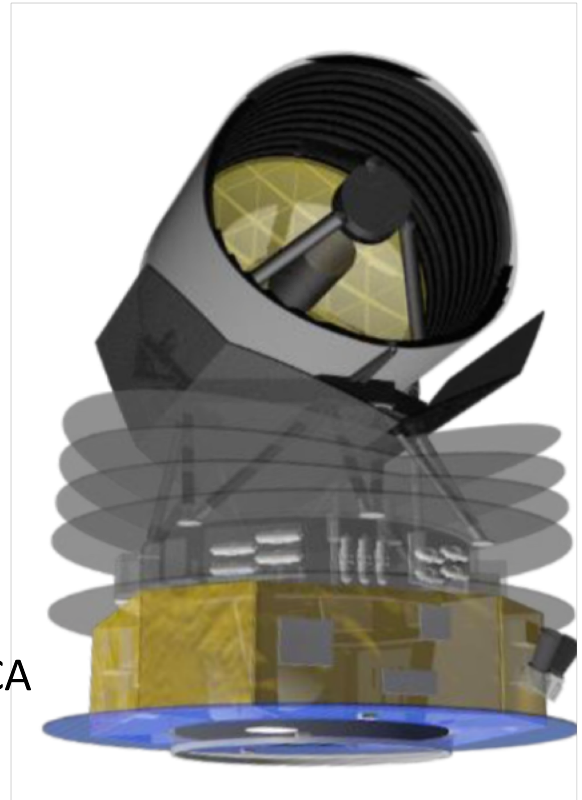
Compact spectroscopy imaging detectors for astrophysical applications

Sophie BOUNISSOU

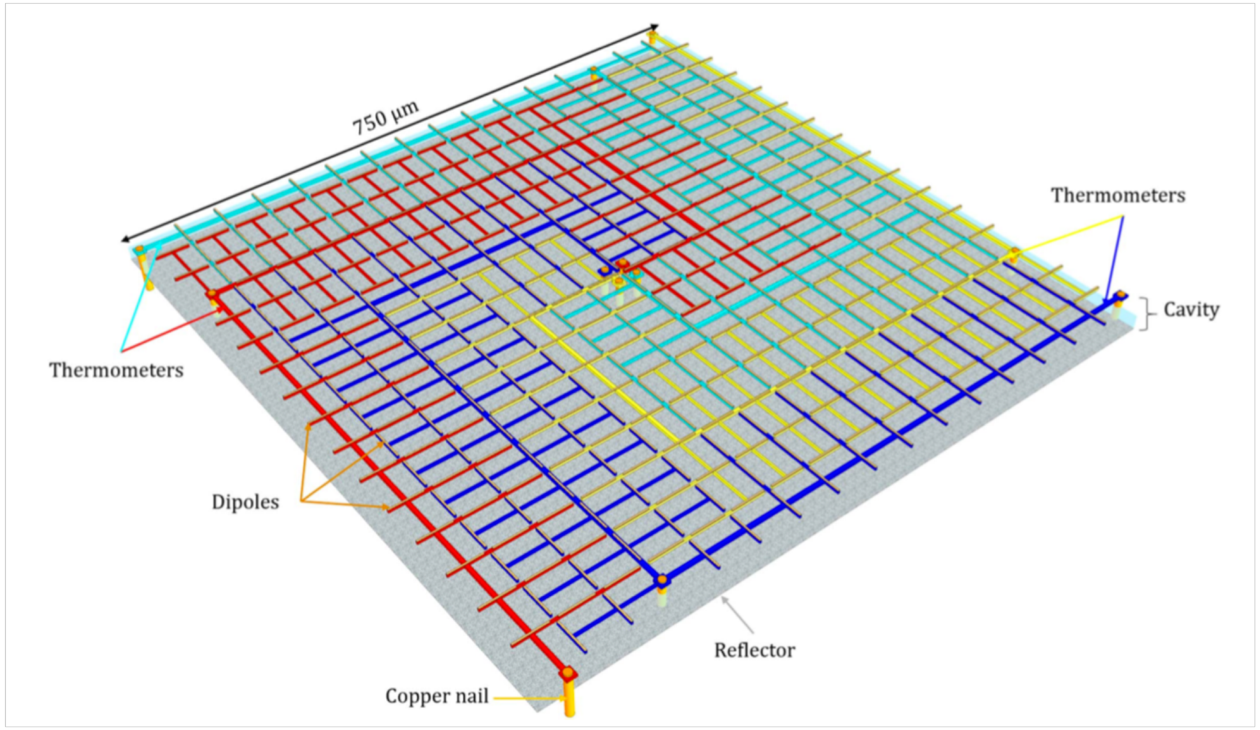
Collaboration: CEA Paris Saclay / CEA LETI
L. Rodriguez, A. Poglitsch, C. Delisle, V. Revéret, J. Martignac, J-L Sauvageot, O. Adami
L. Dussopt, G. Lasfargues, A. Aliane, V. Goudon

I will not talk about …



SPICA

One B-BOP bolometer



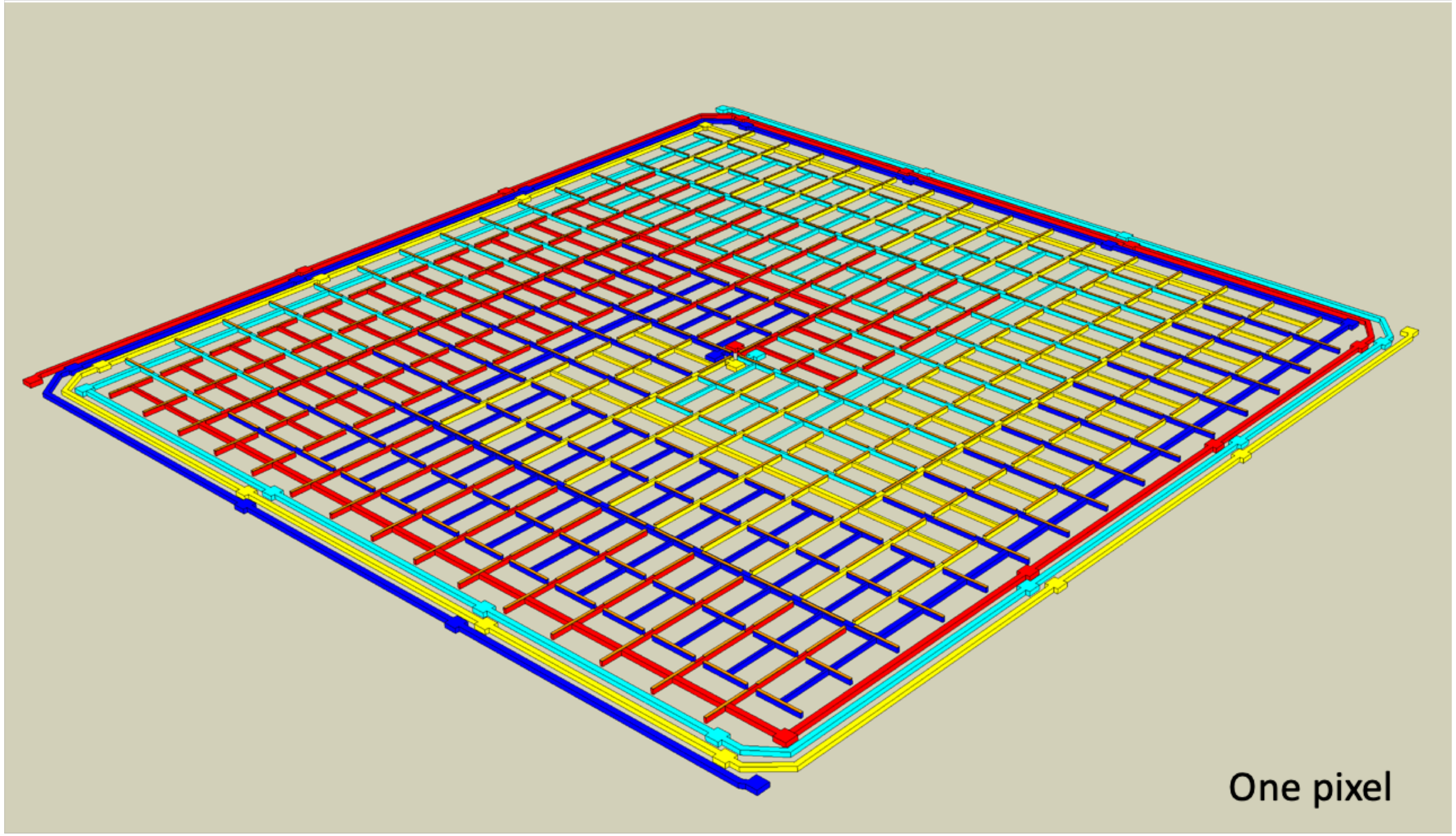
365. L. RODRIGUEZ → On-chip polarimetry for the SPICA B-BOP instrument

367. O. ADAMI → Highly sensitive detectors for the B-BOP instrument

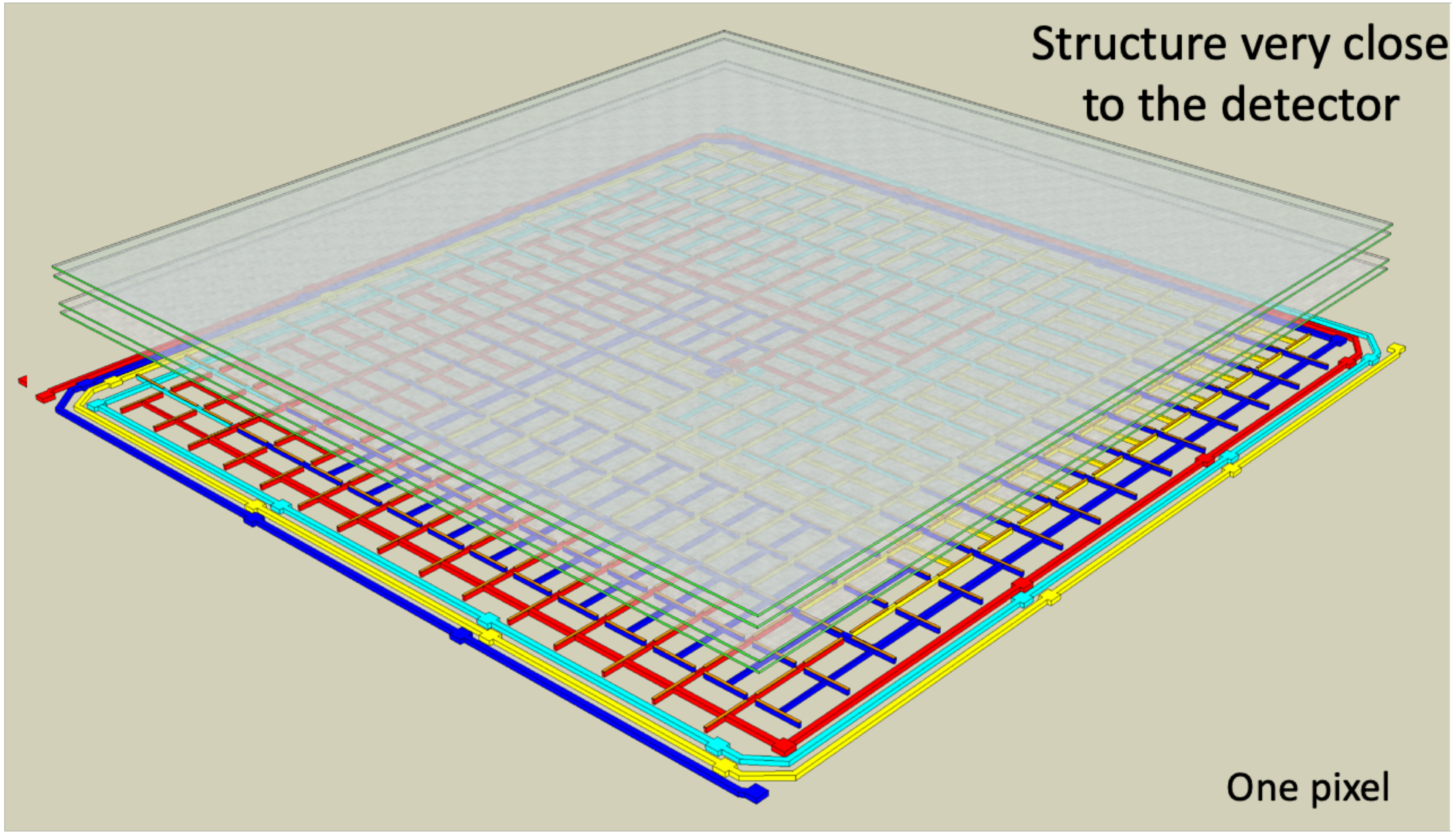
34. A. ALIANE → Design, simulations and fabrication of highly sensitive cooled silicon bolometer for millimetre wave absorption

On-chip polarimetry & silicon bolometers

But … compact spectroscopy imaging detectors



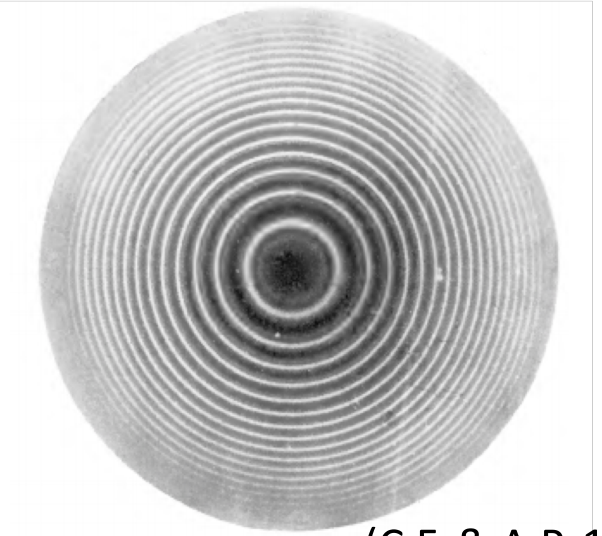
But … compact spectroscopy imaging detectors



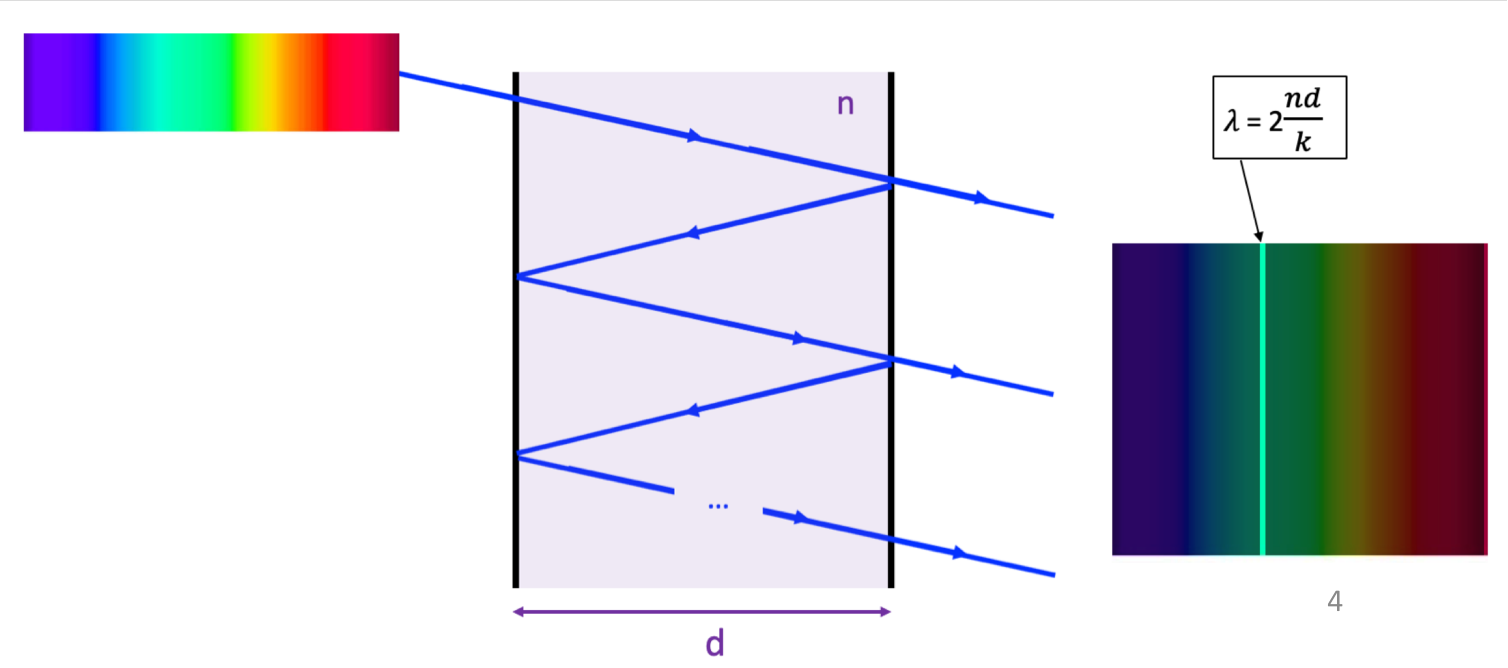
Compact spectroscopy imaging detectors

- Choice of the spectrometer:

Fabry Pérot Interferometer



(C.F. & A.P. 1899)

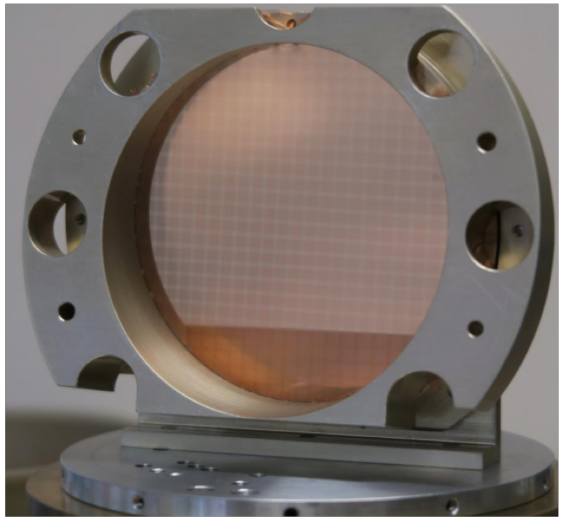


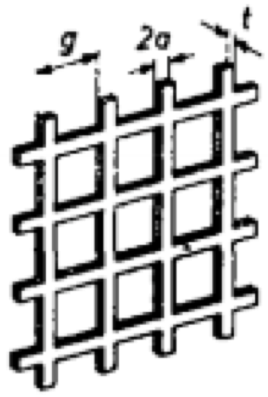
- Scientific applications:

  - High Resolution → Mapping fine-structure lines (as [CII] at ~160 μm)
  - Low Resolution → CMB surveys (combined with polarization?)

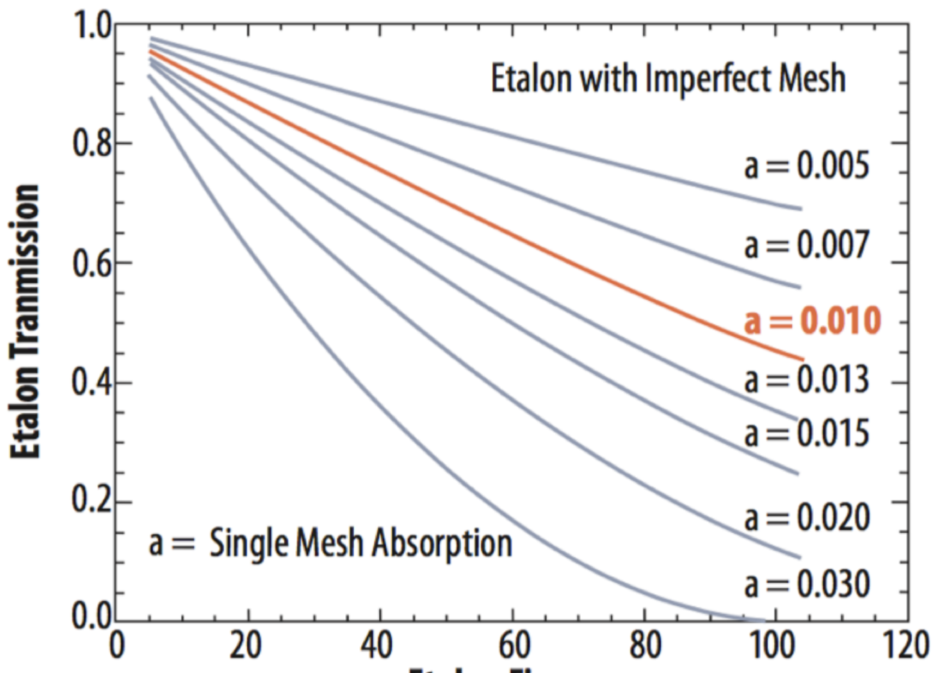
Fabry Pérot Interferometer (1)

Dielectrics mirrors instead of metallic mirrors ?





(a) inductive grid

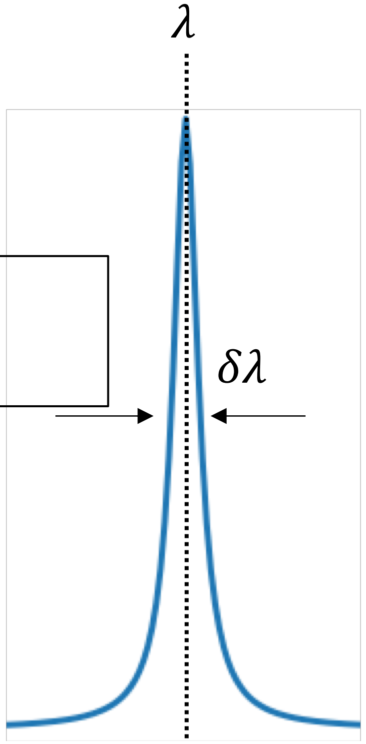


(Douthit 2018)

Drawback of metallic mirrors

Finesse $\mathcal{F} = \frac{\lambda}{\delta\lambda}$

(at 1rst order)

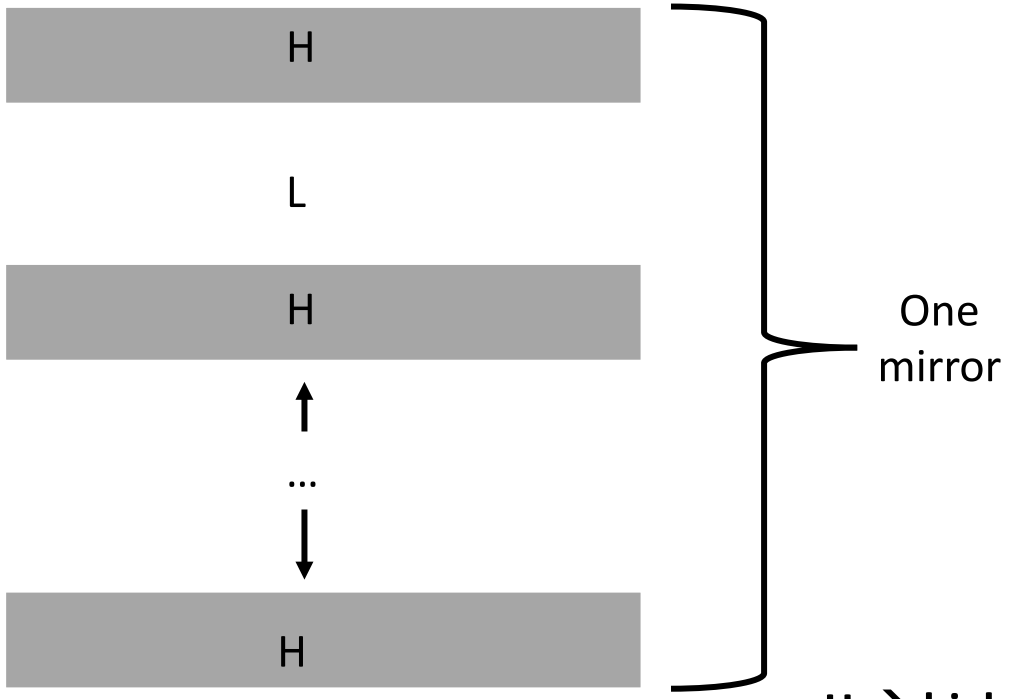


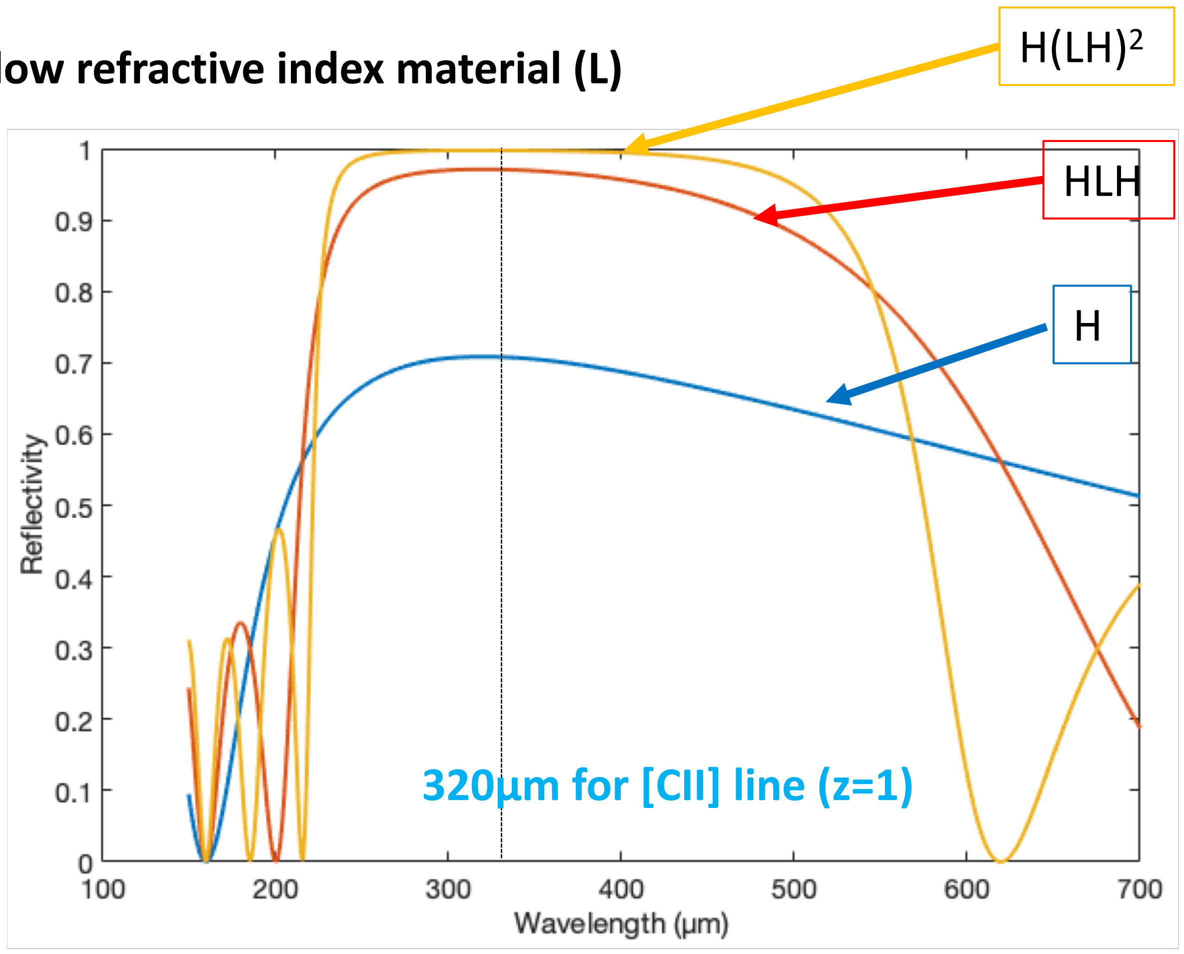
High resistivity silicon (~1 kΩ.cm) + cold temperature

Fabry Pérot Interferometer (2)

Dielectric Bragg mirrors improve mirrors reflectivity

- **Successive layers of high refractive index material (H) / low refractive index material (L)**
- ***λ*/4n thickness**



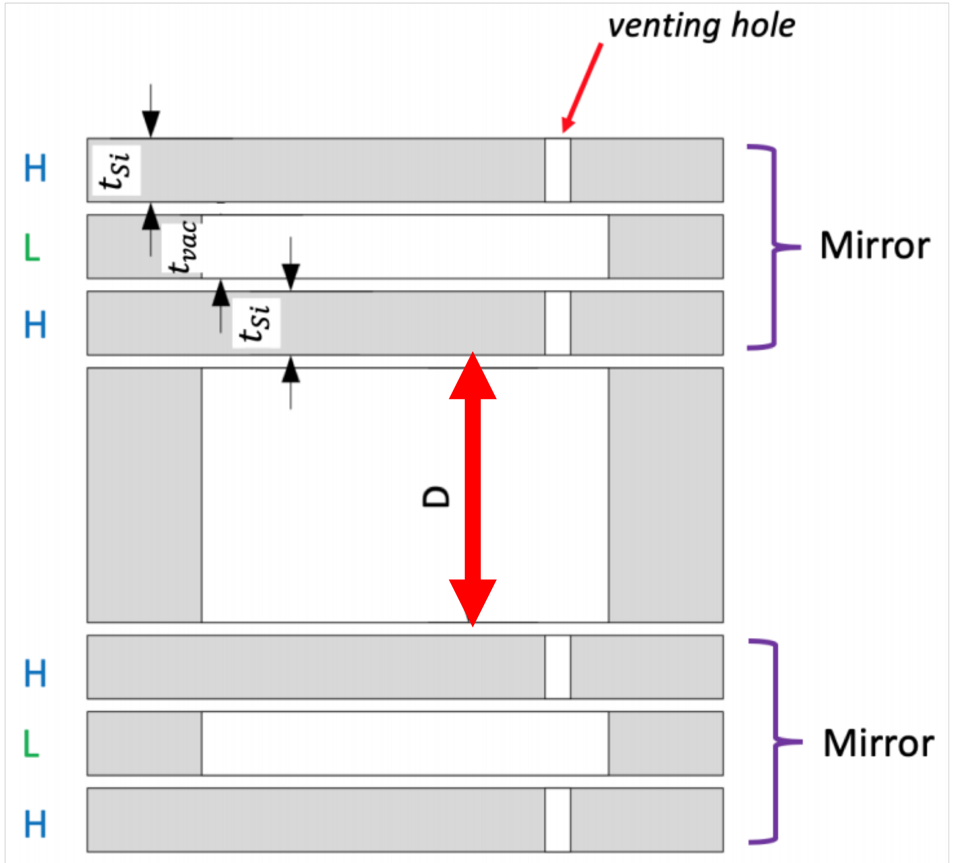


H → high resistivity silicon
L → vaccuum

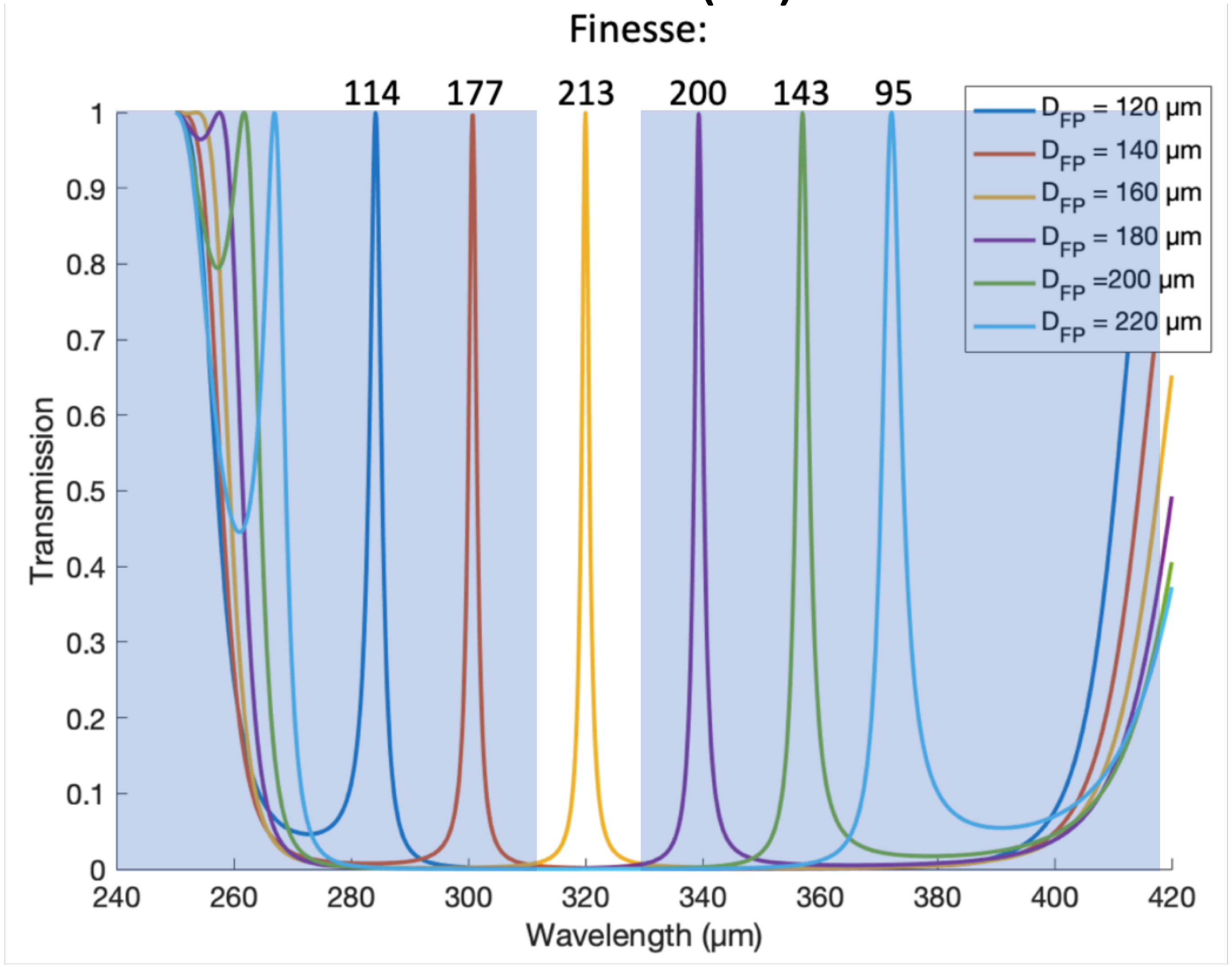
→ In the following:
one mirror = (HLH)

Fabry Pérot Interferometer (3)

<u>Our solution for the Fabry-Pérot:</u>



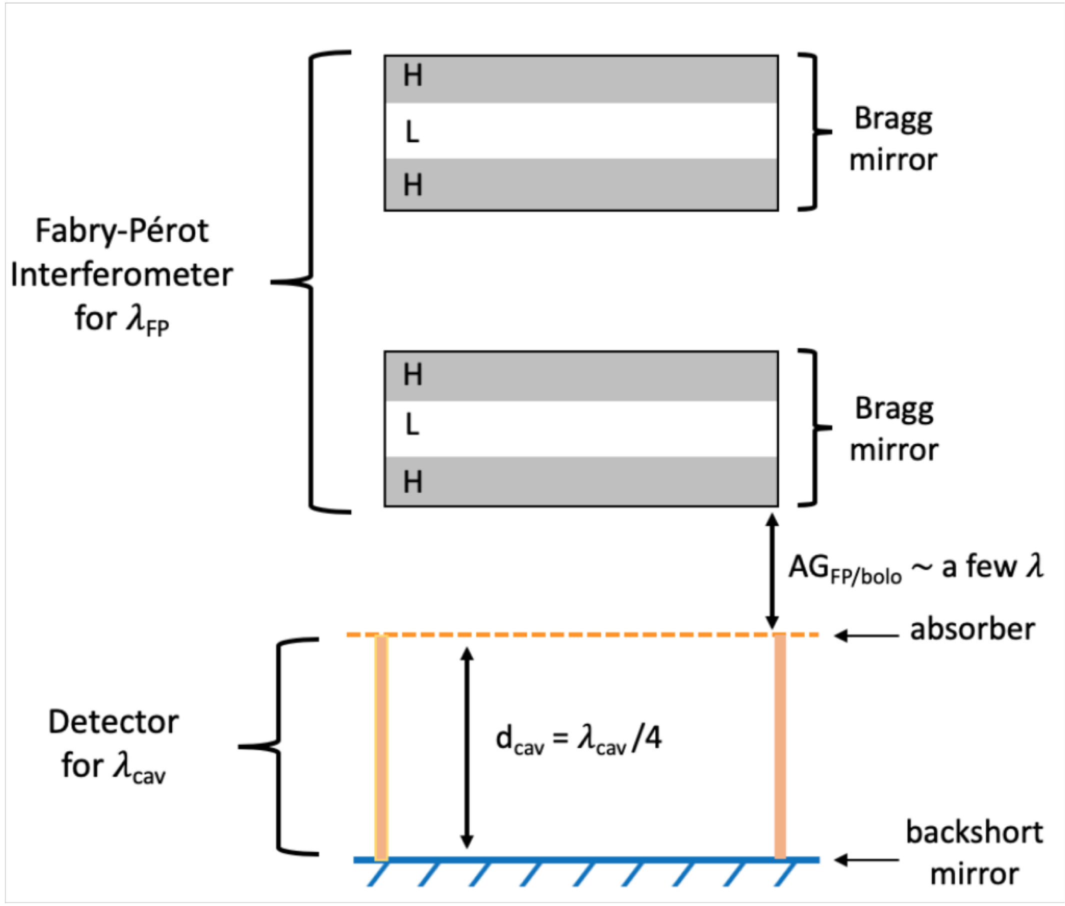
The etalon

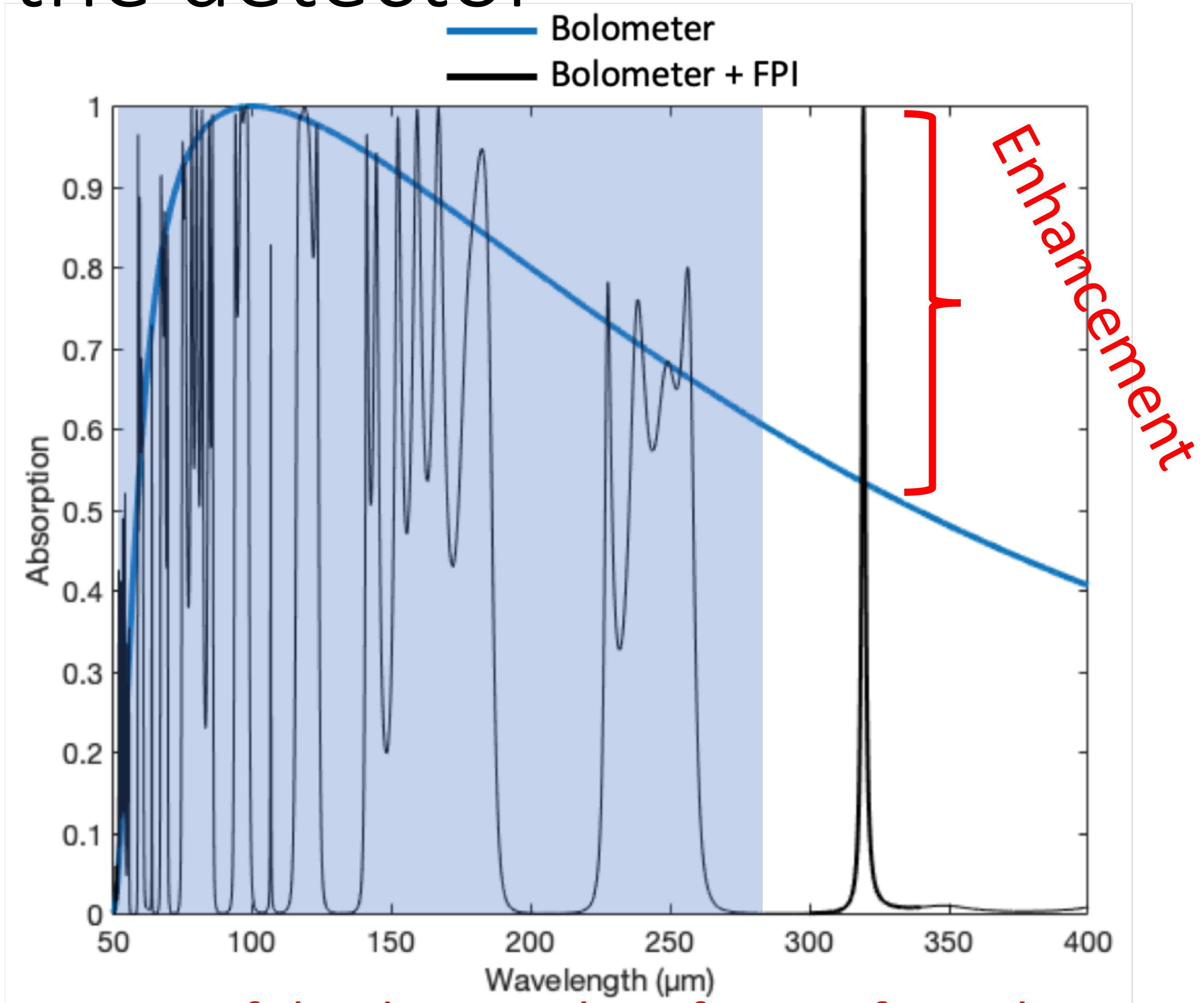


→ Focus on a etalon (rather than the tunable FPI) to work on optical issues

Foreseen performances from simulations

Coupling of the FP to the detector

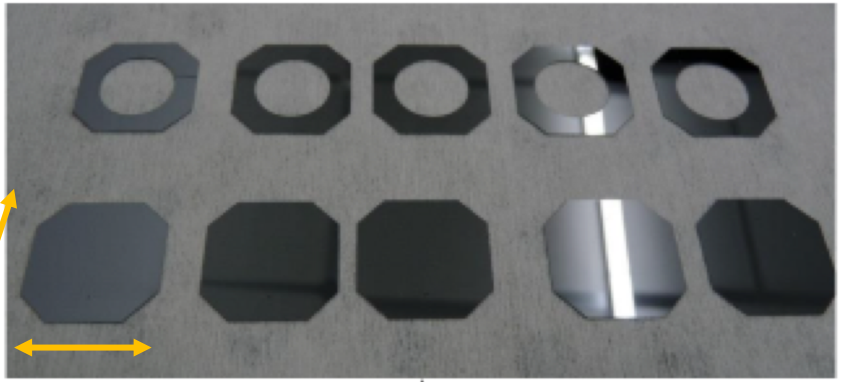




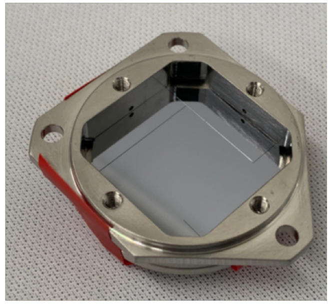
Coupling → Enhancement of the absorption of the detector by a factor of 2 with the spectral capability

In practice … (1)

Grinding of the silicon wafer:
→ Thicknesses : 80 µm /71 µm

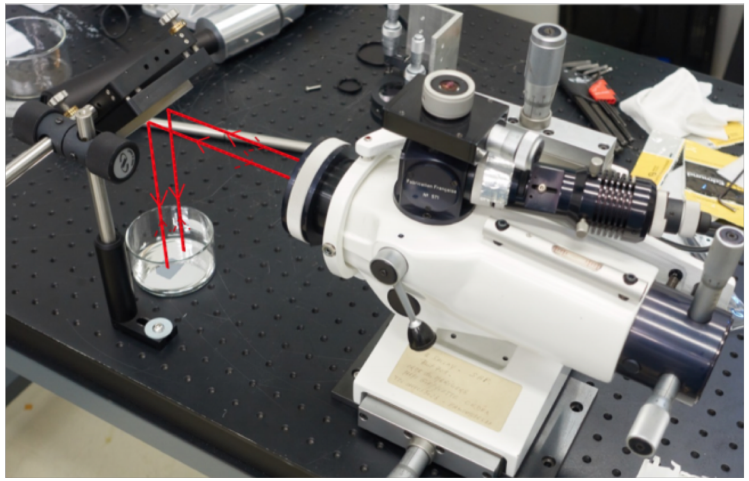


25 mm
25 mm



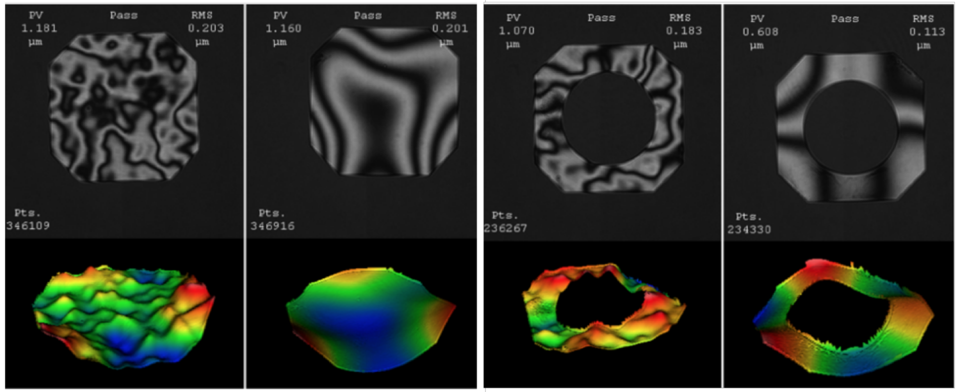
the etalon

Measurement of the thicknesses at the µm-precision ✓

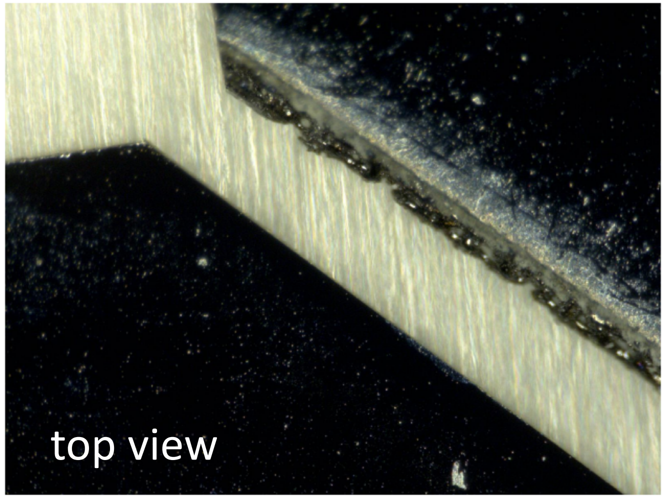


Parallelism of each layer: wedge < 7'' ✓

Roughness of each layer ~ 1 µm ✓

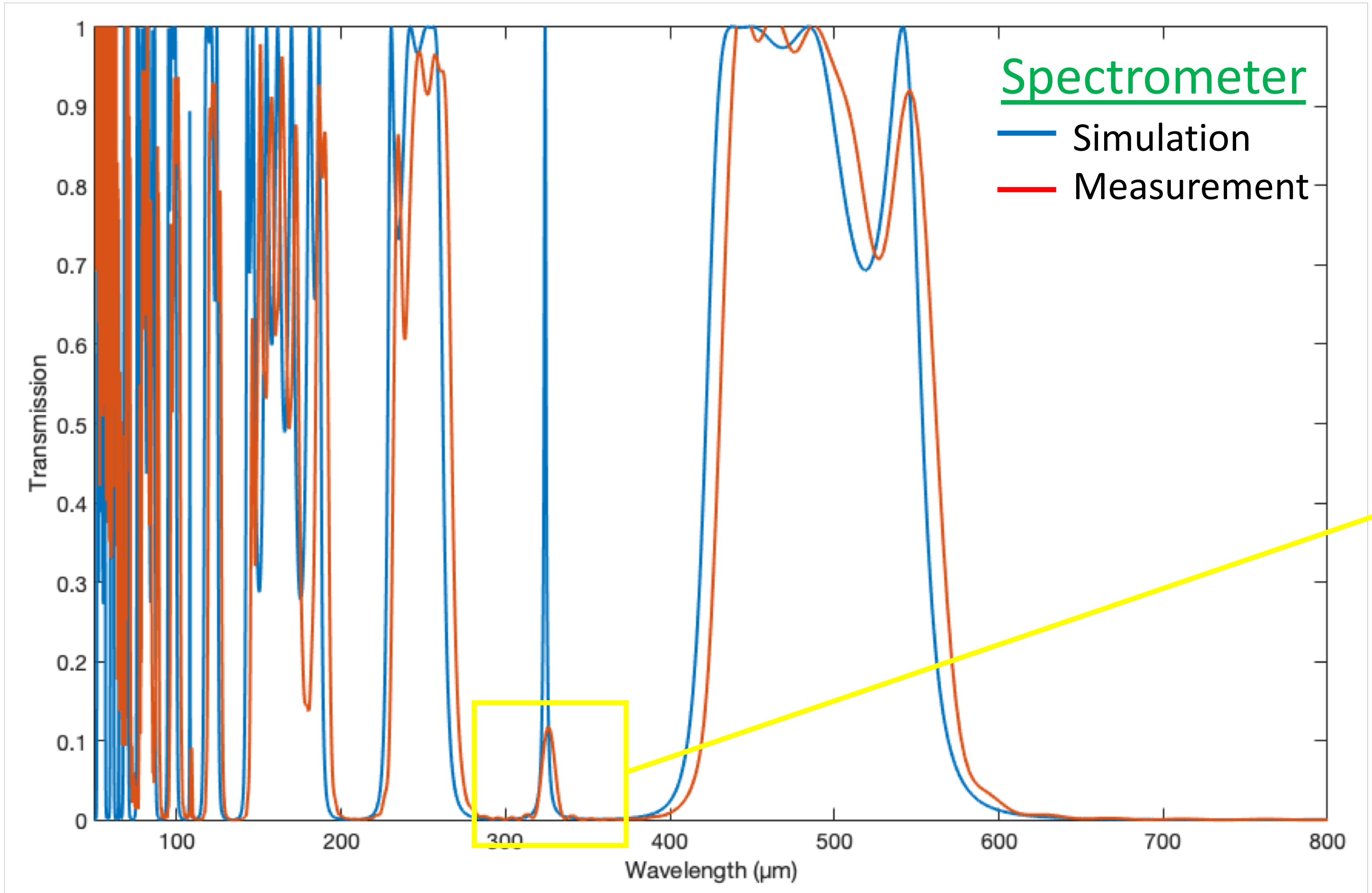


Cleaness of the edges ✓

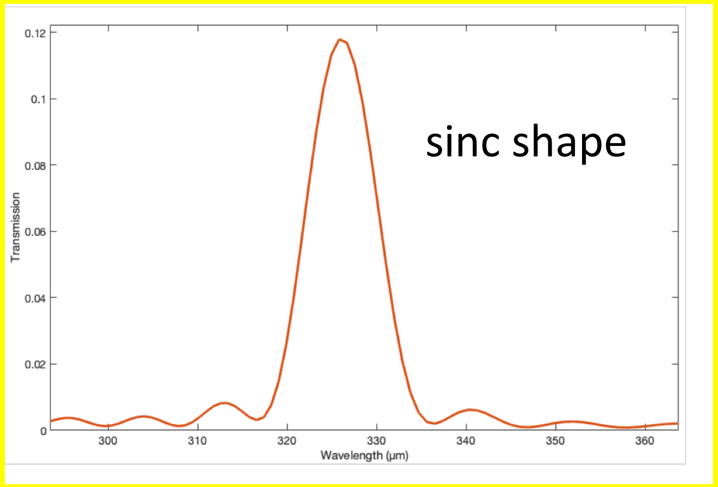


In practice … (2)

Measurement with a Time-Domain Spectrometer (TDS) at room temperature



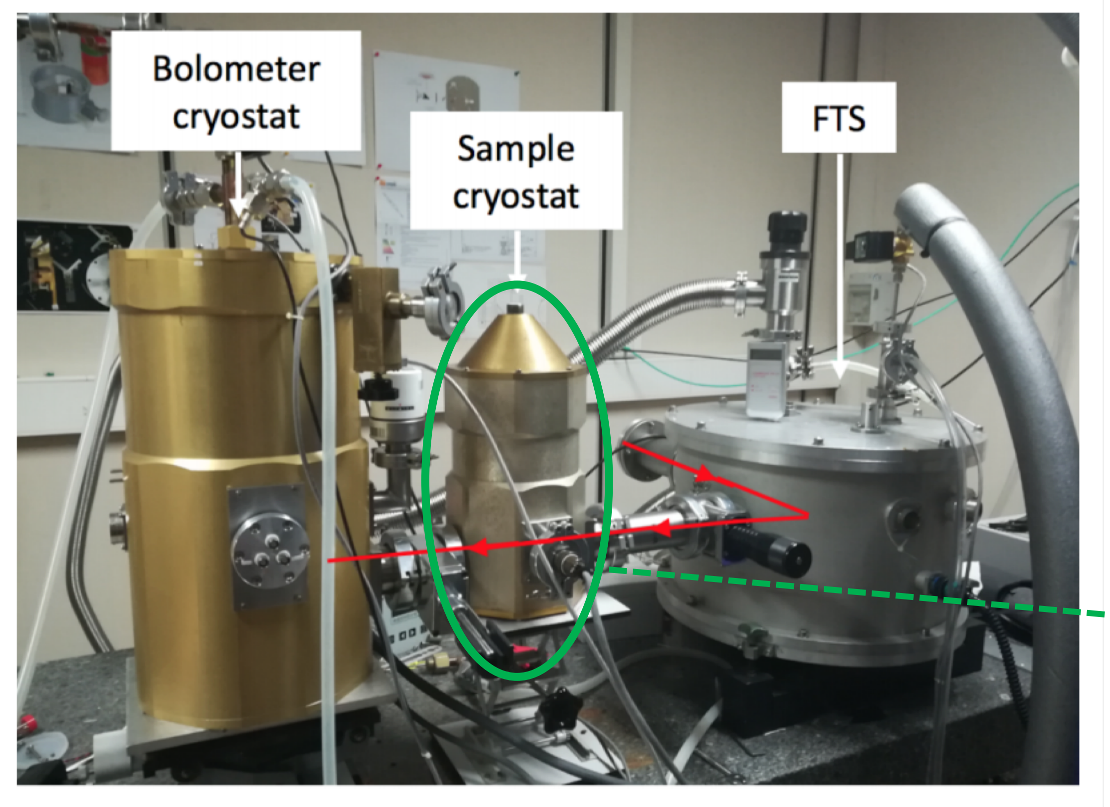
- Shift between simulations and measurements probably due to actual material thicknesses (need for sub-μm precision)
- Transmission peak at 320 μm not resolved by the TDS

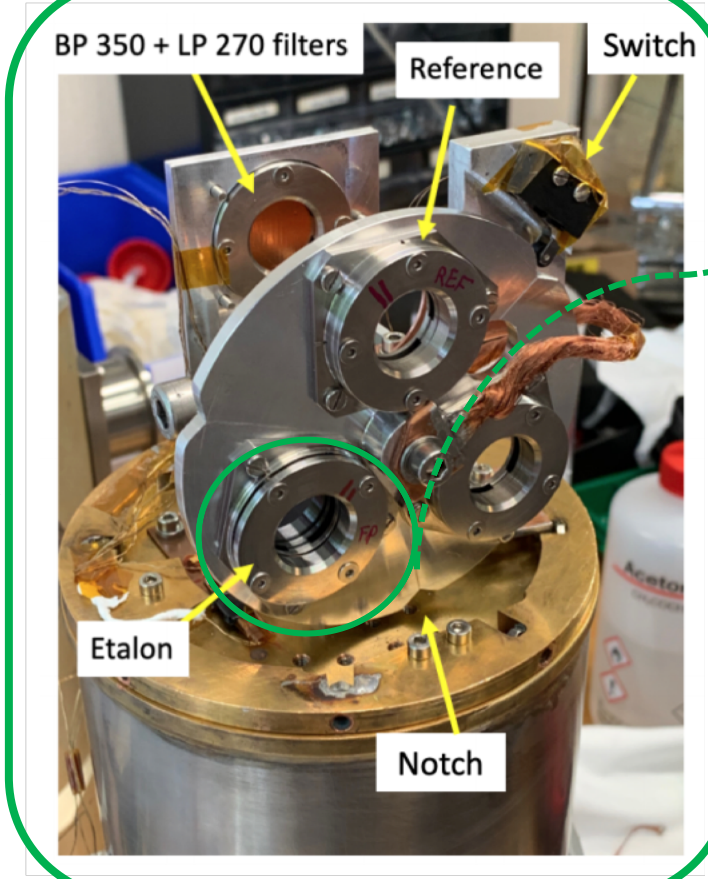


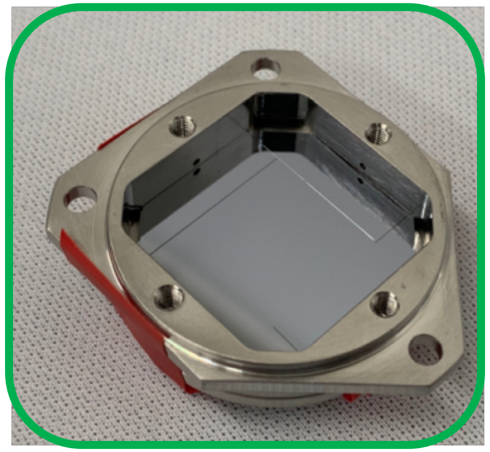
Simulations only based on thin film theory ✓

In practice … (3)

Measurement with a Martin Puplett Interferometer at cold T (77K)





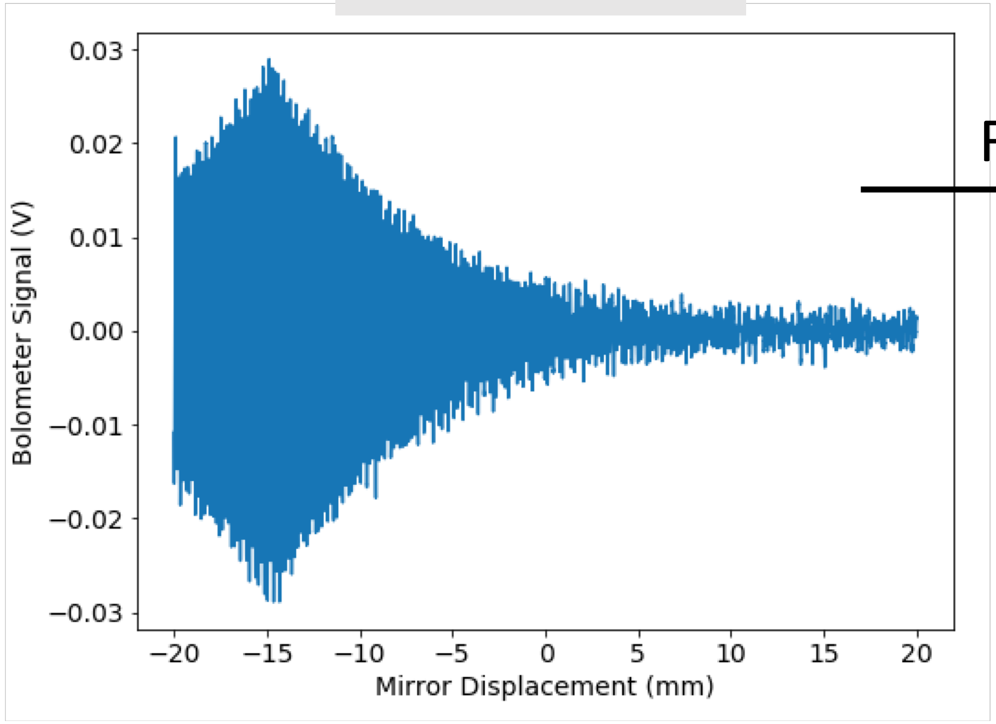


Wheel with open position (reference) and the etalon

* Optical filtering (Band-pass) to remove everything except the ~ 320 µm

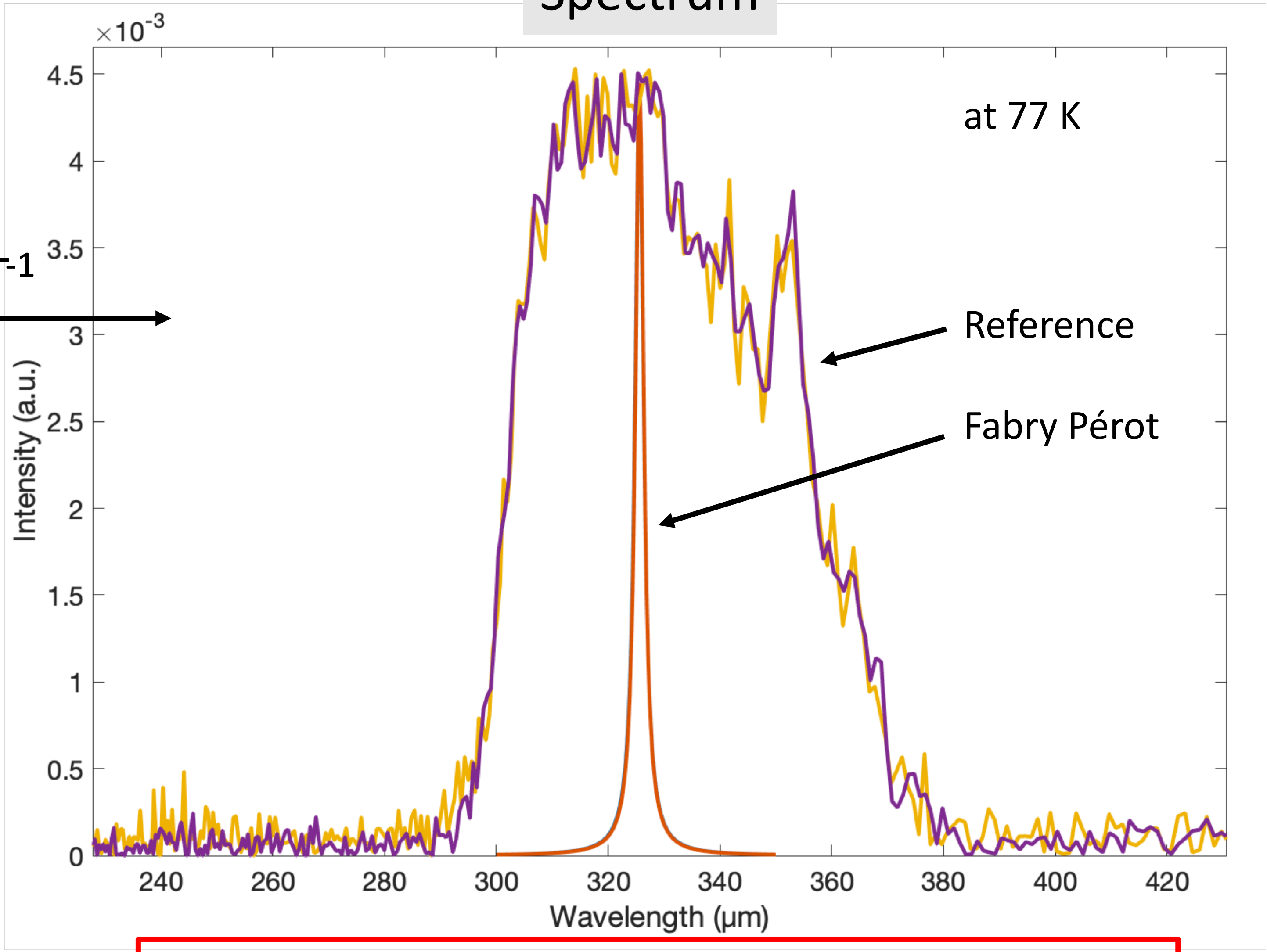
In practice … (4)

Interferogram



FT^{-1}

Spectrum



Shape of the measurement corresponds to the expected interferogram: *(cosine) x (exponential decay)*

Finesse = 178 $\pm$ 2 (theoretical : 213)
Transmission ~ 100 %

Conclusions & Perspectives

- Promising coupling between the FP spectrometer and the detector
  - FP for high resolving and high transmission spectroscopy ✓
  - Efficiency of the coupling detector/ FPI → To be experimentally confirmed (Summer 2019)
  - Tunability: add the cryo-motor (PZT) above the detector to tune the upper mirror

→ OK for narrow-band spectroscopy but what about wide-band spectroscopy ?

- Multiplex Fabry Pérot Interferometer

Fabry-Pérot as several FTS at different spectral resolutions

→ Still under investigation …

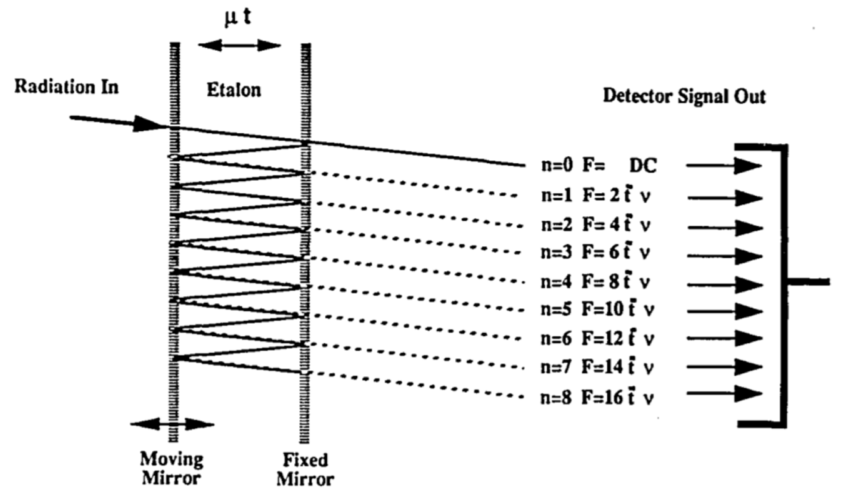


Fig. 2. Illustration of the carrier frequency for each harmonic passing through the étalon. Each of the harmonics is equivalent to a single Michelson interferometer.

(Hays 1991)

Water Jet laser