X-Lab as a new X-ray Facility at LNF

Dariush Hampai

5th September 2010 - Channeling 2010

Ferrara

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Collaborations

Channeling 2010

- Prof. S.B. Dabagov (Resp.)
- Dr. D. Hampai
- Dr. G. Cappuccio
- Dr. V. Guglielmotti

Detectors

INFN - ENEA - CERN

X-ray Spectroscopy – X-ray Imaging

INFN – Diamond Light Source - ENEA – University of Rome "Sapienza" - CNR – University of Bicocca – University of Florence – University of Minsk - Lebedev Physical Institute - UNISANTIS

Novel Source – Nanoray (Eur. Proj.)

Labor, University of Rome "Sapienza" - University of Rome "Tor Vergata"

CENTRO RICERCHE FRASCATI

AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

Partecipants

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Detectors

1) GEMINI Project

- INFN – LNF (F. Murtas)
- ENEA (L. Gabellieri, Resp.)

2) LiF Detector - ENEA

- R.M. Montereali
- F. Bonfigli
- M.A. Vincenti

3) Diamond Detectors (Univ. of Florence)

- Dr. E. Pace

4) CERN-UA9 – Channeling

University of Rome "Sapienza" (G. Cavoto)

F. Murtas

X-ray Spectroscopy – X-ray Imaging

- INFN – LNF (A. Marcelli – A. Gorghinian)
- Univesrity of Bicocca - Milan (V. Maggi)
- Diamond Light Source (G. Cibin)
- CNR – ISMN (S. Nunziante Cesaro)
- University of Rome "Sapienza" (C. Lemorini)
- CNR – IM (Resp. L. Allocca)

Novel Source – Nanoray (Eur. Proj.)

- Labor
- University od Rome "Sapienza" (M. Rossi)
- University od Rome "Tor Vergata" (M.L. Terranova)

A great change for XLab...

"someone" said ... one small step for man...
and now we also can say something similar...

The main XLab purposes

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X-ray Optics – Polycapillary and Compound Refractive Optics

Material Analisys. The X-ray Spectroscopy:

- X-ray Fluorescence (normal and total reflection modes)
- X-ray diffraction
- X-ray Imaging

Diagnostic Applications.

- X-ray Imaging for large object with high spatial resolution

Crystal Characterization for hadron beam collimation through crystal channeling

Novel technologies and experimental setup

- Prototype for XRF – TXRF and X-ray Imaging
- X-ray tube based on Carbon Nanotube Cold Cathode

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X-ray Optics (I)

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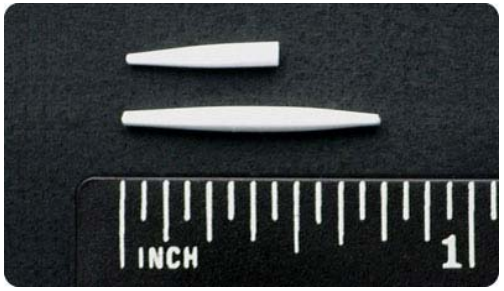
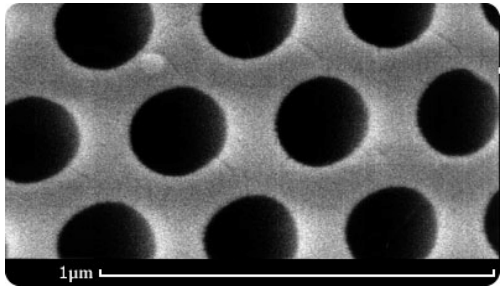
•Polycapillary Optics:

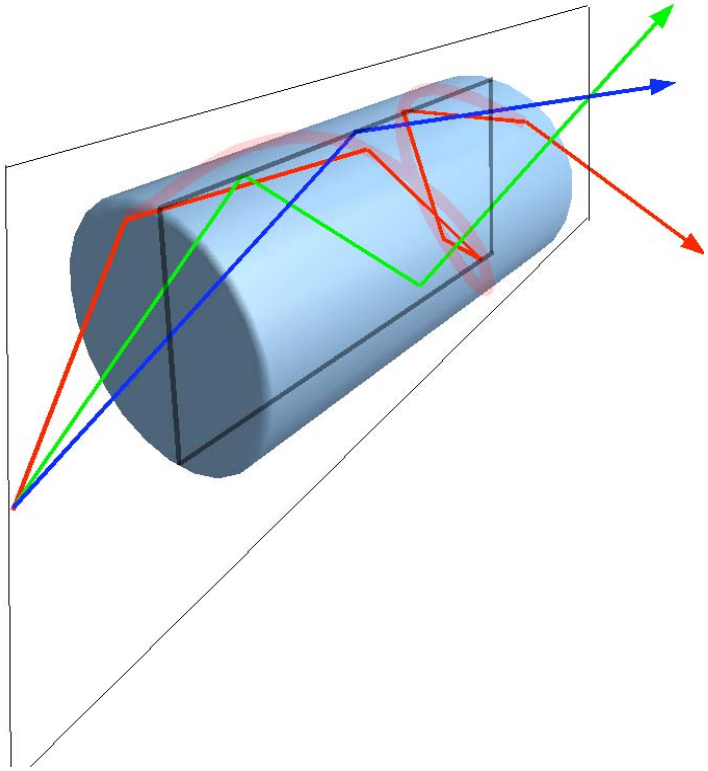
•In the X spectral region as a first approach, Polycapillary Optics works in Total External Reflection regime.

•Glass: the critical angle is

$$\theta_c[mrad] \sim \frac{30}{E[keV]}$$







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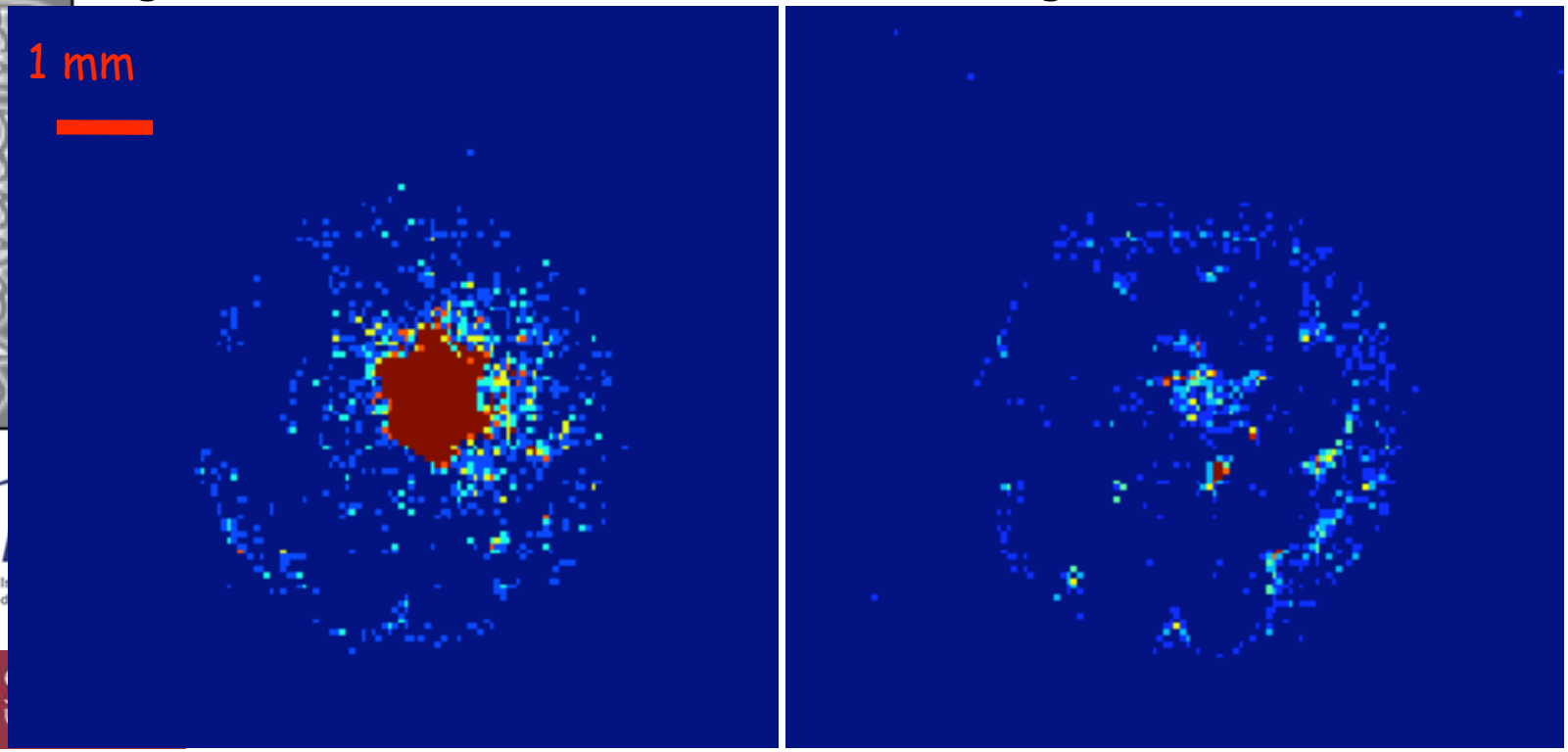
X-ray Optics (I)

How is critic the alignment of a Polycapillary Optics? Results... for a 8 keV energy beam, less than 10 mrad...

Aligned

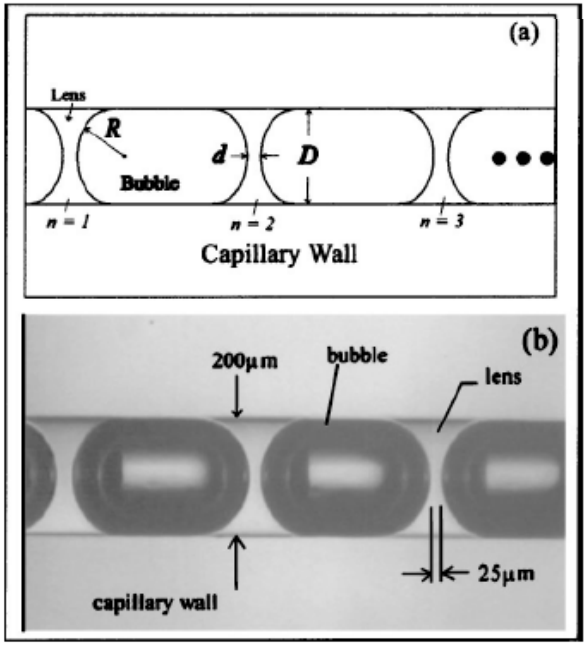
Not Aligned



Bundle of Polycapillary optics, with a millimeter dimater. The budle is obtained without any glou or heavy material between the pillars

X-ray Optics (II)

Compound Refractive Lens



Focal Distance: $f_1 = R/2\delta \sim m \rightarrow$

N bubbles: $f_N = R/2N\delta \sim mm$

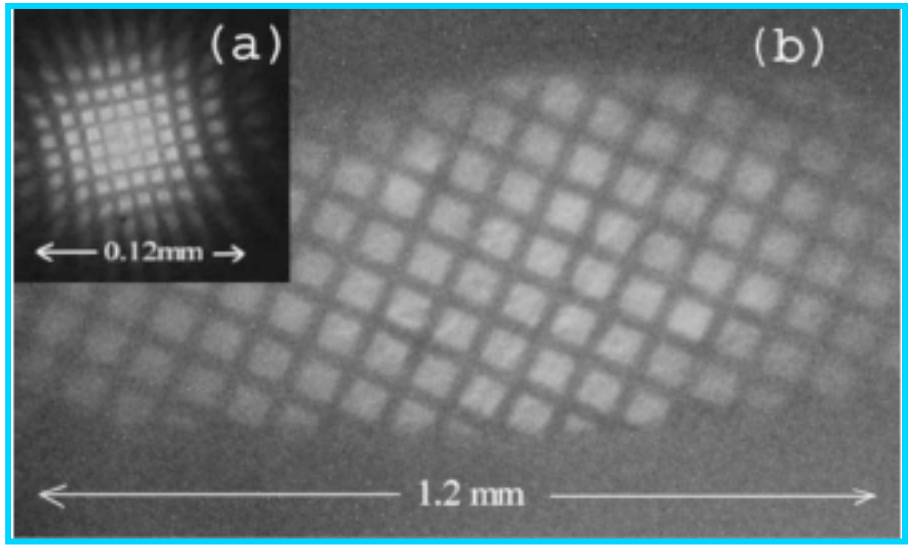
Spot Dimension: $\Delta f_1 \sim mm \rightarrow$

N bubbles: $\Delta f_N \sim \mu m$

Moreover, f=f(Energy)... focusing selecting by energy

a) Image 5.4x of a 2000 mesh grid obtained with Synchrotron Radiation (8 keV)

b) Image of a 400 mesh grid obtained with a conventional X-ray cupper tube (8 keV)

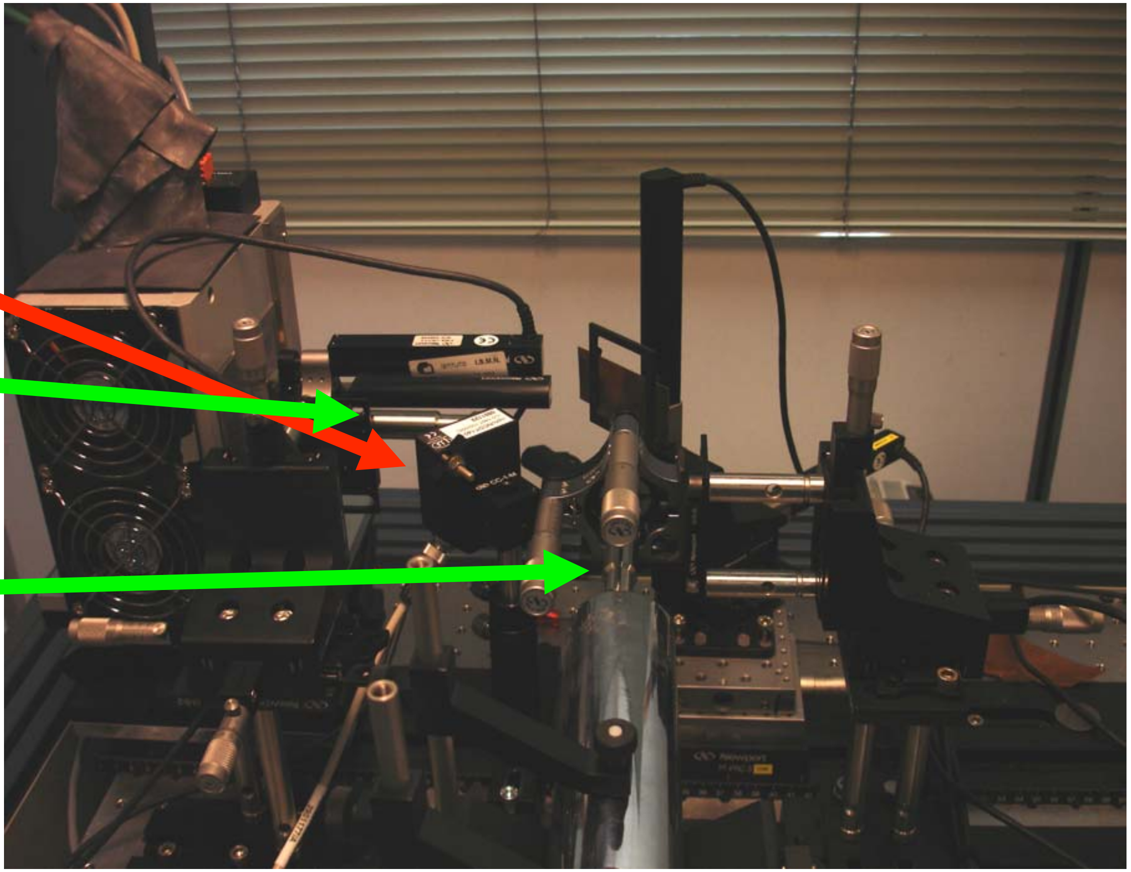


X-ray Spectroscopy (I)
X-ray Fluorescence

Channeling 2010

Experimental Equipment:

- SDD Detector – by XGLab
- Laser Prophilometer (Spot size ~ 100 μm, Resolution ~ 10 μm)
- First Lens: Polycapillary Optics
    - Focal Spot ~ 100x100 μm
    - Trasmission ~ 40%
- Secon Lens: Polycapillary Optics
    - Focal Spot ~ 100x100 μm
    - Trasmission ~ 50%
- Change the Second Lens with a 5^{th} Generation Lens → Focal distance very small → Increase of Angle Solid Relative



X-ray Spectroscopy (I)
Mapping on Fe_2O_3

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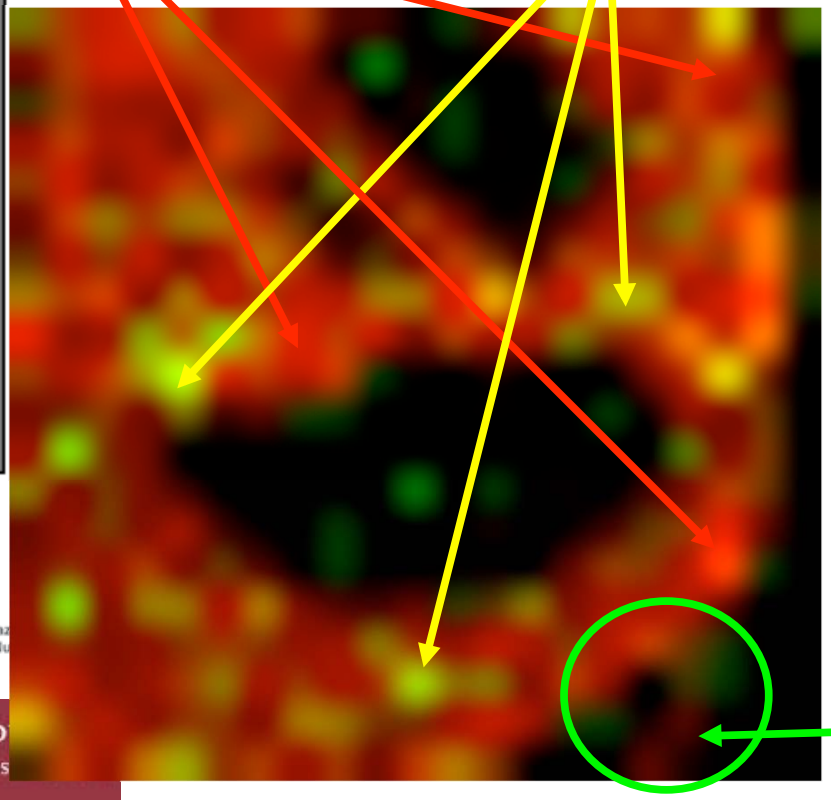
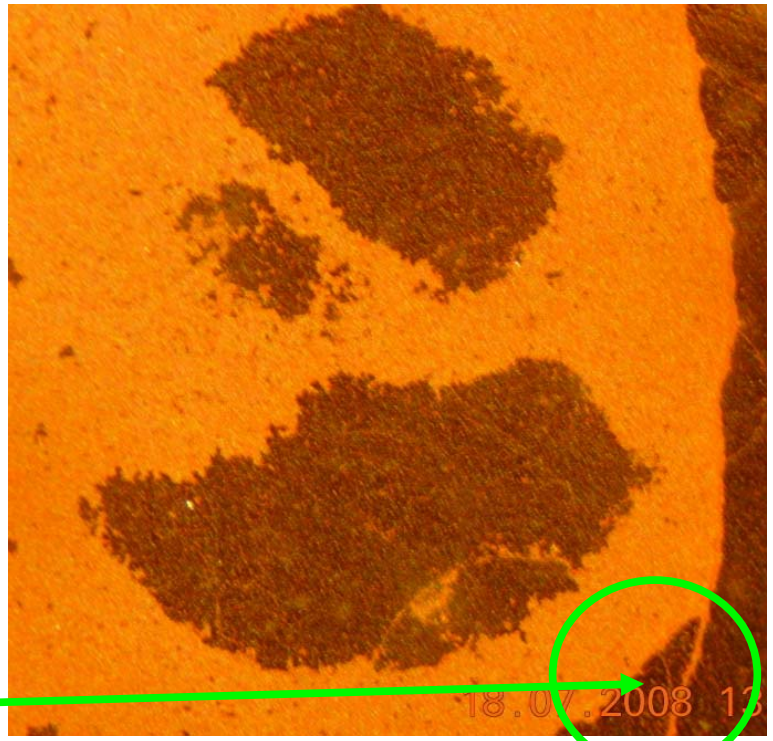
Fe

Mn



µXRF Mapping – 200x200 µm² spot
4x4 mm² measured area (21x21 steps)
2 minutes for each spot
CuKa Tube; V=24 KV, I=0.750 mA



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X-ray Spectroscopy (I)
X-ray Fluorescence

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Study and classification of Eneolithic/Chalcolithic (about 3000 b.c.) flint arrowhead by FTIR spectroscopy.

A problem... the tip and the tail are red and seems to be an amorphous material, much similar to a magmatic rock than a sedimentary one.
An help should be come from XRF

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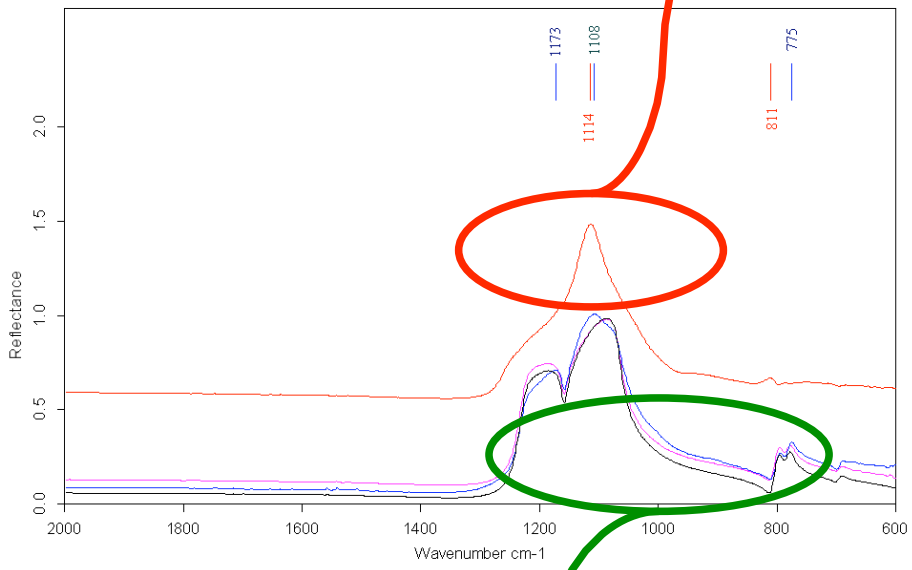
Acknoledgment: dott.ssa A.P.Anzidei, Sovrintendenza Archeologica di Roma

X-ray Spectroscopy (I)
X-ray Fluorescence

Typical FTIR spectrum of Obsidian (Volcanic glass, 70-75% SiO_2, plus MgO, Fe_3O_4)



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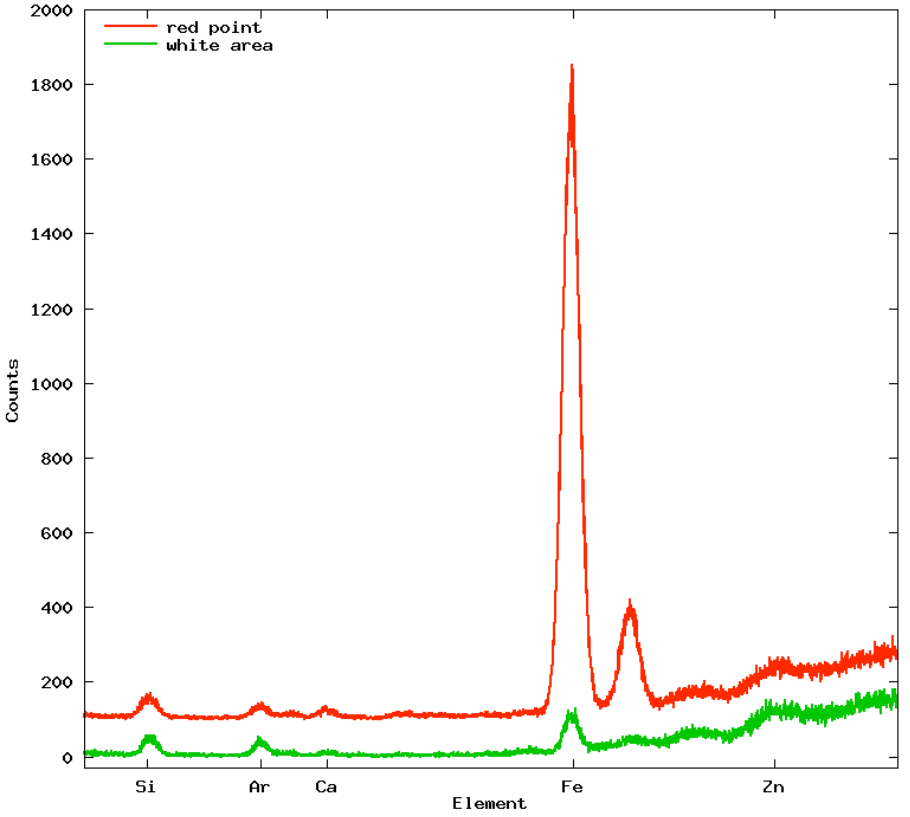

Typical FTIR spectrum of flint

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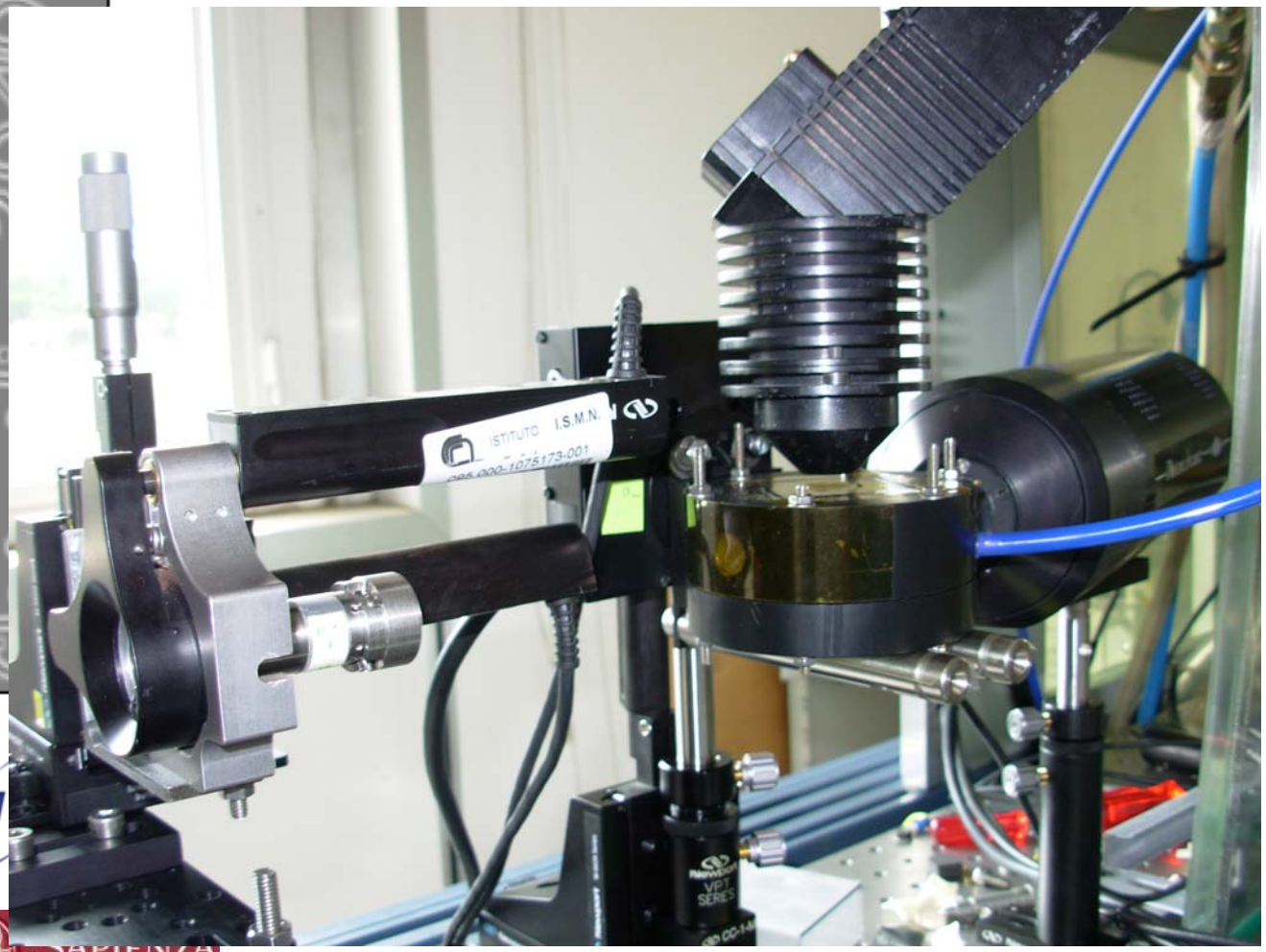
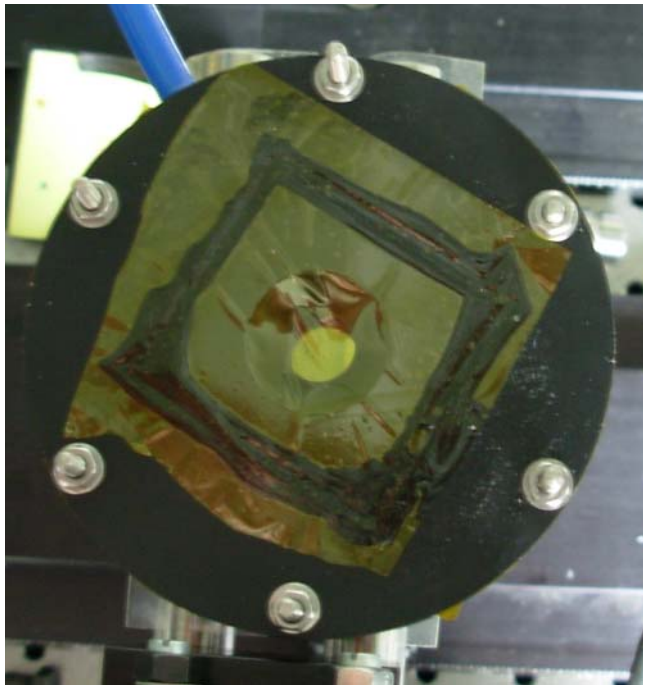
X-ray Spectroscopy (II)
TXRF - experimental setup





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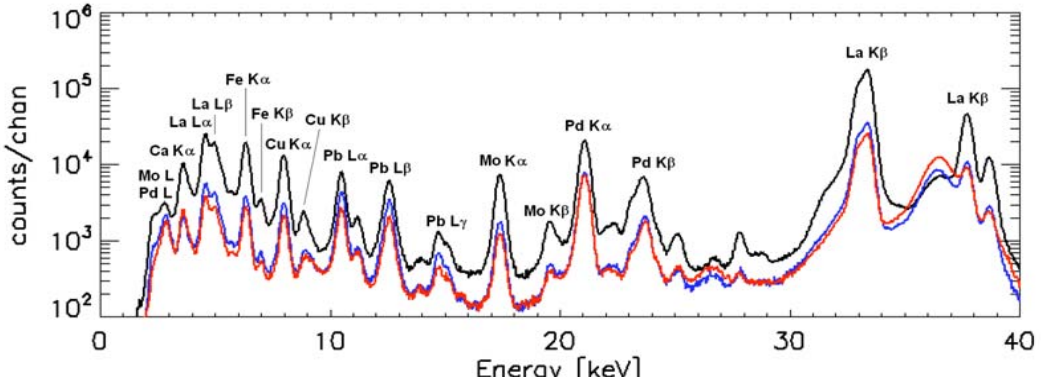
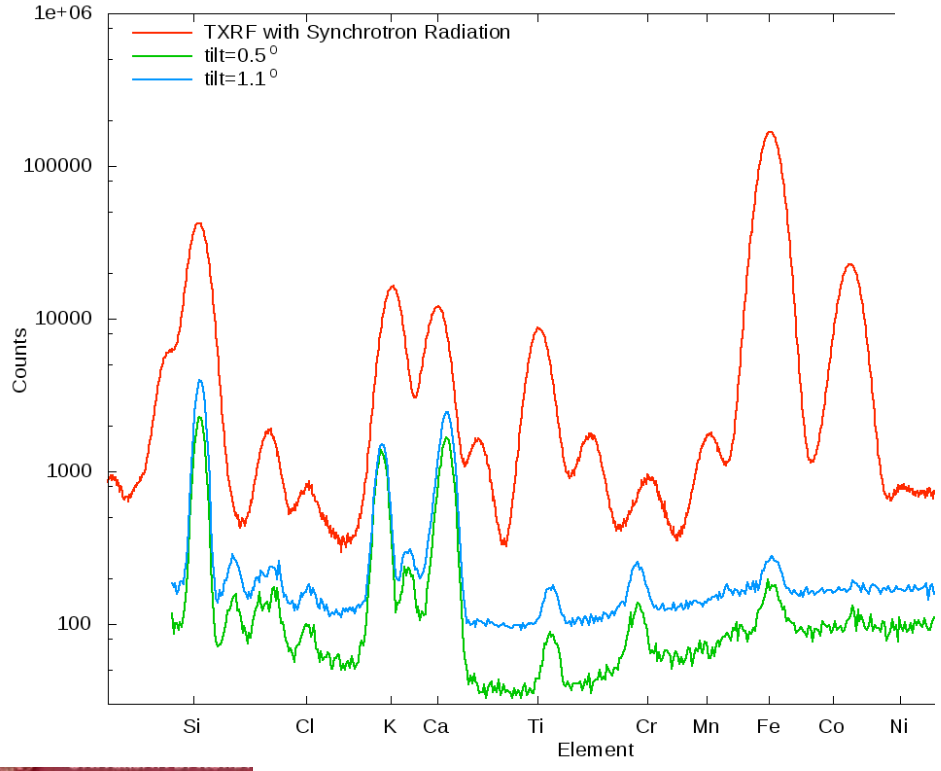
X-ray Spectroscopy (II)
TXRF – some results

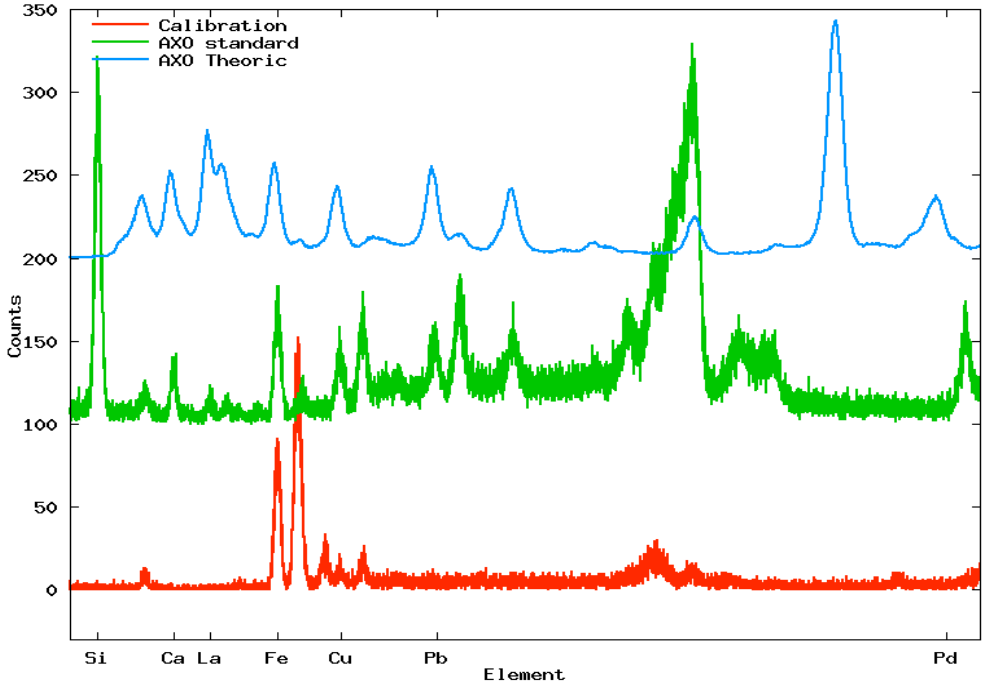
2010

Low concentration samples:

- Standard (AXO Dresden GmbH)
- Antartics dust







X-ray Spectroscopy (III)
X-ray Diffraction

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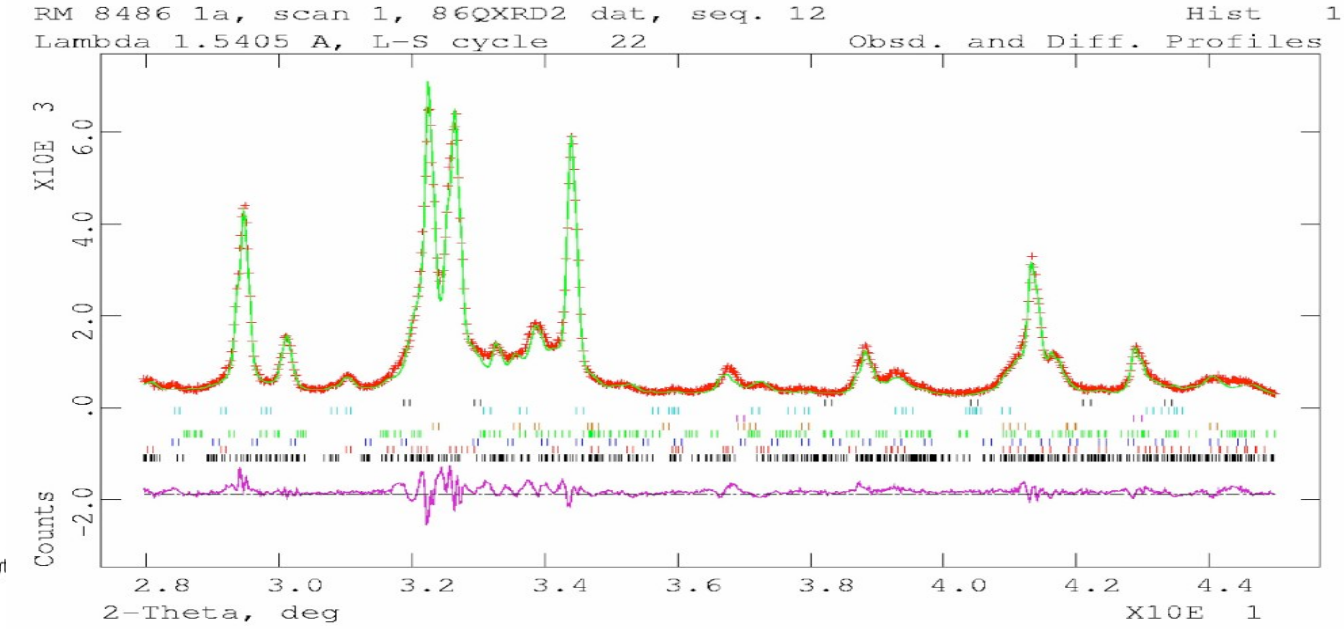
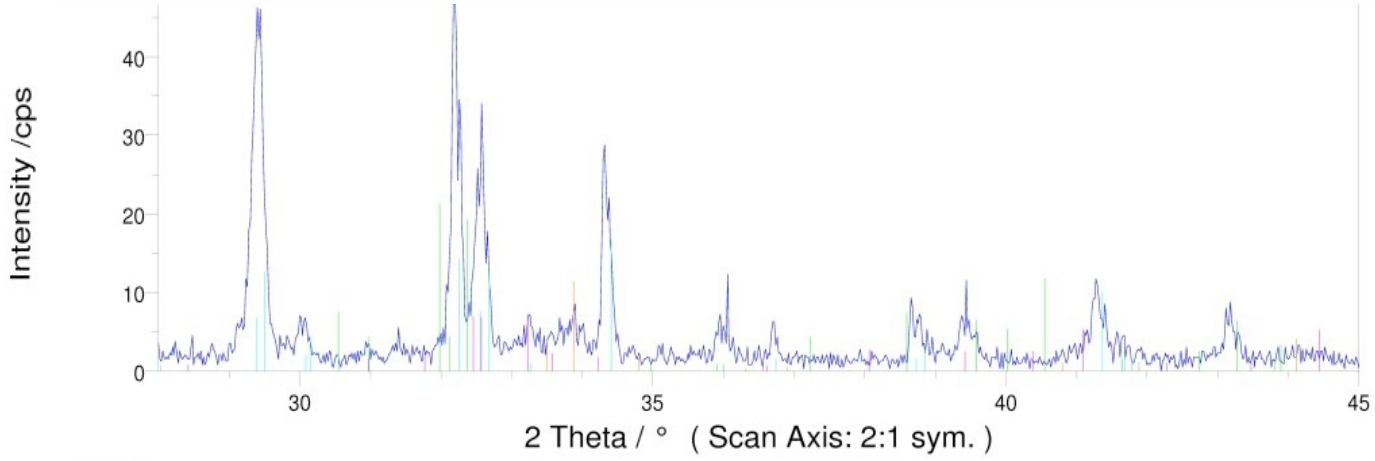
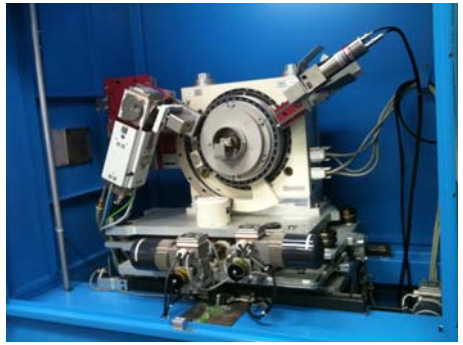


Portland NIST Standard



XLab Result

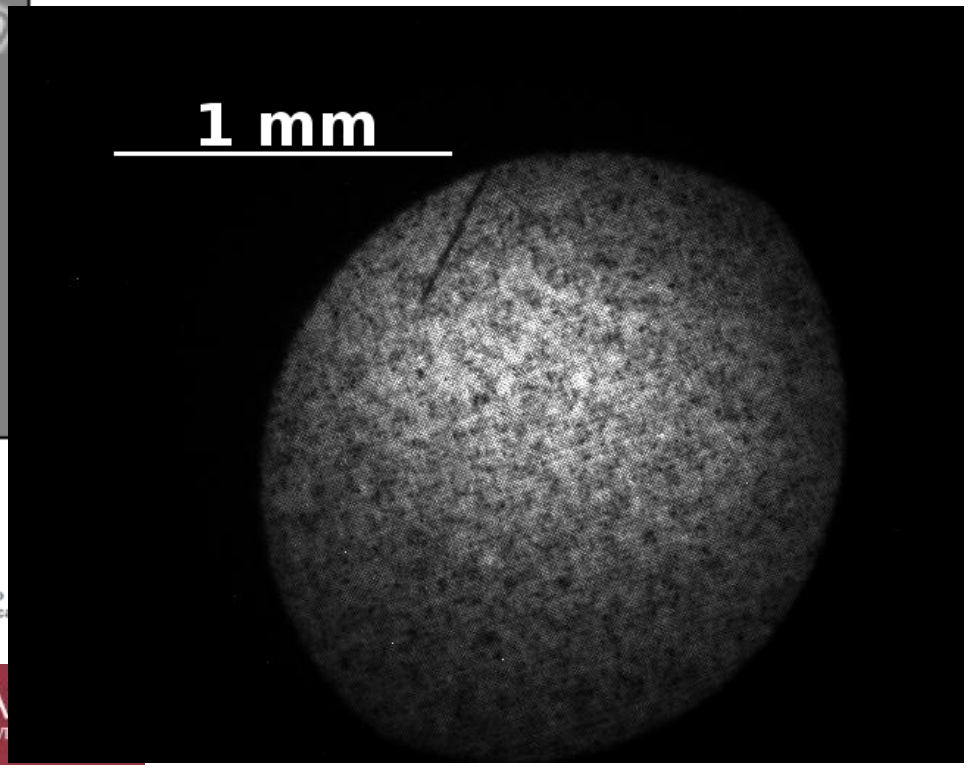


High Resolution X-ray Imaging (I)

Channeling 2010

High resolution X-ray images for a standard gold mesh 1000 Hole width ~ 19 μm, Bar width ~ 6 μm

With our CCD detector (res. 3.5x3.5 μm^2) the problem is the detector...



High Resolution X-ray Imaging (I)

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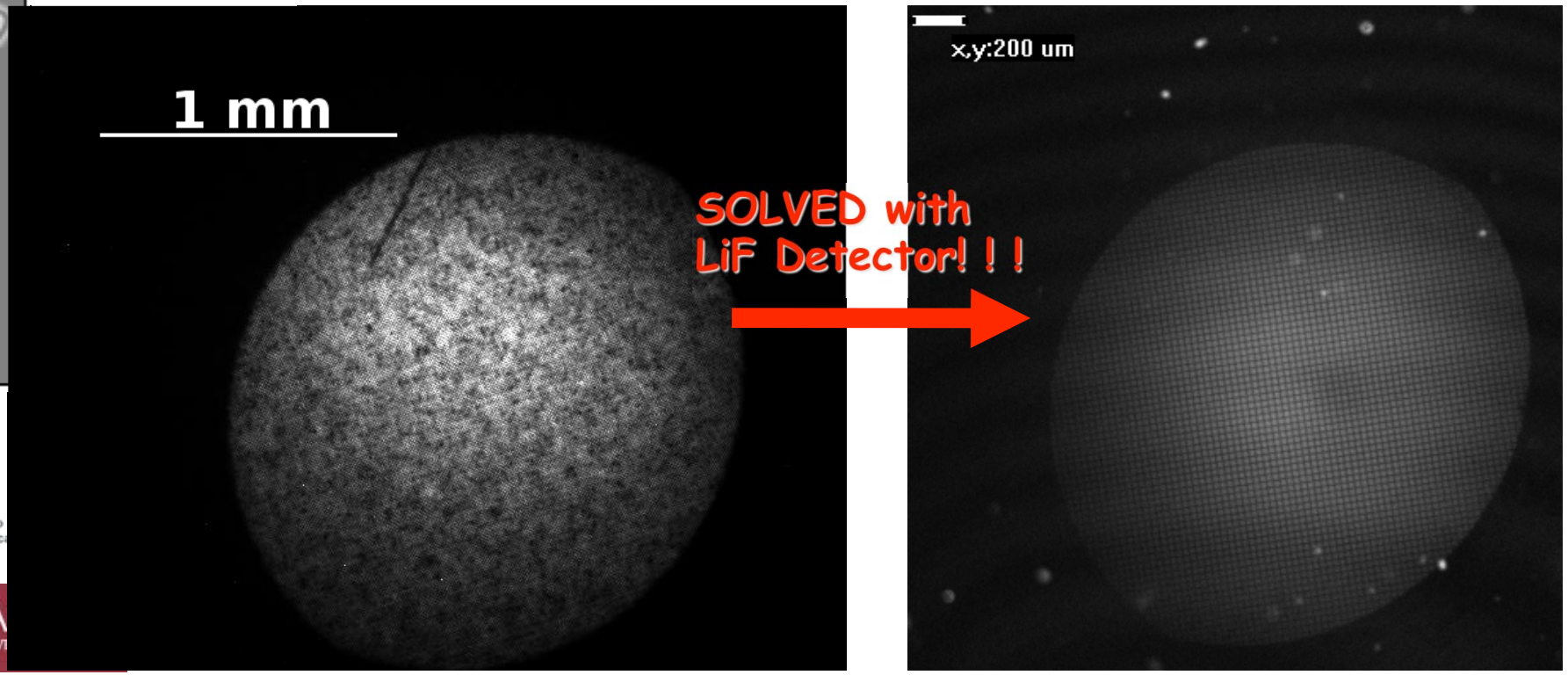

High Resolution X-ray Imaging (I)

or better...

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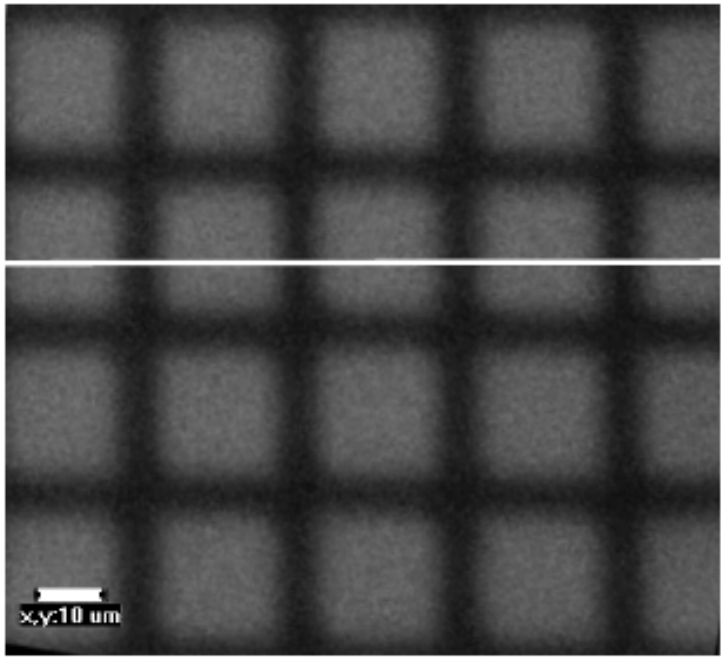
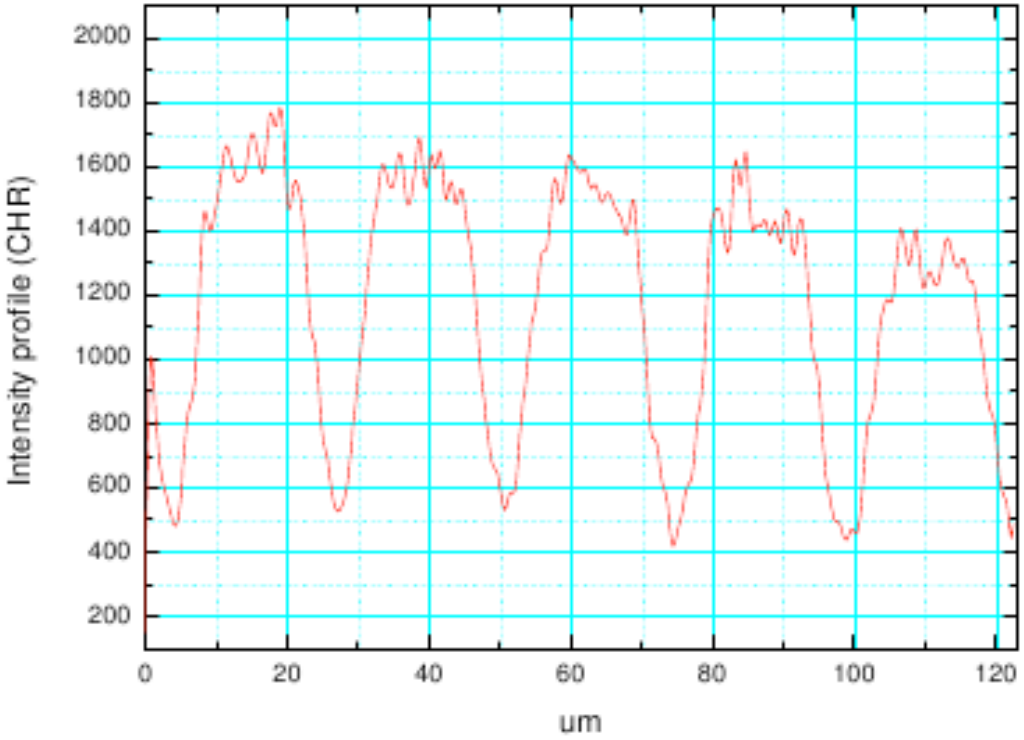


40X zoom



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High Resolution X-ray Imaging (I)

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High Resolution X-ray images in transmission mode:
First Combination Polycapillary Optics (semi-lens) - LiF detector

LiF detectors are based on CCs (Colour Centers)
→ the resolution is "in principale" paragonable to the lattice dimensions

The LiF detectors are read through an Optical Confocal Microscope → the difficulty now is how to read an image (the optical limit resolution is about 200nm)

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High Resolution X-ray Imaging (II)

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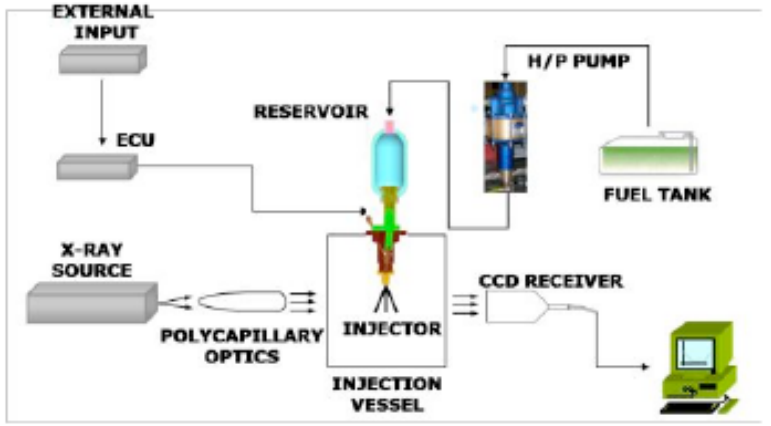
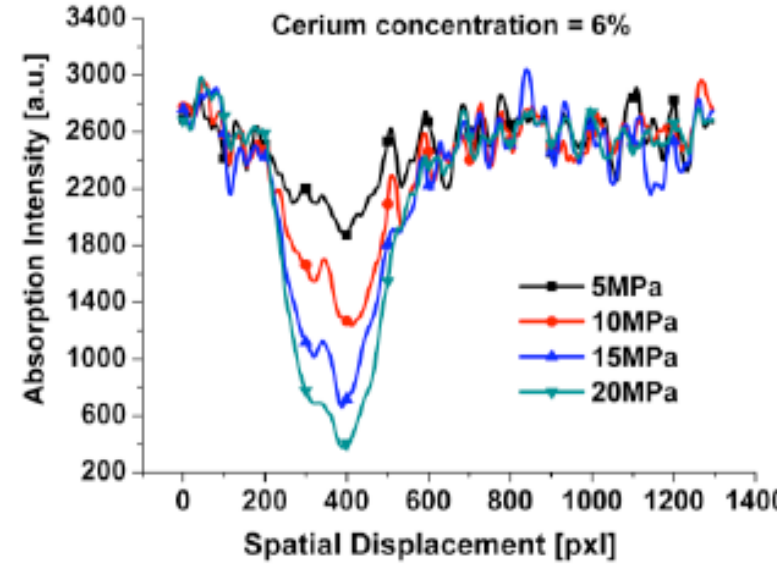
A preliminary investigation on fuel sprays from a Gasoline Direct Injection (GDI) six-hole nozzle by polycapillary X-ray technique is shown.
The GDI in Spark Ignition (SI) engines represents an interesting test case and has a practical application in engine technology for both fuel economy and performance improvements.

The goal of these investigations is to characterize the droplet sizes as well as their spatial and temporal distributions, to define fundamental parameters for the injection system design and database in order to calibrate necessary codes (CFD).





X-ray absorption profile for different fuel injection pressures through a fuel spray at 5 mm from the nozzle in the spot centerline for 6 keV incident energy. Pixel size 10.4 μm.

more detail – Poster PS2-25

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Diagnostic Applications GEMINI project

Channeling 2010

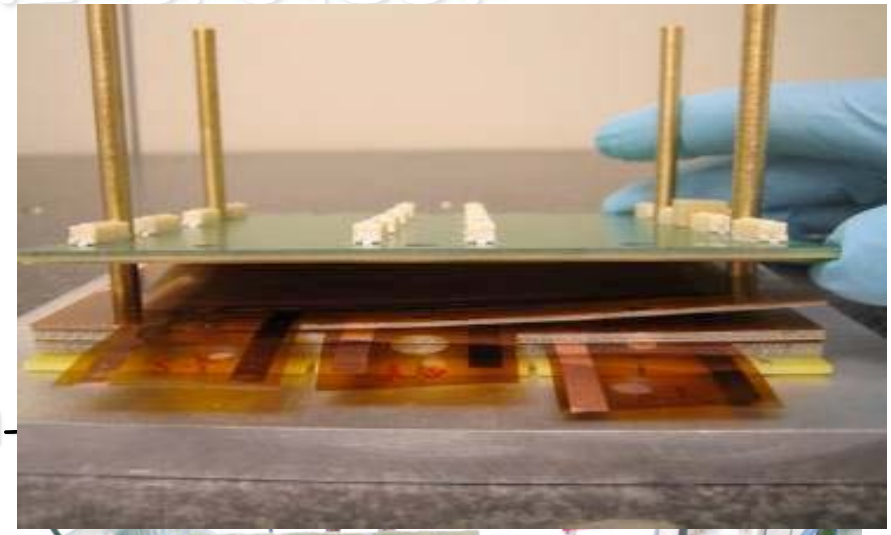
Very stable system

Wide Linear Dynamic Range

Irradiation resistant (by dose and time)

Compact and fast Read/Out INFN-Patent for any kind of radiation: hadrons (CERN), leptons (INFN - DAFNE), X-ray

GEMINI aims to realize new detection syste based on combination of GEM and Polycapillary Optics (ITER)



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more detail Pacella et al., Session S4.2

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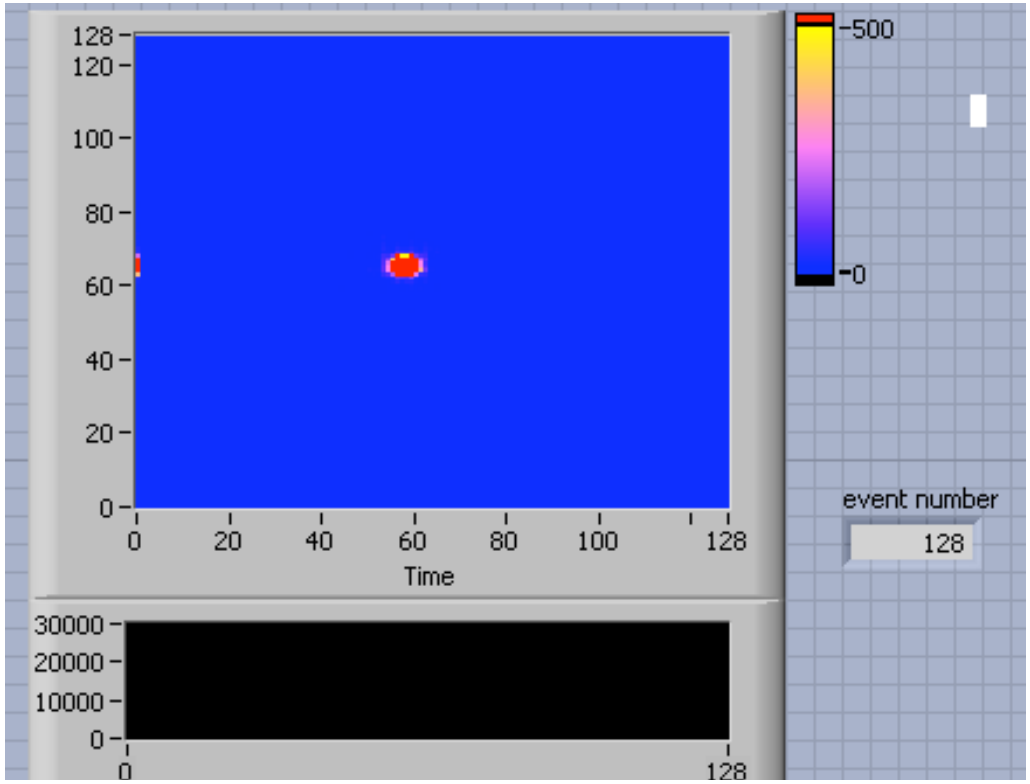
Diagnostic Applications GEMINI project

Polycapillary Collimator + GEM for images scanning. The GEM has 128 pad with a 500 μm of resolution.

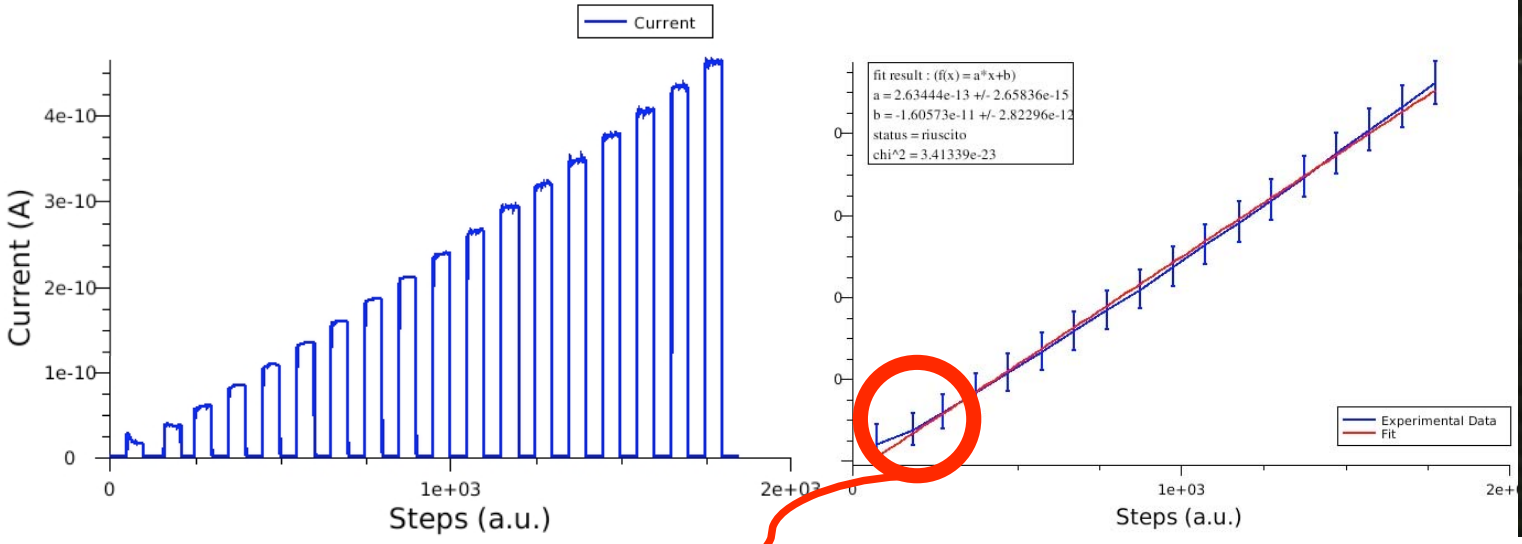


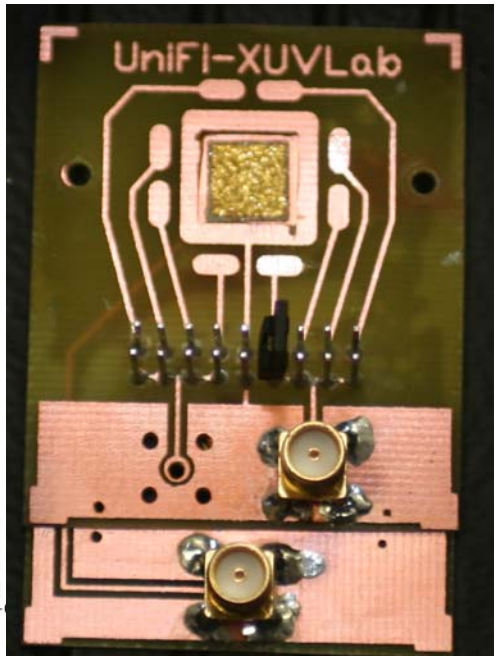
Diamond Detector

Diamond detector are very stable with a wide dynimic linear range

Possibility to obtain a very light and compact and counting system. Possible application:

- portable XRD
- ad hoc systems (Diamond Light Source collaboration)





At this point, a Saint Gobain Scintillator goes out of linearity

First prototype for X-ray Spectroscopy

Channeling 2010

Time to finilize the spectroscopy single studies...

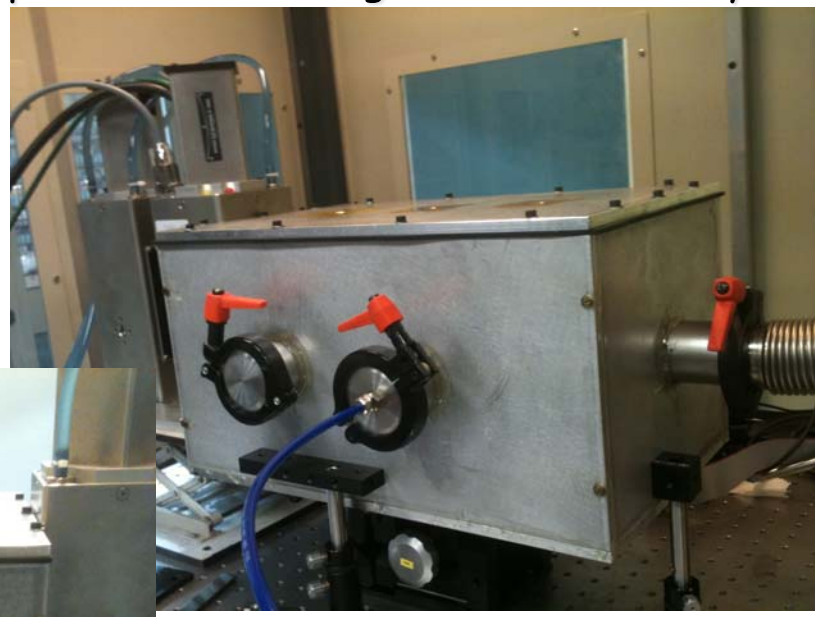
As a first prototype, we have realized a single setup for TXRF and high resolution X-ray imaging.

It works in vacuum regime

(10^{-5} - 10^{-6} mbar) for light elements.

X-ray images are obtained

with LiF detector



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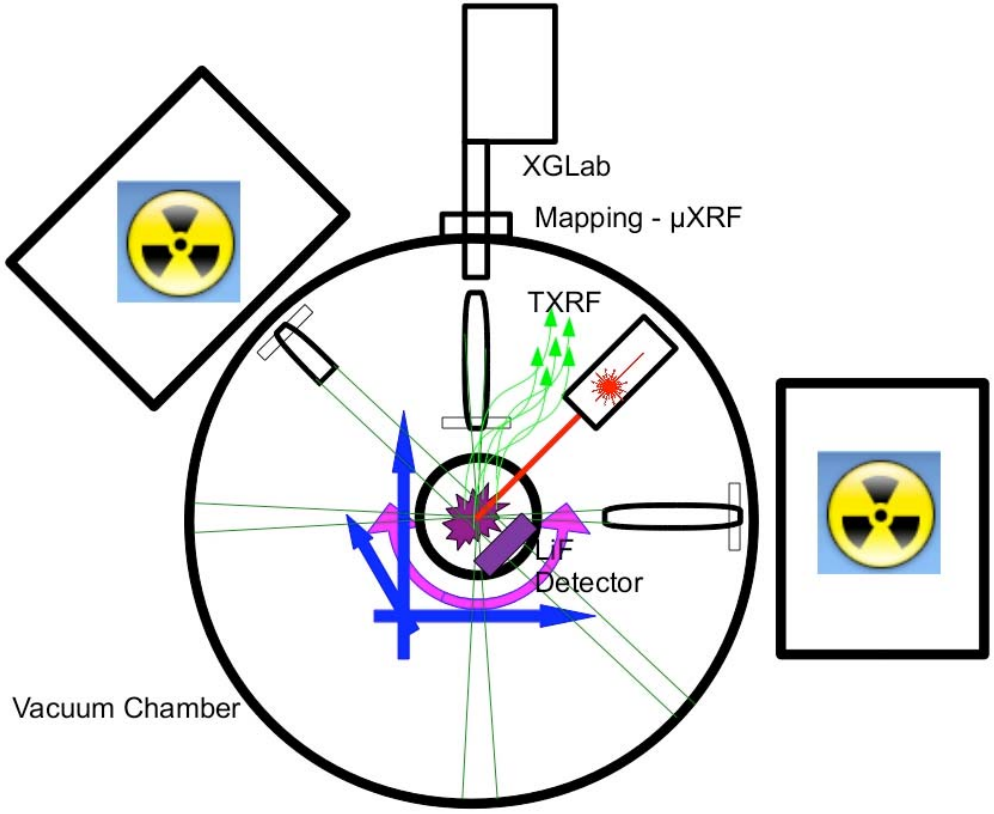
Final prototype for X-ray Spectroscopy

Time to finilize the spectroscopy single studies...

We are designing and realizing a single setup for μXRF, TXRF and high resolution X-ray imaging.

The final setup should be work also in low vacuum for light elements.

X-ray images are obtained with LiF detec



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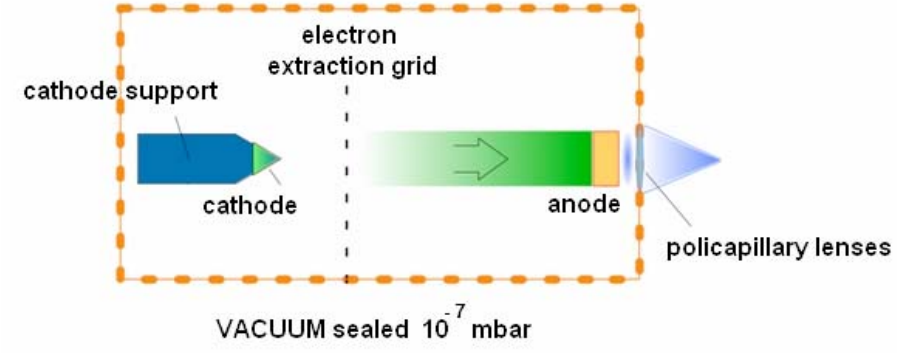
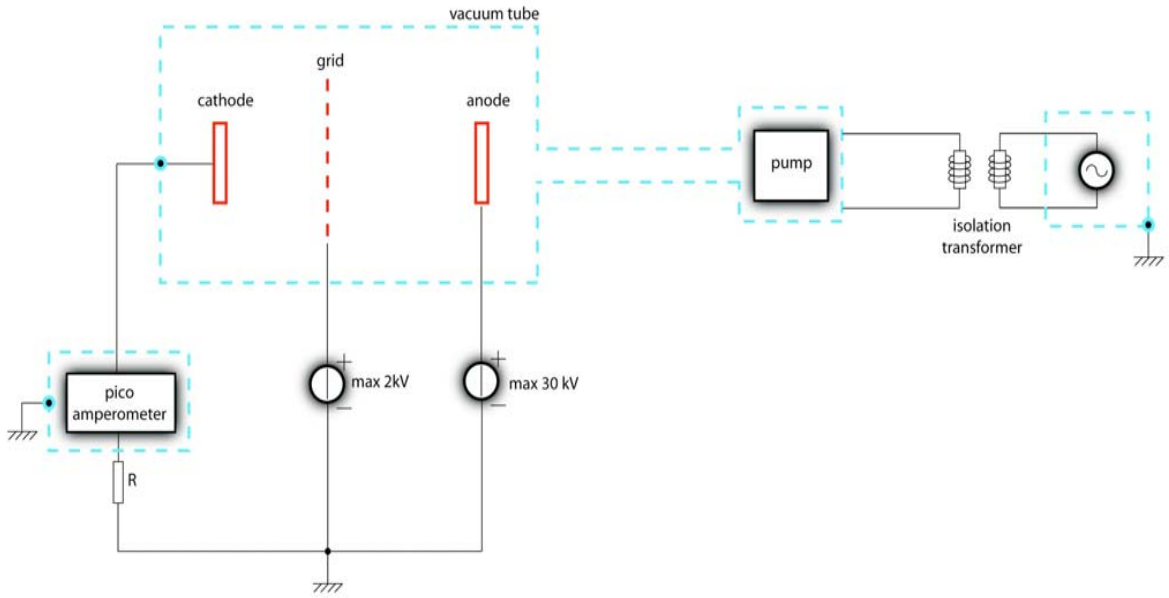
Nanoray - a novel X-ray tube: CNT cold cathode



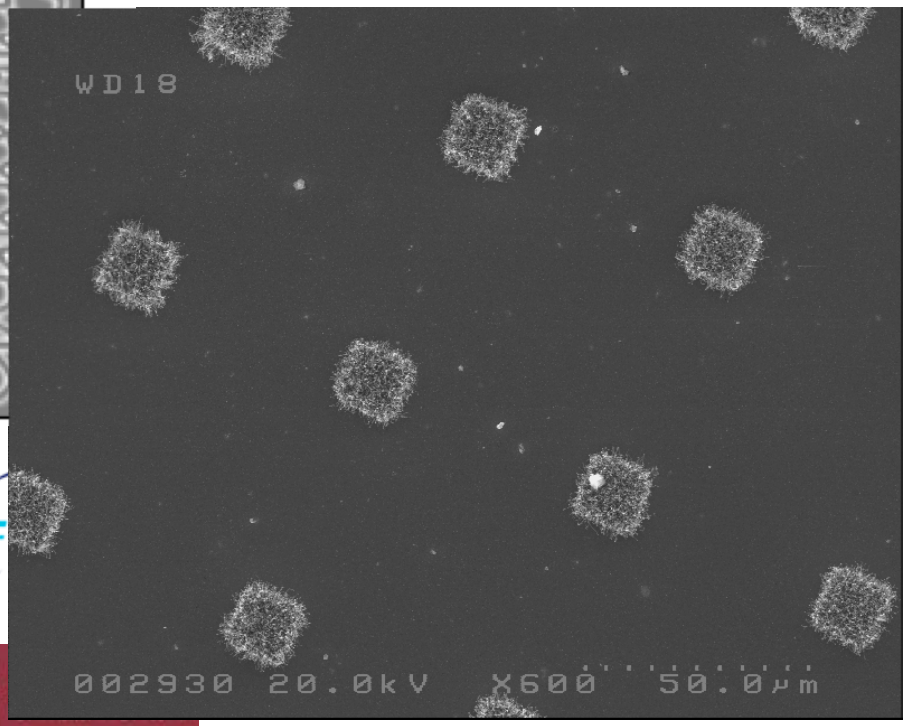


more detail – Guglielmotti et al., S4.1

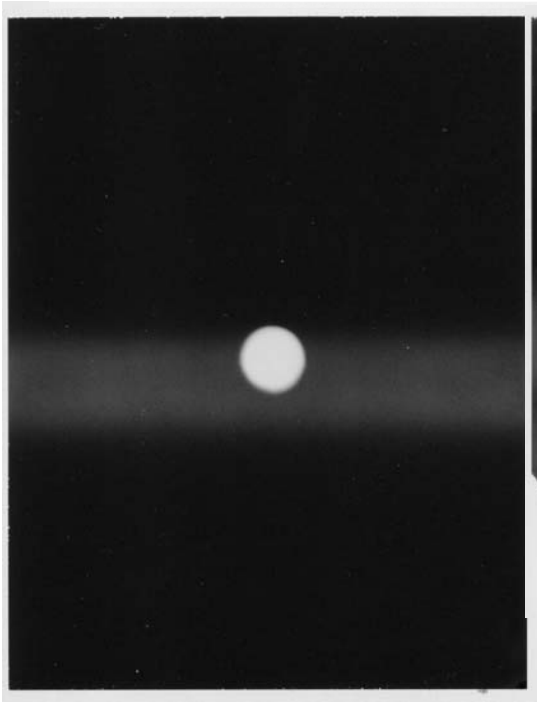
Nanoray - a novel X-ray tube: CNT cold cathode

Preliminary results with a lithography areas with full with SWNT cathode.

With only 10 keV at anode and 5 minutes of exposition...



HV Grid On



HV Grid Off

Conclusions

Channeling 2010

We have shown our activities at Frascati (LNF – INFN).

They are principally based on:

- X-ray Optics – Polycapillary and Compound Refractive Optics
- X-ray Spectroscopy (XRF – XRD – X-ray Imaging)
- Diagnostic Applications.
- Crystal Characterization for hadron beam collimation through crystal channeling
- Novel technologies and experimental setup
  - Prototype for XRF – TXRF and X-ray Imaging
  - X-ray tube based on Carbon Nanotube Cold Cathode

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new collaborations...

Channeling 2010

you are welcome to perform fine experiments at our facility, XLab (welcome from resp. prof. Dabagov)

Moreover, it's under consideration a possibility to include XLab facility for the users within TARI (Transnational Access to major Research Infrastructures - European founds to be used in European infrastructures, included LNF-INFN)

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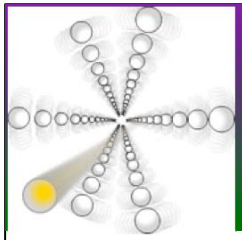

Channeling 2010

Thank you for your attention

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