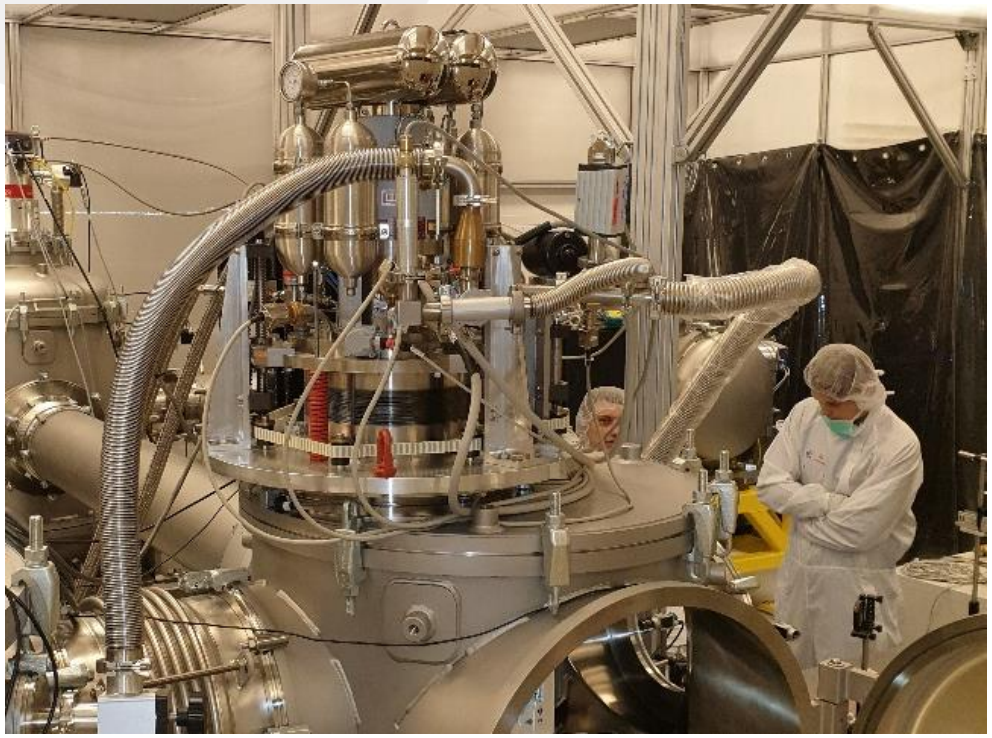
Nomarski interferometer

# TERESA Campaign

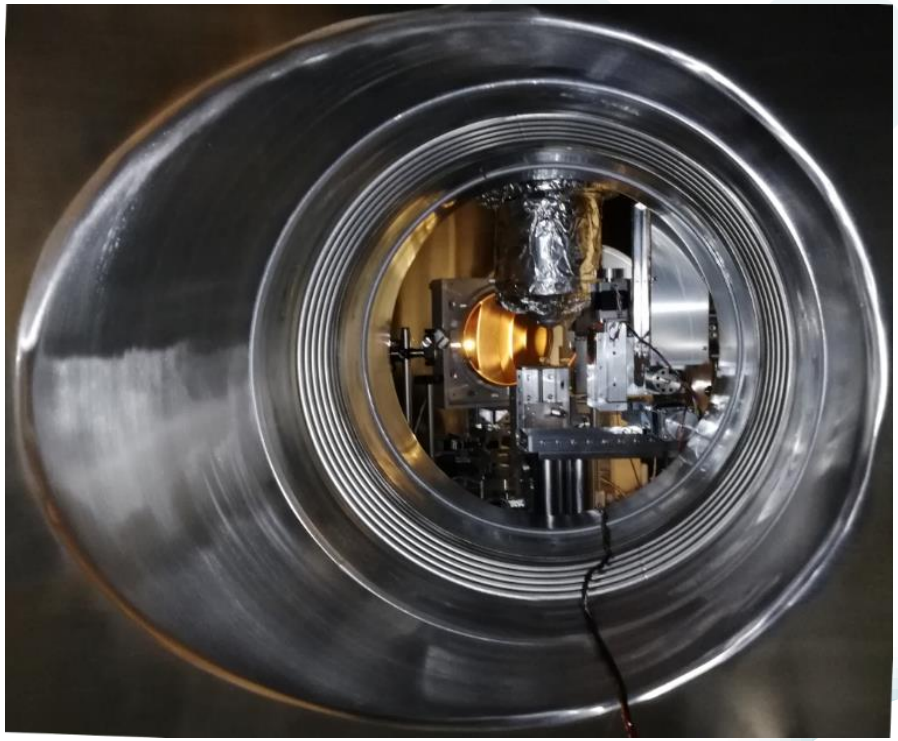
- **Testbed for high Repetition-rate Source Accelerated particle**

**30 TW laser :**

- 700 shots with an energy from few mJ  to 1 J
- Frequency from 0.1 Hz to 3.3 Hz



Teresa chamber



Inside of Teresa chamber

# TERESA Campaign

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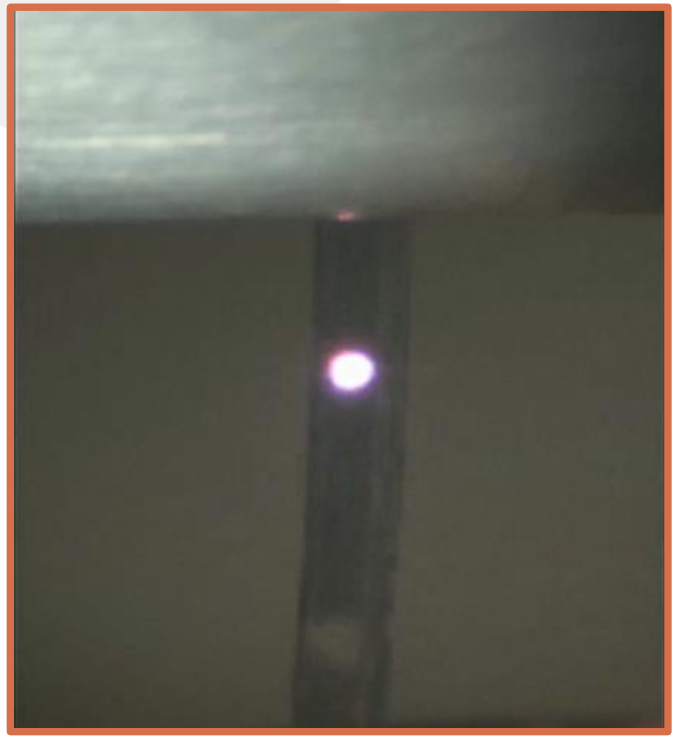
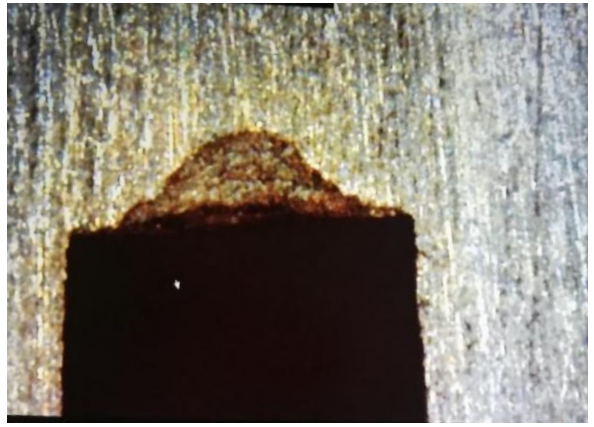


Laser shot on ELISE target



Before / After
Nozzle damage after 100 shots.

# Conclusion

- Cryogenic hydrogen targets are of high interest for **high repetition rate** laser facilities
- Protons up to **55 MeV**
- Variety of **target type** $H_2$, $D_2$, $CH_4$, Ar, Kr

# Prospects

- **Thinner ribbons** to produce higher energy ions
- **Ceramic nozzles** to mitigate long term damages
- Improvements of ribbon angular positioning

# Conclusion

## Thank you for your attention and many thanks to

CEA Grenoble: F. Viargues, J Manzagol, JP Périn, N. Luchier, F. Bancel, B. Rollet, T. Goy, P. Bonnay, JM Mathonnet, J. Ceszkowsky, S.Michaux, A. Girard, D. Chatain

ELI beamlines: T. Chagovets, M. Tryus, F. Grepl, A. Velyhan, D. Margarone

LULI: J. Fuchs and ELFIE team

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DE GRENOBLE

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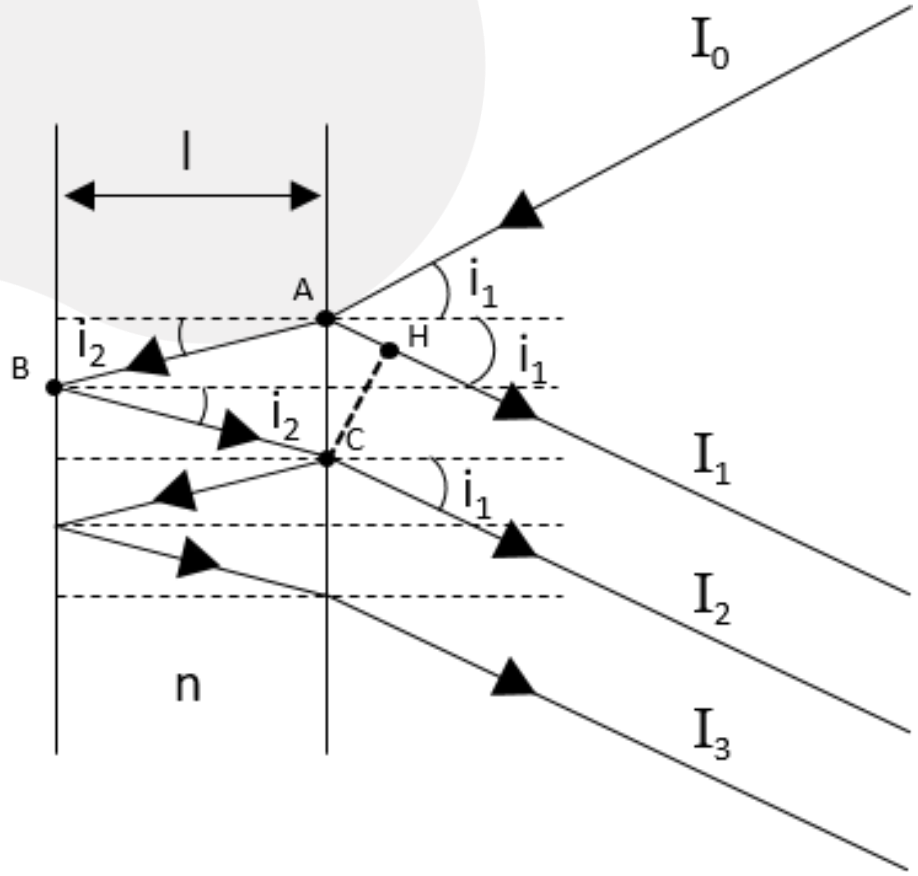
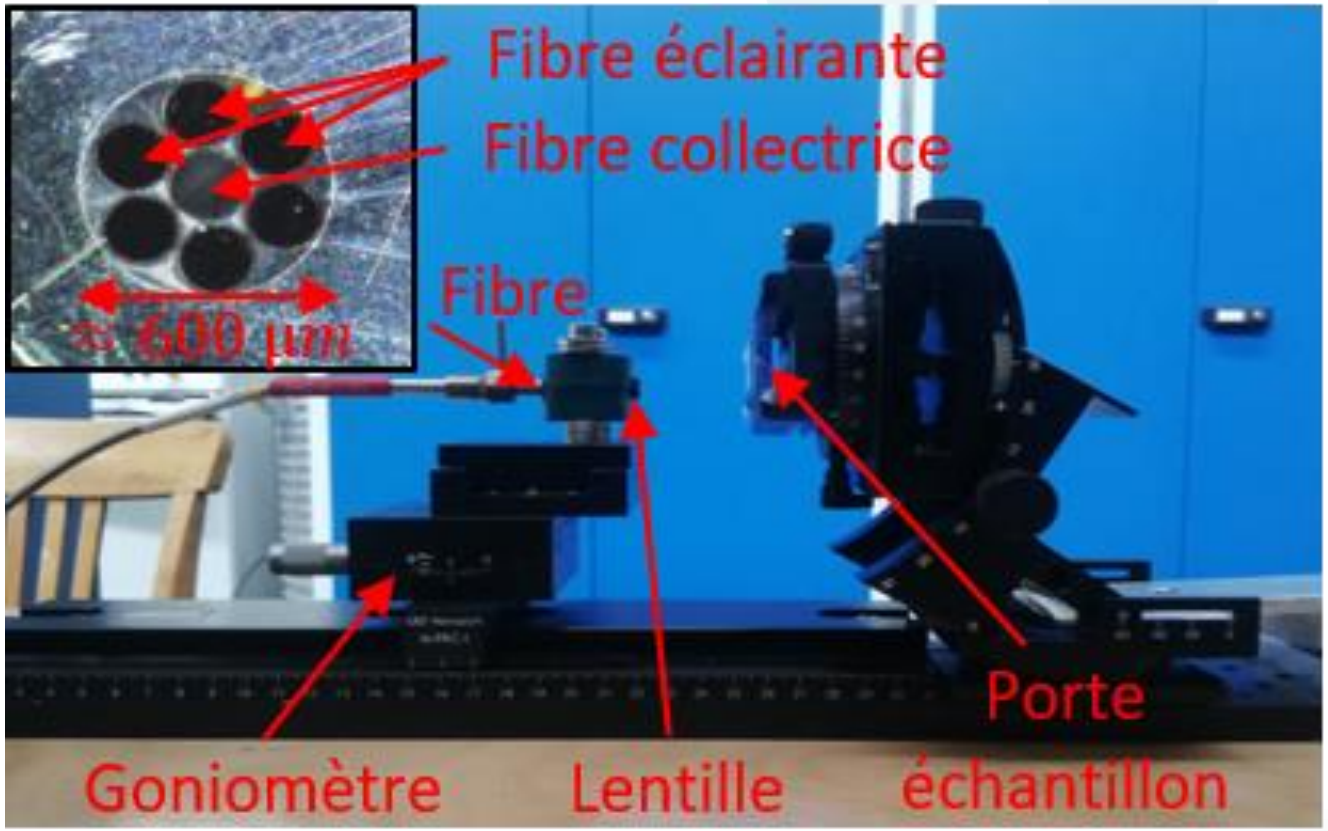
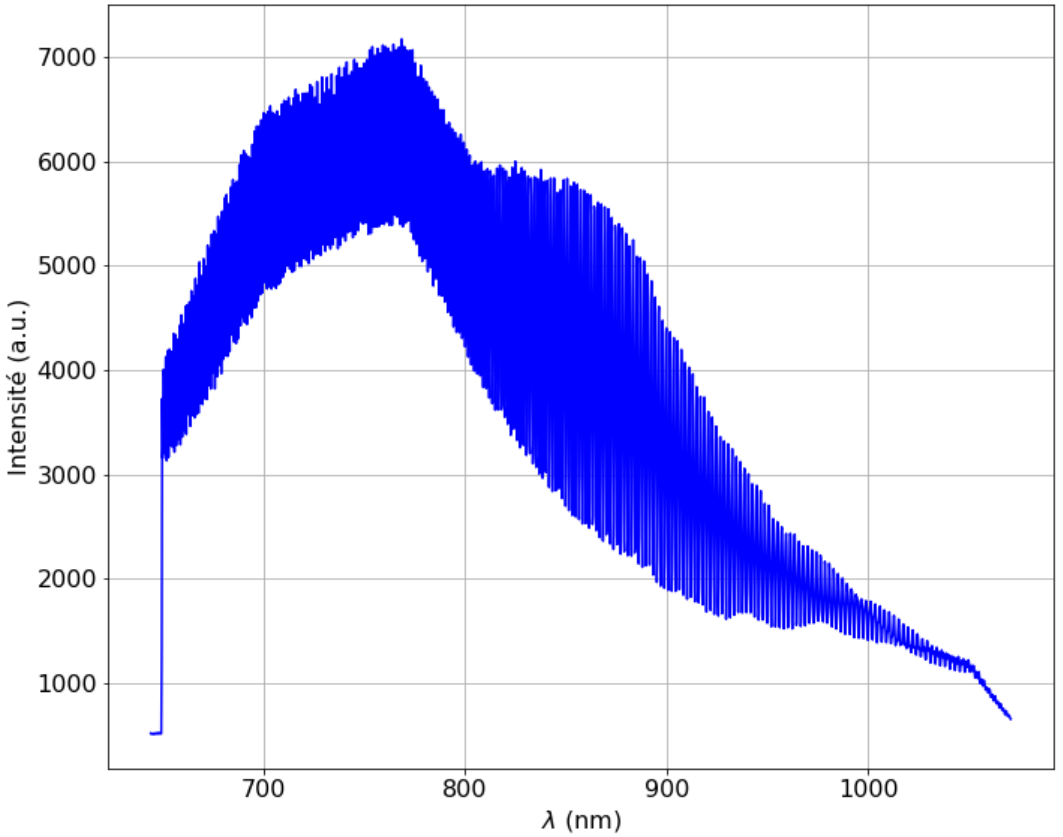
# Thickness measurement

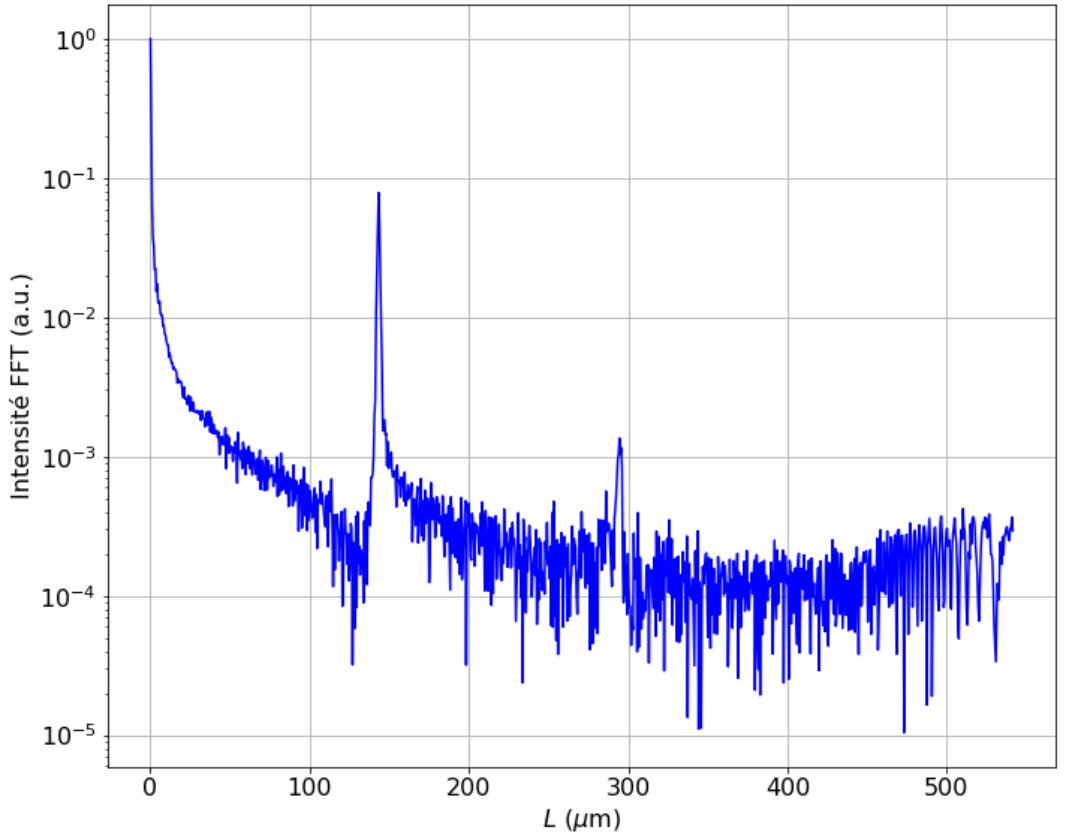



White light interferometer.

# Thickness measurement




Raw data from spectrometer and fast Fourier transform to get the thickness