Structure and dynamics of aerodynamically levitated liquids

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CRMHT

10 octobre 2007

Outline

- I - Technical aspects (Louis Hennet)

- ✓ **Aerodynamic levitation and laser heating**
  - **Principles**
  - **Necessary equipments**
- ✓ **Various Developments**
  - **Synchrotron sources**
  - **Neutron sources**
- ✓ **Alternative heating system**

- II - Some results (Irina Pozdnyakova)

Aerodynamic levitation

How does it work ?

What happens when the ping-pong ball is placed in the air stream?

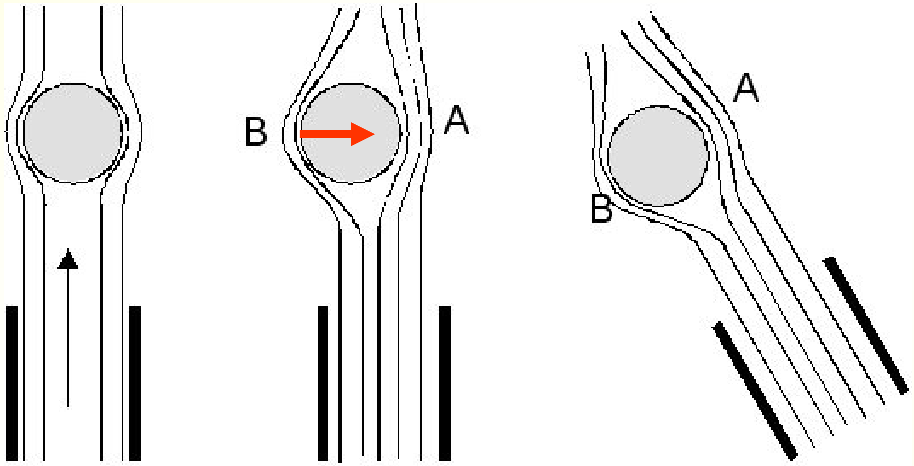
Initially, the equilibrium position is on the axis

If the ball moves laterally (to point B), the air flow speed at A becomes higher than at B.

Then the pressure at B becomes higher than at A and the ball moves back to the centre.

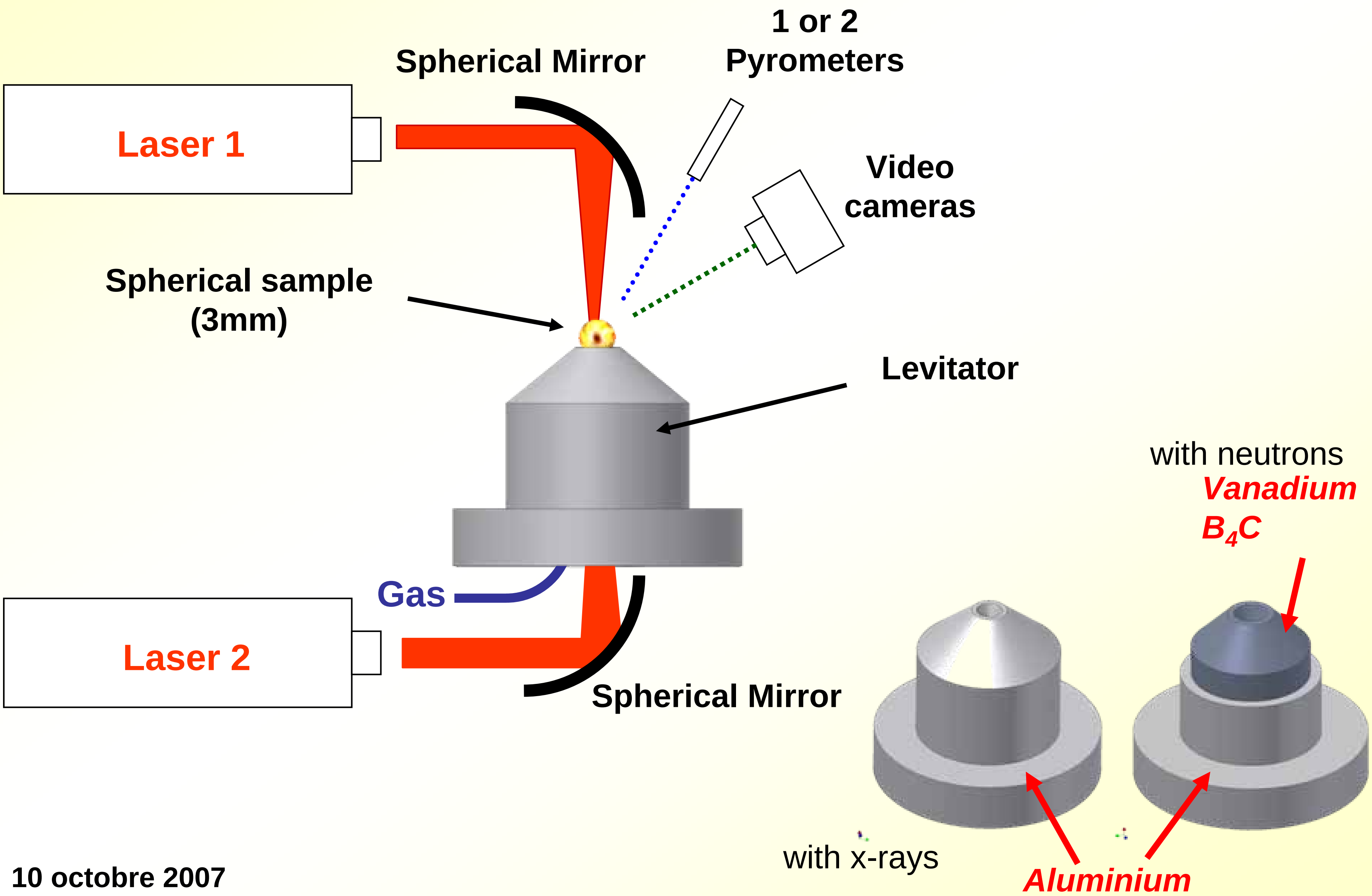
This leads to a stabilisation of the ball in the air stream.

Daniel Bernoulli (1700-1782)



Up to a certain limit (~40°), it is possible to rotate the hair dryer keeping the ball levitating.

Aerodynamic levitation and CO_2 laser heating



Heating system: CO_2 lasers

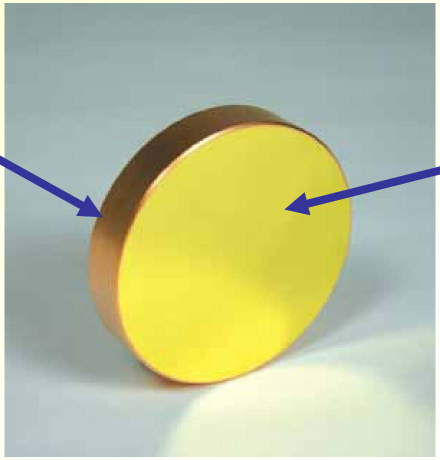
Several lasers with various powers

240 W
134 cm
38 kg

125 W
124 cm
16 kg

Laser beam focusing: spherical copper mirrors

Copper



Gold coating

Mirror mounts with micrometric screws enable precise adjustments

Primary laser beams have a diameter of approximately 5 mm

Focal lengths are calculated to have a beam size of about 1mm at the sample position

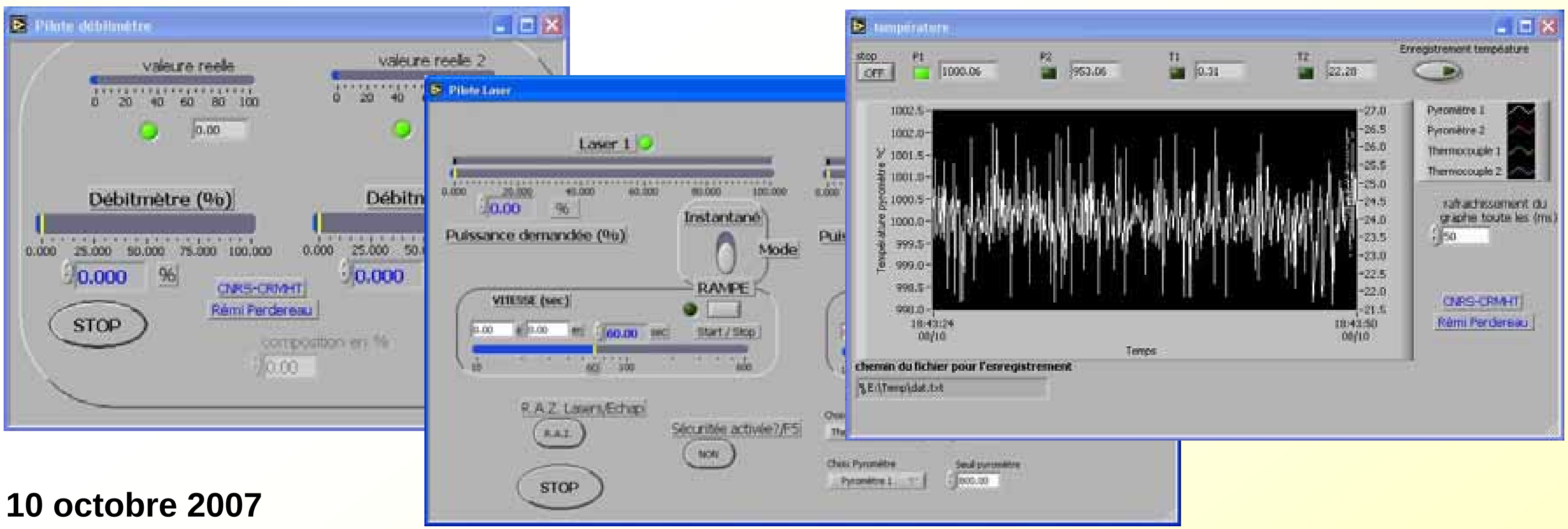
Levitation: mass flow controller

It contains a precise valve with a calibrated maximum flow rate (we usually use 2.5l/min)

Applying a voltage, It is possible to open it from 0 to 100%

For 3mm samples, typical flow rate : 0.5l/min

Remote control: NI cards + Labview programs



Temperature measurements: Optical Pyrometers

$$\frac{1}{T}-\frac{1}{T_a}=\frac{\lambda}{C_2}\ln(\varepsilon_\lambda)$$

***T** :* True temperature

T_a : Apparent temperature

λ : Pyrometer wavelength

C_2 =1.4388 cm K : Planck's second radiation constant

ε_λ : Spectral emissivity of the material at the wavelength λ

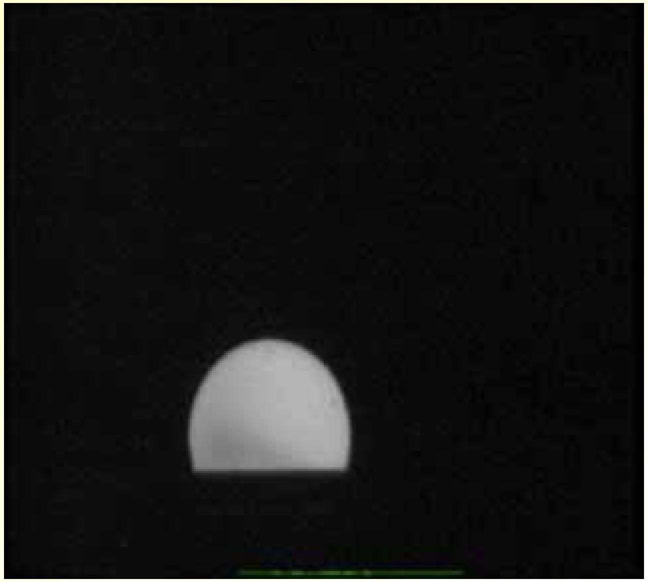
Typical emissivities for oxides and metals:

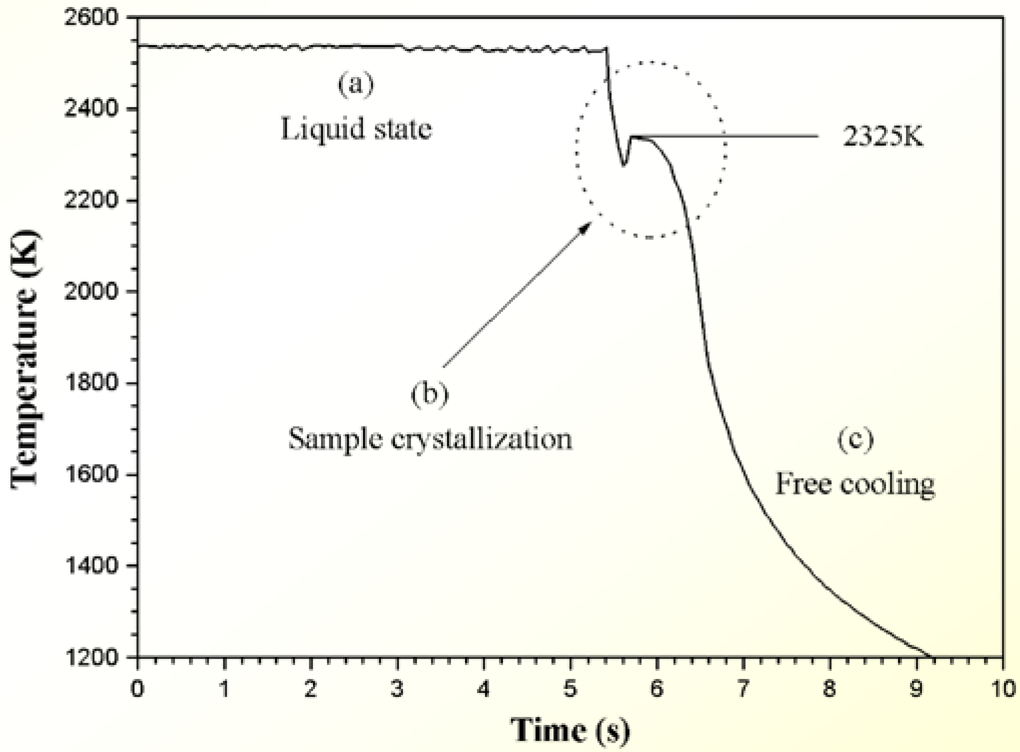
At λ=0.85 µm

$Al_2 0_3$: ε ~ 0.95

Zr : ε ~ 0.35

Temperature calibration





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Sample preparation

Calibrated spheres are made by melting a weighted amount of material

From bulk materials
From powders

Diameter

$$m = \rho\pi\frac{D^3}{6}$$

Mass *Density*

Pellet die

Press

Various developments at

synchrotron sources

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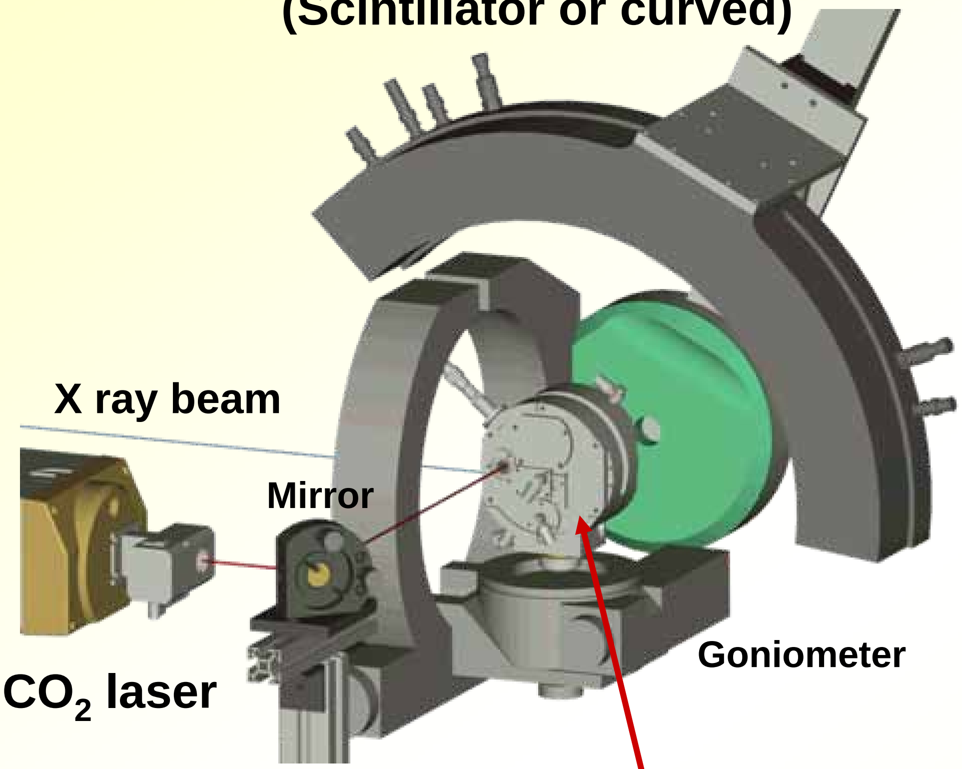
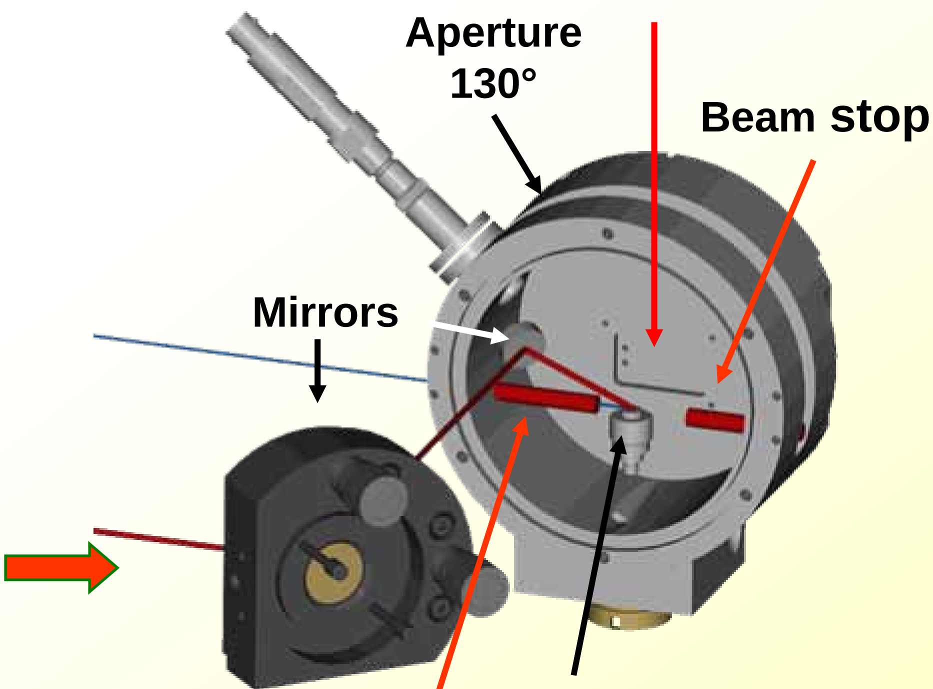
X-ray Diffraction
X-ray Absorption
Experimental setup :
BM2 beamline @ ESRF





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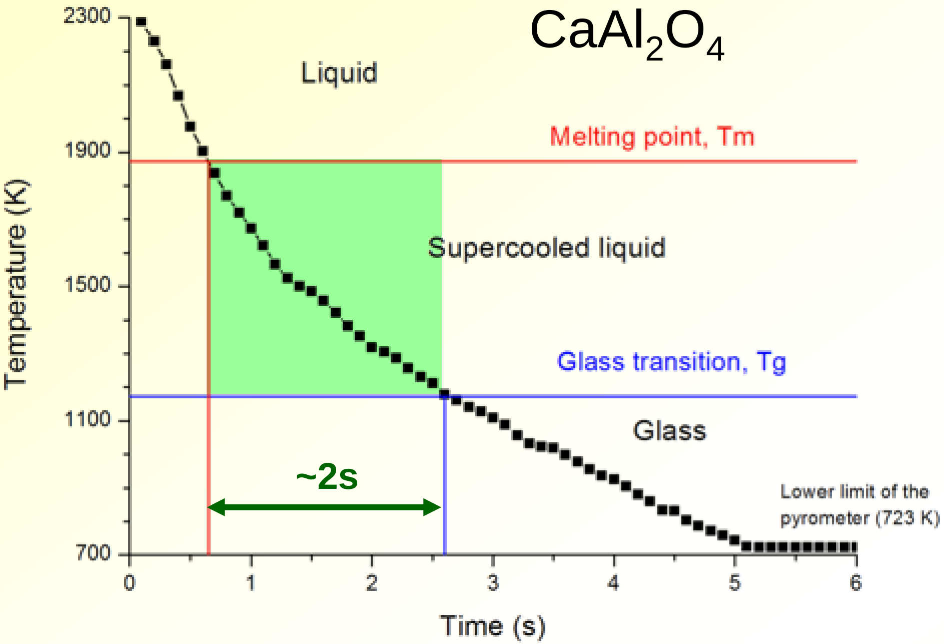
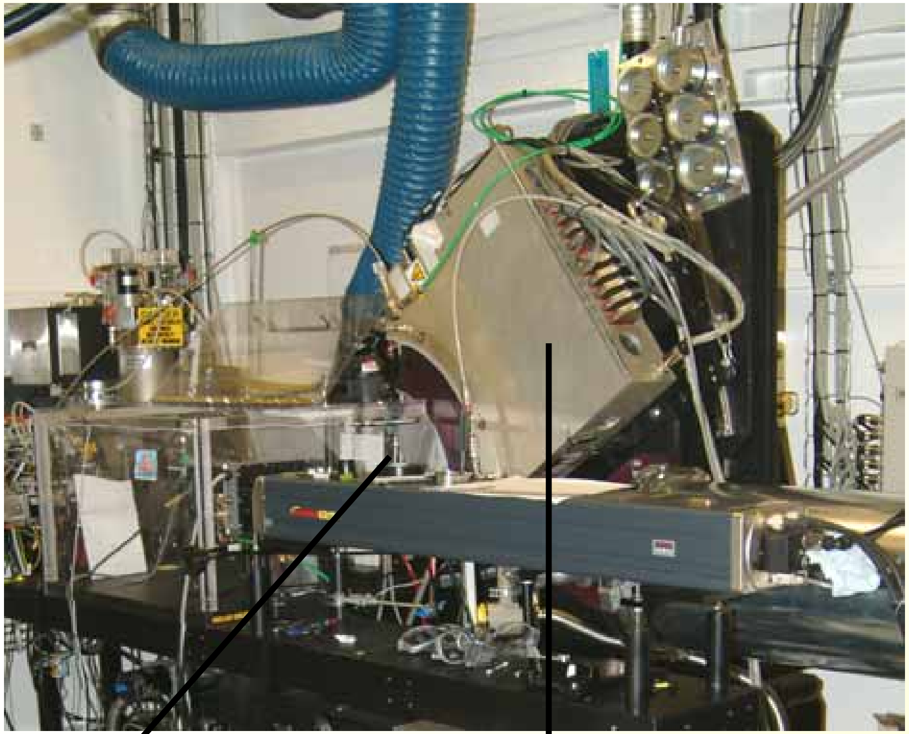
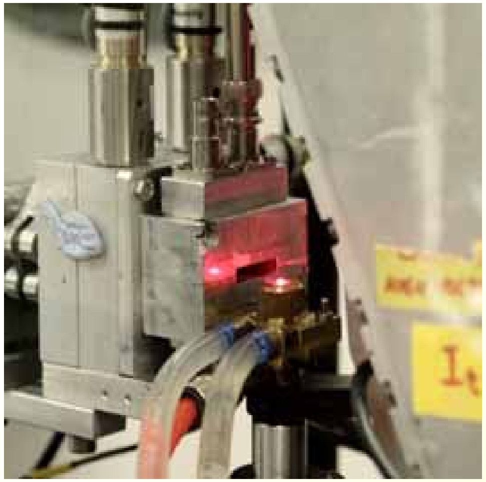
Structural evolution of glass forming liquids during solidification



Fast x-ray scattering measurements
Counting time 100ms

6.2 beamline at SRS (Daresbury, UK)





RAPID2 Detector

Angular aperture : 60°

Prifysgol Cymru Aberystwyth 1872 The University of Wales

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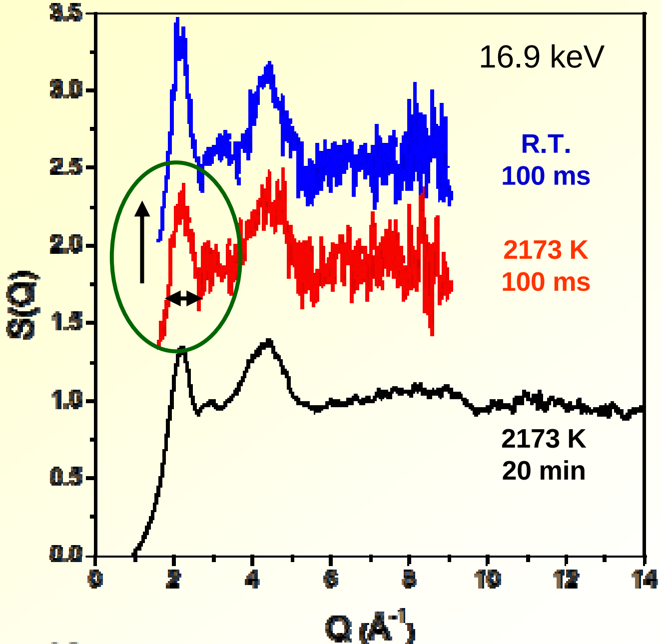
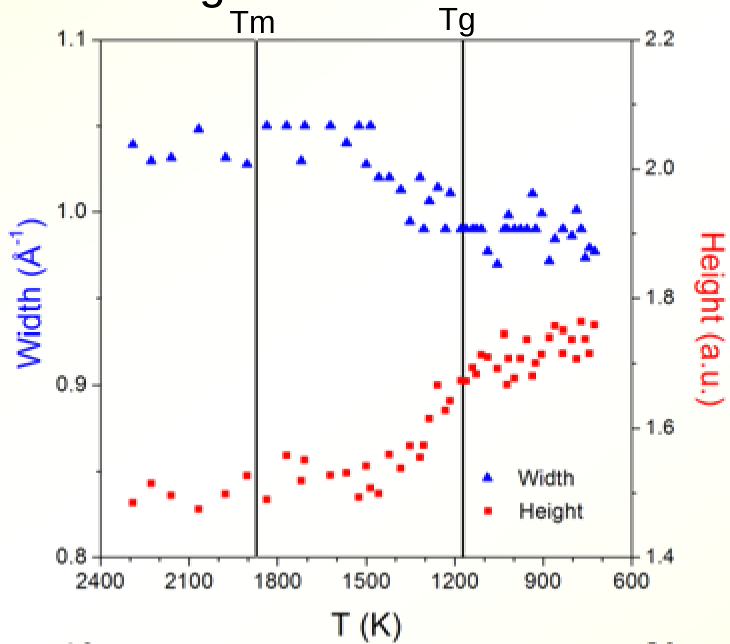
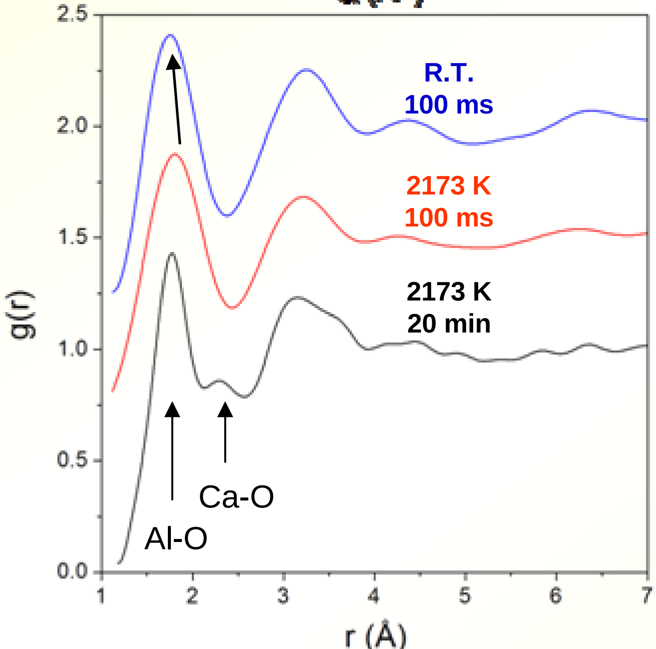
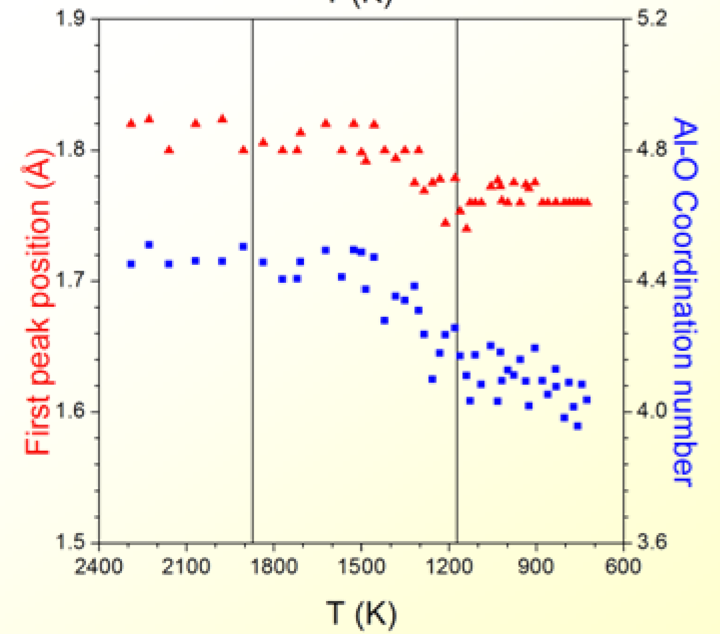
Medium Range Order





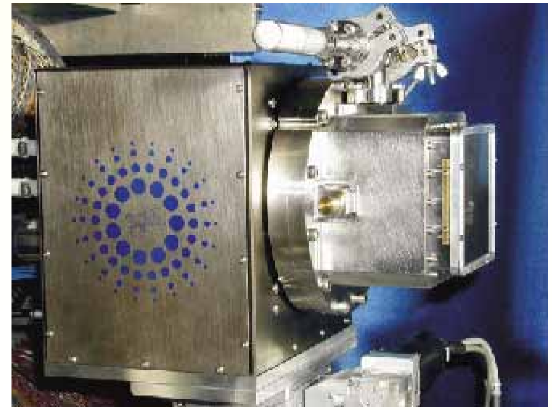




Short Range Order

Experimental setup at ID11 (ESRF)

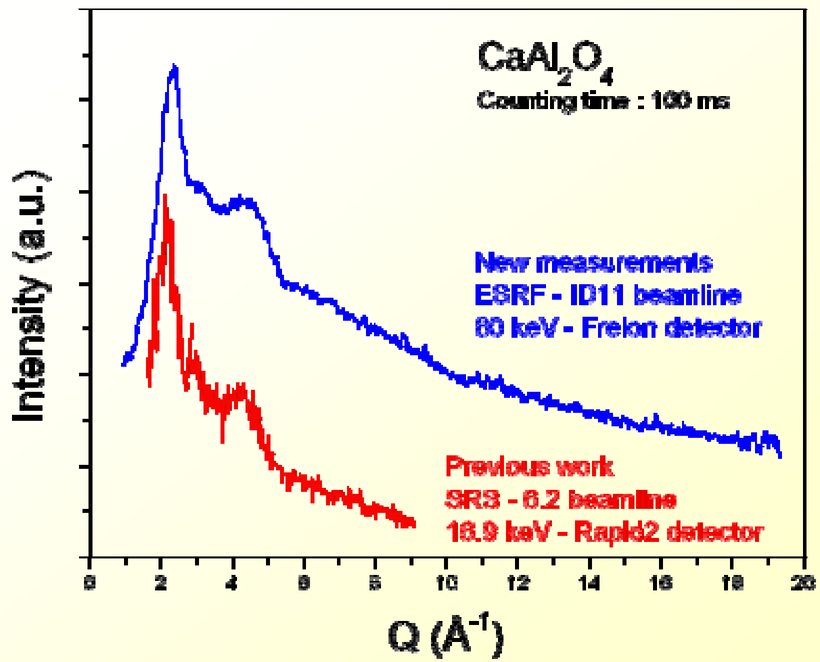
High Energy X-ray beamline



Frelon detector
(made at the ESRF)

- Better statistics
- Wider Q-range → it will improve the resolution by a factor 2

Calculations are in progress and should give good results



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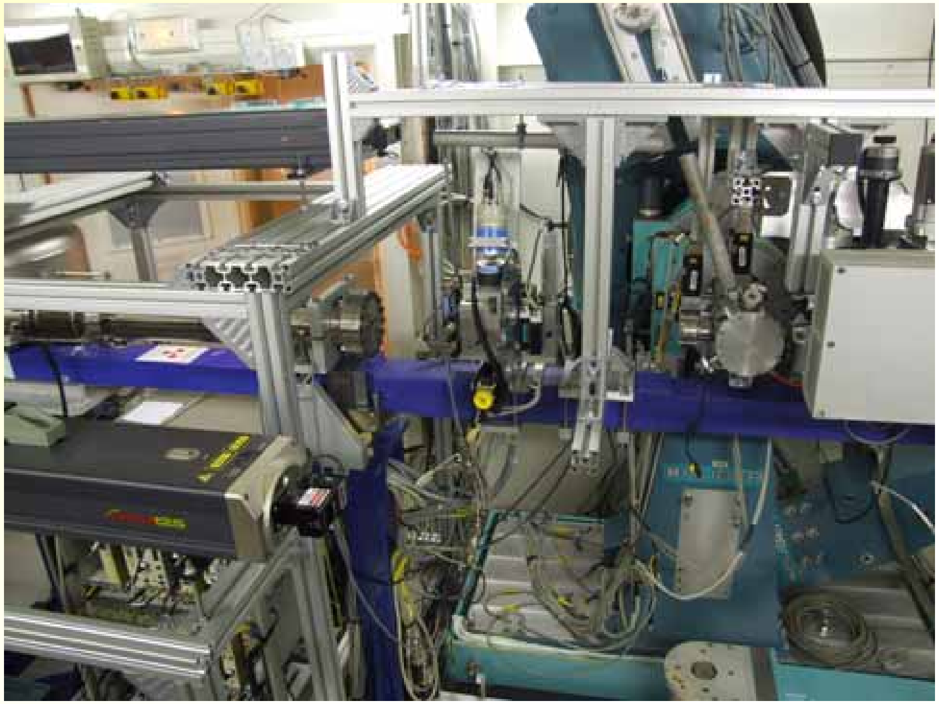
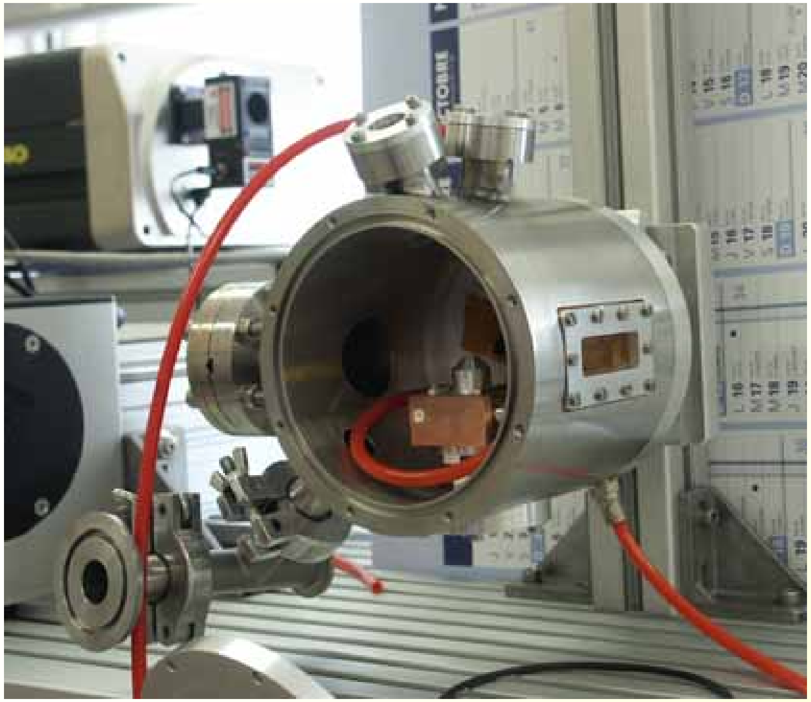
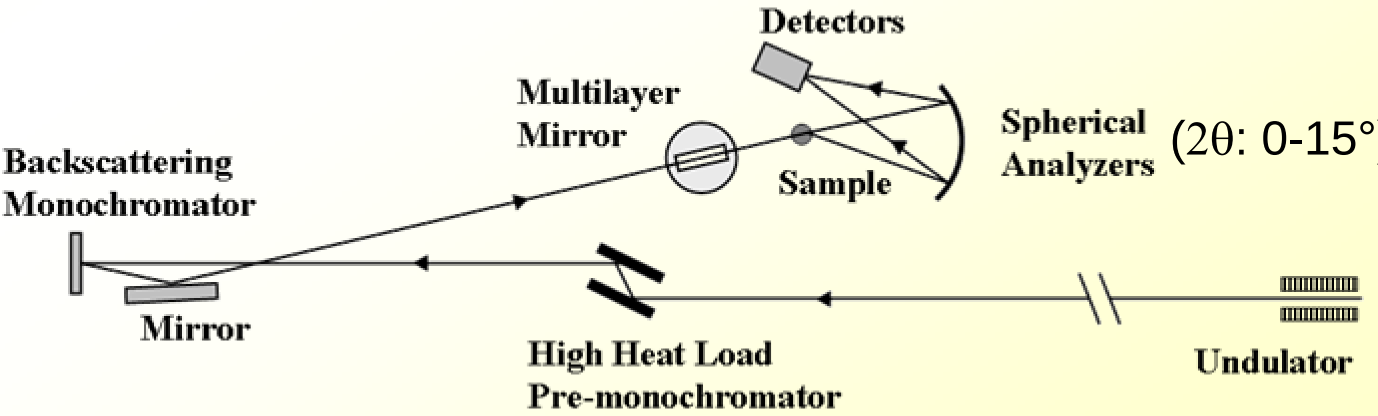
Experimental setup at ID16 (ESRF)







(2θ: 0-15°)

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Various developments at

neutron sources

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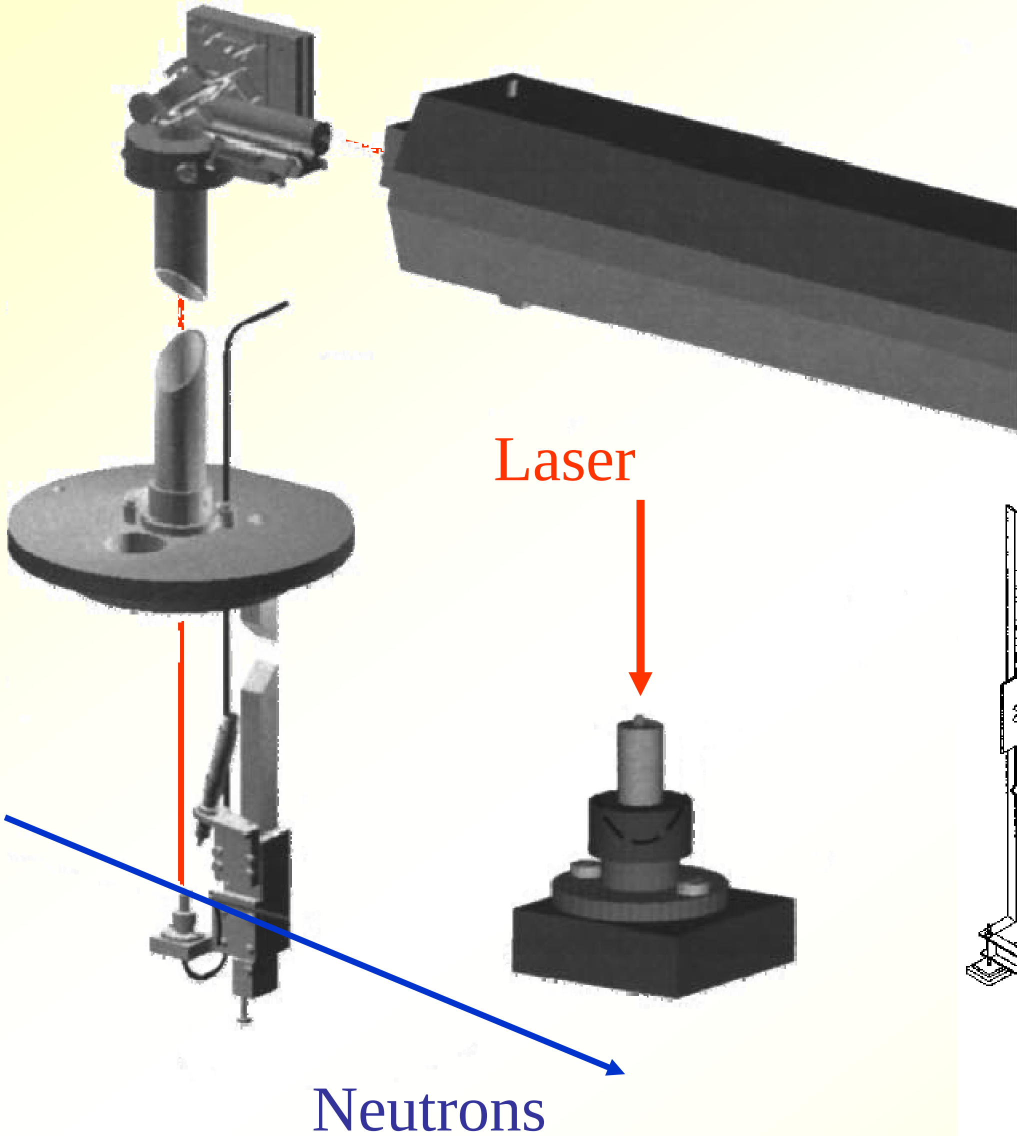
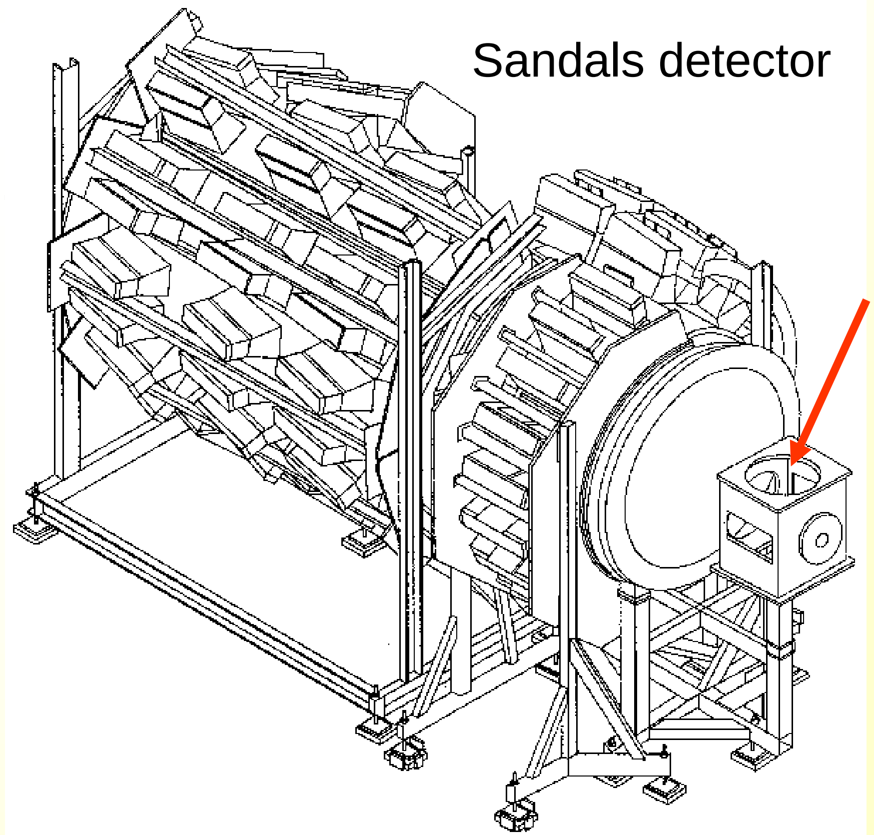
Neutron scattering at ISIS (1999)

With Neville Greaves (Aberystwyth)

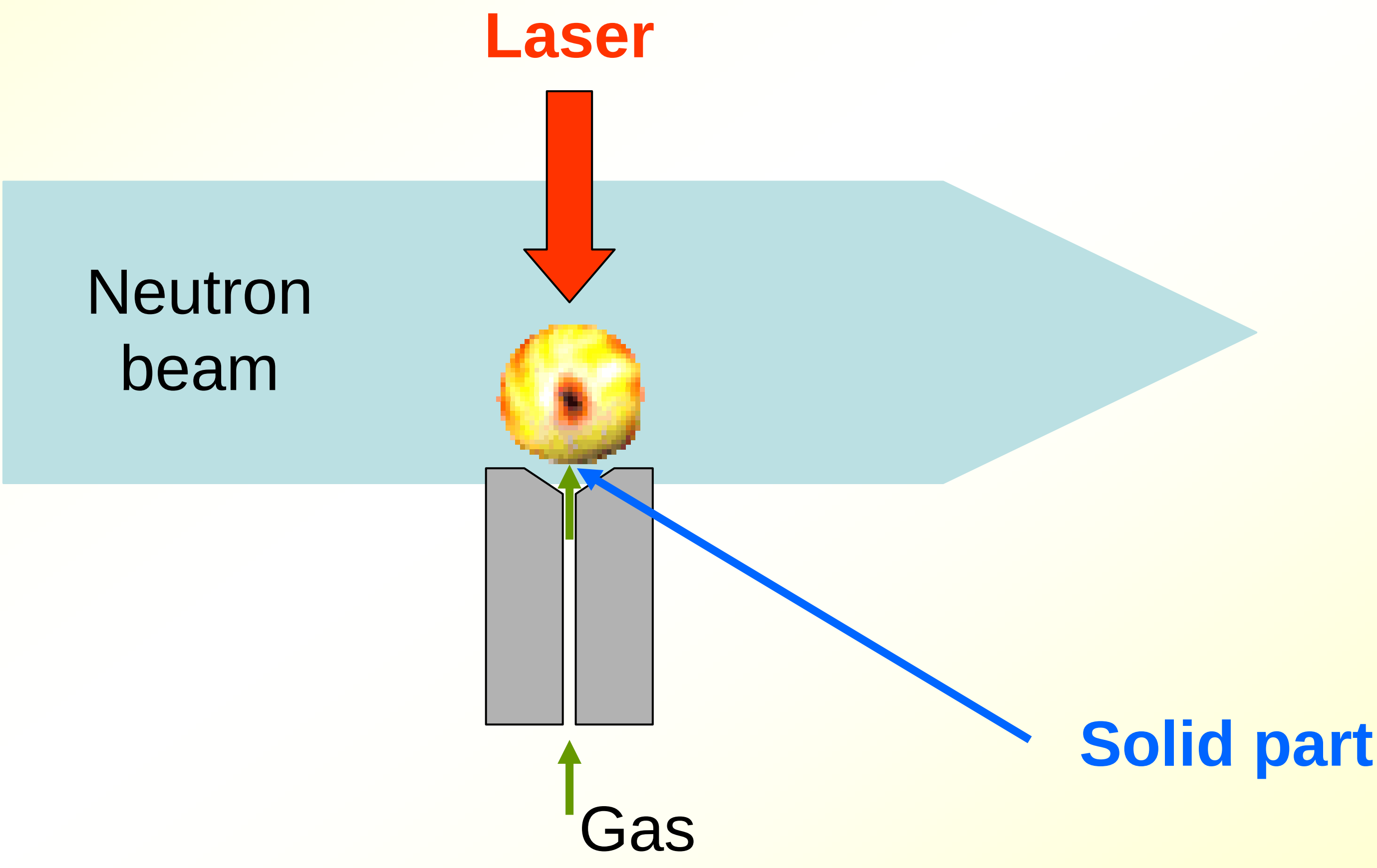




Problem

Not possible to completely melt the sample

We had diffraction peaks on the high temperature measurements



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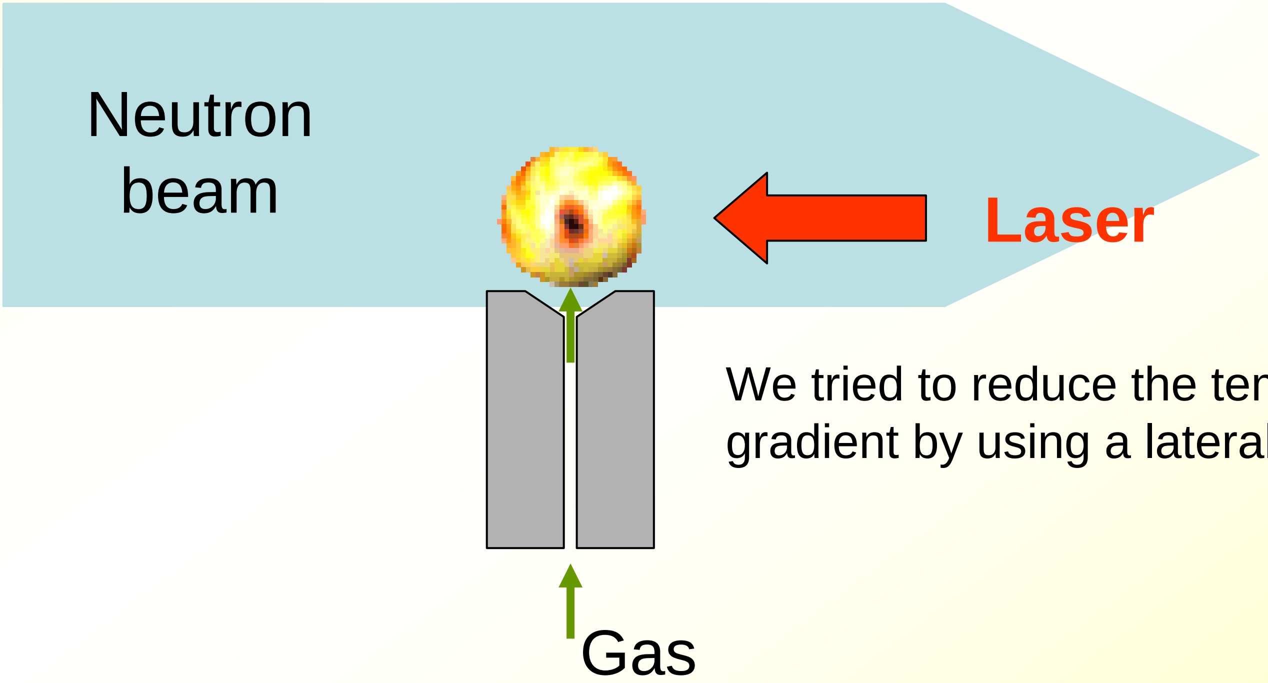
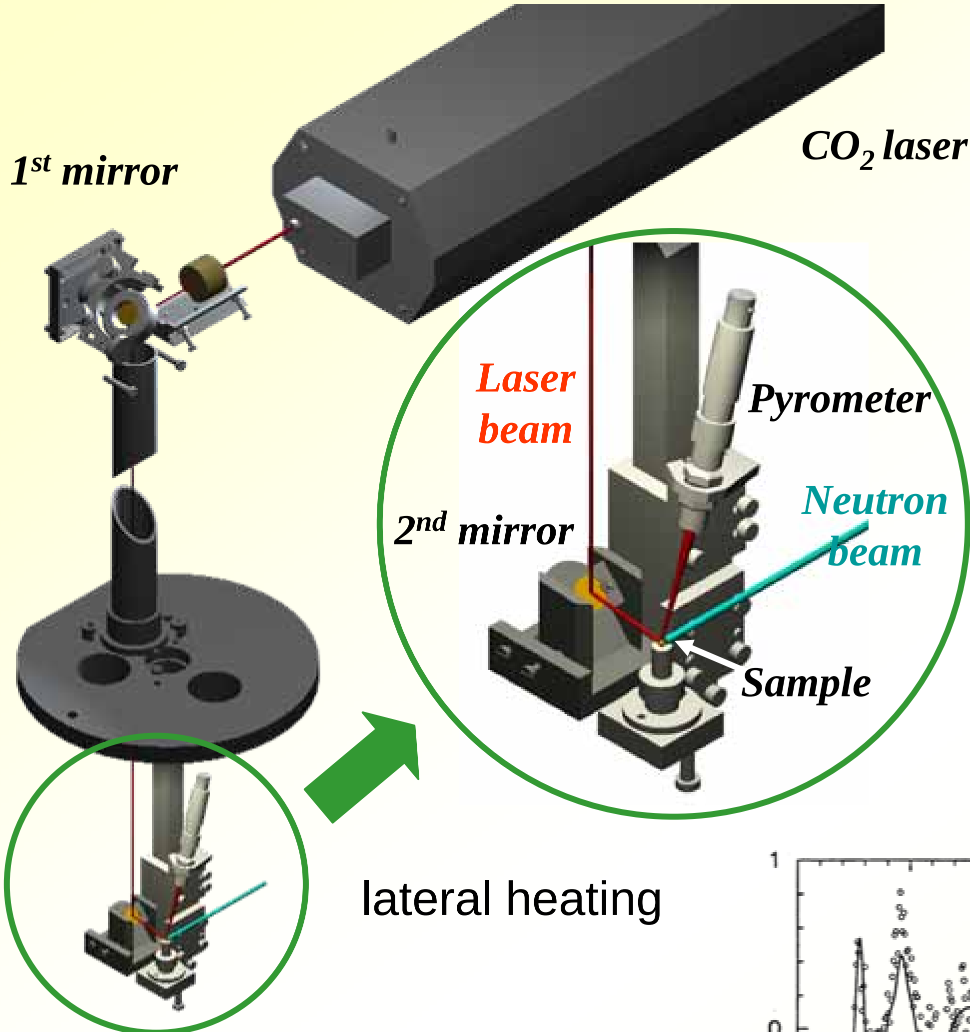
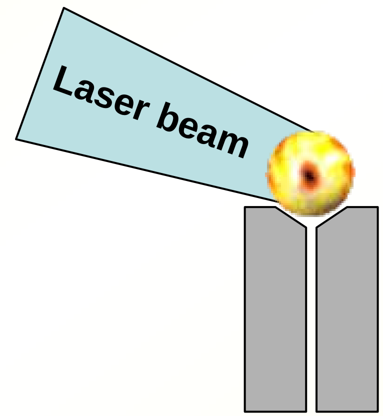


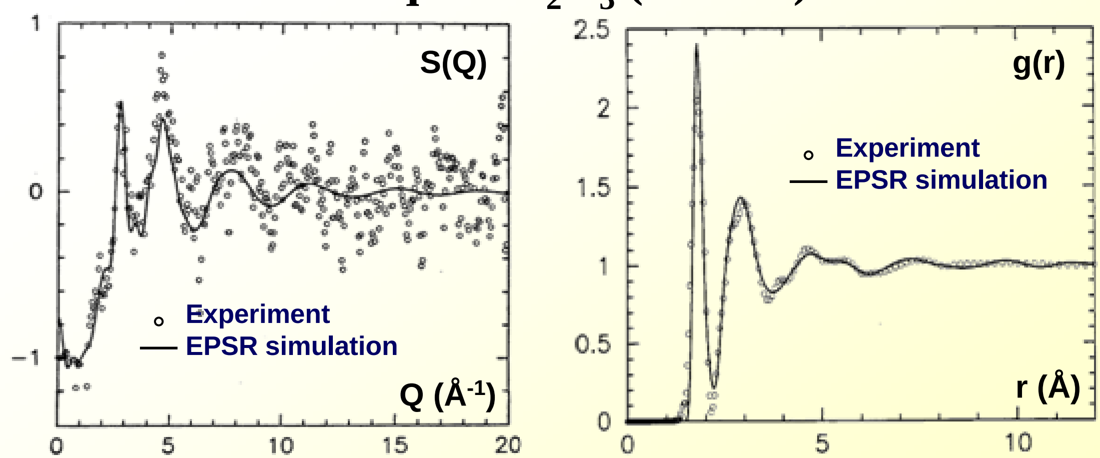
We tried to reduce the temperature gradient by using a lateral heating

New setup (2000)





Liquid Al_2O_3 (2250°C)



Good agreement with x-ray measurements

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Aberystwyth
1872 The University of Wales

ISIS

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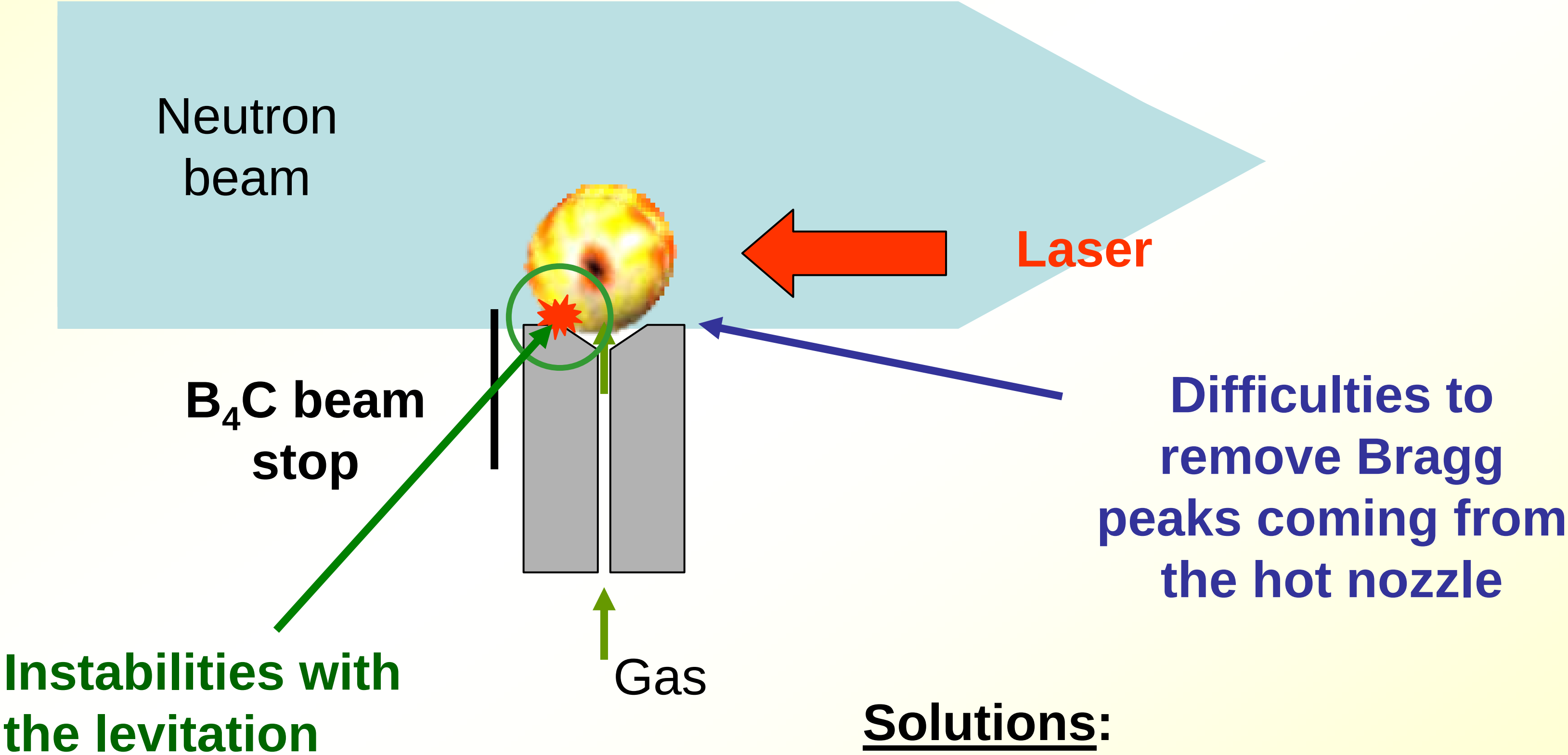
New problems

In 2001, we tried to work on yttrium oxide at higher temperatures

We had again Bragg peaks in some measurements



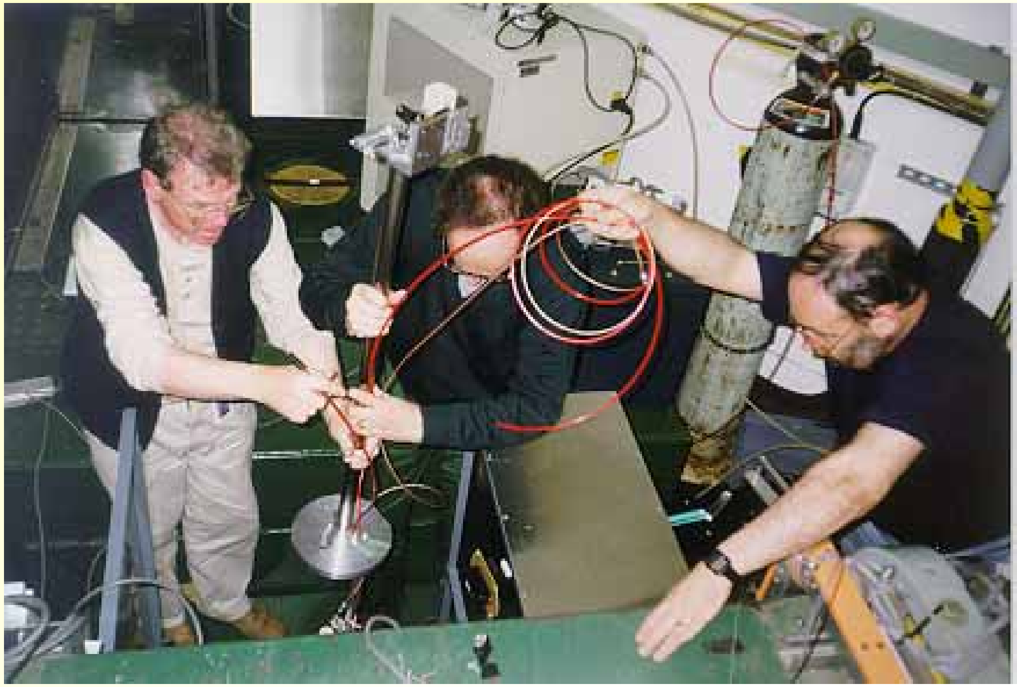
Crystallisation due to contacts

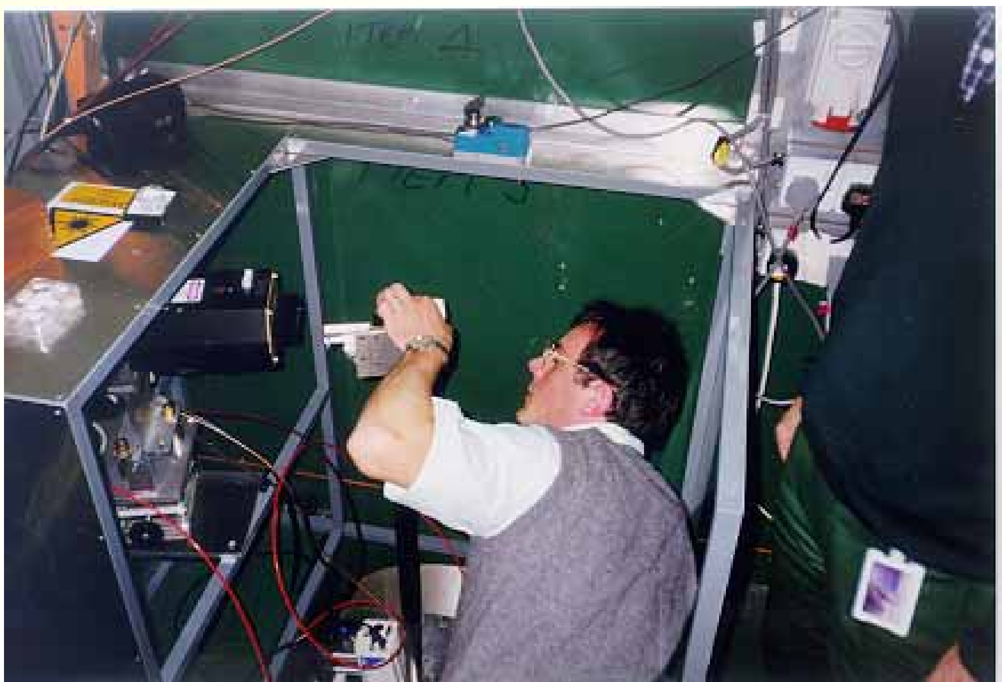
<u>Solutions</u>:

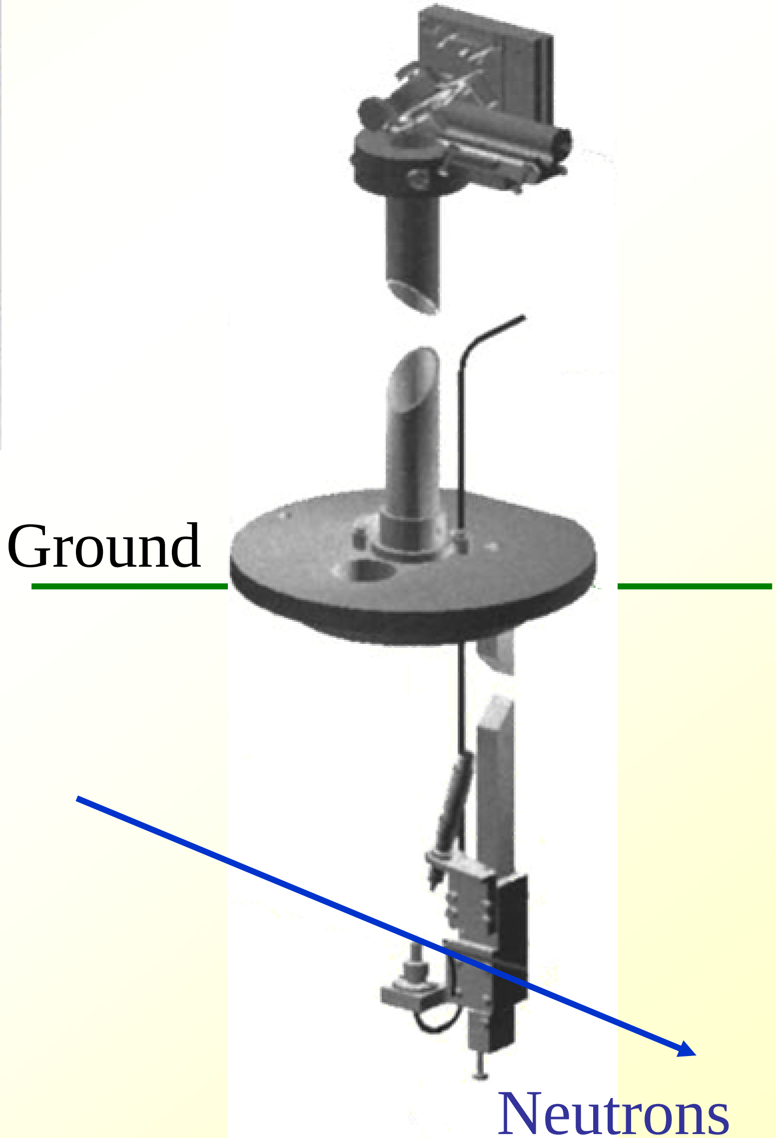
Improvement of the levitation

Use of a beam stop in front of the nozzle

Other Difficulties



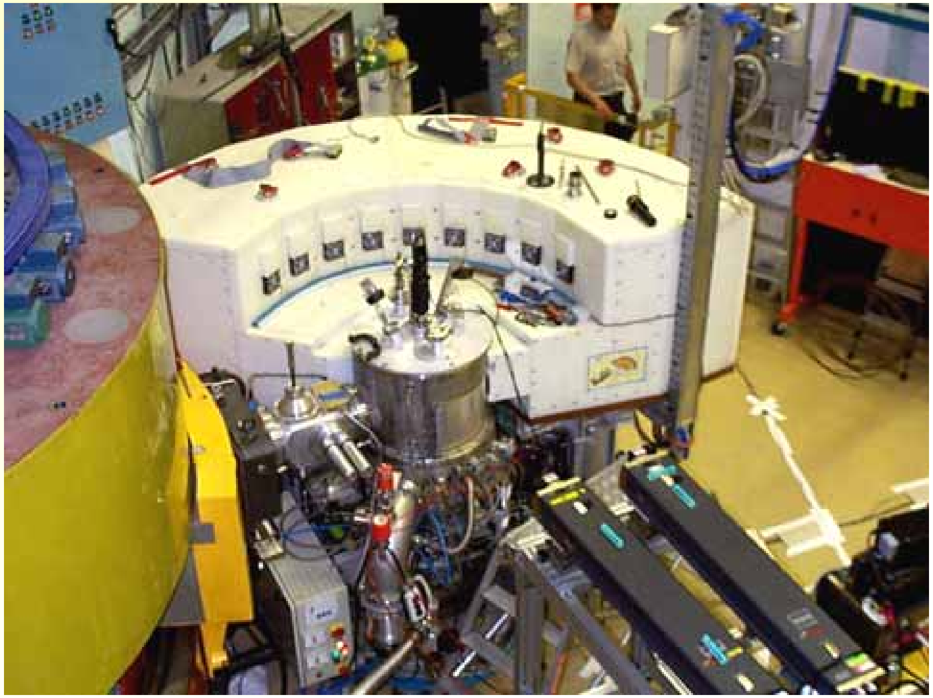


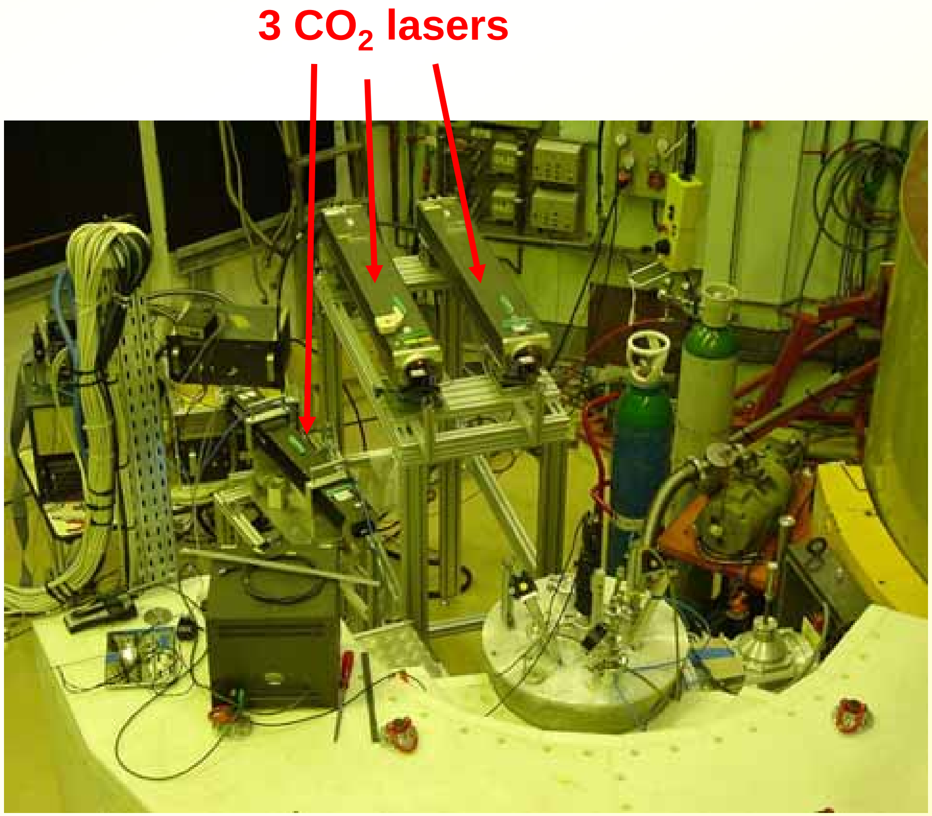


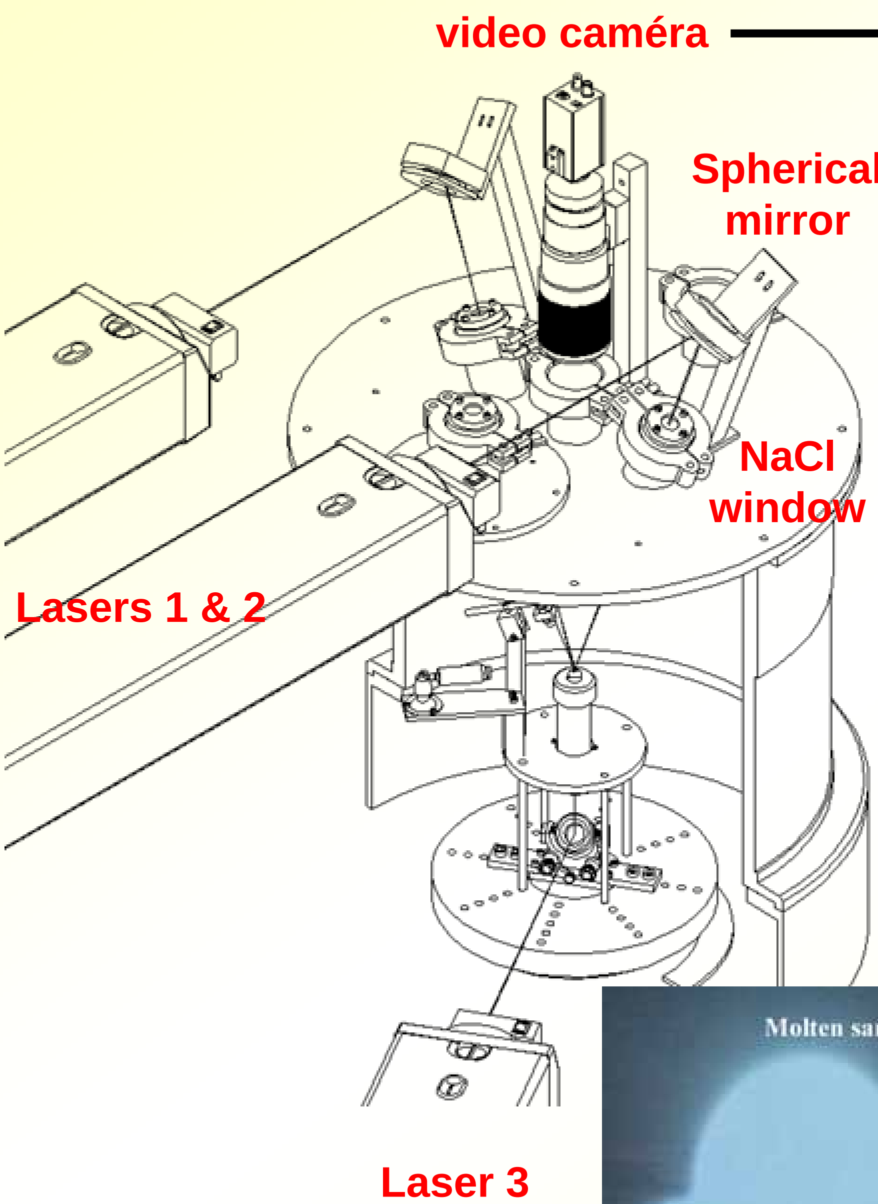
NEUTRONS FOR SCIENCE

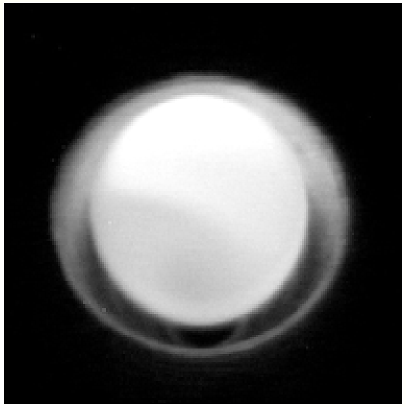
Neutron scattering

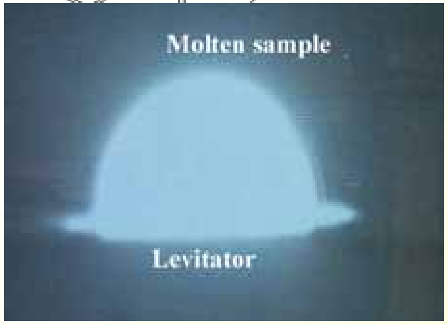
D4C diffractometer @ ILL

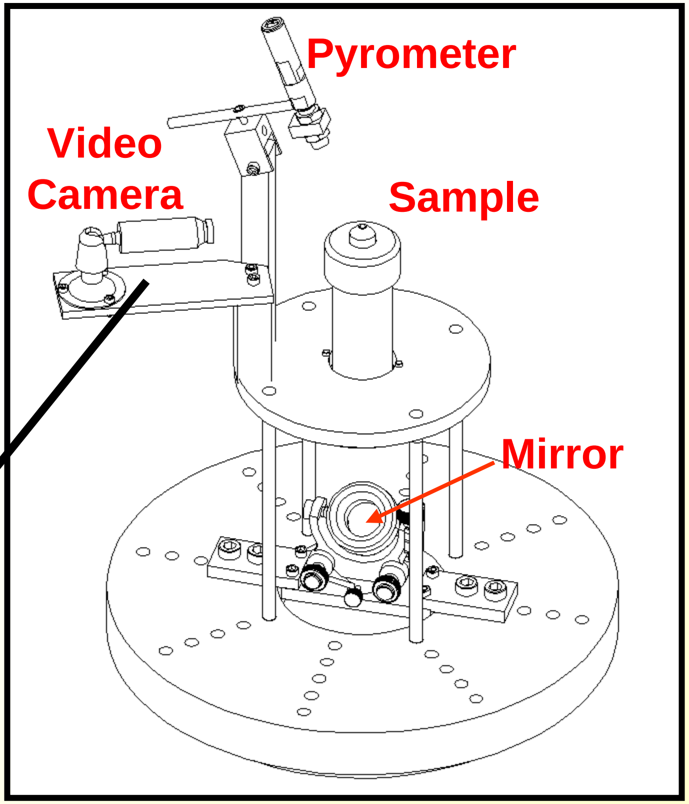





video caméra
Spherical mirror
NaCl window
Lasers 1 & 2
Laser 3




Molten sample
Levitator


Pyrometer
Video Camera
Sample
Mirror

"Fast" measurements at D4c

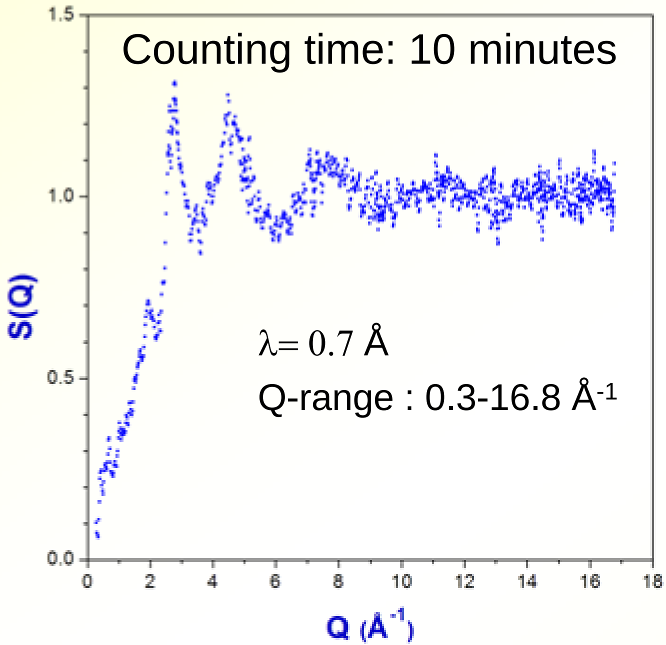
$(Y_20_3)_x$-$(Al_20_3)_{1-x}$

X=0.15

(Melting point : 1840°C)

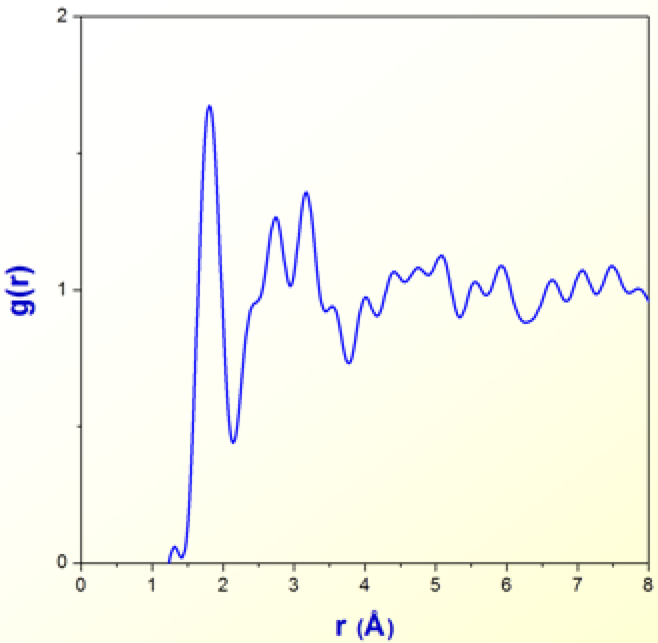
Contrary to x-rays, it's difficult to make very fast neutron scattering measurements

Possible to obtain good statistics with relatively short counting times



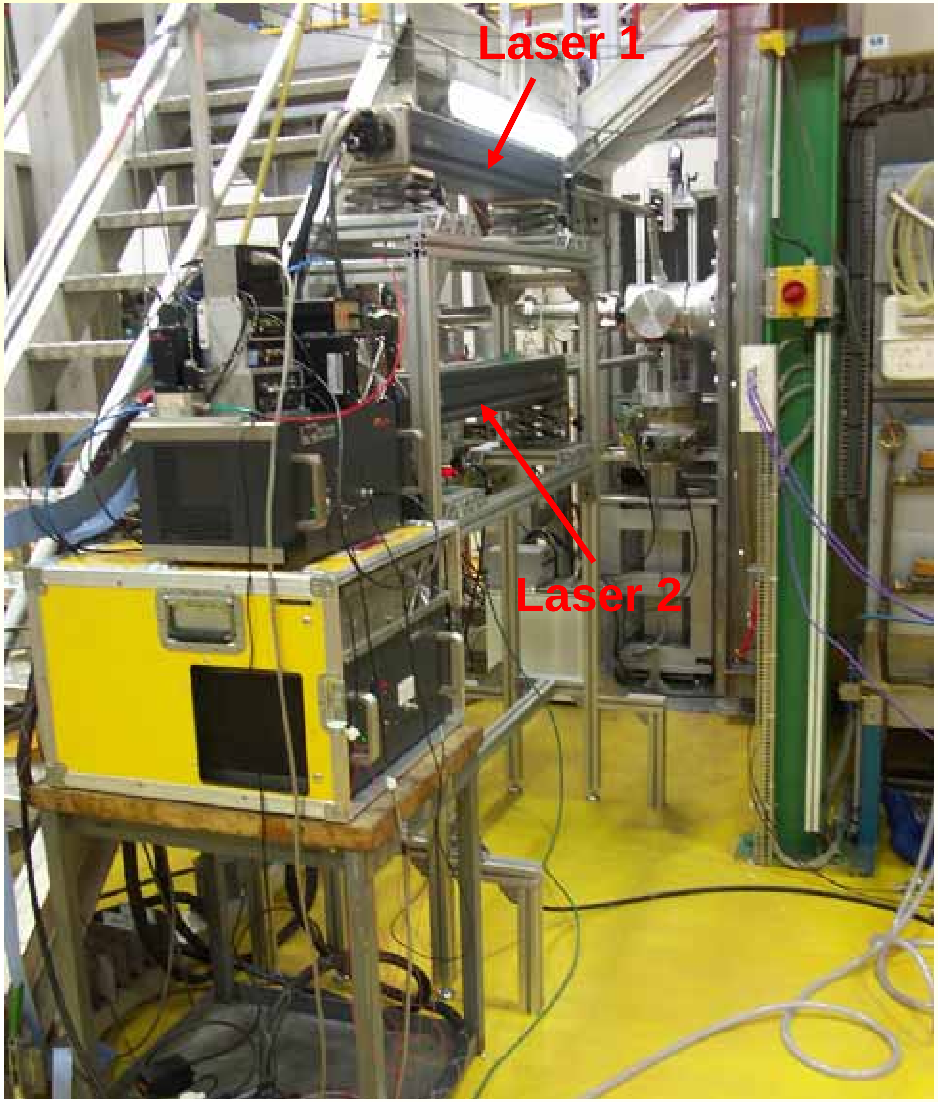
Statistics are relatively good in spite of the small sample size.

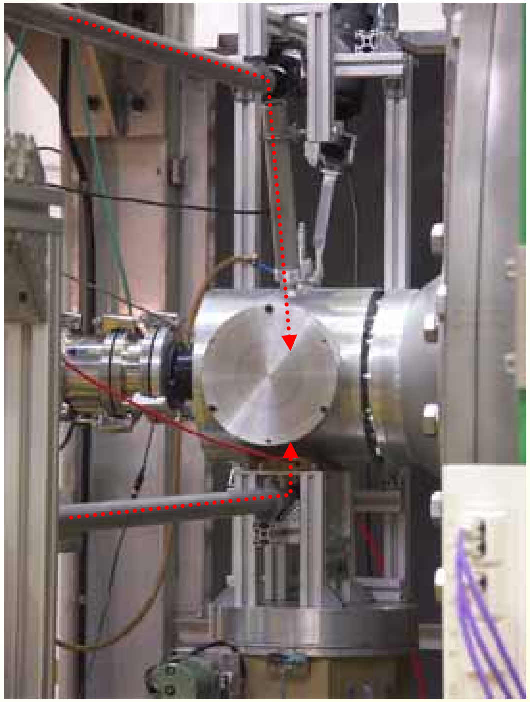
Preliminary calculations give reasonable results

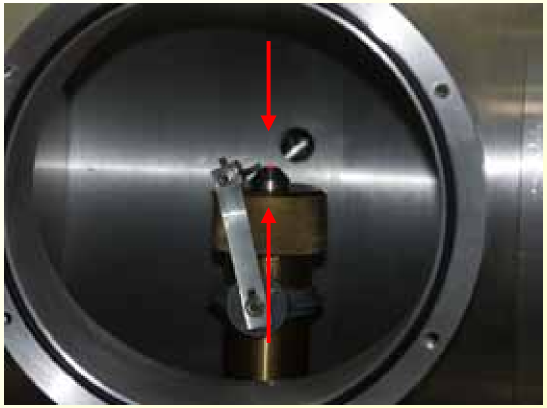


we use counting time of at least 1 hour to get better statistics

D22 @ ILL (Small Angle Neutron Scattering Spectrometer)







possible to study either oxides or metals

An alternative heating technique

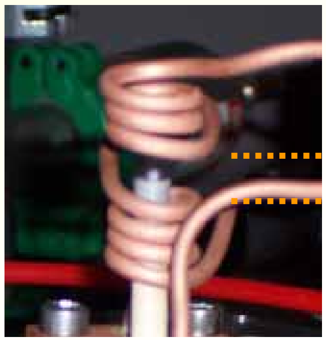
Aerodynamic levitation and RF heating

Collaboration DLR / CRMHT

Optimization of an aerodynamic levitation system associated with a RF heating

<u>Coil (Helmholtz geometry)</u> R=d

2R



d

Boron nitride

Generator

Oscillator

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ID15 @ ESRF

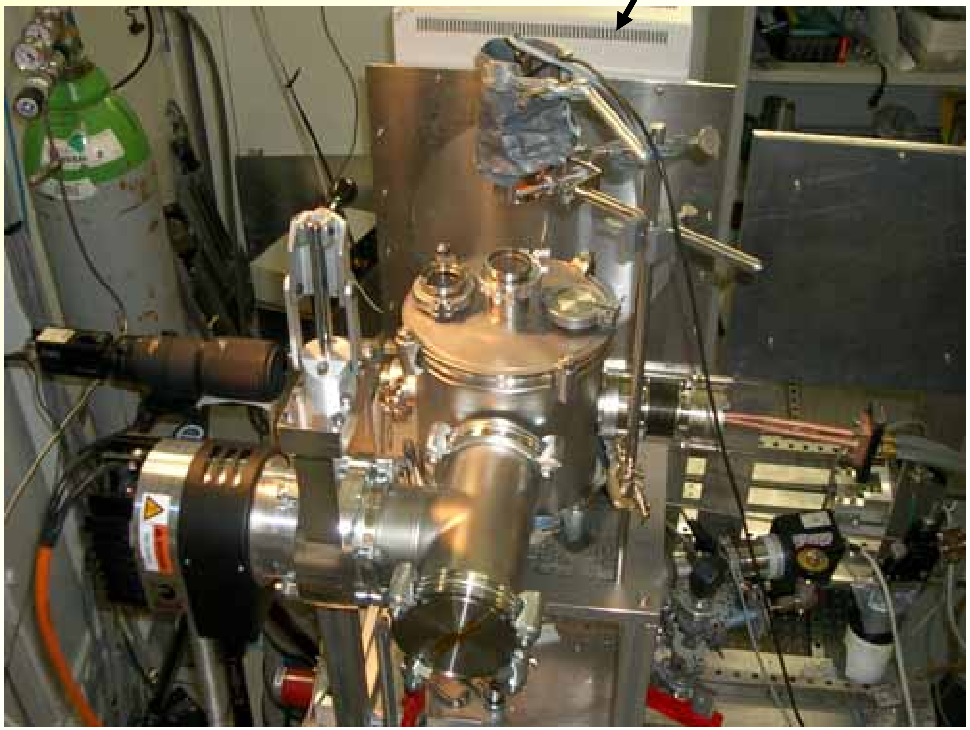
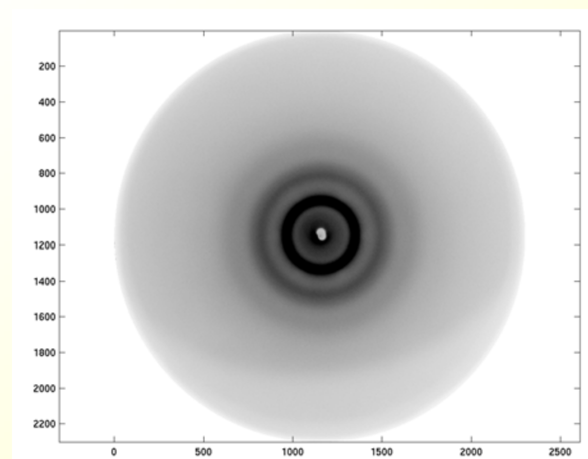


Image plate scanner



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Current developments

- The CRMHT is associated with the ***DiffAbs*** Beamline at the new French synchrotron ***SOLEIL*** and a new setup is being installed.

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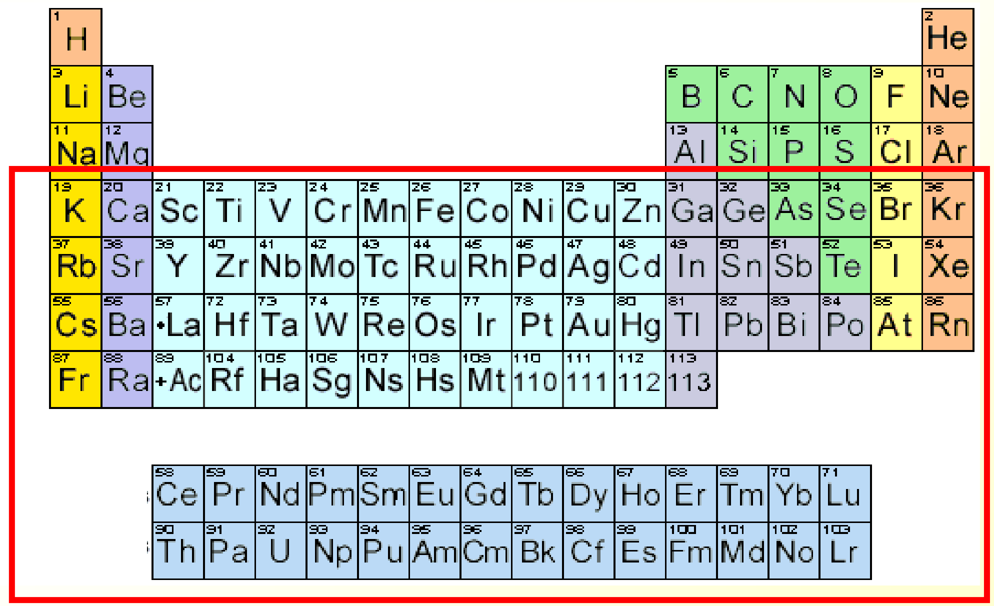
It will be possible to combine Absorption and Diffraction experiment in the 3-23 keV energy range (K or L absorption edges of a large number of elements).



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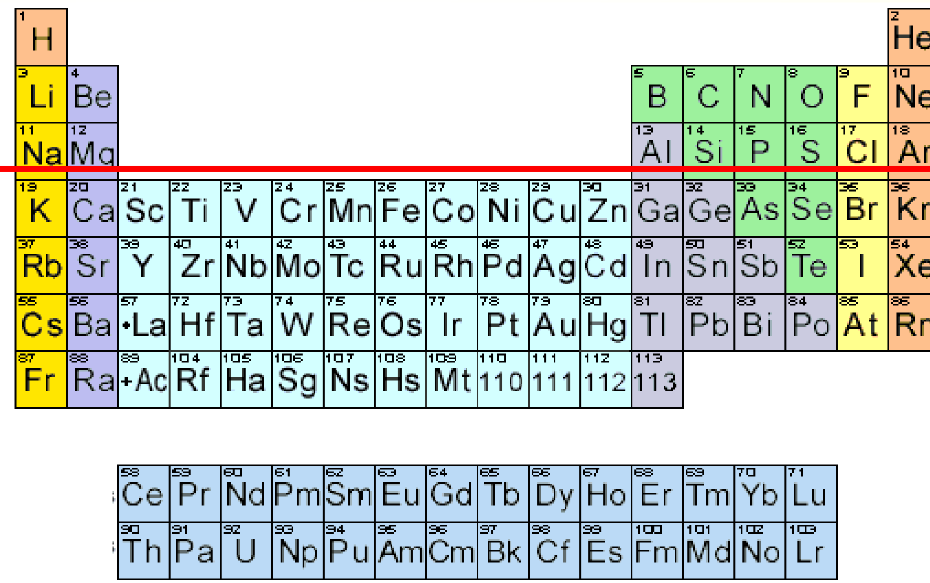


- First Quasi Elastic Neutron Scattering (QENS) experiments at IN8 (ILL) are very promising.

Summary of various x-ray and neutron techniques combined with aerodynamic levitation

X-rays

- ✓ X-ray Absorption Spectroscopy
- ✓ Wide Angle X-ray Scattering
  - High Energy Diffraction
  - Anomalous Scattering
- ✓ Small Angle X-ray Scattering
- ✓ Inelastic X-ray Scattering

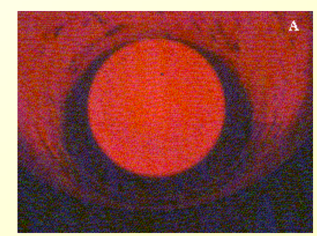
Neutrons

- ✓ Wide Angle Neutron Scattering
- ✓ Small Angle Neutron Scattering
- ✓ Inelastic Neutron Scattering

Some other techniques already combined with aerodynamic levitation

NMR

Raman



Imaging techniques