In-situ optical reflectance characterization of ion beam irradiation damage on crystalline (quartz) and amorphous (silica) SiO_2

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In-situ optical reflectance characterization of ion beam irradiation damage on crystalline (quartz) and amorphous (silica) SiO_2

•Outline:

- Motivation, aim
  - Complement waveguide data on silica
  - Optical data in quartz
  - Detailed analysis, i.e. both fluence kinetics and resolution
  - Efficiency of irradiation and analysis, samples, time…

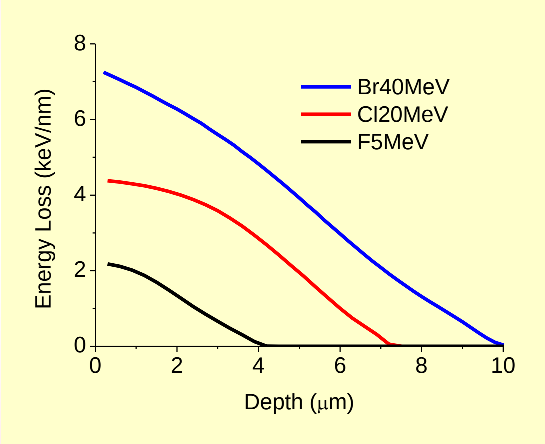
- Experimental set-up description
  - Reflectance procedure
  - Options: light source (lasers, white light..), detectors, configurations

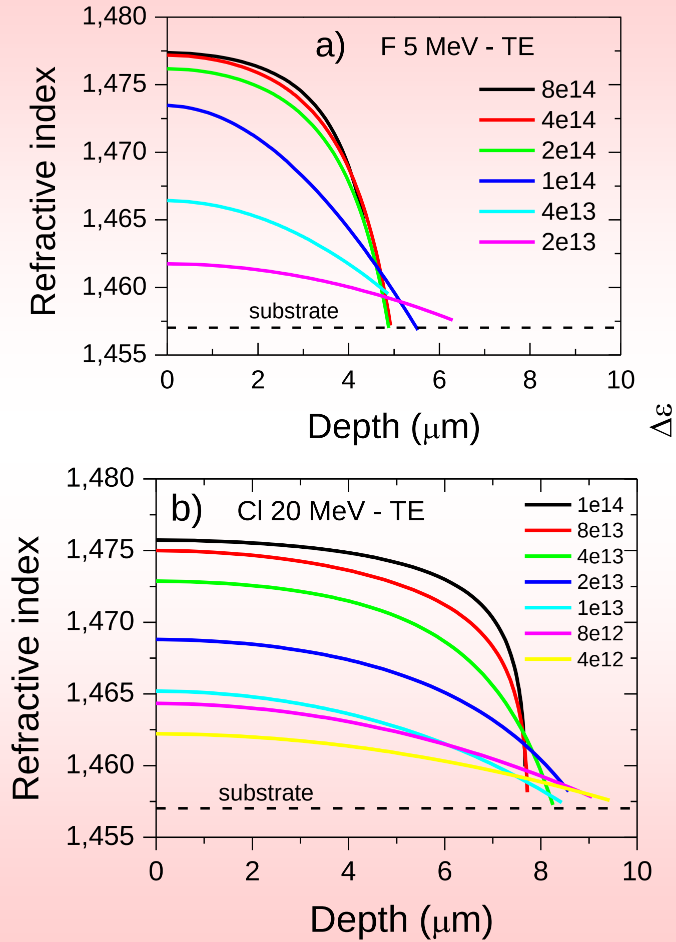
- Results and discussion
  - Comparative of amorphous and crystalline phases

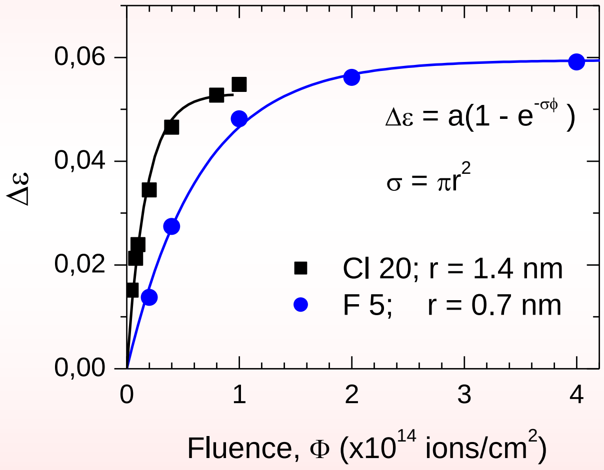
In-situ optical reflectance... ion irradiation damage on SiO_2

Motivation.

Previous work on Silica
Optical waveguides =
mean of characterization



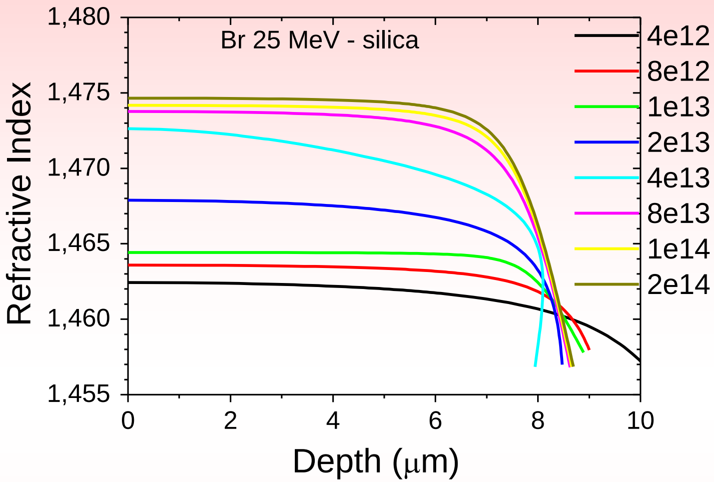


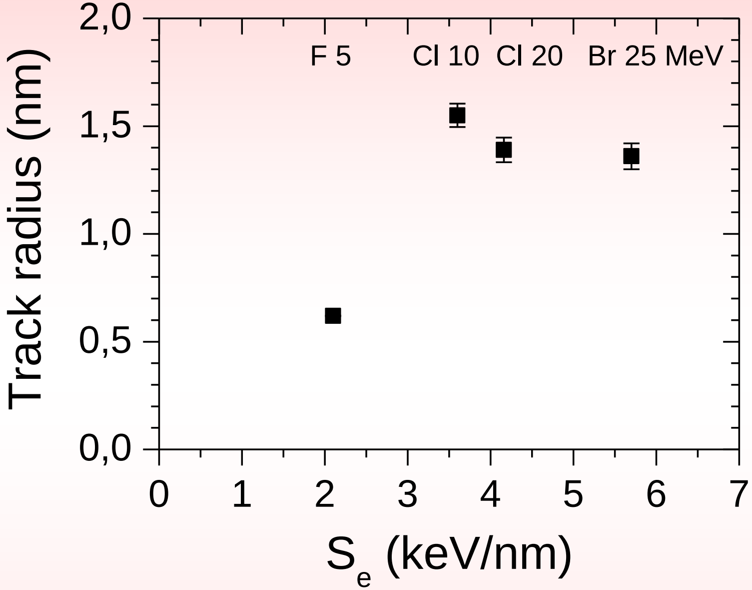


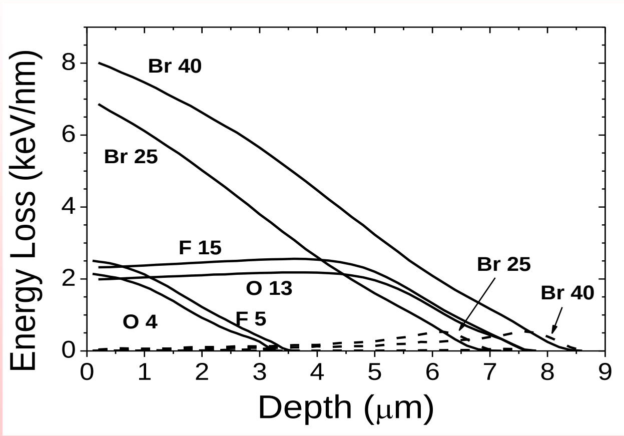
J. Manzano et al, NIMB 2010

In-situ optical reflectance... ion irradiation damage on SiO_2

Motivation. Previous work on Silica

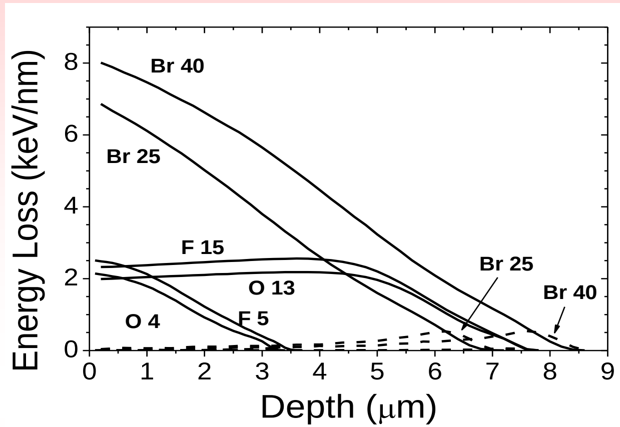


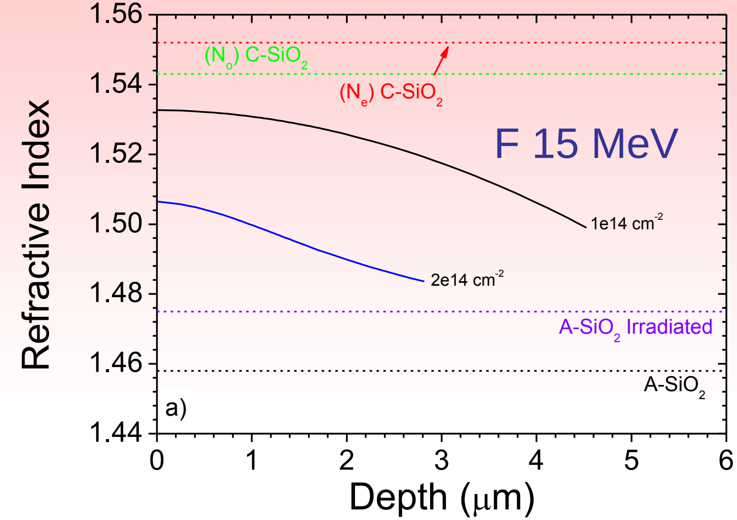




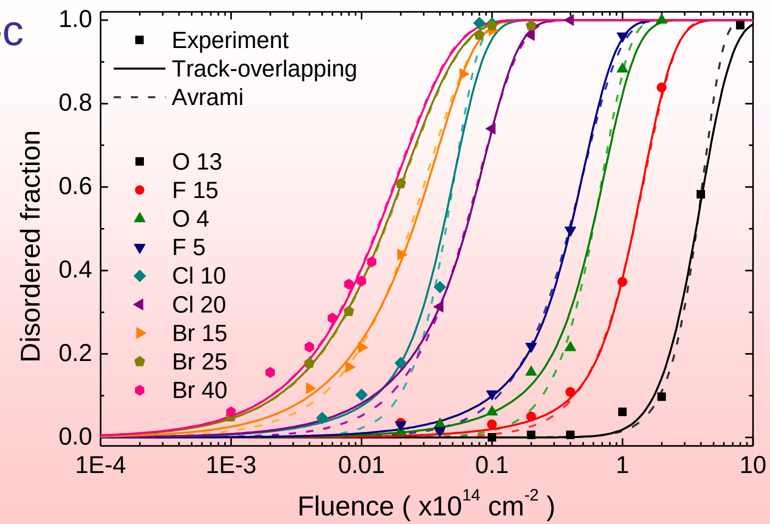
In-situ optical reflectance... ion irradiation damage on SiO_2

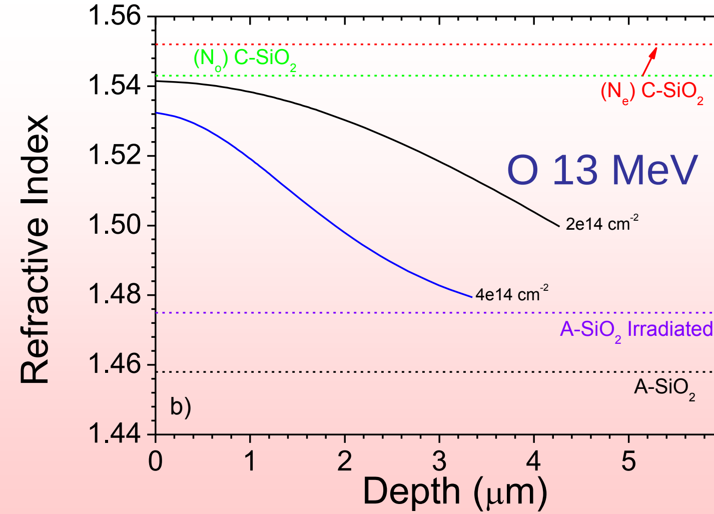
Motivation. Previous work on QUARTZ





RBS-c





J. Manzano et al, NIMB 2011

In-situ optical reflectance... ion irradiation damage on SiO_2

- Motivation, aim…
  - Complement waveguide data on silica…
  - Optical data “at the surface” in quartz not available yet
  - Obtain detailed analysis, i.e. both fluence kinetics and resolution
  - Efficiency of irradiation and analysis, cost of samples, time…

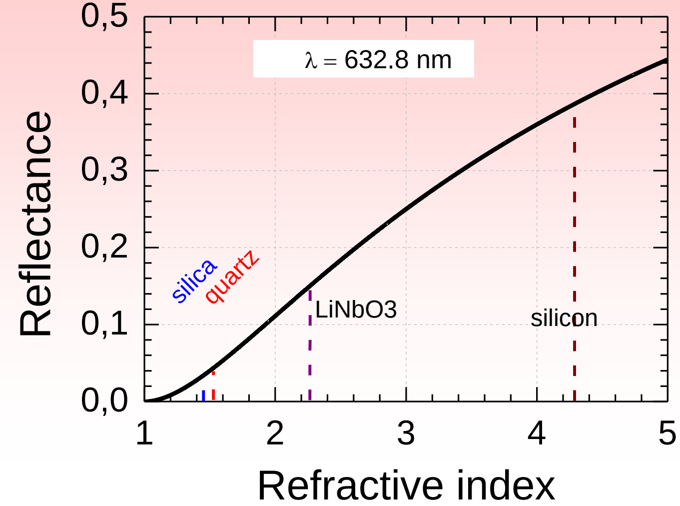
In-situ optical reflectance... ion irradiation damage on SiO_2

Reflectance procedure

1. Measuring reflectance, R
2. From R determining:
   - Refractive index, $\varepsilon = n^2$
     - Direct Fresnel
     - or multilayer fittings

$$R = \frac{(n-1)^2}{(n+1)^2}$$

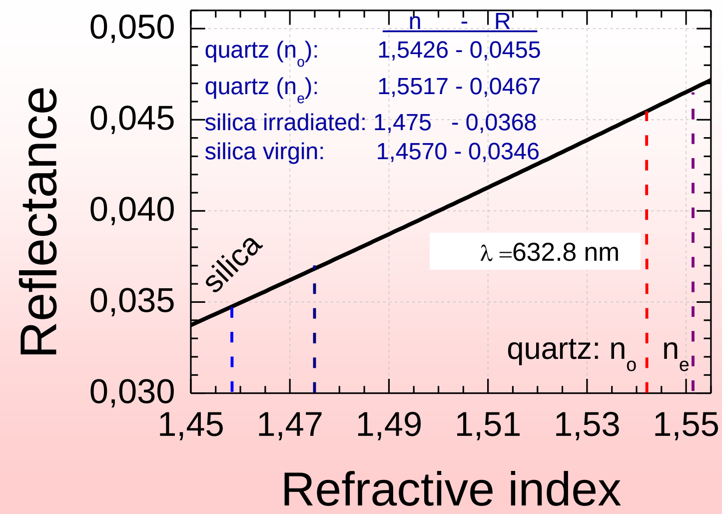
$k = 0$
$\vartheta = 0^o$



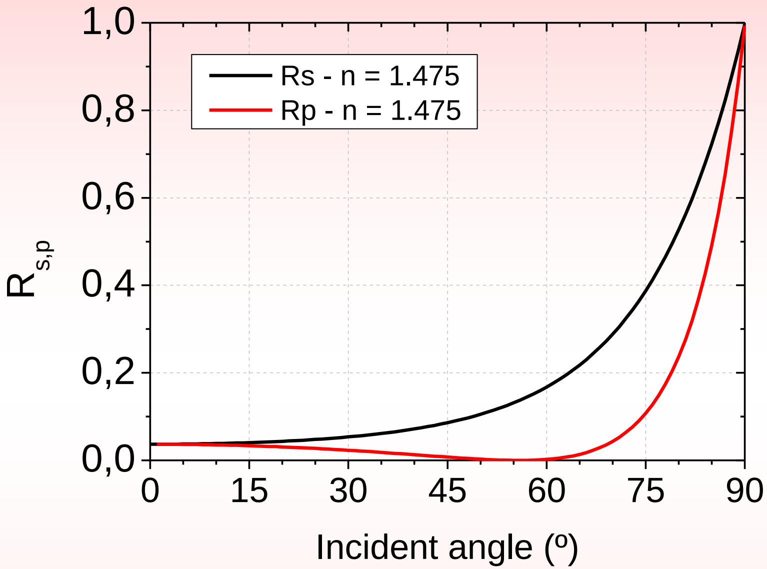
3. Normalized change: $(\varepsilon - \varepsilon_o)/(\varepsilon_{sat} - \varepsilon_o)$
   - Poisson-like behaviour
     → cross section, track radius
     Effective medium:

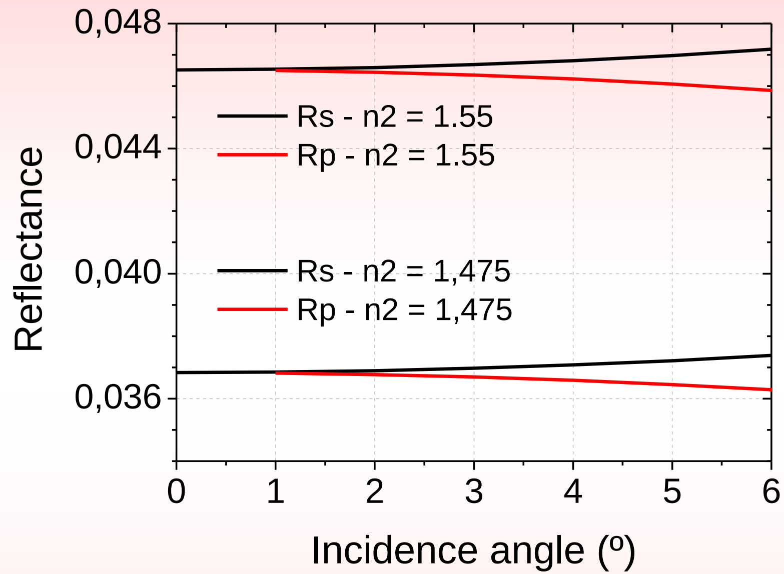
$$\varepsilon = \varepsilon_{sat}\, f_{sat} + \varepsilon_o\,(1 - f_{sat})$$

$$(\varepsilon - \varepsilon_o)/(\varepsilon_{sat} - \varepsilon_o) = f_{sat}$$



In-situ optical reflectance... ion irradiation damage on SiO_2

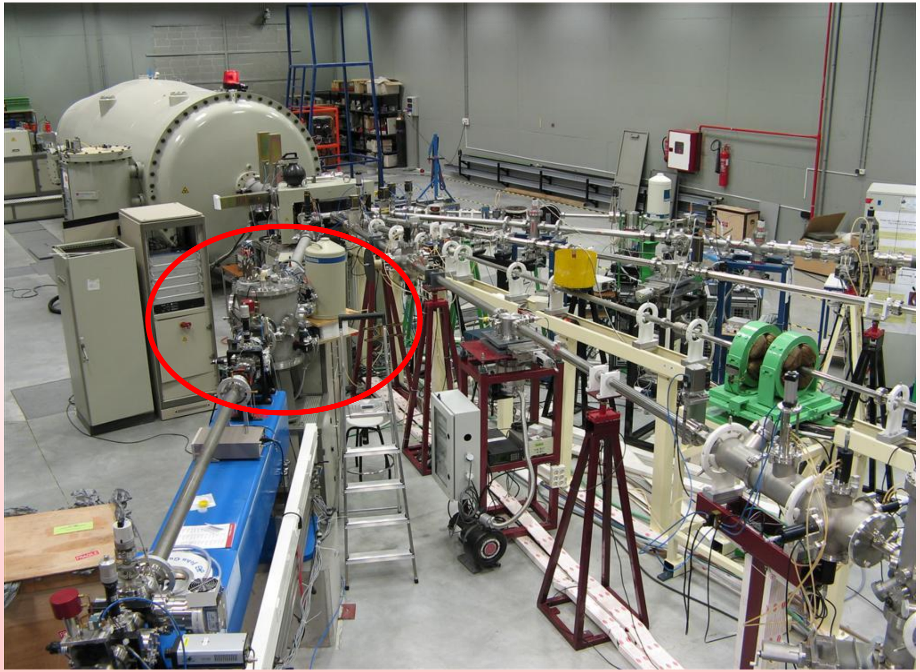




In-situ optical reflectance... ion irradiation damage on SiO_2

- <u>Experimental</u>
  - Ion facility at CMAM, UAM, Madrid, Spain
  - 5 MV tandem   E → ~(0.5 – 50) MeV

www.uam.es/cmam



In-situ optical reflectance... ion irradiation damage on SiO_2

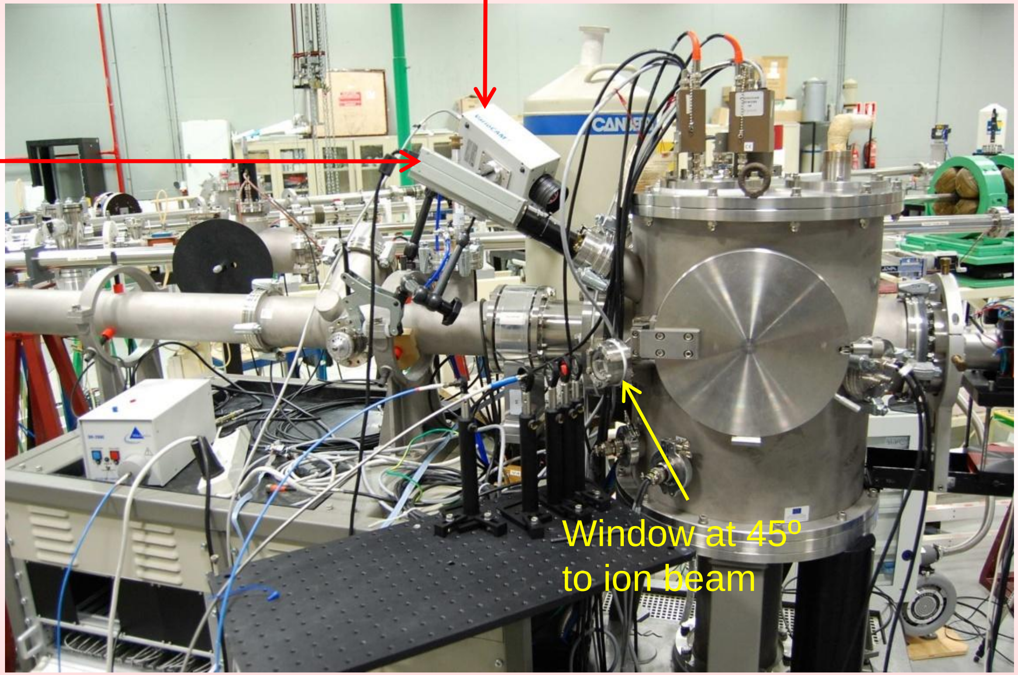
- Experimental

CCD colour camera:

- For alignements and
- Beam homogeneity with ionoluminescence

Thermal Infrared camera:

- In-situ surface temperature



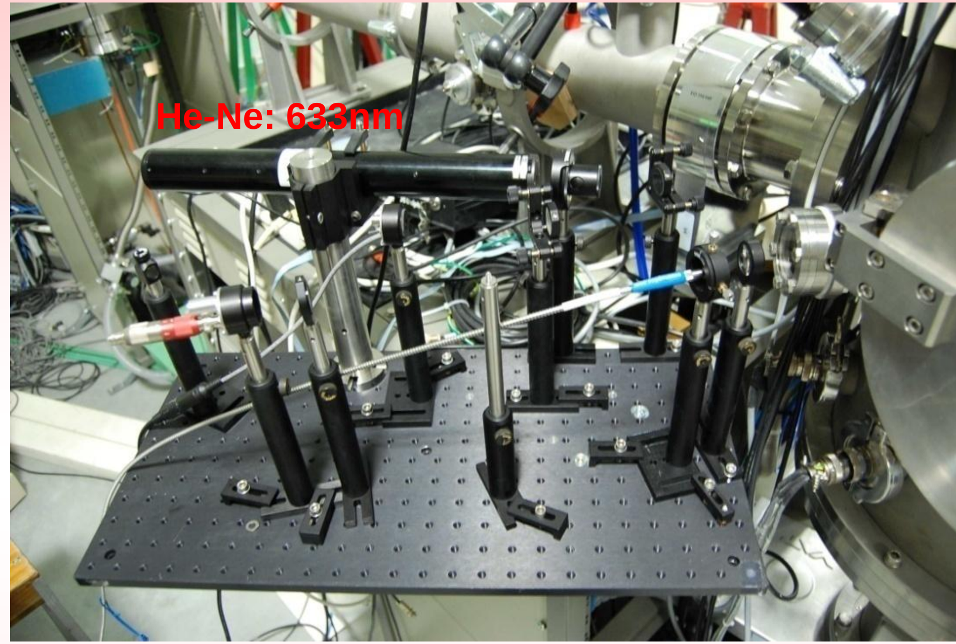
In-situ optical reflectance... ion irradiation damage on SiO_2

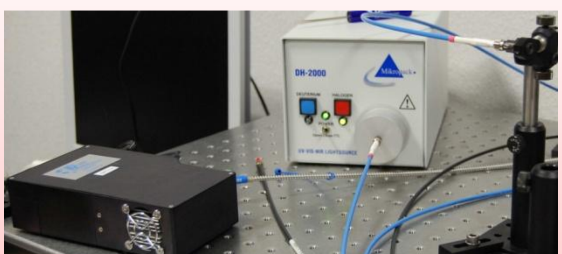
- <u>Experimental</u>

Light sources:

- <u>Lasers</u>
  - Easy alignement, good collimation, small spots…
  - High power → low integration time

- <u>White light</u> (λ: 200…400 - 900 nm)
  - More spectral information
  - Better stability…



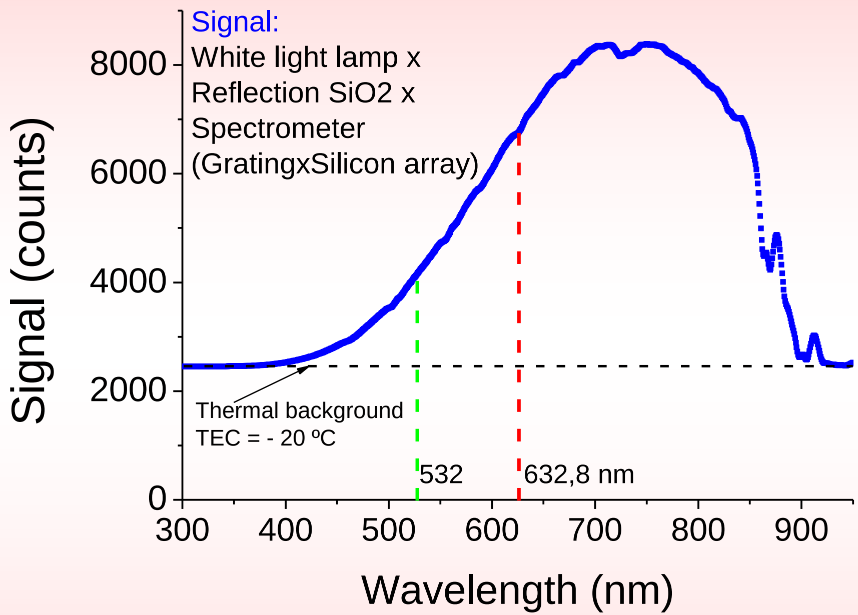


Optical fibers:
ϕ1000 μm: more light
…400 μm
ϕ 50 μm: better collimation

QE65000 OceanOptics
Back-thinned “CCD” sensor
TEC: -20 ºC; 16 bits; 65000 counts

In-situ optical reflectance... ion irradiation damage on SiO_2

- <u>Experimental</u>



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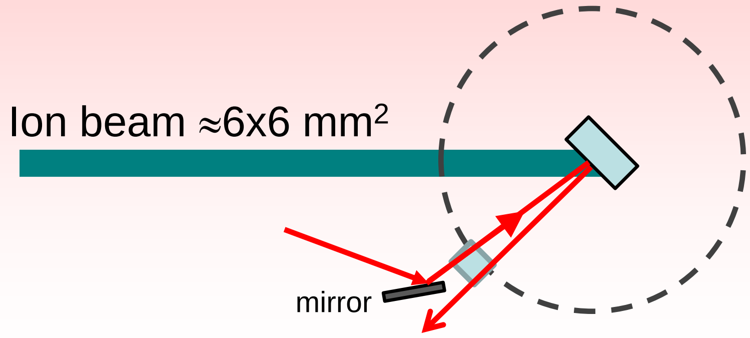
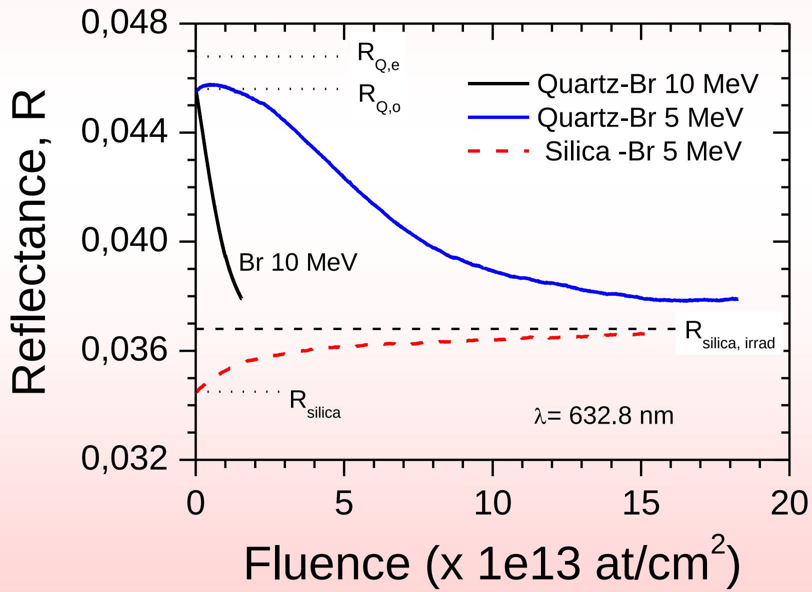
In-situ optical reflectance... ion irradiation damage on SiO_2

- Experimental

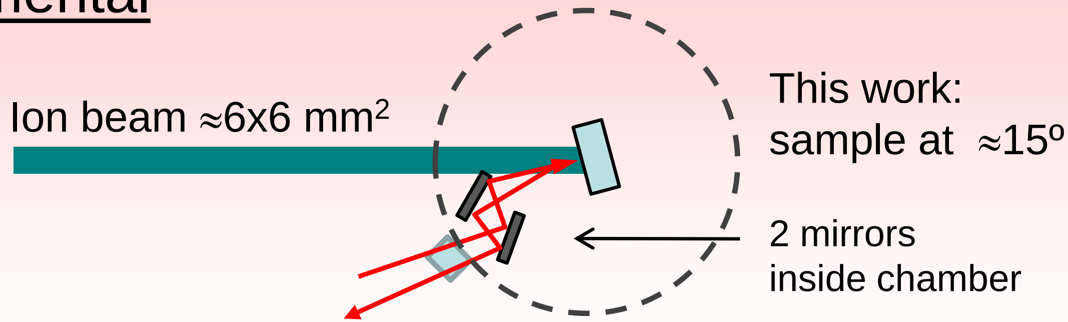


Initial tests:
sample at ≈45º

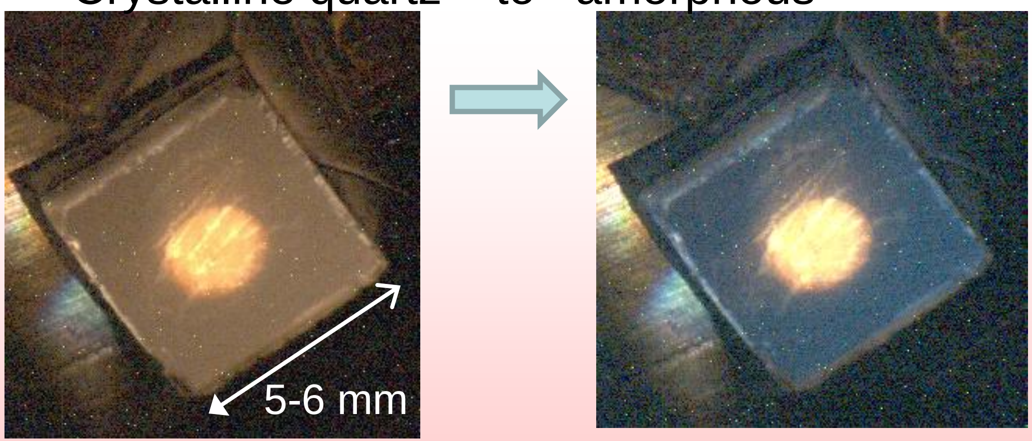


In-situ optical reflectance... ion irradiation damage on SiO_2

- <u>Experimental</u>



Crystalline quartz to amorphous

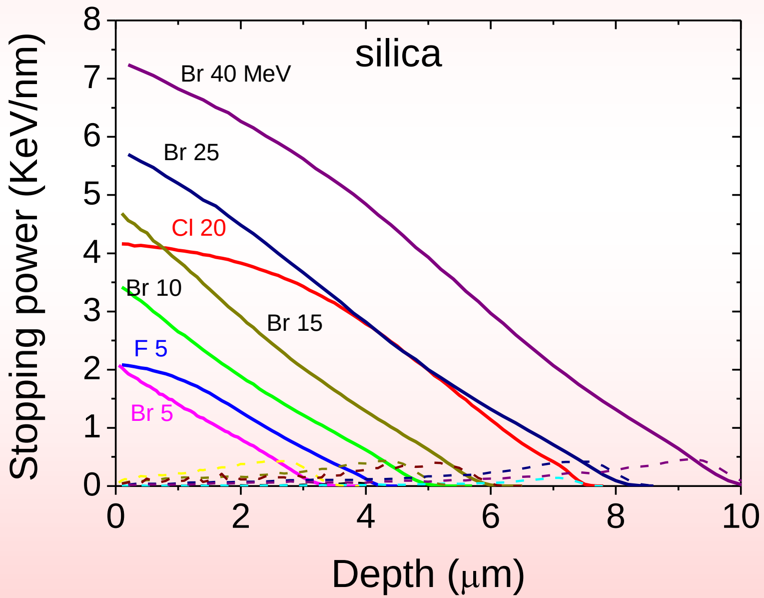


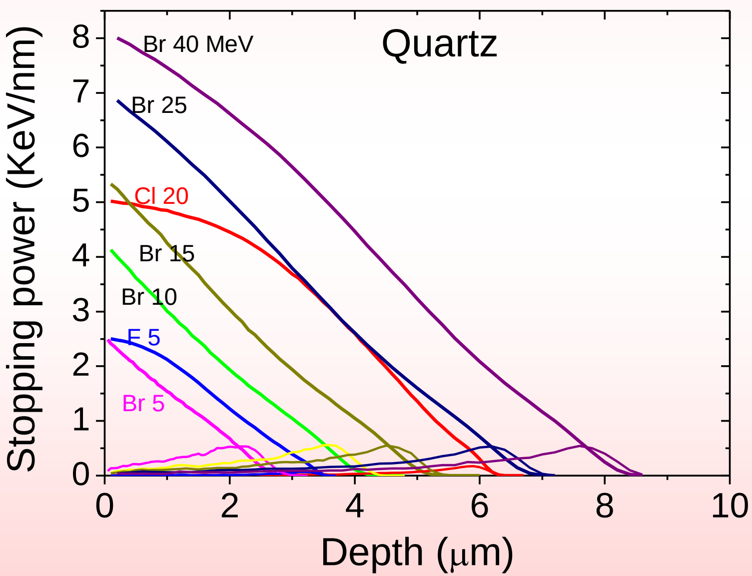
In-situ optical reflectance... ion irradiation damage on SiO_2

- <u>Experimental</u>

<u>Ions</u>
Br 5, 10, 15, 25, 40 MeV
F 5 MeV

<u>Samples</u>
Silica
α-quartz
Thermal SiO2-Si

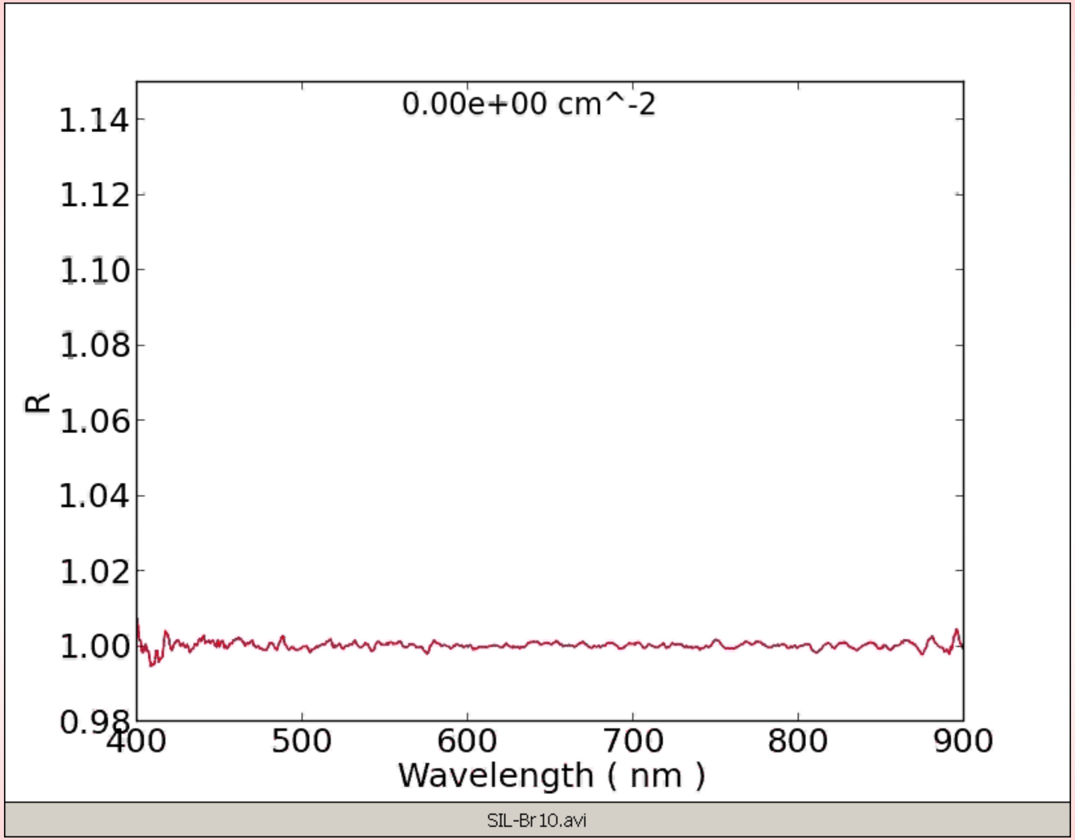




In-situ optical reflectance... ion irradiation damage on SiO_2

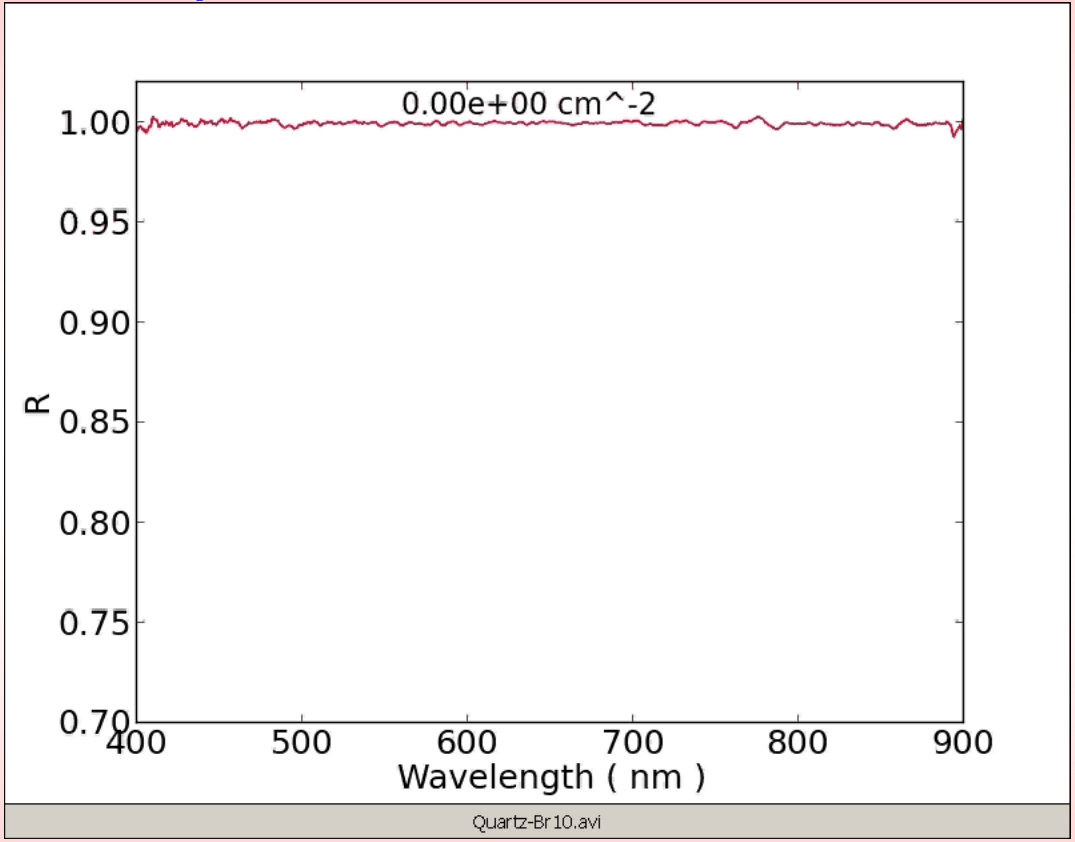
In-situ optical reflectance... ion irradiation damage on SiO_2

Silica – Br 10 MeV

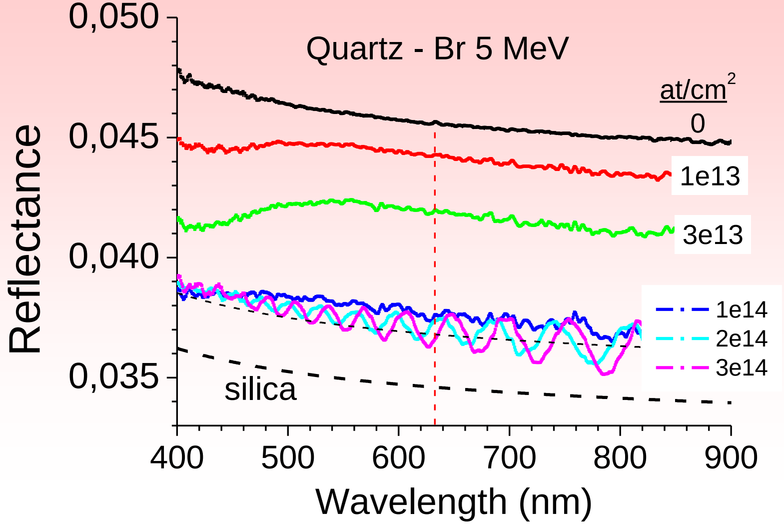


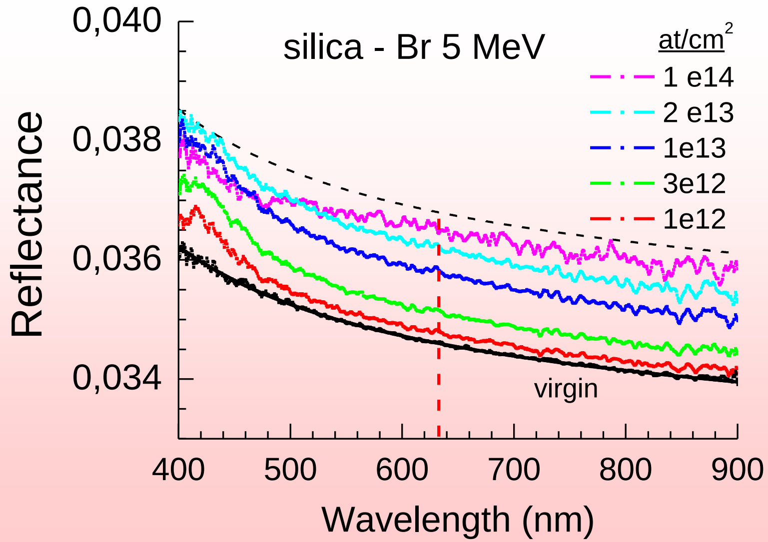
In-situ optical reflectance... ion irradiation damage on SiO_2

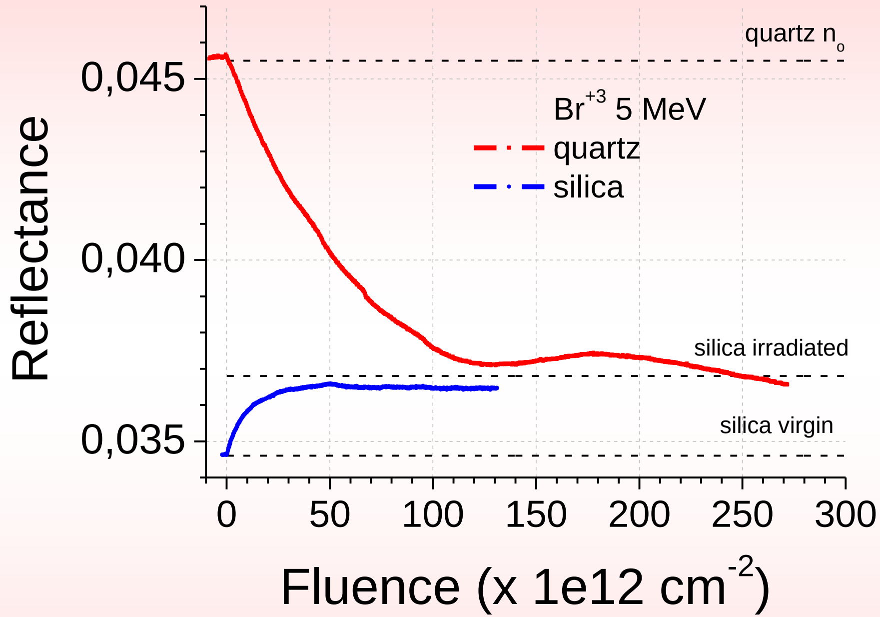
Quartz – Br 10 MeV



In-situ optical reflectance... ion irradiation damage on SiO_2







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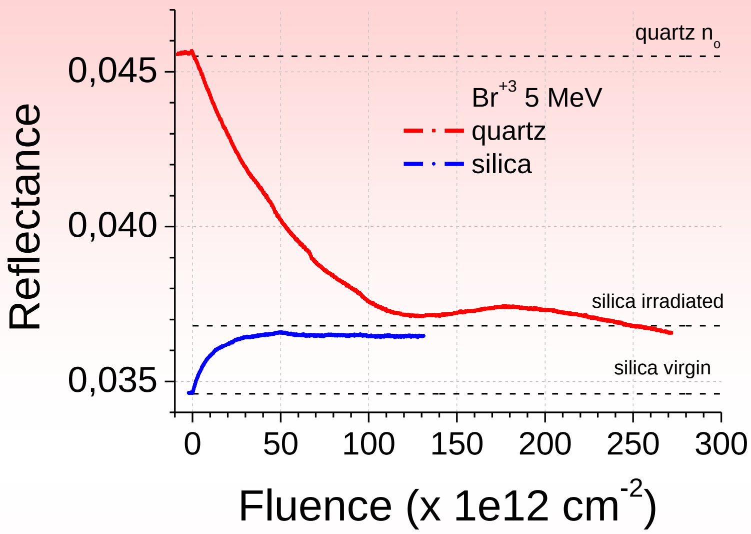

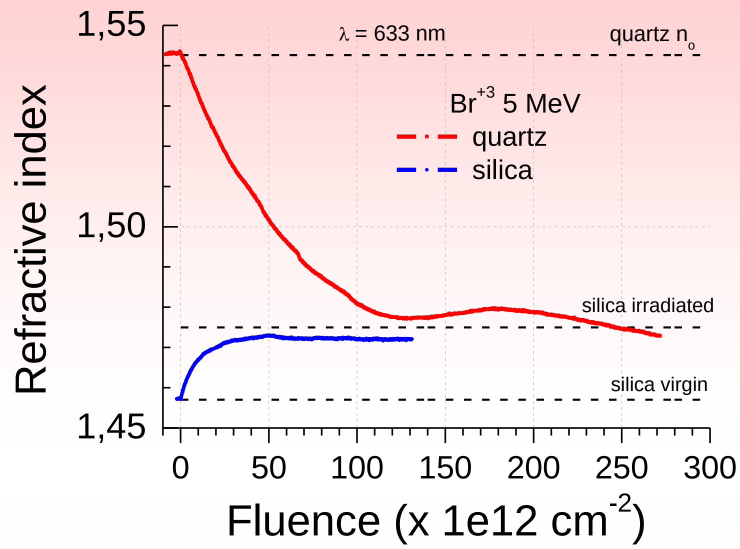

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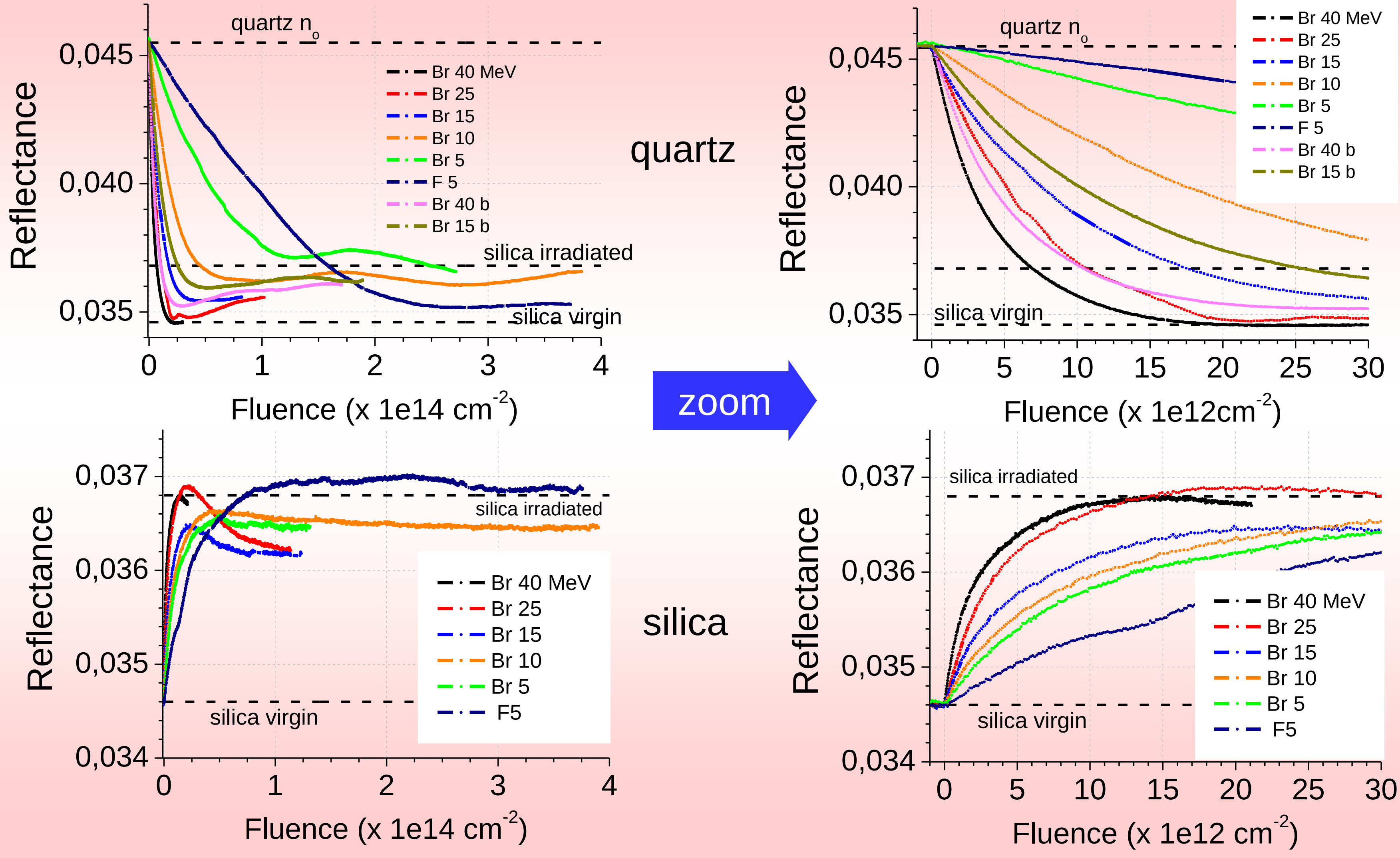

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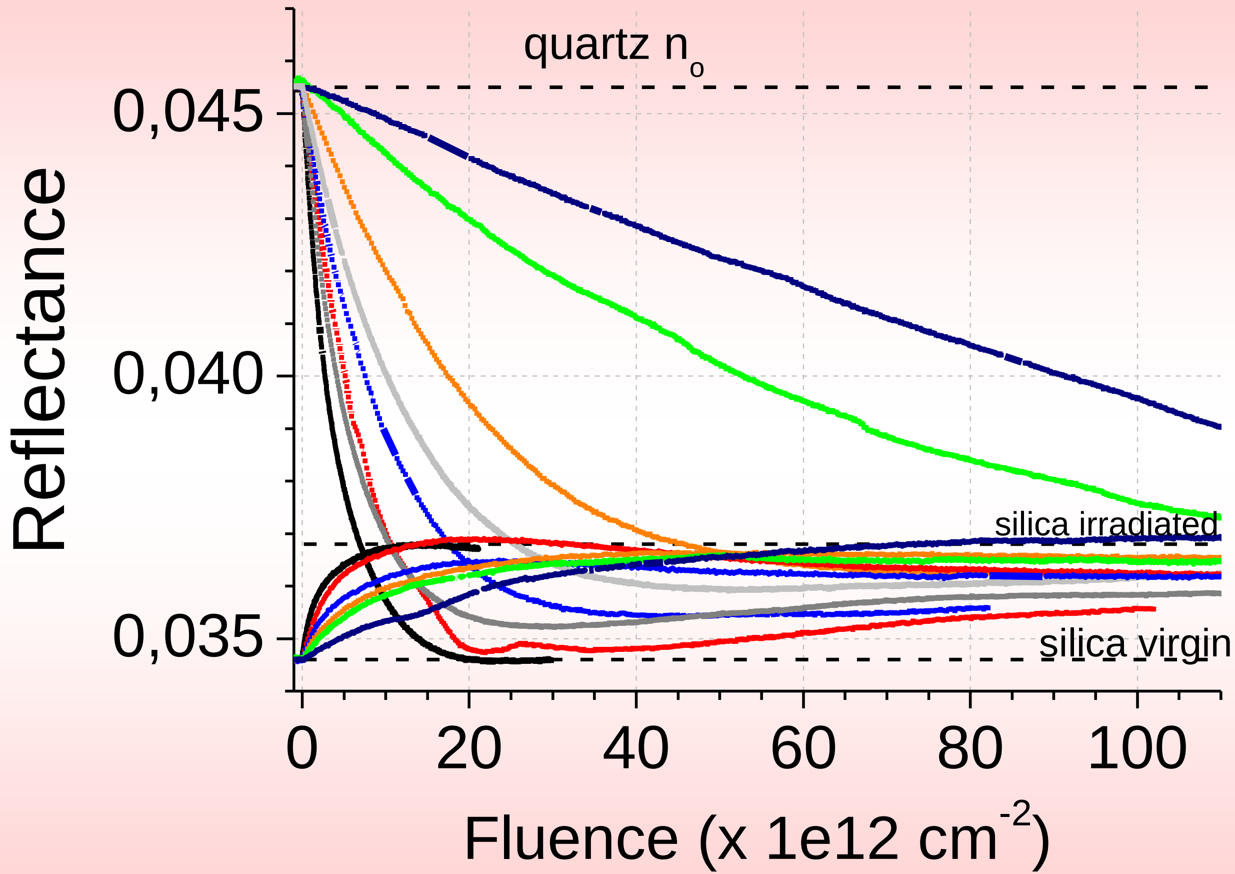

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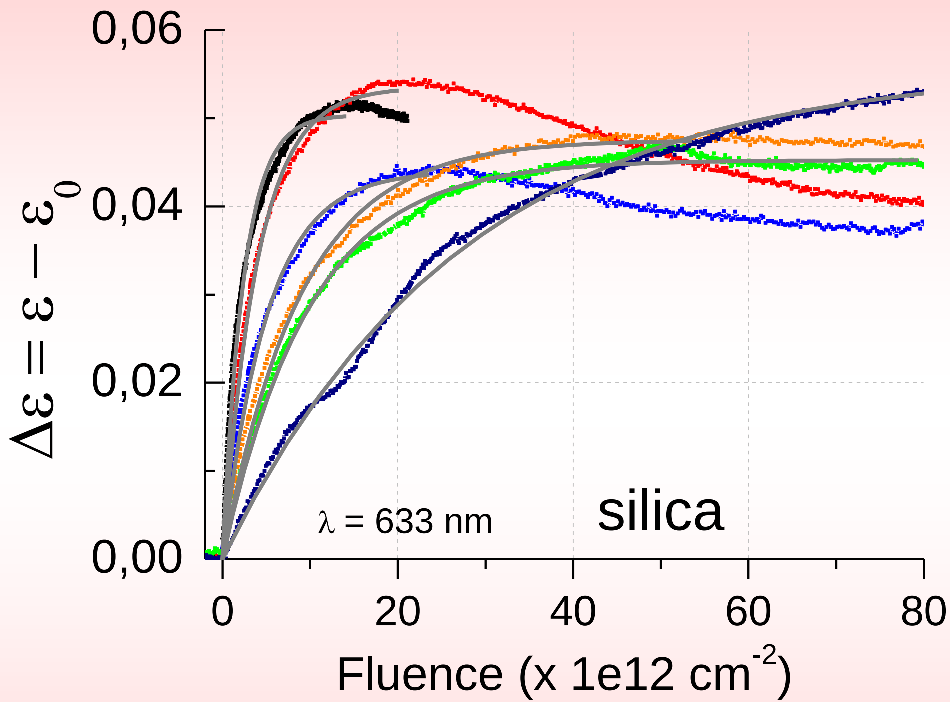
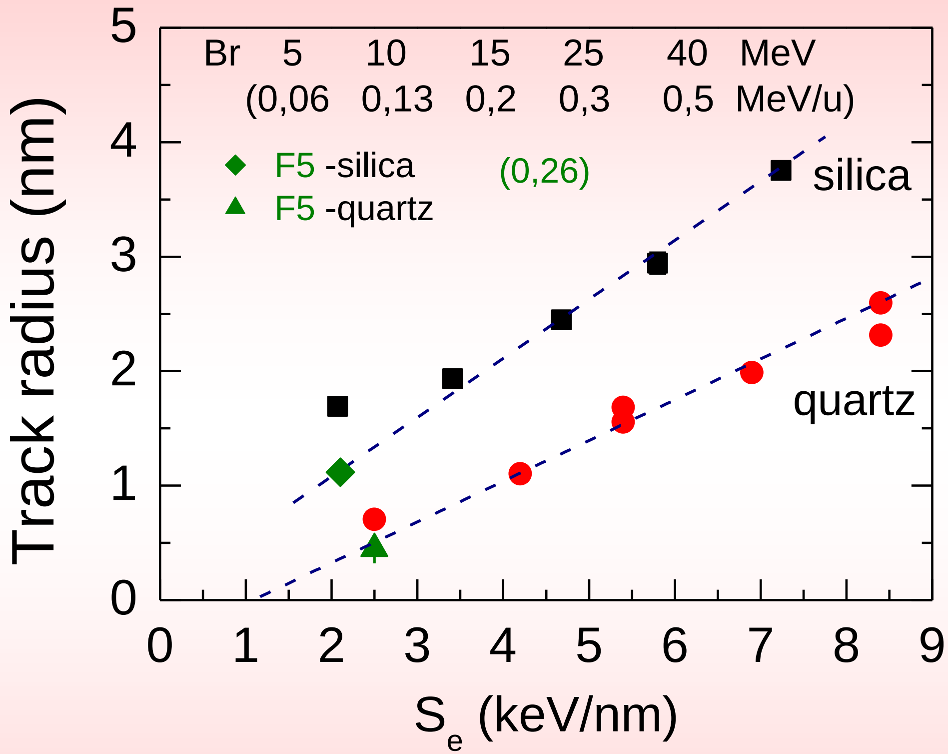


Good Poisson fittings both silica and quartz

We obtain:
- cross sections σ
- and track radius

$\sigma = \pi r^2$

In-situ optical reflectance... ion irradiation damage on SiO_2



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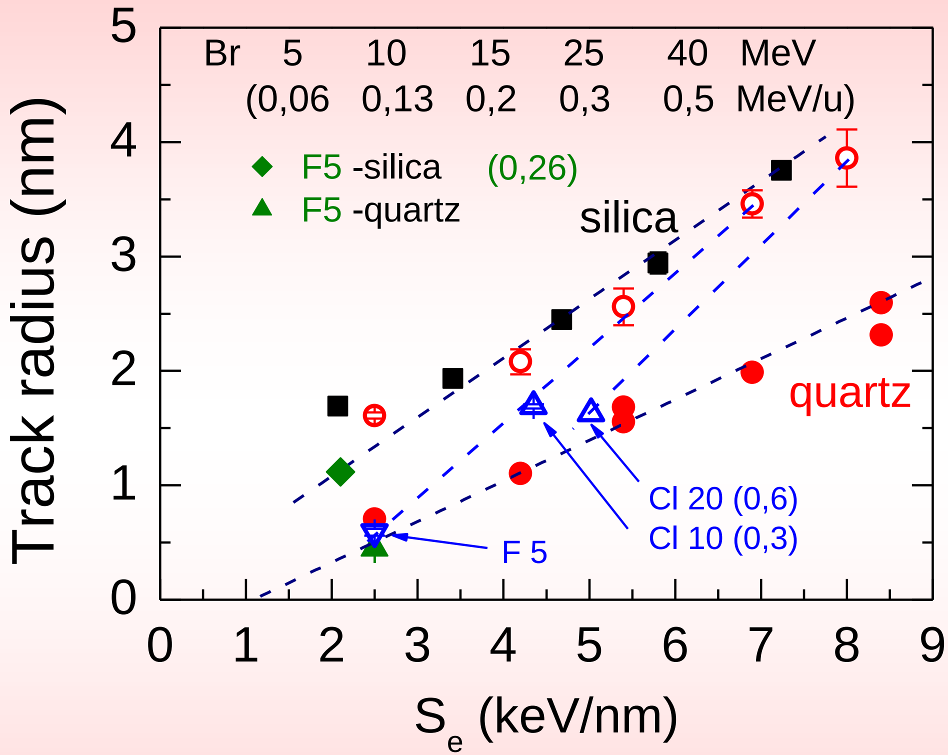
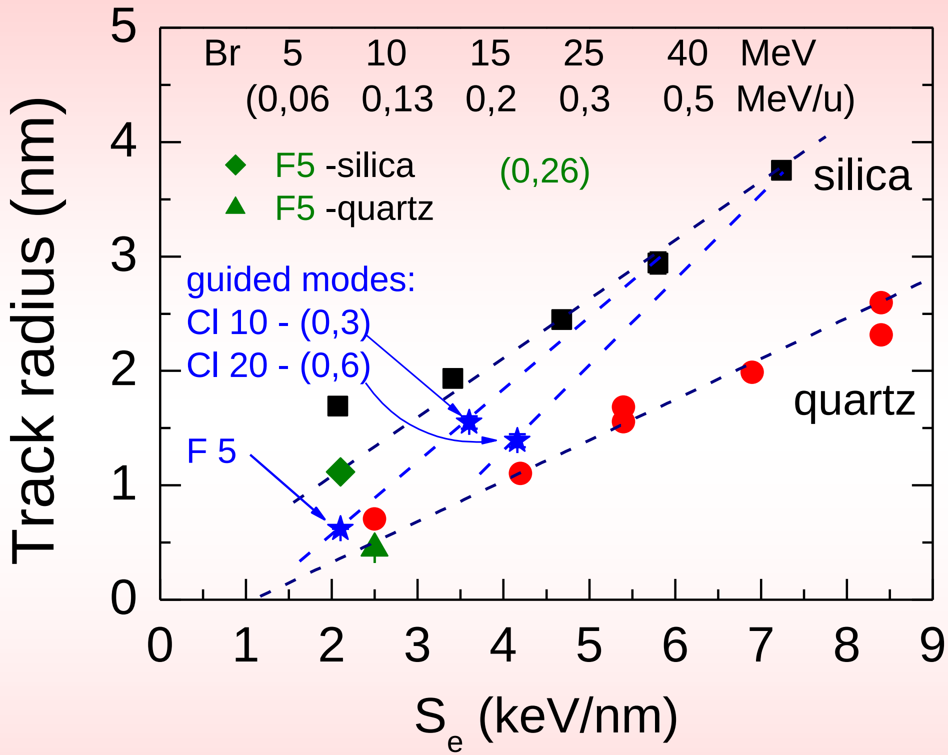


Reflectance data
+
RBS-c data (quartz)

Tracks = core + halo

In-situ optical reflectance... ion irradiation damage on SiO_2



Reflectance data

+

old waveguides data

In-situ optical reflectance... ion irradiation damage on SiO_2

Conclusions:

- The in-situ reflectance is a powerful technique for efficient and reliable damage assessment

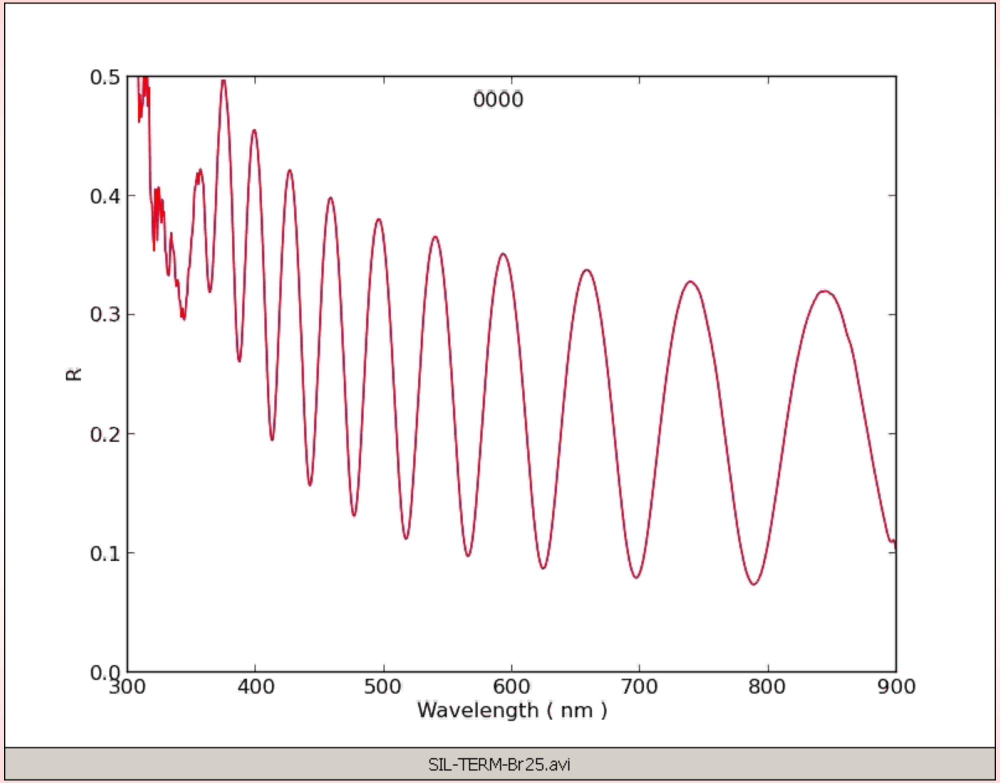
- Moreover is not expensive…

- The simultneous measurement of silica and quartz has opened new insights…

In-situ optical reflectance... ion irradiation damage on SiO_2

Further pending work
with thermal silica-silicon

Ask for this movie!



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Thank you for your attention!

Acknowledgements:

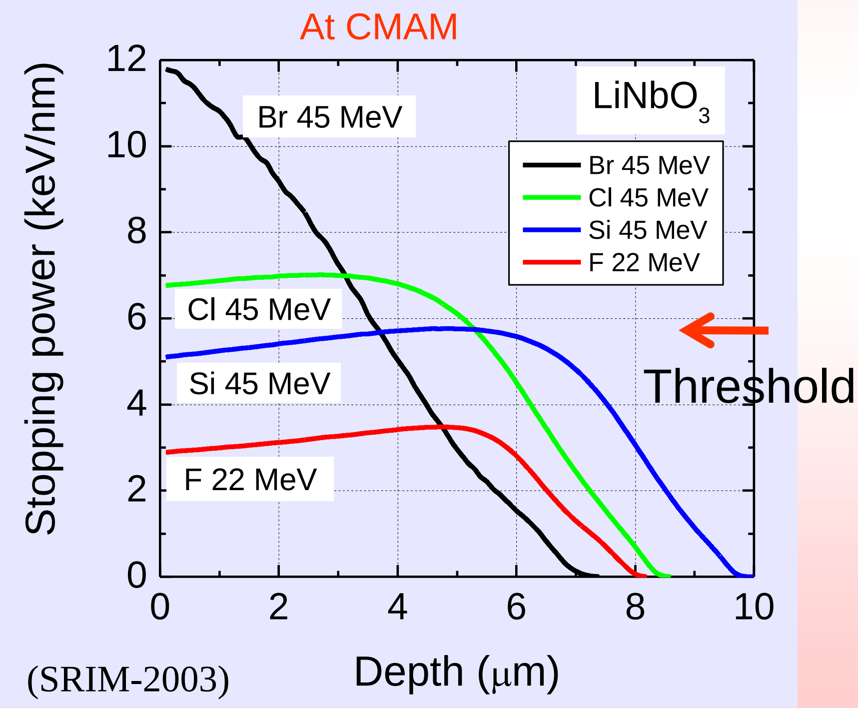
Projects:

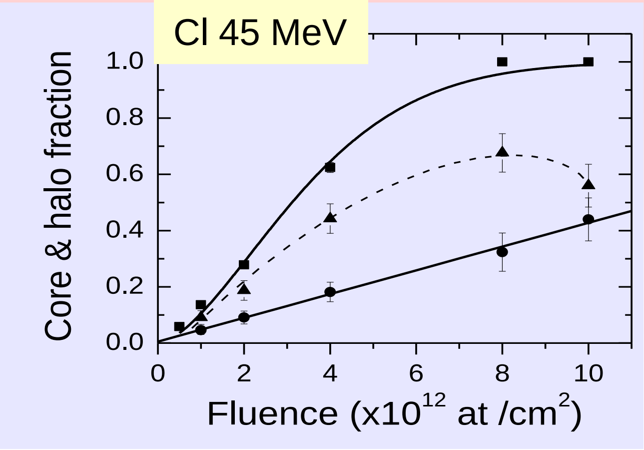
- MAT-2011-28379-C03-02, from national MEC, Spain
- TECHNOFUSION (S2009/ENE-1679) from Regional Government CAM, Madrid

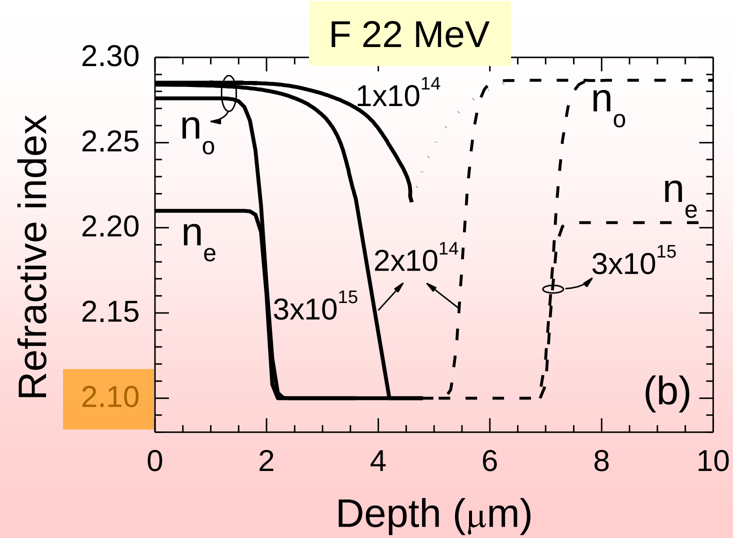
In-situ optical reflectance... ion irradiation damage on SiO_2

Motivation

- Summary of previous work on LiNbO3
  - after optical waveguide fabrication…
  - optics interesting for damage assessment,
  - sub-threshold damage vs over-threshold



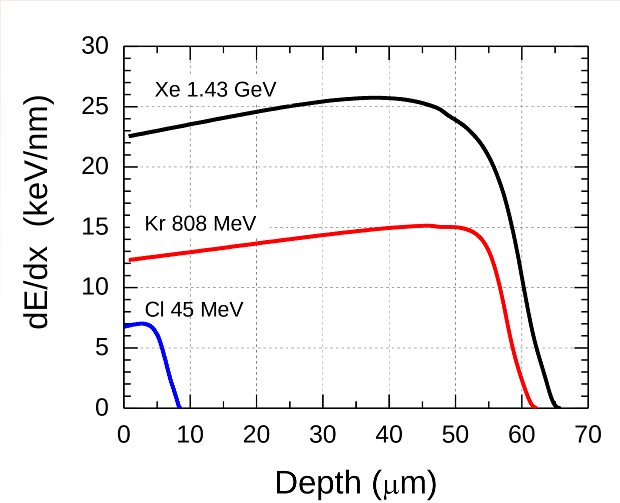




In-situ optical reflectance... ion irradiation damage on SiO_2

Motivation…

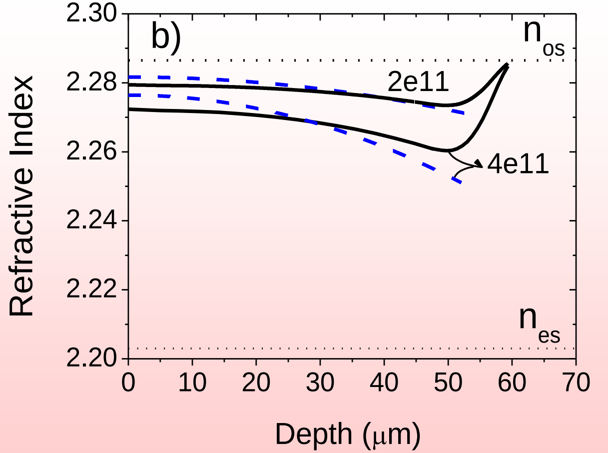
Summary of previous work on LiNbO3



Effective medium:

$$\varepsilon_{o,eff}(x) = \varepsilon_a f_a + \varepsilon_o (1 - f_a)$$

$$\varepsilon_{e,o} = (n_{e,o})^2$$
$$\varepsilon_a = (2.1)^2$$



J. Olivares, et al Optics Express (2009)