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Advanced European Infrastructures for Detectors at Accelerators

Presentation

Rare earth doped silica-based optical fibres for high energy physics detectors

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26 September 2016

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Rare earth doped silica-based optical fibres for high energy physics detectors

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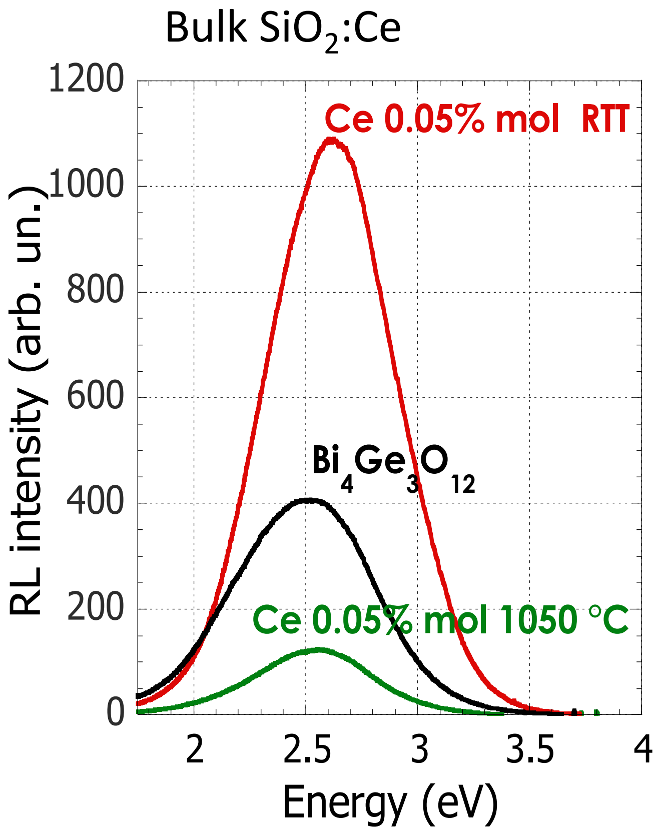
SiO_2:Ce fibres for medical applications

❖ Real time in-vivo dosimetry is a new challenging methodology in the medical field

❖ It is necessary in order to ensure beam quality of new medical irradiation systems and to precisely control dose levels to patients

❖ Silica based optical fibre radioluminescence (RL) dosimeters are promising systems for this purpose



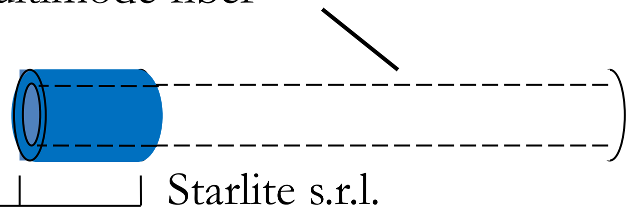
Chiodini et al. APL 81, 4374 (2002)

SiO_2:Ce fibres for medical applications

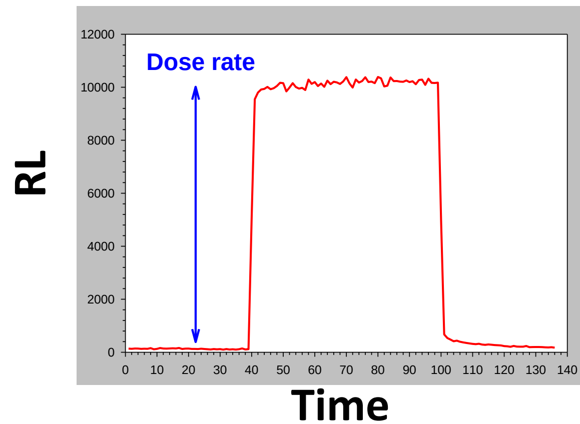
Hard polymer clad multimode fiber

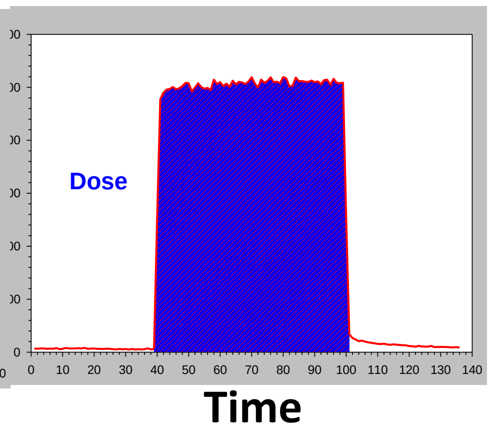
PMT detection

Active portion
Ce-doped SiO_2



Starlite s.r.l.
ELSE srl/Fraen srl

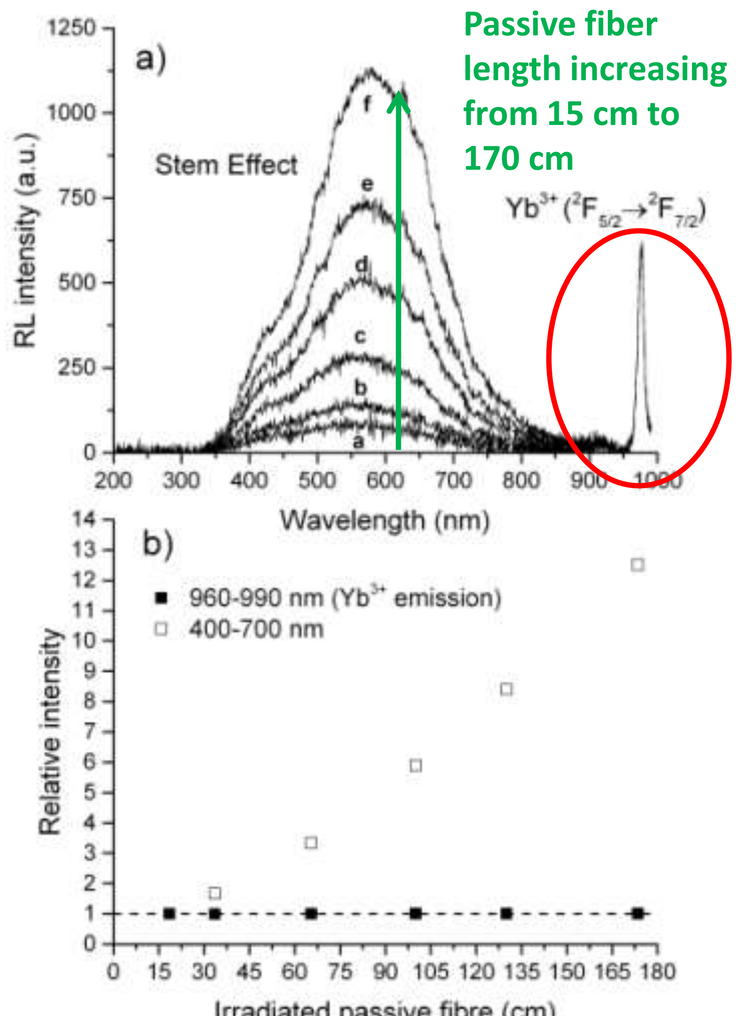




Error < 1% below Cerenkov threshold

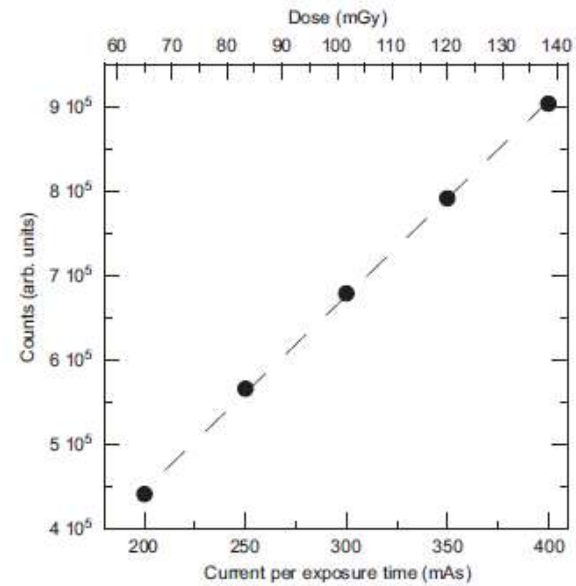
High temporal resolution (luminescence decay time of Ce^{3+} radiative transition: 60 ns)

SiO_2:Ce fibres for medical applications: some examples



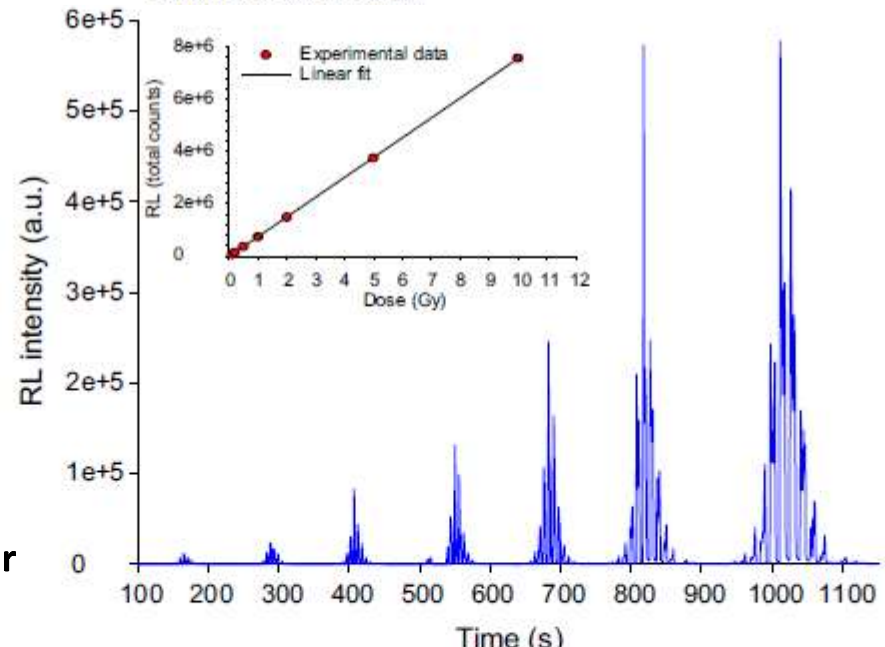
6 MV photons. Stem effect removal by using other activator ions

I. Veronese et al. APL 105, 061103 (2014) ,
JPhysD 46, 015101 (2013), JPhysChemC 119, 11572 (2015)



Dose evaluation in CT

Caretto et al., NIM A 612, 407 (2010)

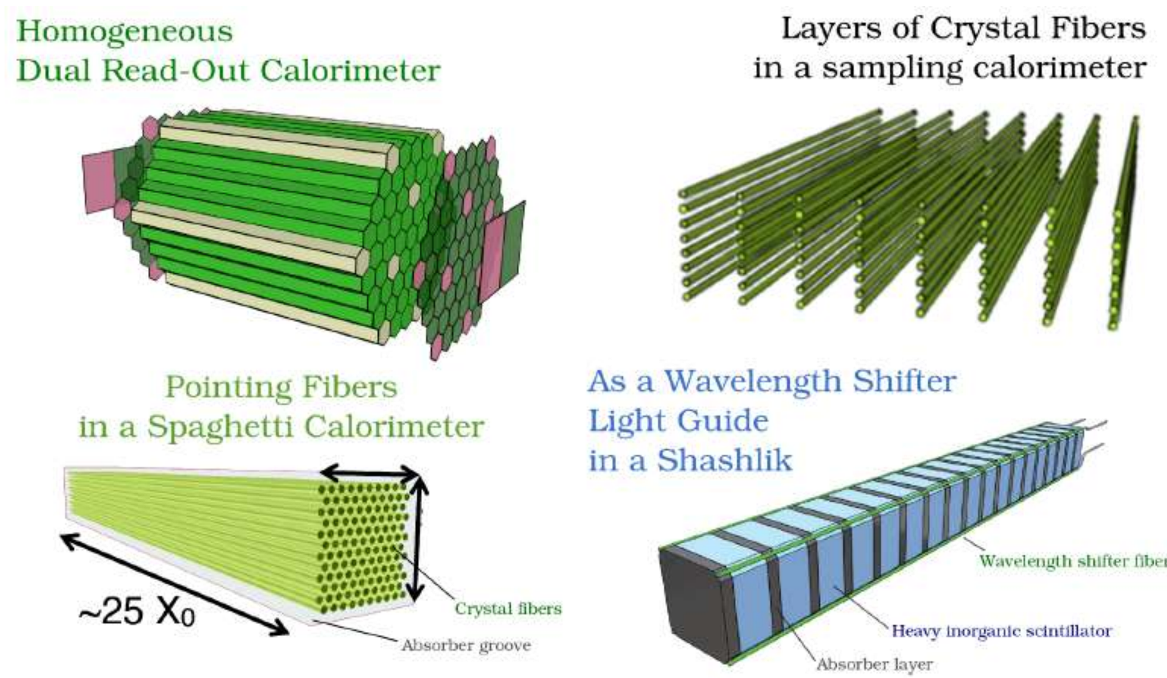


Fiber response to 138 MeV proton irradiation

I. Veronese et al., Rad. Meas. 45, 635 (2010).

Fibres in HEP new calorimeters

Next generation of detectors in HEP experiments will require high spatial resolution and very good timing performaces: some proposed calorimeters are based on scintillating optical fibres



Lucchini, PHD thesis

Can we use SiO_2:RE (RE= Ce, Pr) optical fibres also in HEP?

SiO_2:Ce, Pr samples and characterization

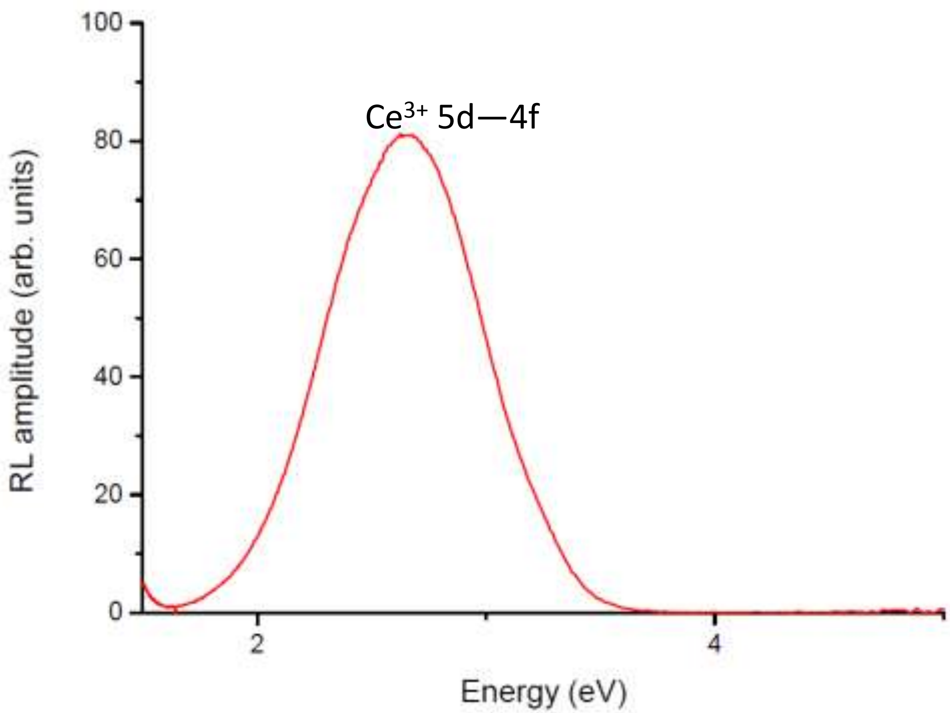
Samples: sol-gel SiO_2 doped with 500 or 125 ppm Ce or Pr in form of
-- preforms
-- optical fibres (Ce only):
2 geometries
core diameter: 600 µm or 365 µm
cladding: F-doped silica and polymeric, respectively

Characterization:
Radio-luminescence (RL)
Optical Absorption (OA) and radiation hardness
Light attenuation
Light Yield and scintillation decay

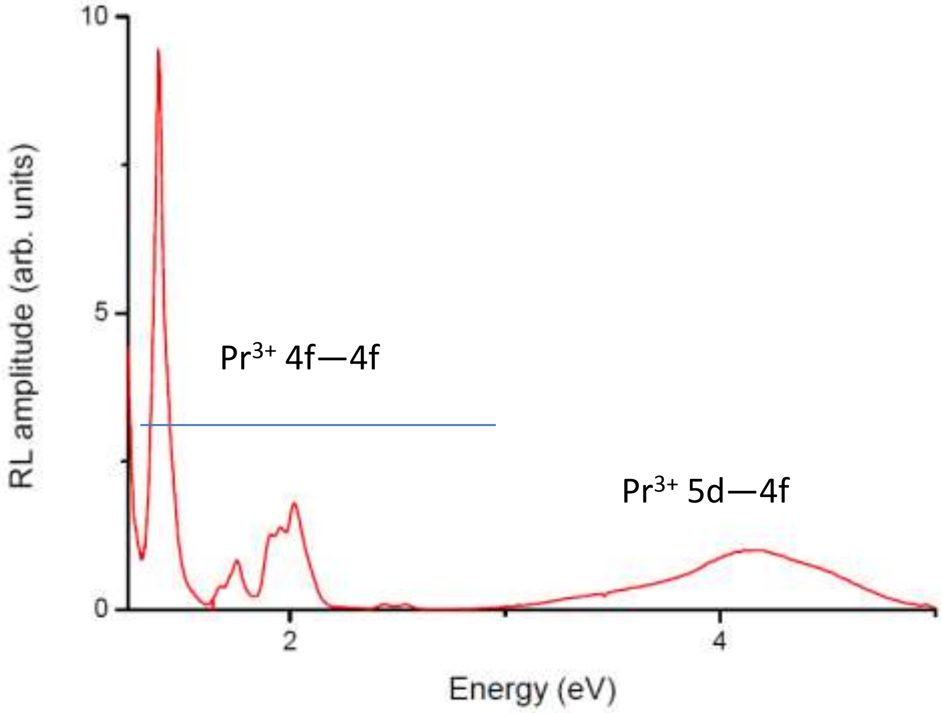
SiO_2:Ce, Pr preforms, Radio-Luminescence RL

RL spectra of SiO_2: Ce, or Pr preforms are typical for the two rare earths
Non-homogeneous broadening of Pr^{3+} 4f-4f transitions is clearly evident

SiO_2:Ce

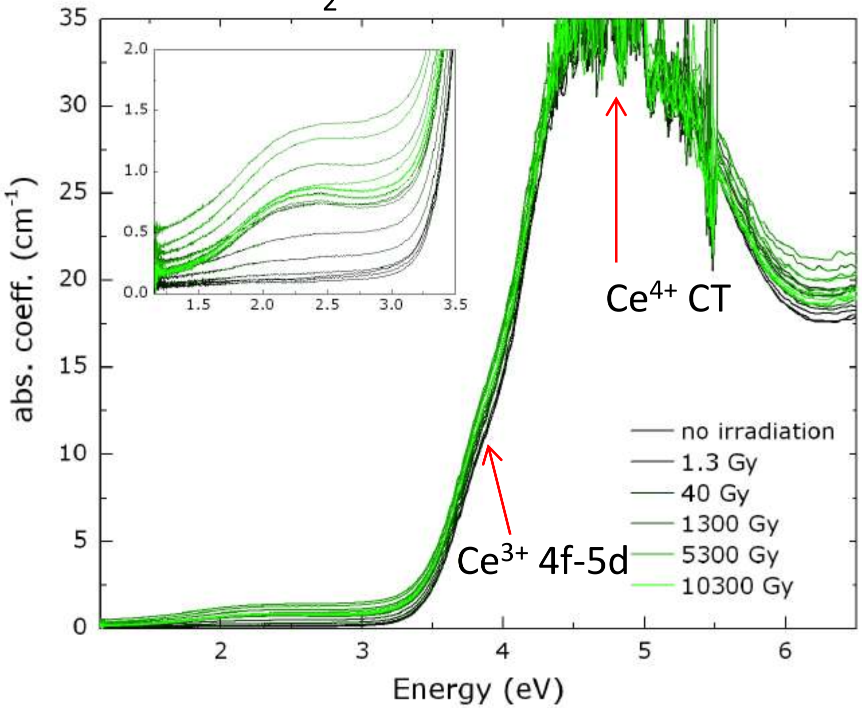


SiO_2:Pr

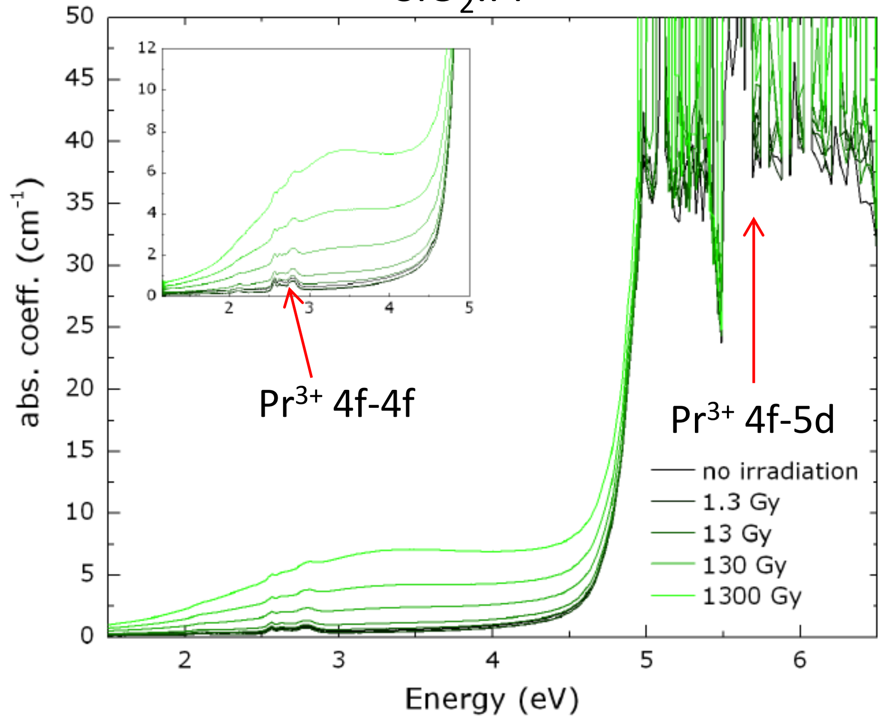


SiO_2:Ce, Pr preforms, optical absorption (OA) and X-ray irradiation

SiO_2:Ce



SiO_2:Pr

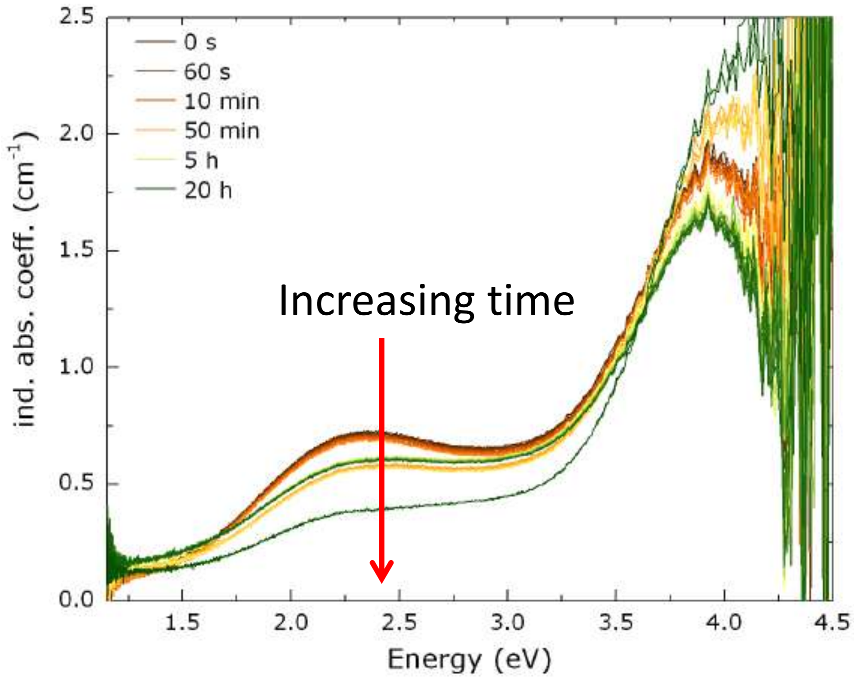


Ce^{3+} and Ce^{4+} absorptions at 3.9 and 4.9 eV, respectively.
X-ray irradiation is the cause of evident, though weak (1.5 cm^{-1}), absorption at about 2.4 eV (516 nm)

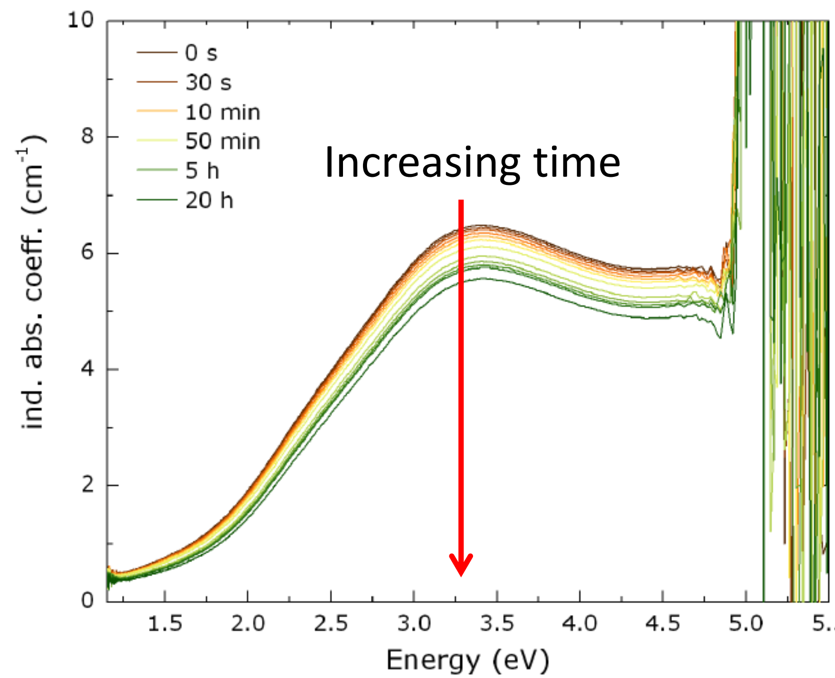
Pr^{3+} related absorptions above 5 eV and 2.7 eV, respectively.
X-ray irradiation is the cause of evident broad absorption at about 3.3 eV (375 nm)

SiO_2:Ce, Pr preforms, optical absorption (OA) and X-ray irradiation: recovery with time at RT

SiO_2:Ce

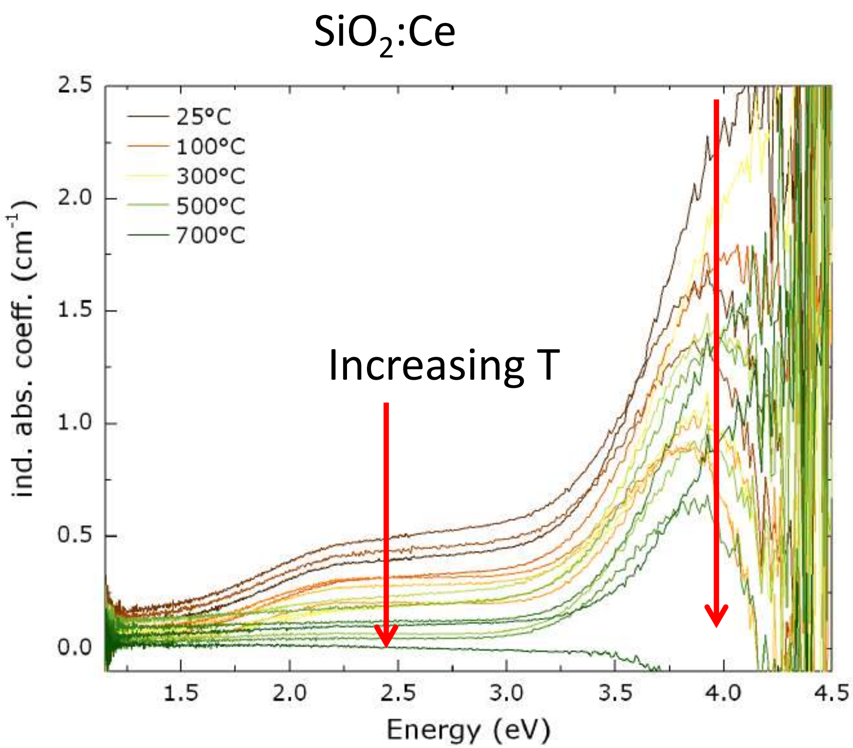


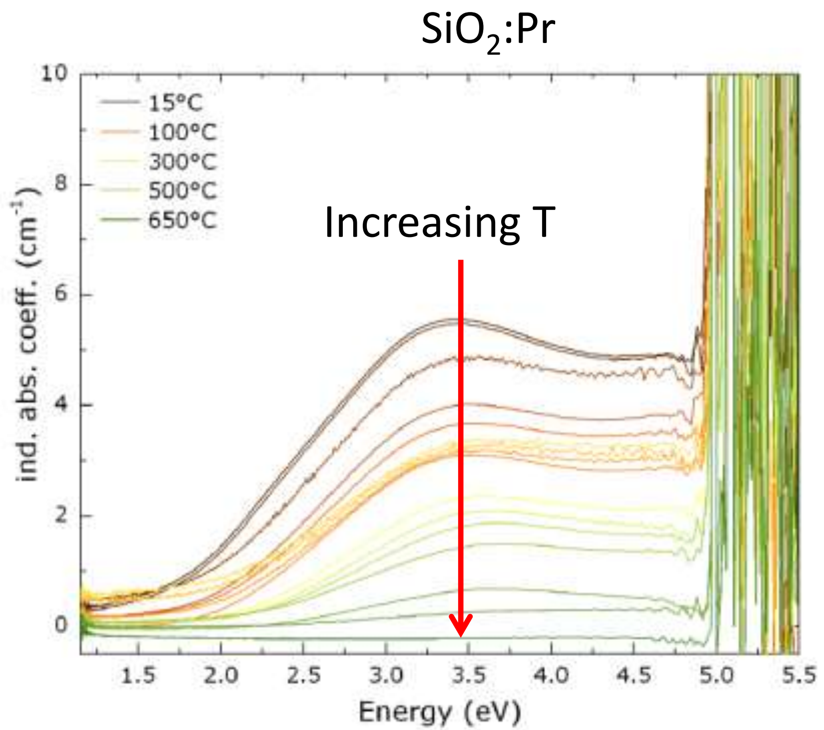
SiO_2:Pr



For both Ce- and Pr-doped SiO_2 preforms time reduces the presence of induced absorptions. Recovery of Ce-doped preform is more evident.

SiO_2:Ce, Pr preforms, optical absorption (OA) and X-ray irradiation: thermal recovery

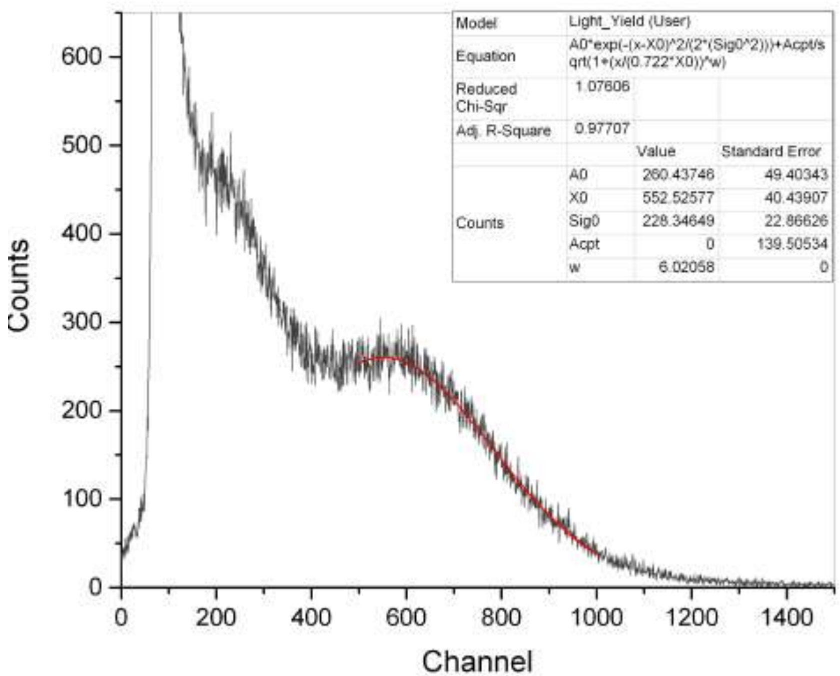




For both Ce- and Pr-doped SiO_2 preforms heating up to 650 °C allows to eliminate the radiation induced absorptions.
Thermal treatment duration 15 min each.

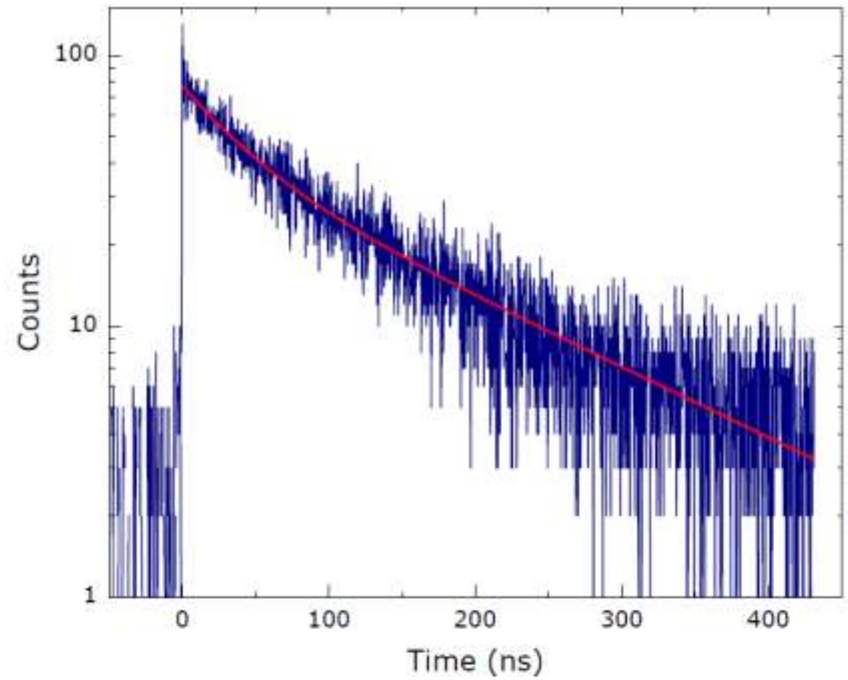
SiO_2:Ce preforms, Light yield and scintillation decay

Light yield @ 59 keV (^{241}Am)



SiO_2:Ce preform LY= 2000 Ph/MeV

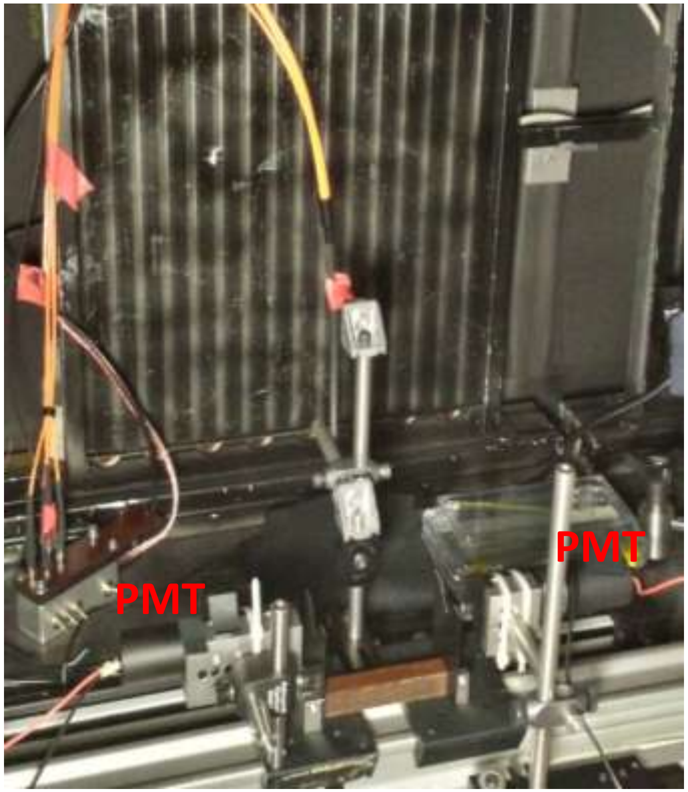
Scintillation decay time (source ^{22}Na)

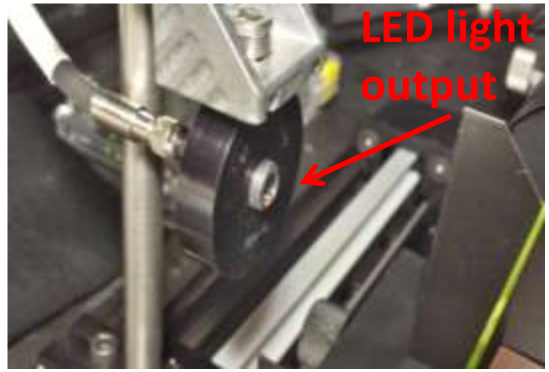


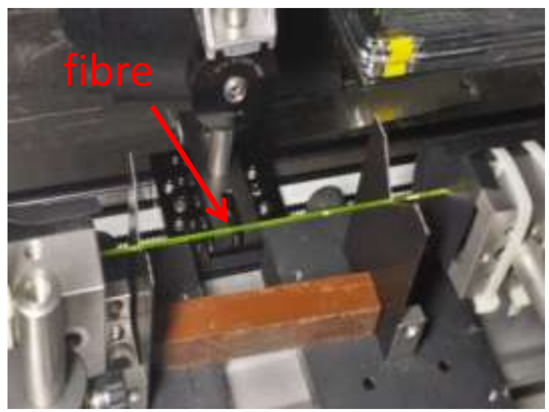
Main scintillation decay time 100 ns

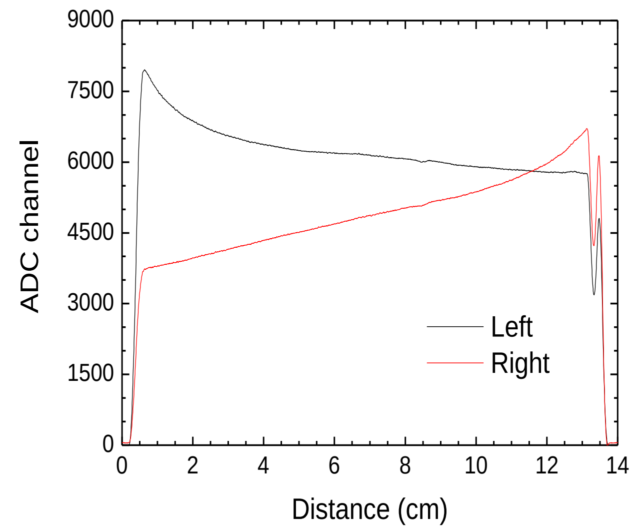
No scintillation signal from Pr doped preform

SiO_2:Ce fibres: attenuation set-up (@CERN)





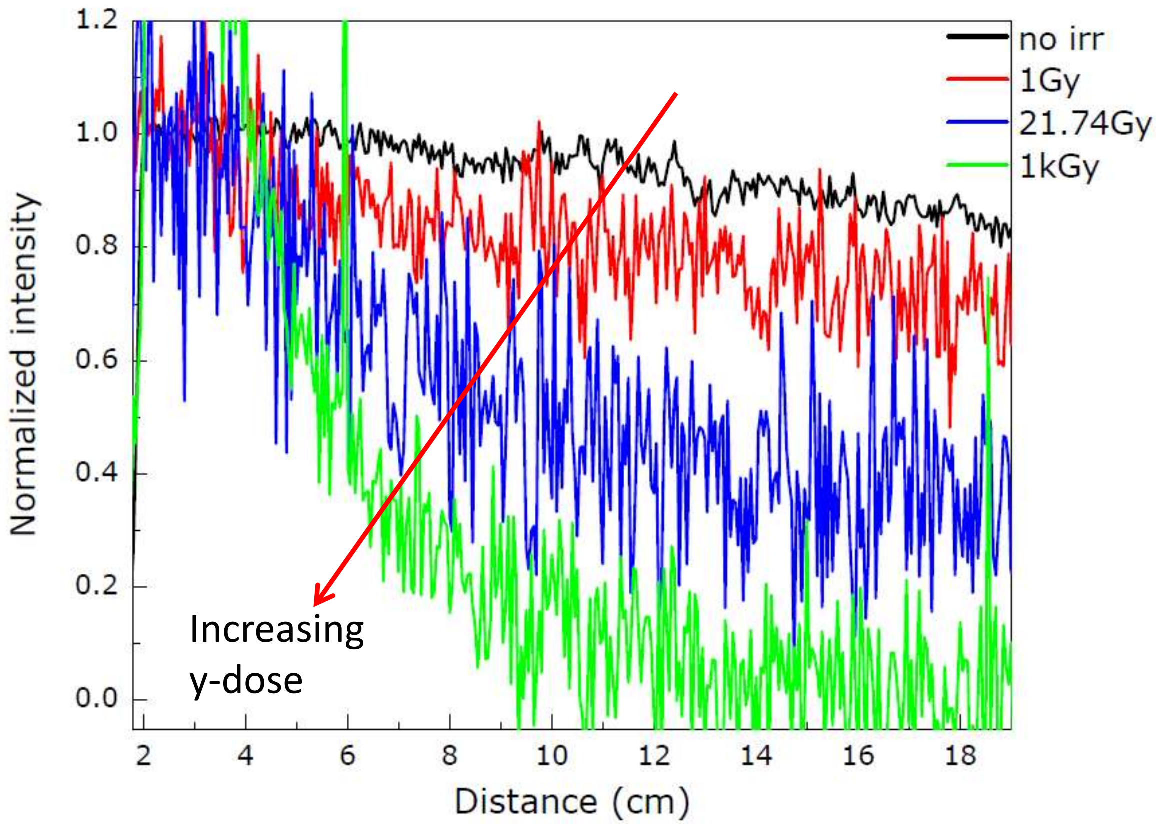




SiO_2:Ce fibres: attenuation VS ^{60}Co γ-ray dose

Excitation diode wavelength 365 nm, not well matched with Ce^{3+} excitation band

Due to the presence of Ce^{4+}, these glasses give rise to weak photoluminescence



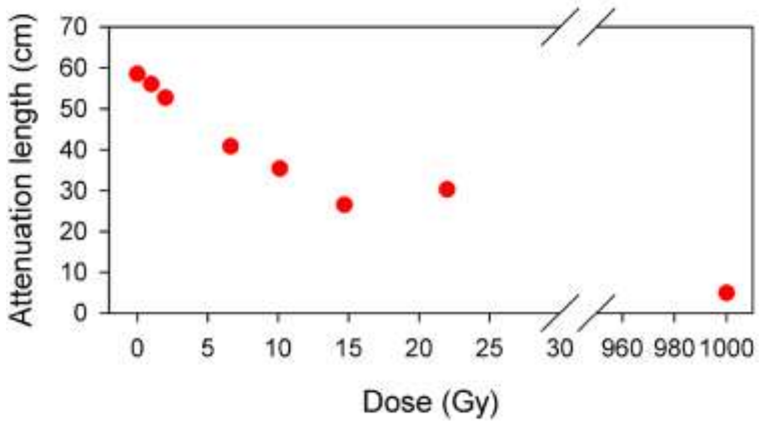
Attenuation length (in cm) for different ^{60}Co cumulative doses imparted to the fibres. These values are rather qualitative

fibre	0 Gy	1 Gy	2 Gy	6.6 Gy	10.13 Gy	14.7 Gy	22 Gy	1 kGy
F-doped cladding	65	34	43	24	27	22	15	6
Polymeric cladding	58	56	53	41	35	26	30	5

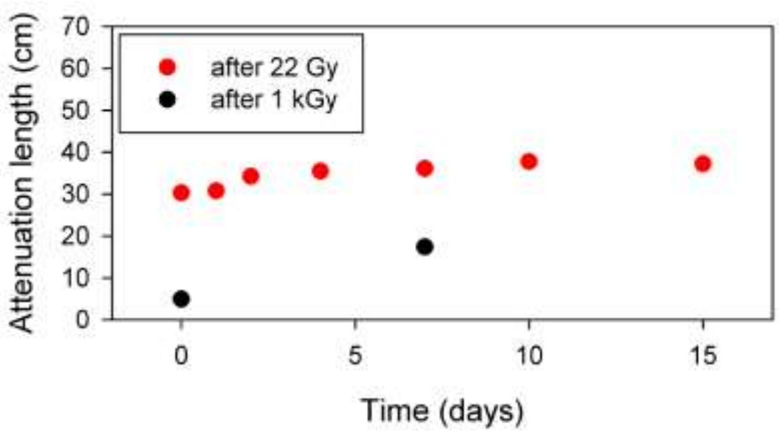
SiO_2:Ce fibre: attenuation and recovery at RT

Qualitative data

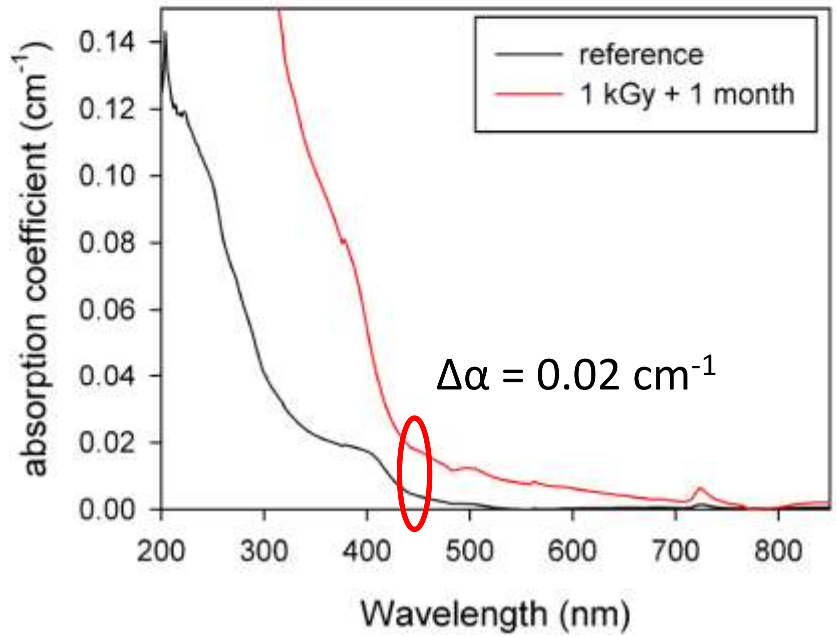
Polymeric cladding fibre



Recovery at RT, polymeric cladding fibre



Faster recovery at RT after 1 kGy than after 20 Gy y-dose



Calculated Attenuation length from OA data

˜50 cm

Is there a further pronounced recovery on a longer timescale after 1 kGy irradiation?

Conclusions and perspectives

- Fibres showed promising results for applications in High Energy Physics, they are, in fact, rather bright and their luminescence decay time is fast. In perspective they could be obtained in large volume at a low price

- At the moment, the fibres seem to be relatively easily damaged by ionizing radiation, though the radiation induced optical absorption band tend to recover with time.

- Further studies are needed in order to increase radiation hardness and light yield.

Acknowledgements

H2020 Marie Sklodowska-Curie RISE

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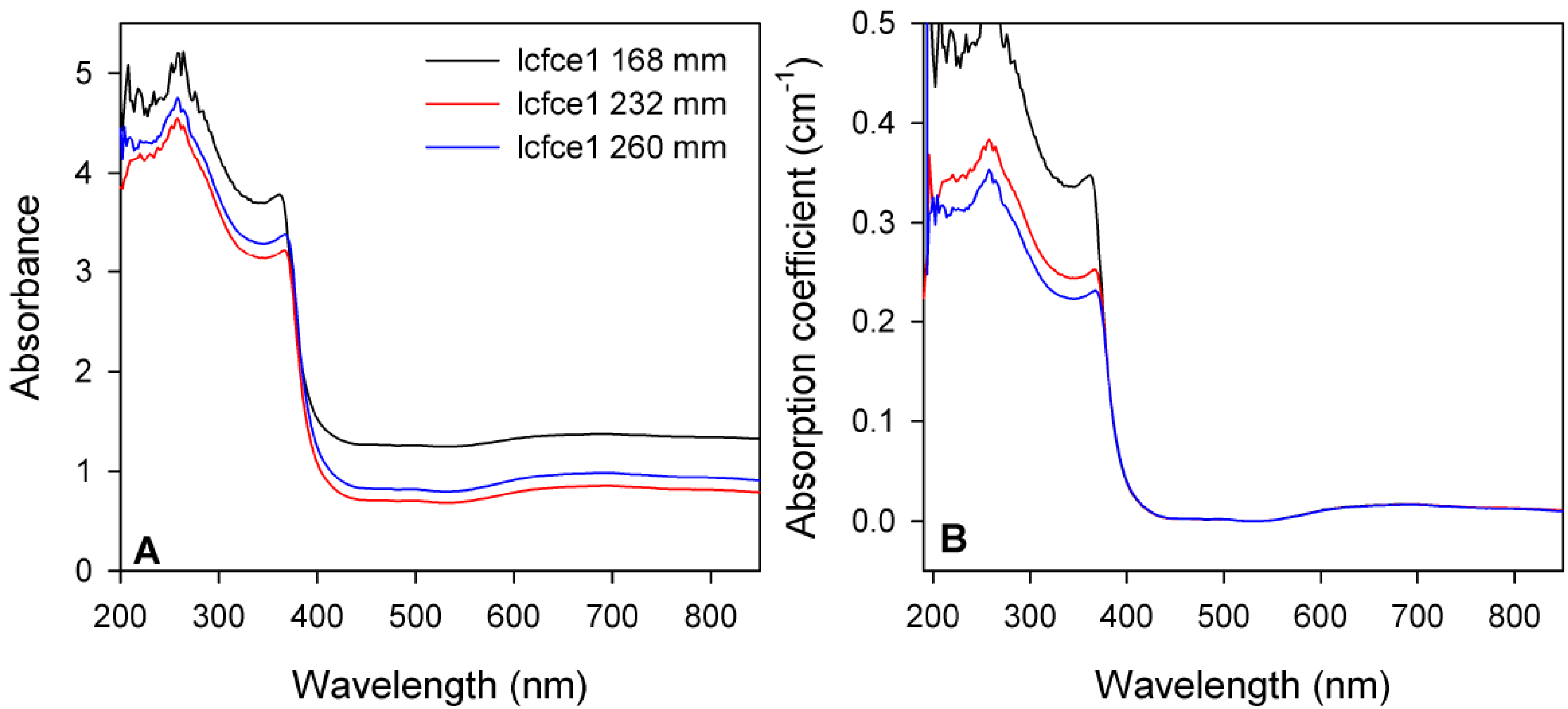
Thank you for your attention!

SiO_2:Ce fibre: Optical absorption

Togliere parte A

Three different fibre lengths (from 16.8 cm up to 26 cm)



- Absorptions below 380 nm are due to Ce3+ and Ce4+ optical absorption: their structuration is due to luminescence phenomena and system saturation.
- Broad bands above 550 nm are of unclear origin, and are barely visible also on preforms