



Stress, strain, texture and some other things ...

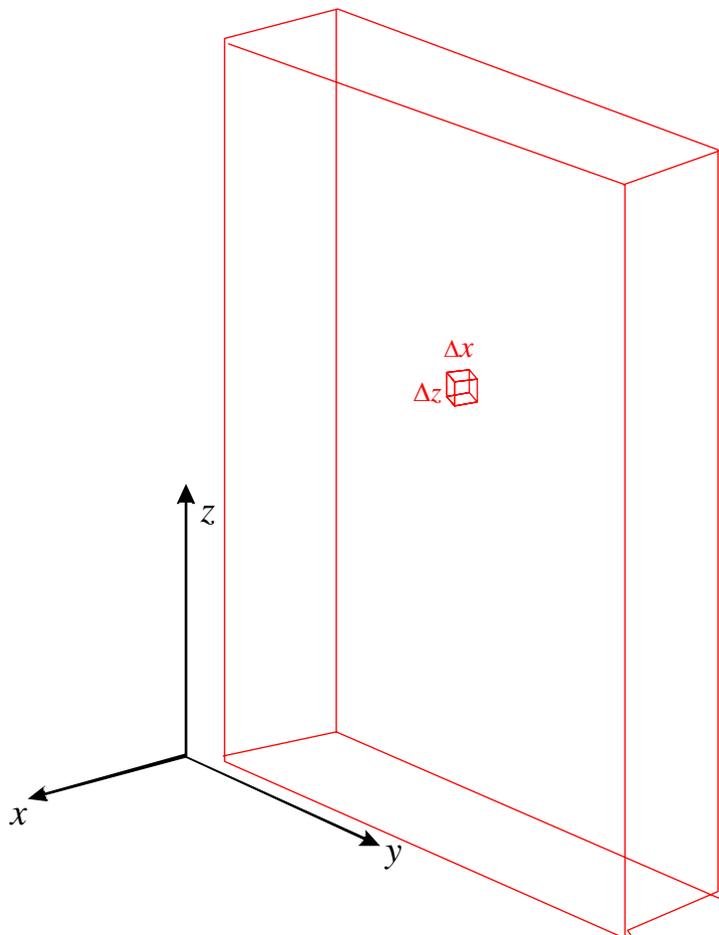
Robert McGreevy

*ISIS Facility,
CCLRC Rutherford Appleton Laboratory,
Chilton, Didcot, OX11 0QX, UK.*



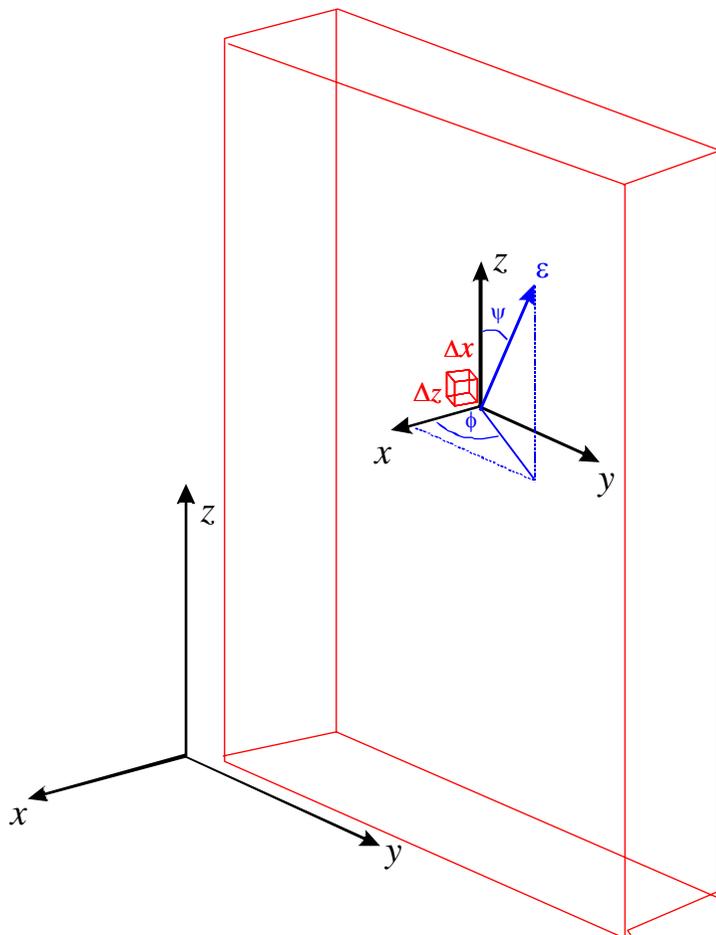


Measure the strain tensor ϵ_{ij} within a gauge volume $\Delta x \Delta y \Delta z$ at (x, y, z)



$$\begin{bmatrix} \epsilon_{xx} & \epsilon_{xy} & \epsilon_{xz} \\ \epsilon_{xy} & \epsilon_{yy} & \epsilon_{yz} \\ \epsilon_{xz} & \epsilon_{yz} & \epsilon_{zz} \end{bmatrix}$$

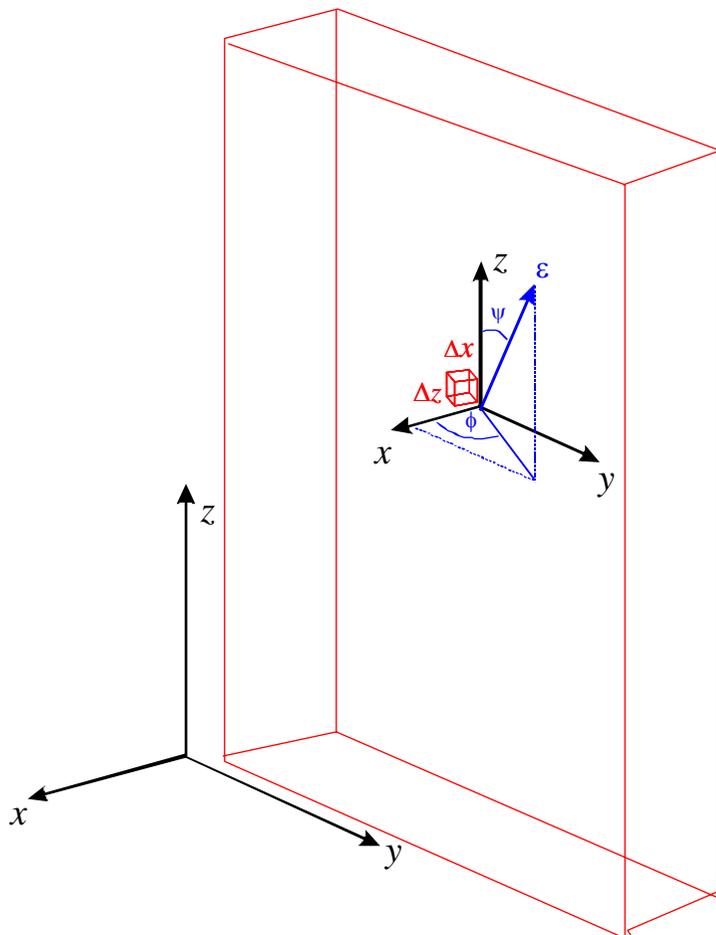
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$$\begin{aligned} \epsilon_{\phi\psi} = & \epsilon_{xx} \cos^2 \phi \sin^2 \psi + \epsilon_{xy} \sin 2\phi \sin^2 \psi + \\ & \epsilon_{yy} \sin^2 \phi \sin^2 \psi + \epsilon_{zz} \cos^2 \psi + \\ & \epsilon_{xz} \cos \phi \sin 2\psi + \epsilon_{yz} \sin \phi \sin 2\psi \end{aligned}$$

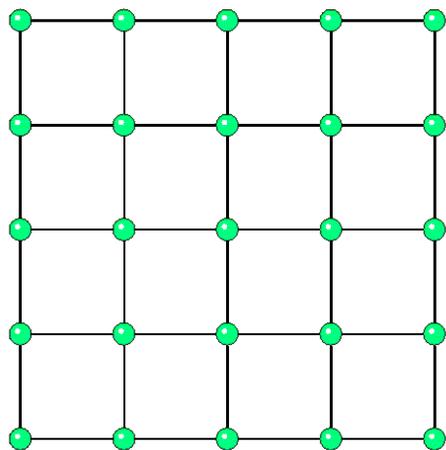
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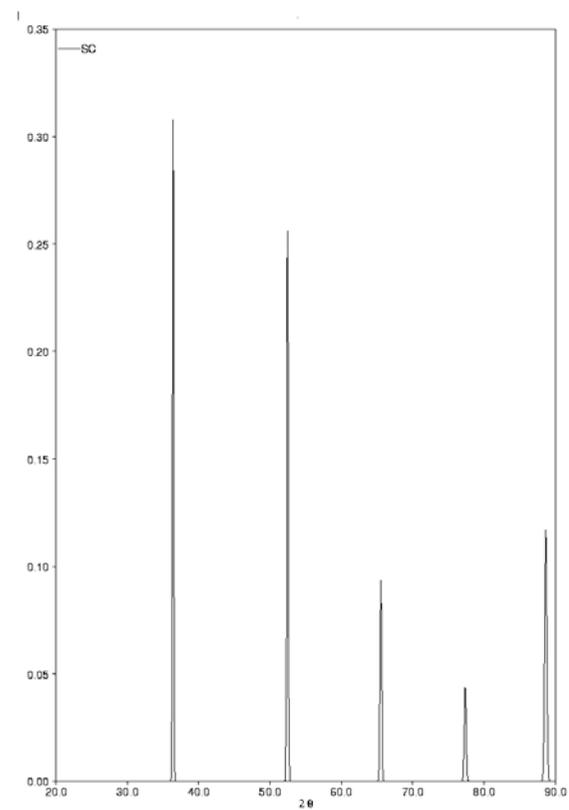
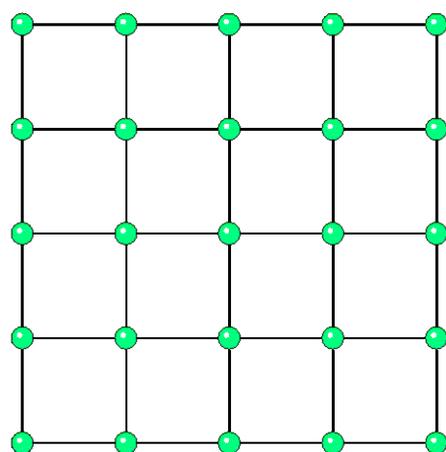


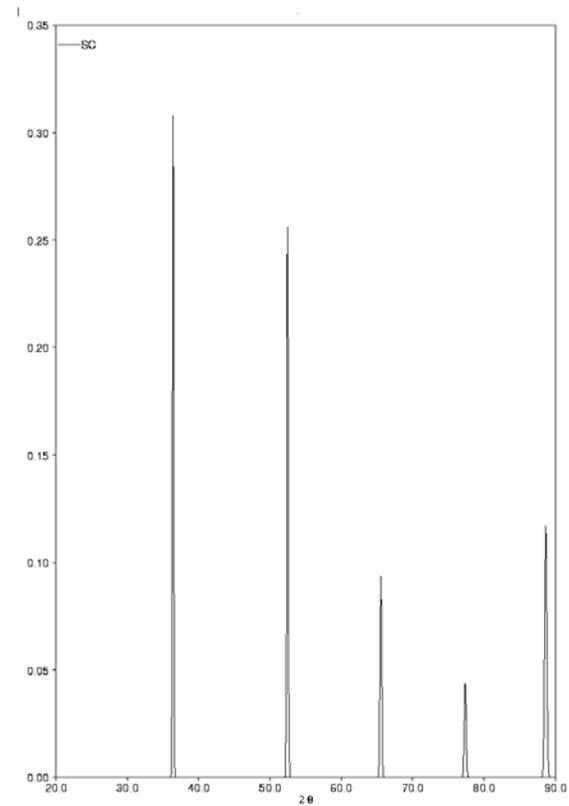
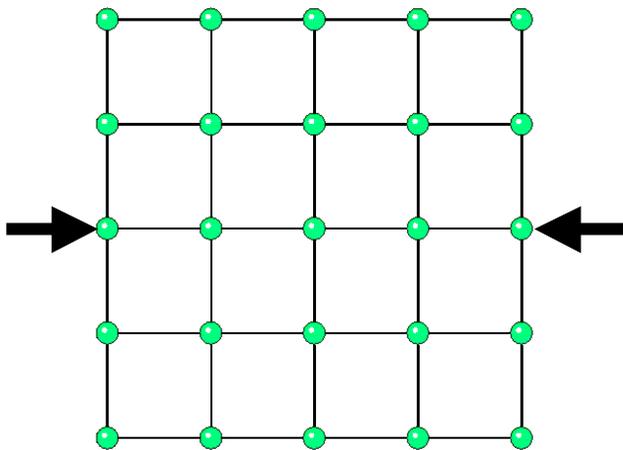
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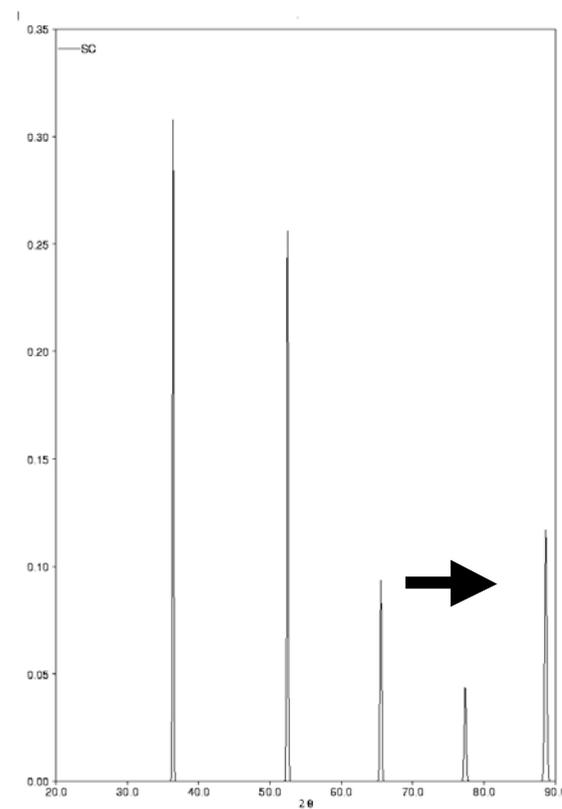
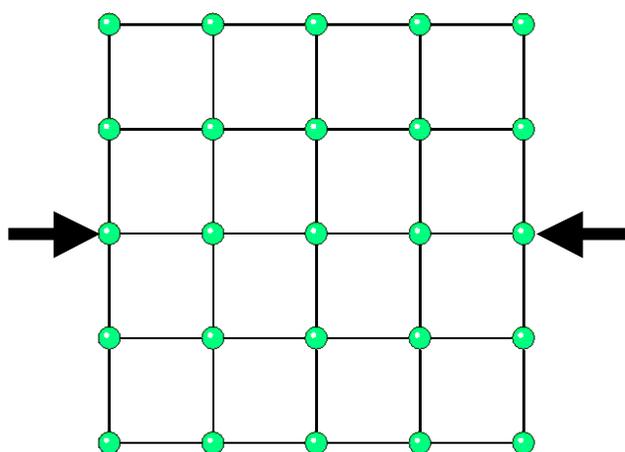
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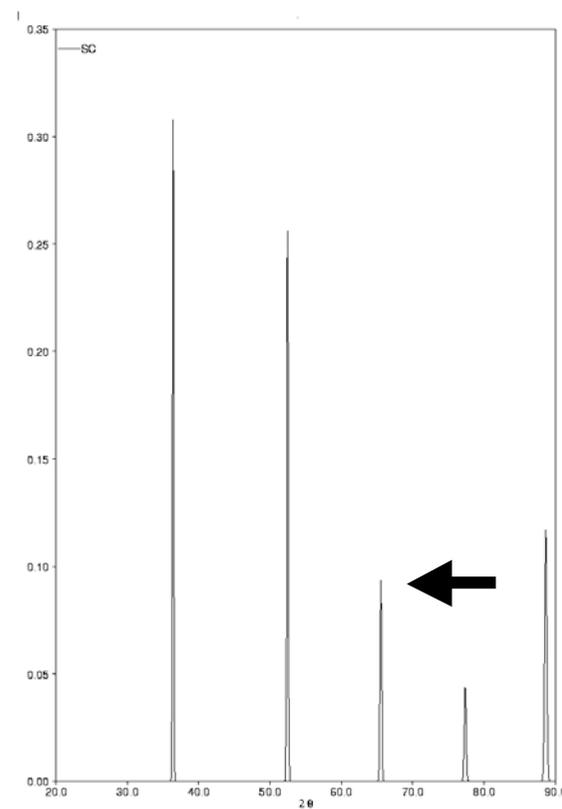
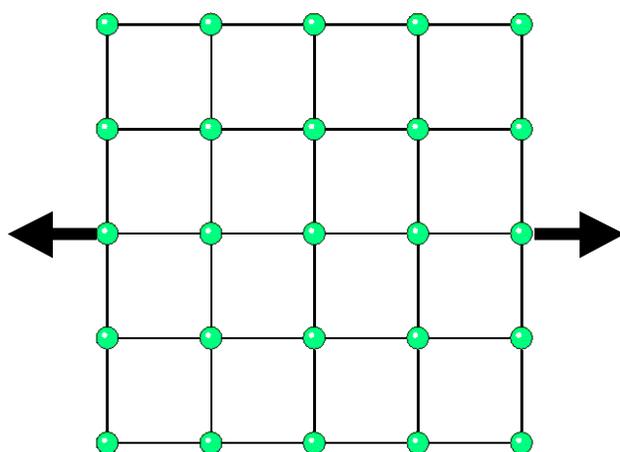
$$\epsilon_{\psi\phi}(x, y, z) = \frac{d_{\psi\phi}(x, y, z) - d_0}{d_0}$$

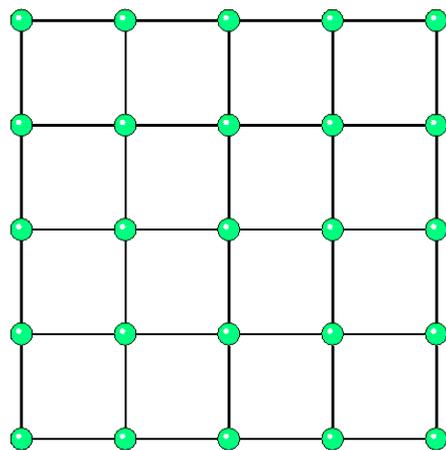


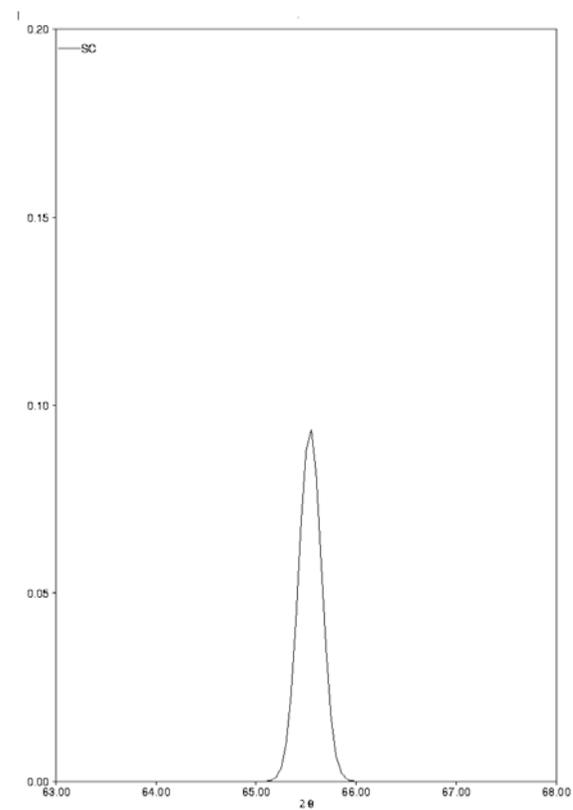
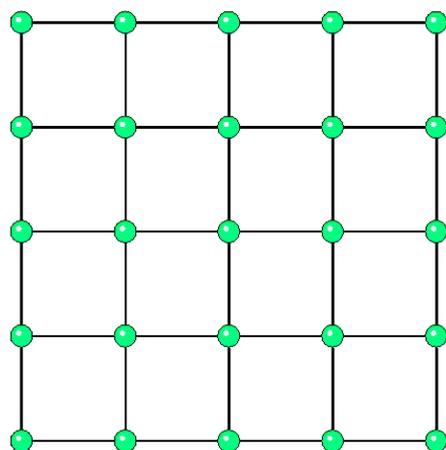


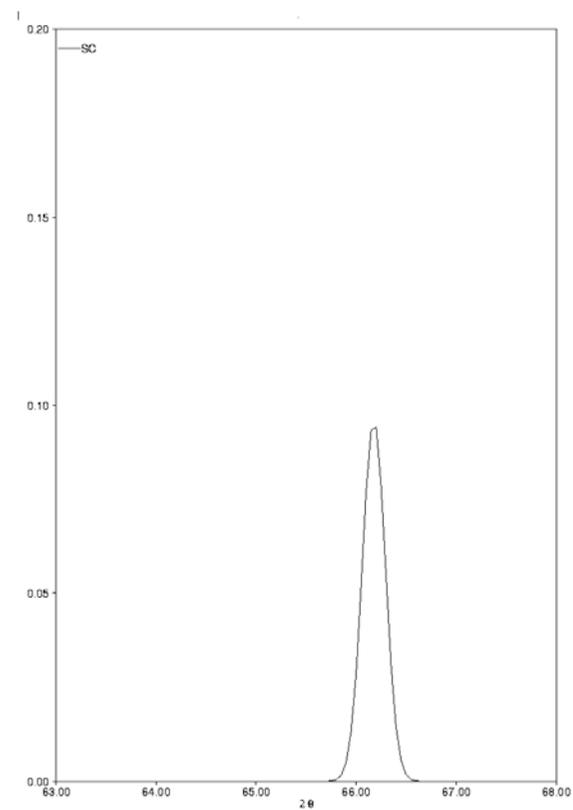
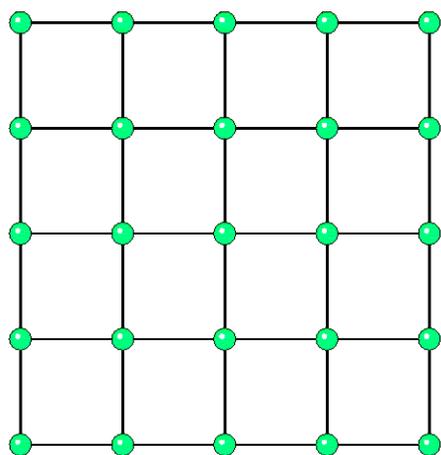


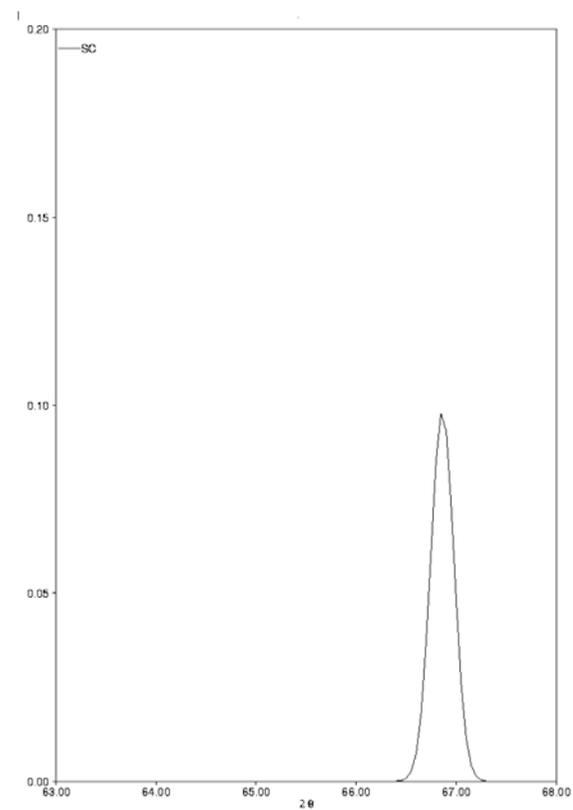
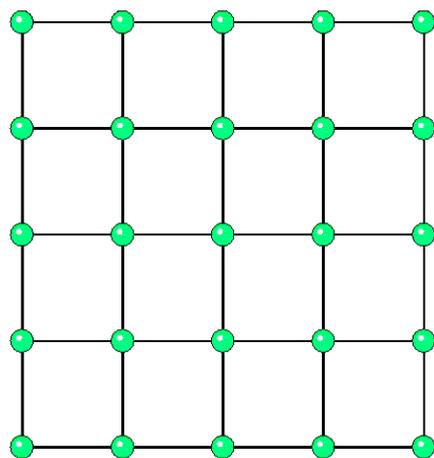


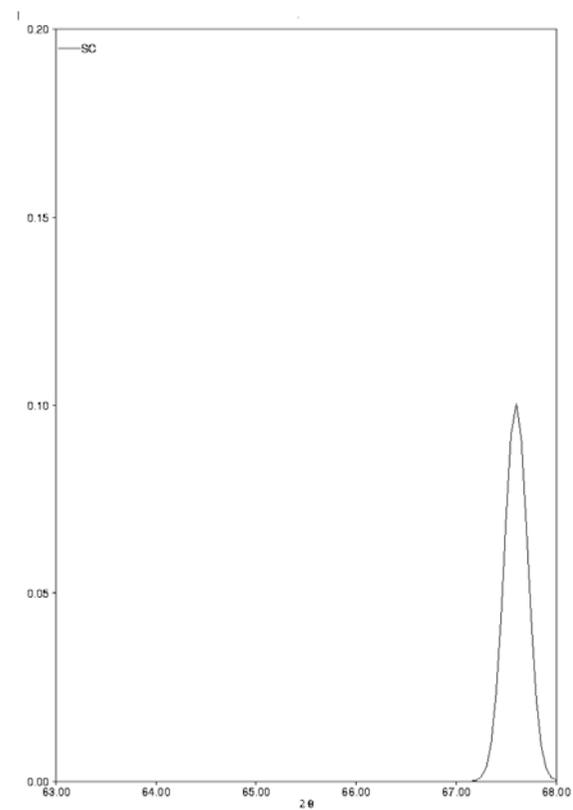
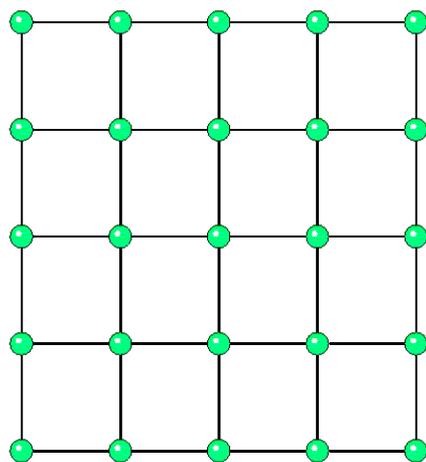


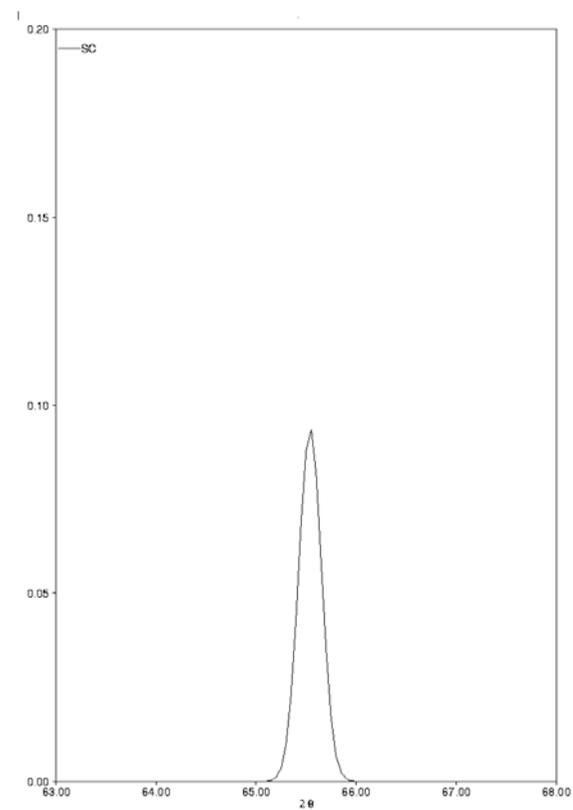
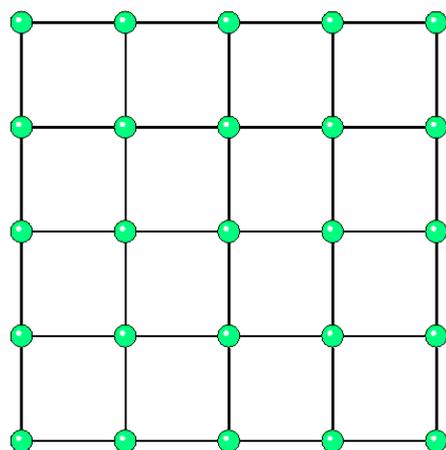


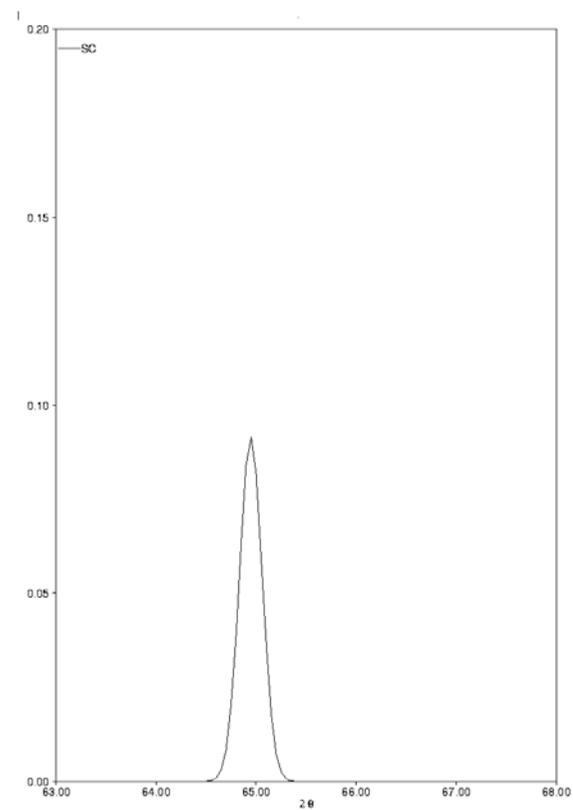
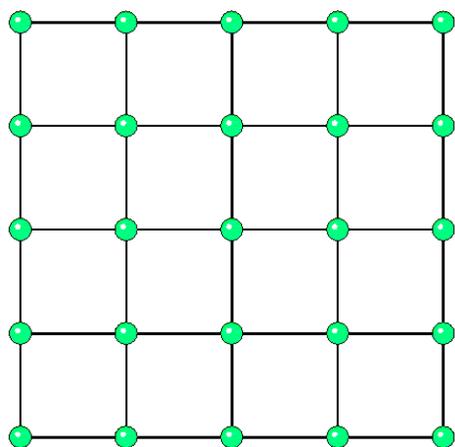


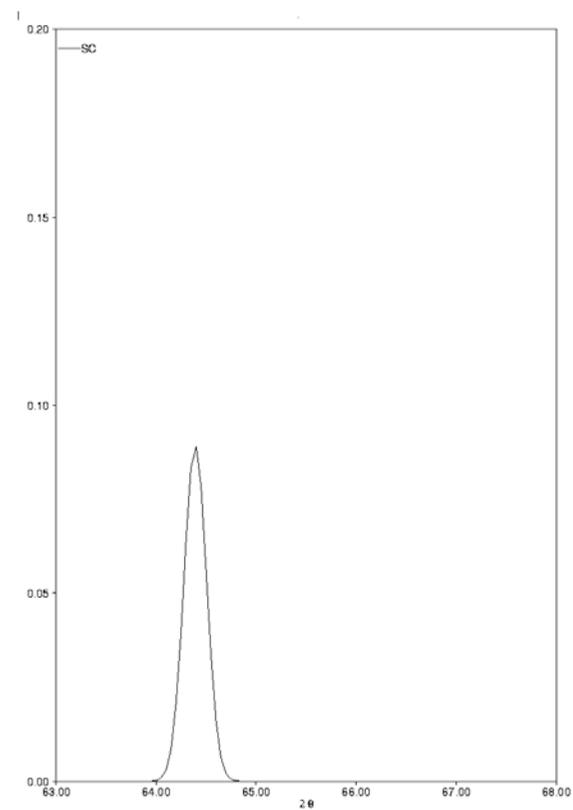
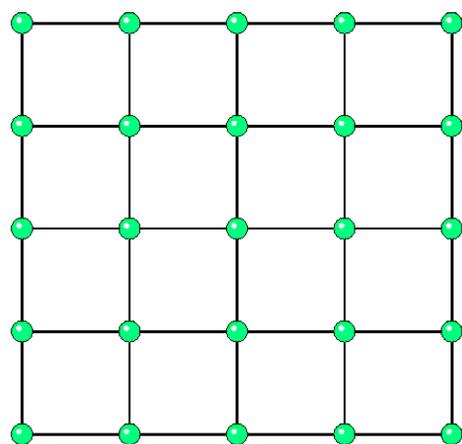


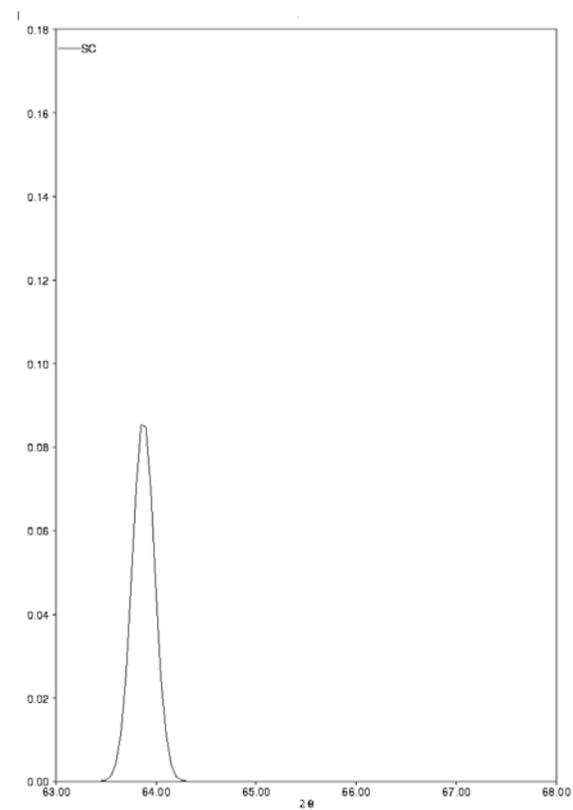
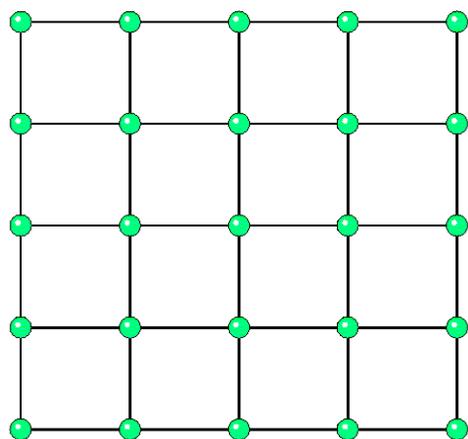


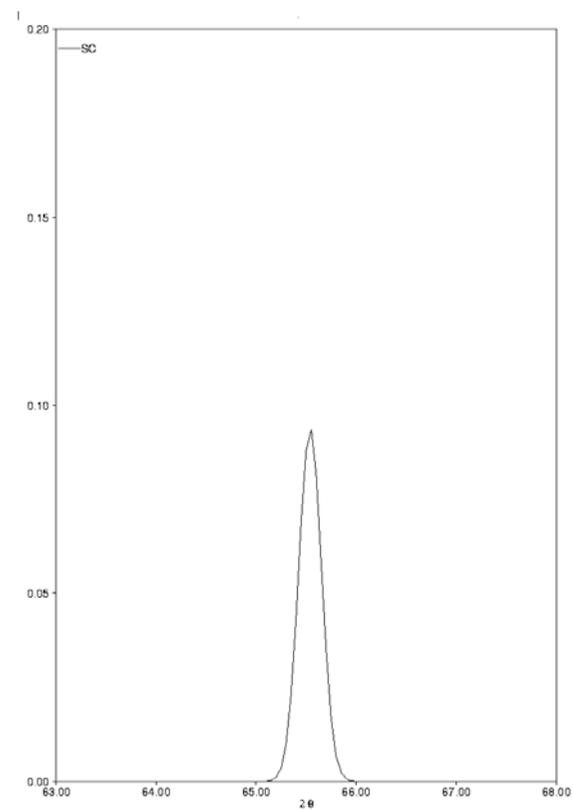
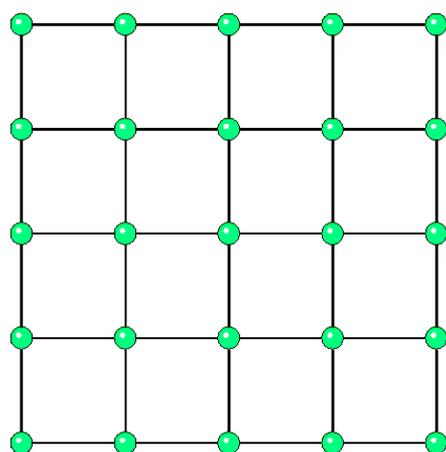




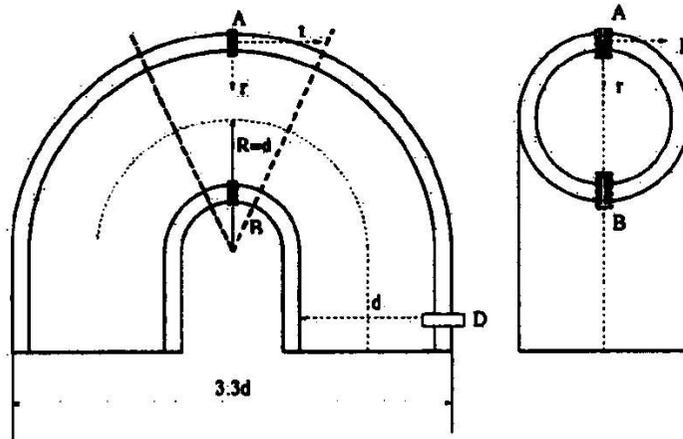






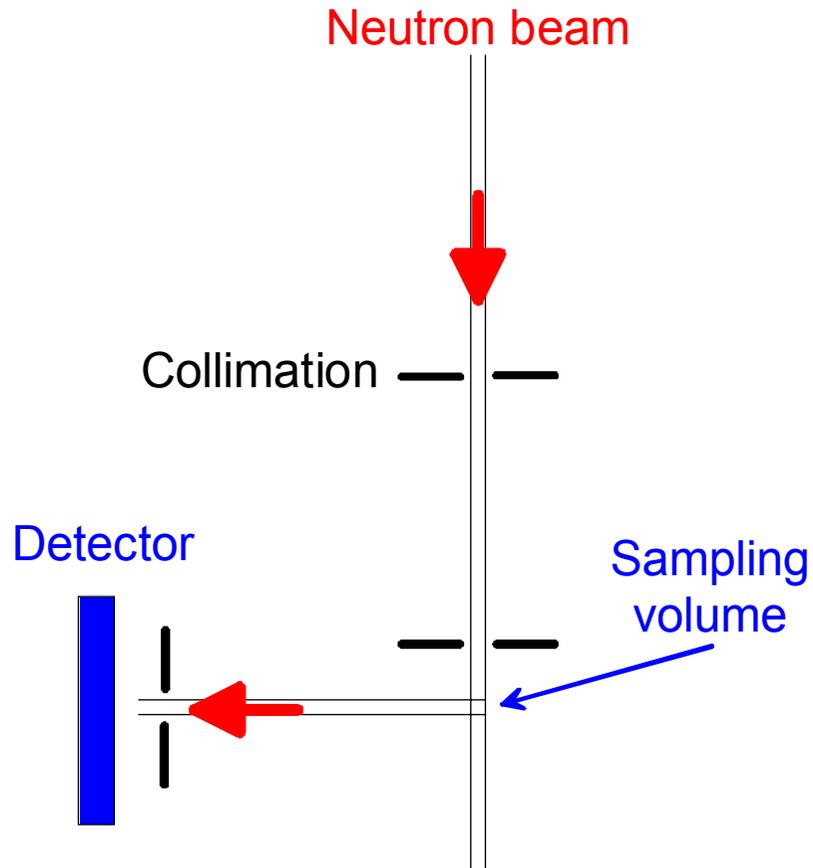


That's the principle.
What do you do in practice?

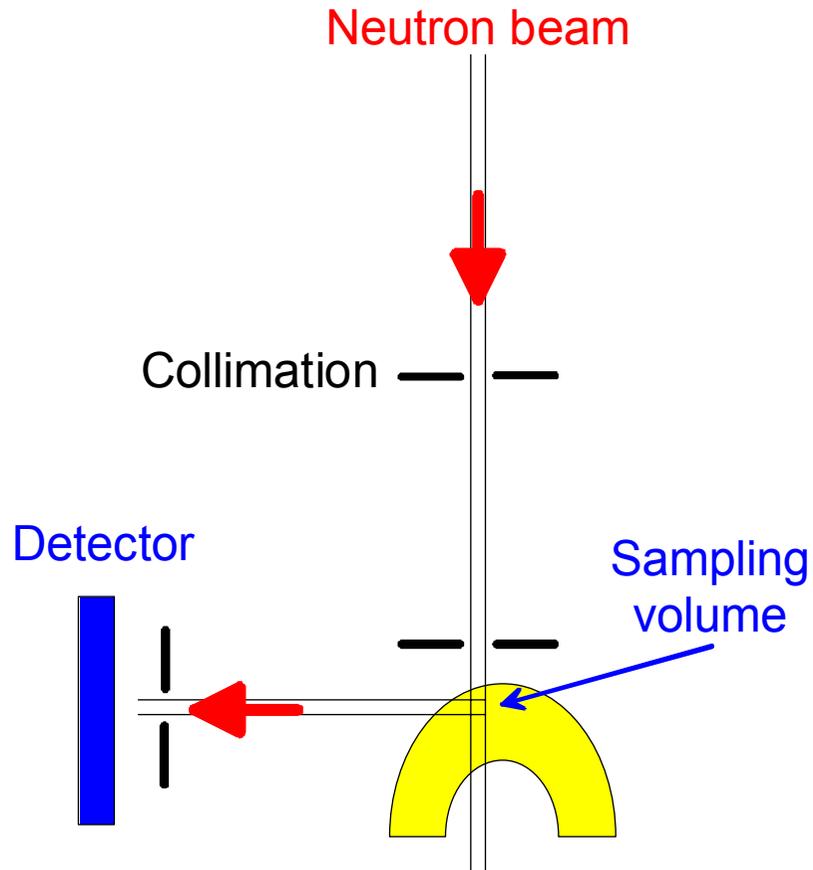


Residual stress in bimetalllic tubes

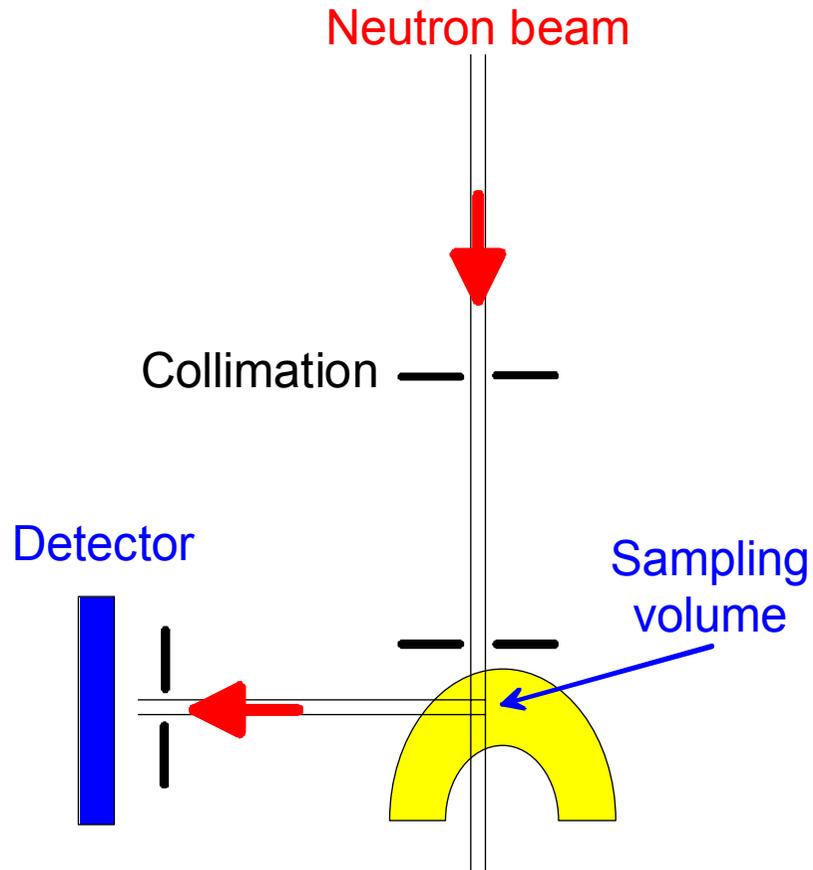
F J Mompean et al., ICMM Madrid, Spain



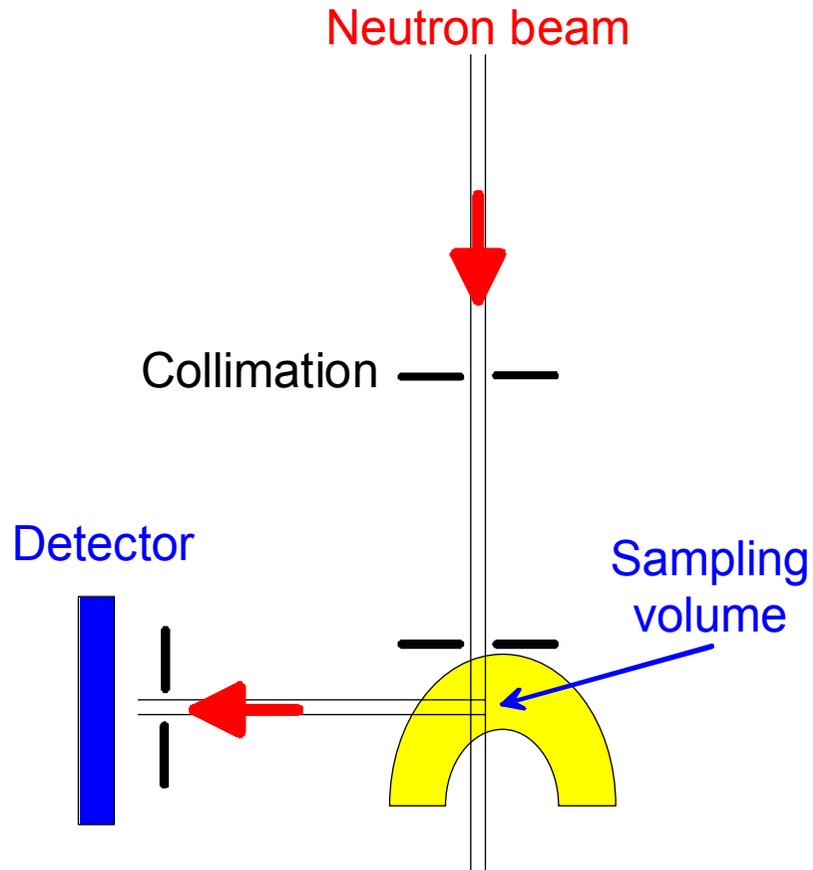
Define a small incident and a small scattered neutron beam, giving a small sampling volume (mm^3)



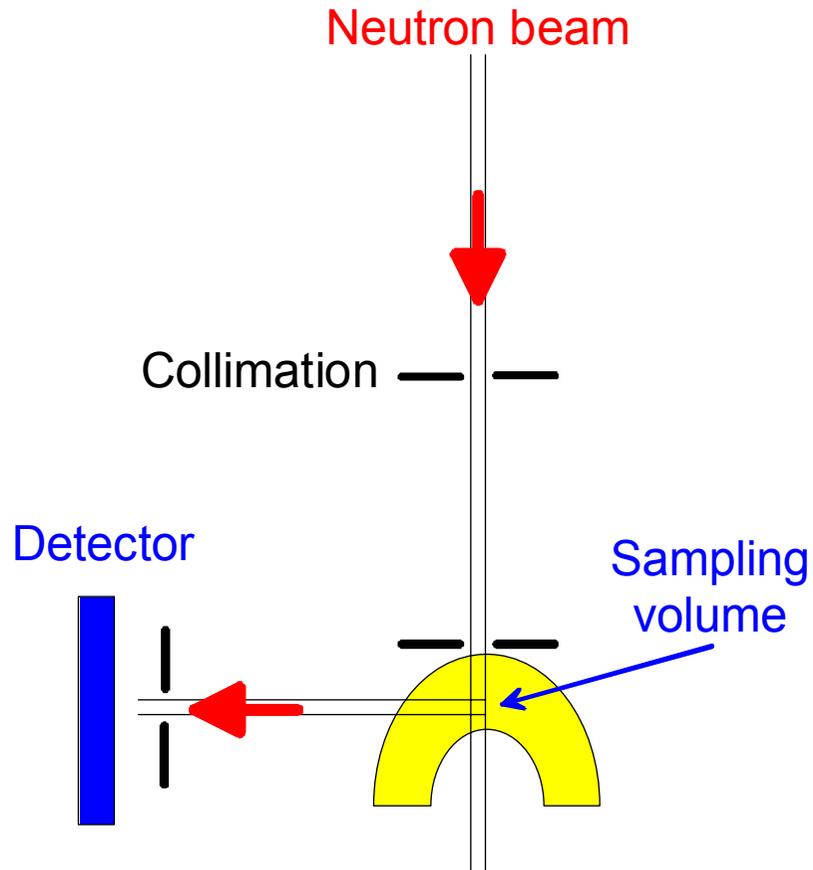
Scan or rotate the component through the neutron beam and measure the peak position on the detector



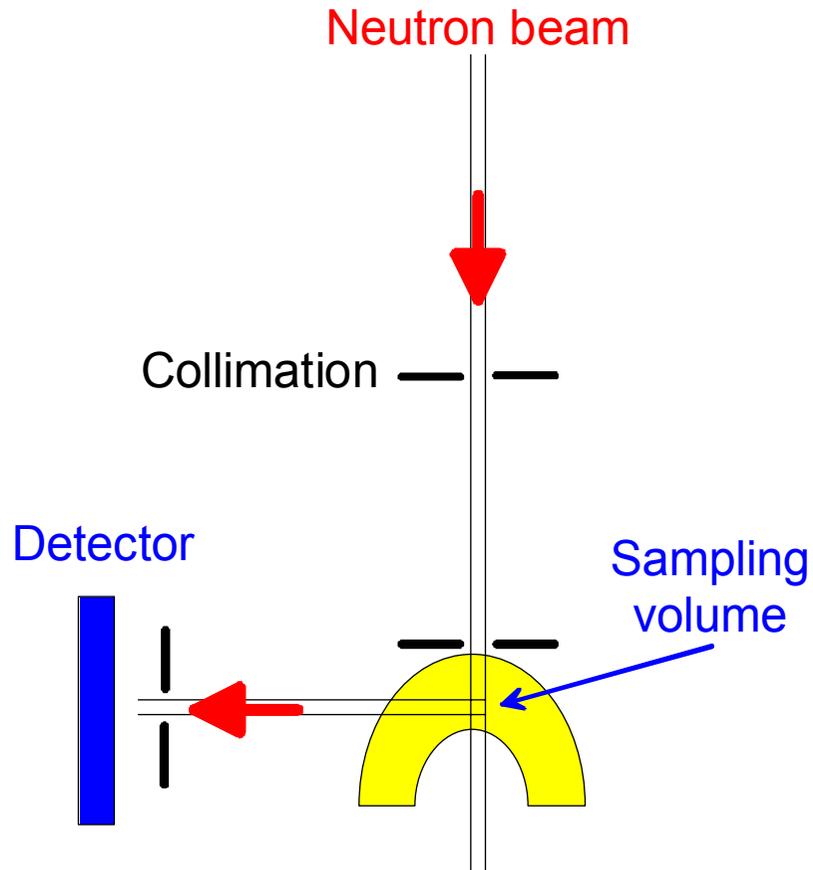
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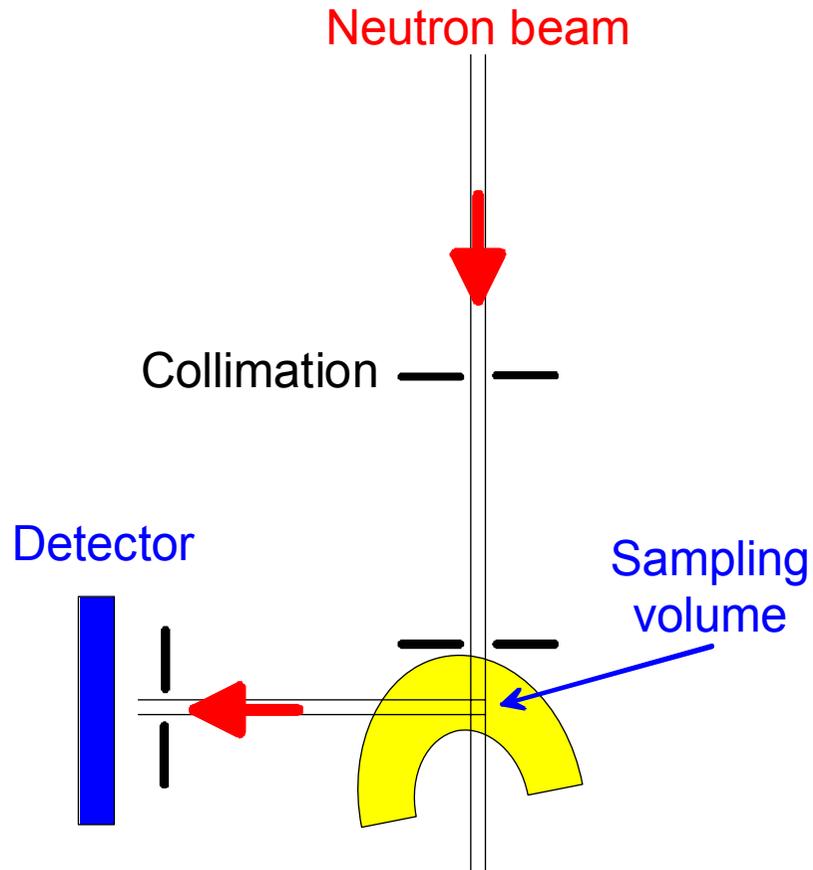
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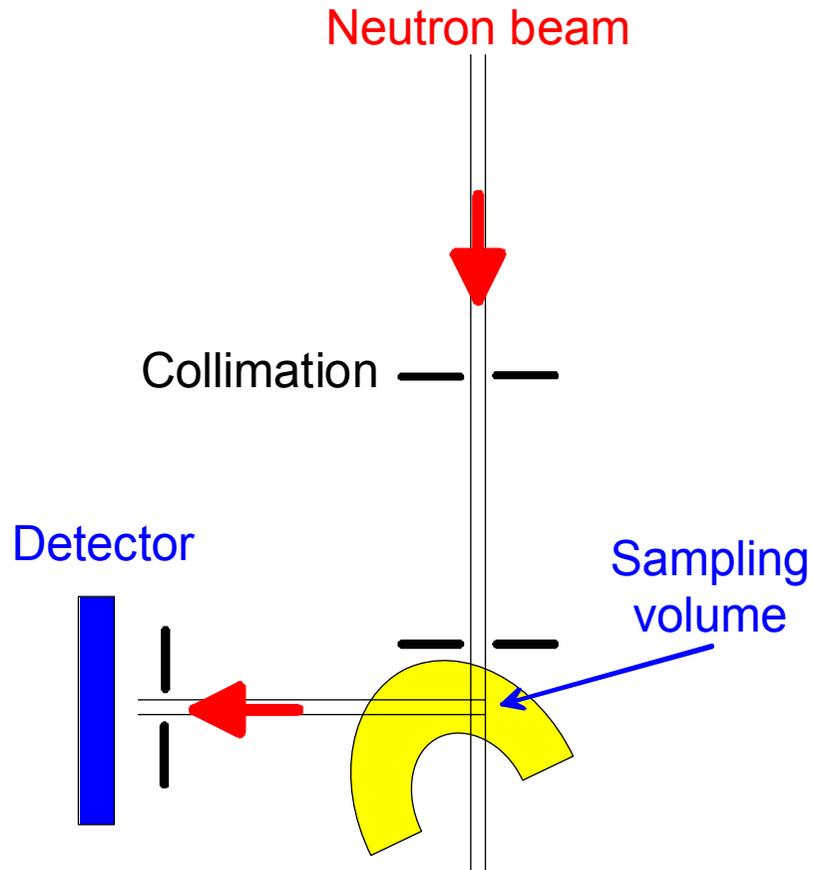
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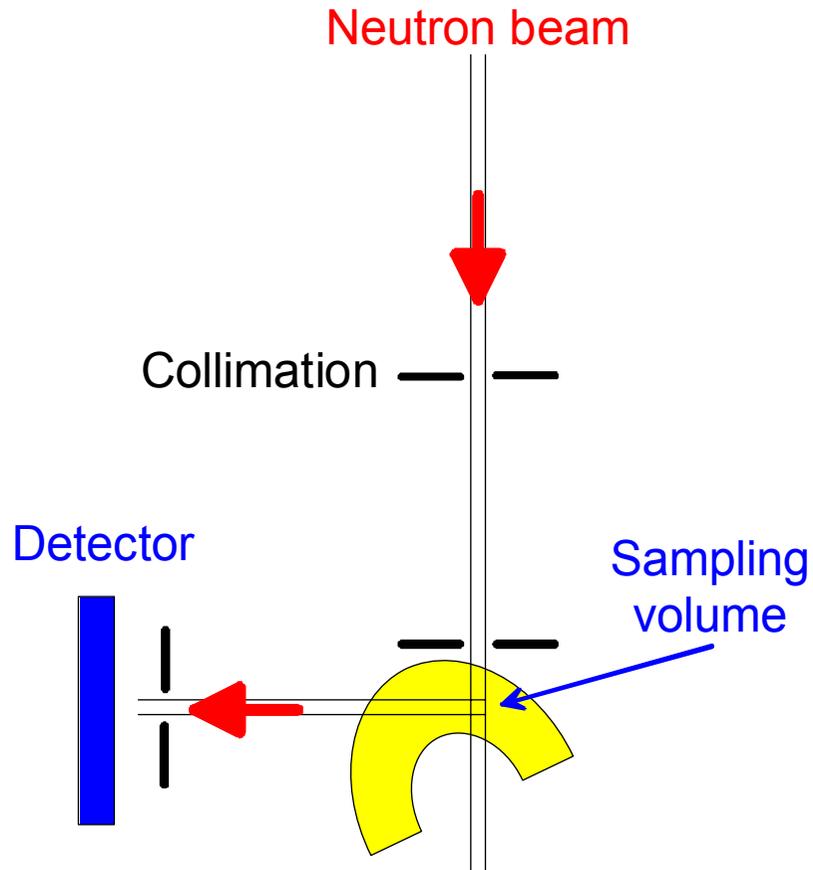
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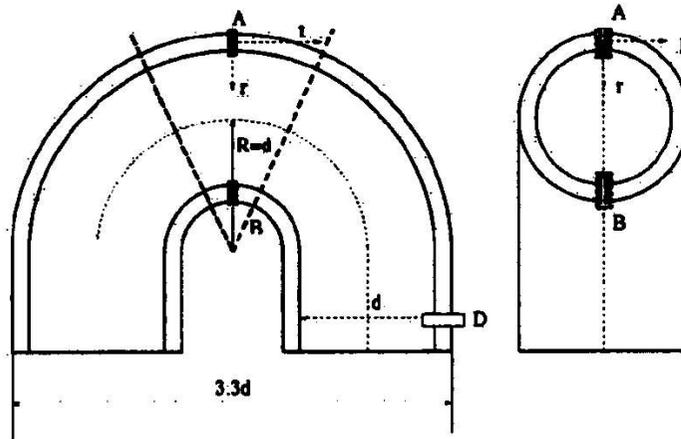


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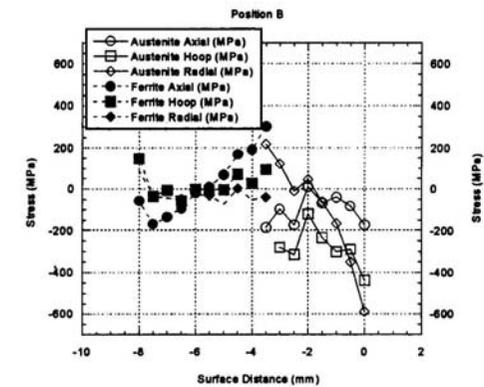
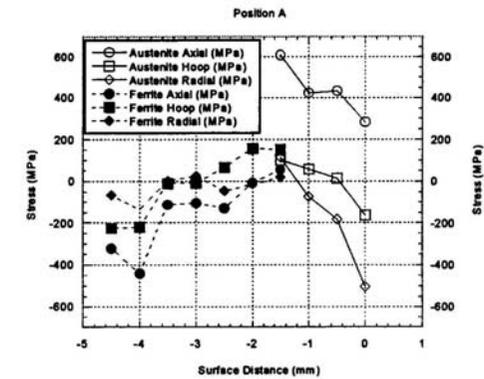
Make a map of the strain and convert it to stress using Hooke's law

(Stress is a tensor so you need lots of strain measurements)



Residual stress in bimetallic tubes

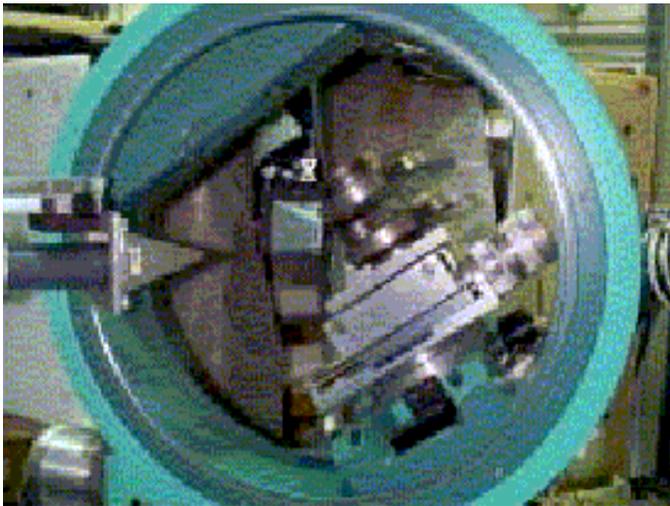
F J Mompean et al., ICMM Madrid, Spain



Why neutrons?

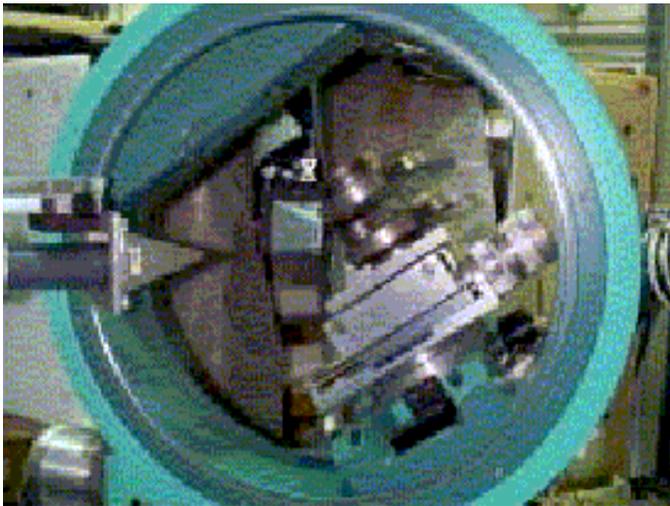
Neutrons have a high penetrating power
Can measure inside large components non-destructively

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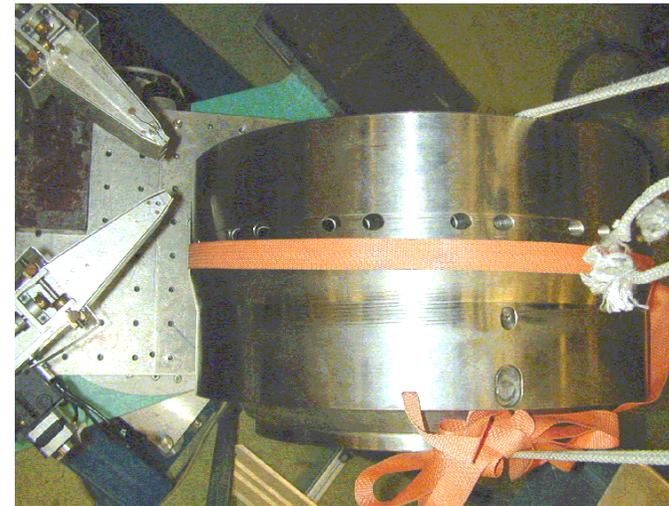


VW crankshaft
(Germany)

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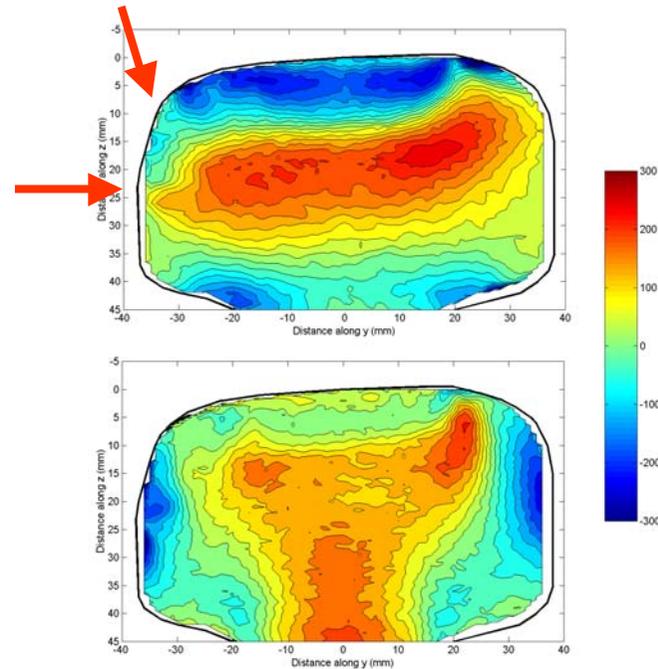


Centrifuge
(Italy)

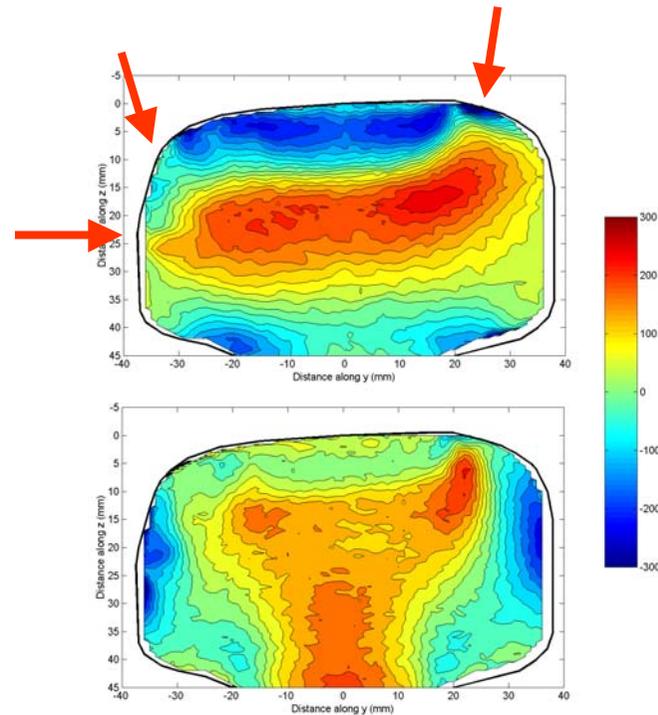
Neutrons have a high penetrating power
Can (generally) measure all three major components of the stress

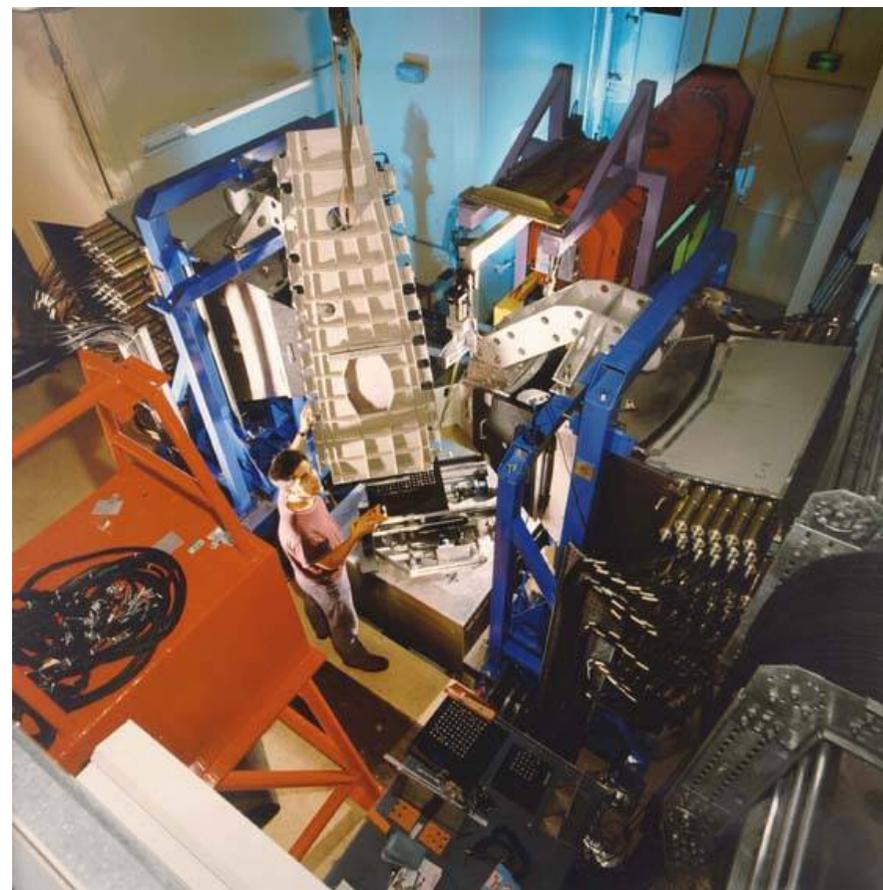
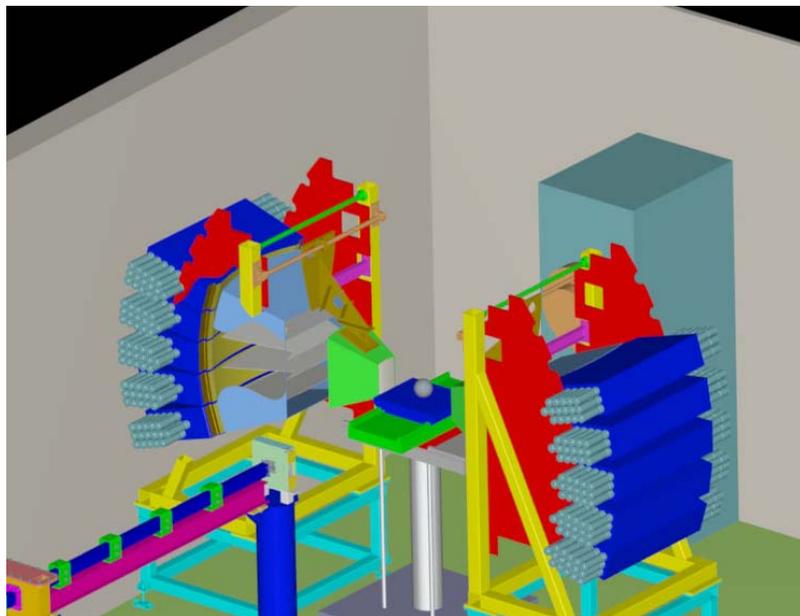


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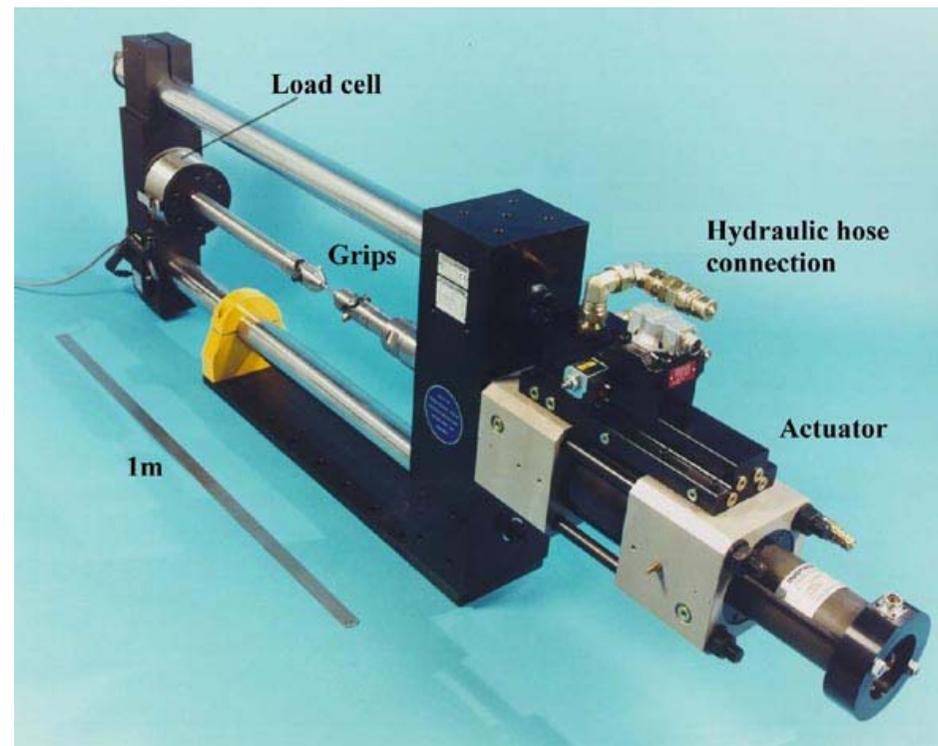




In-situ Loading

Allows study of

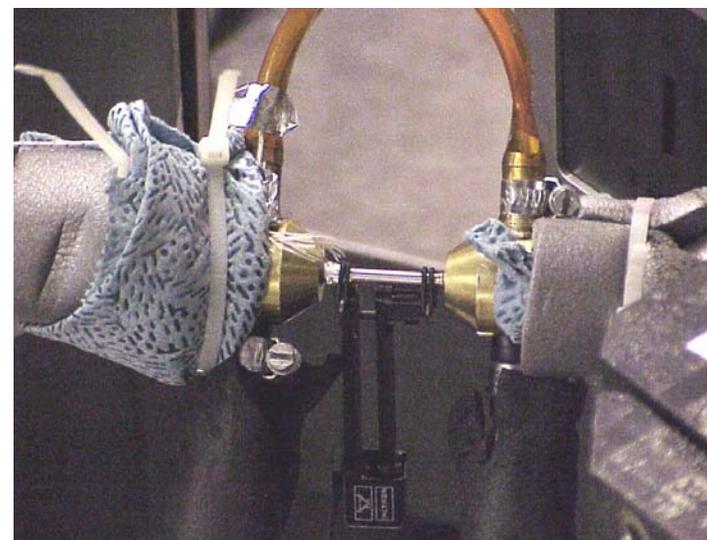
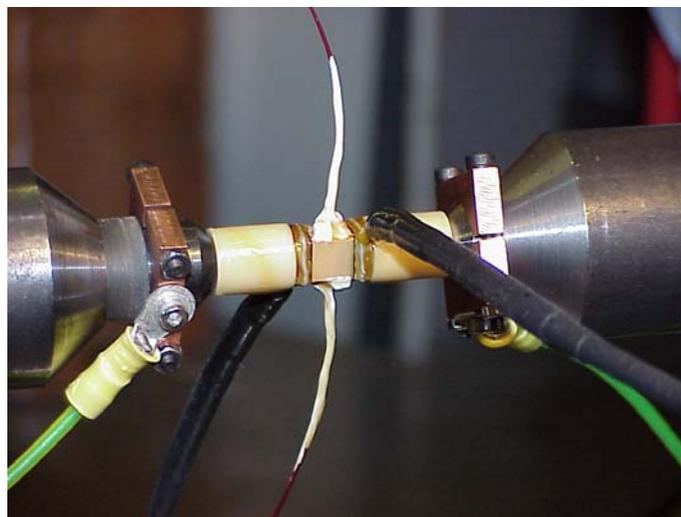
- Deformation modes
- Phase transformations
- Inter- and Intra- grain stresses
- Loading of real components



- Temperature
- Electric field
- Magnetic field



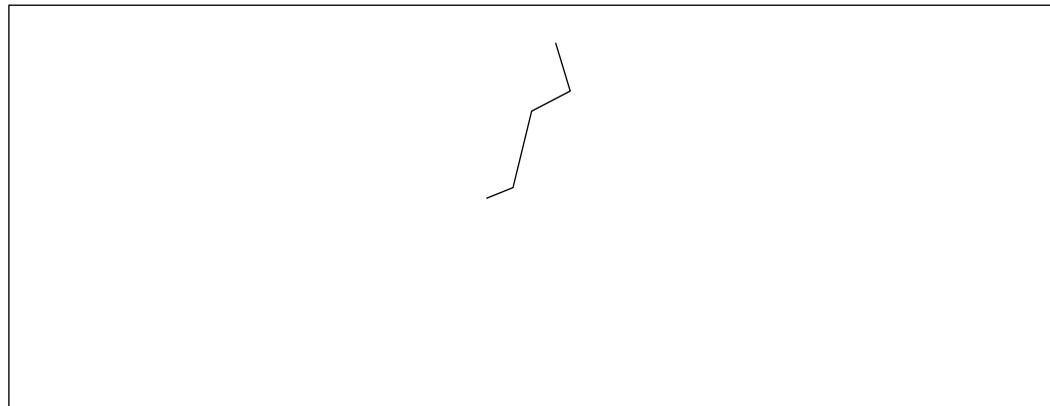
20 to 1000 °C
air / inert gas
atmosphere



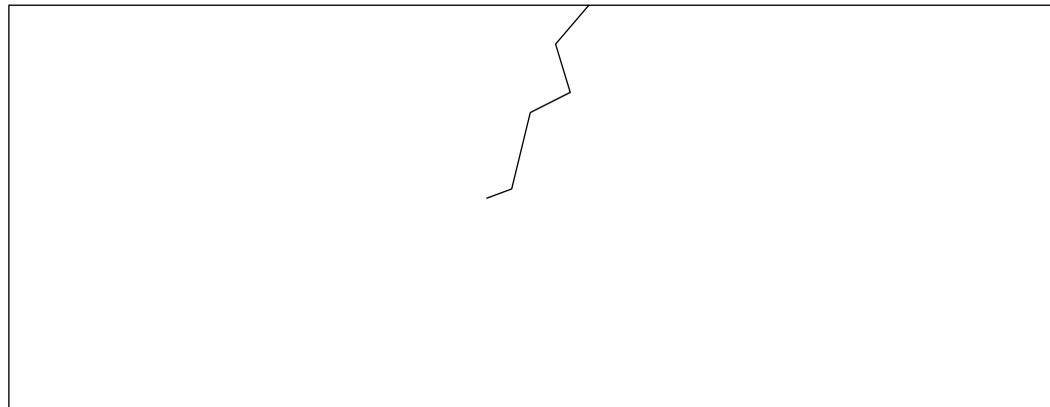
Shot peening



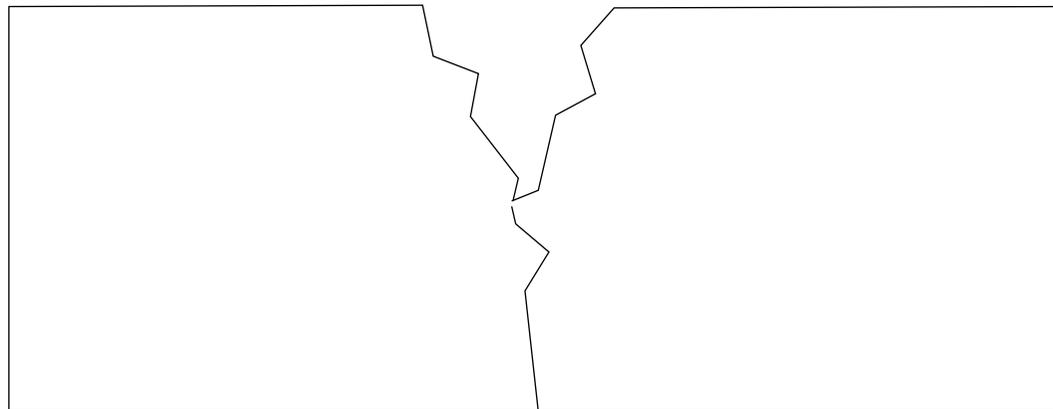
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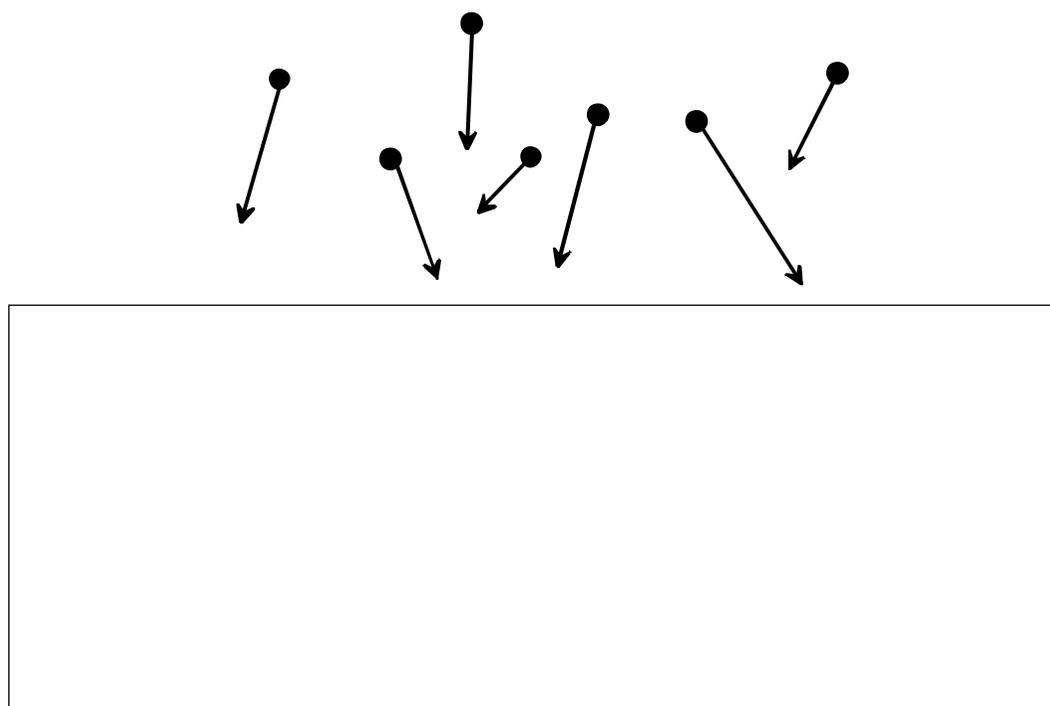
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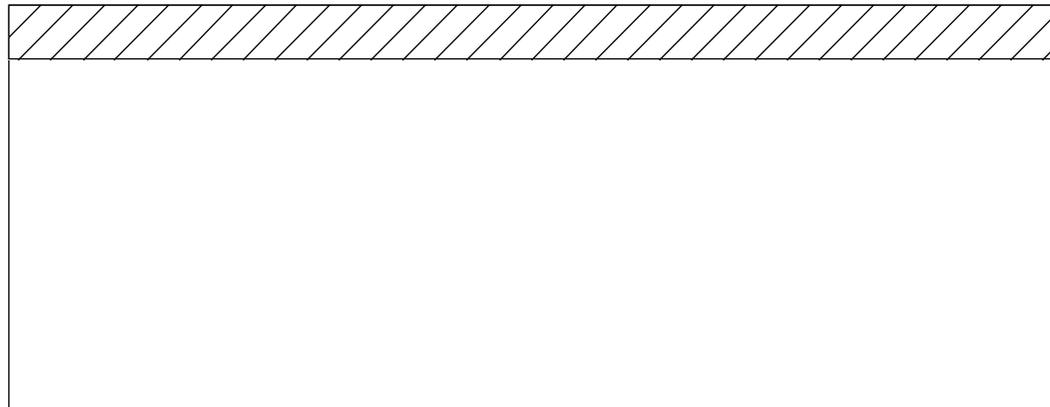
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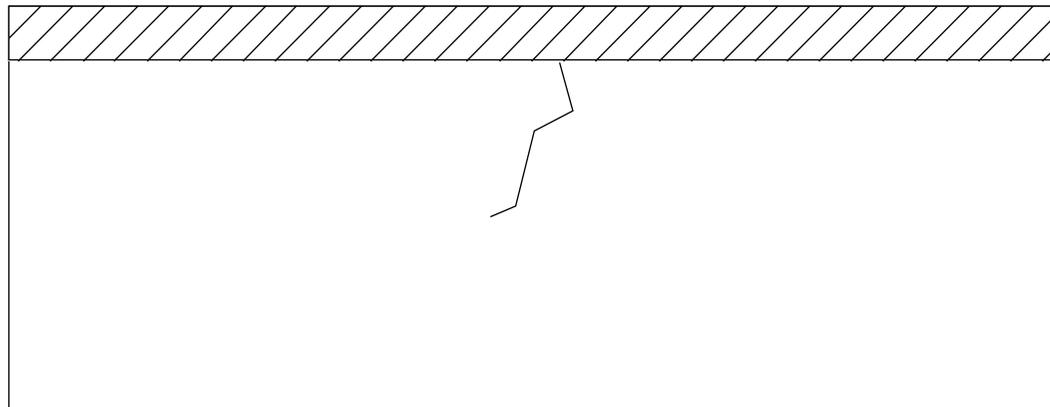
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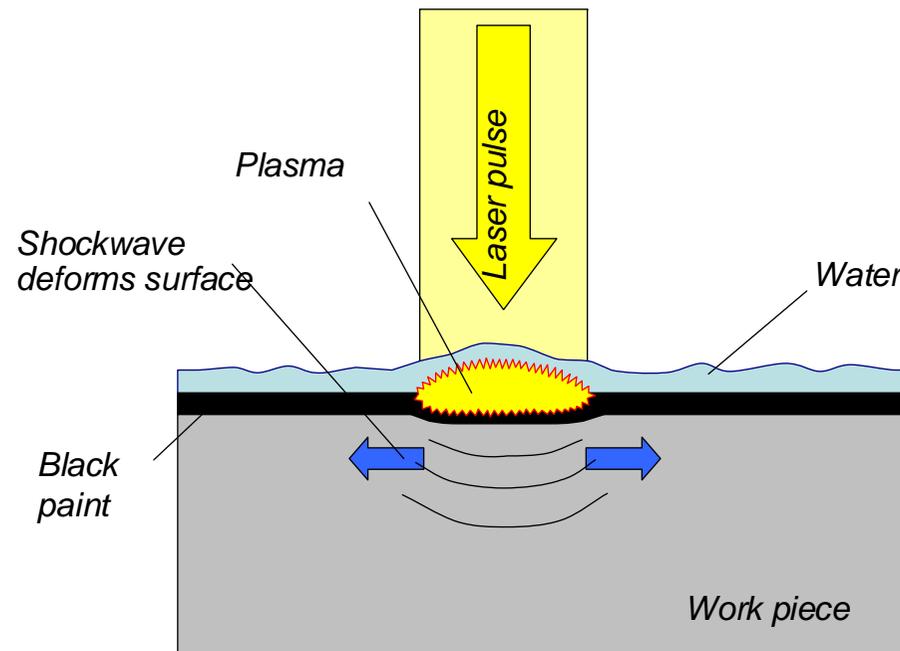
Shot peening



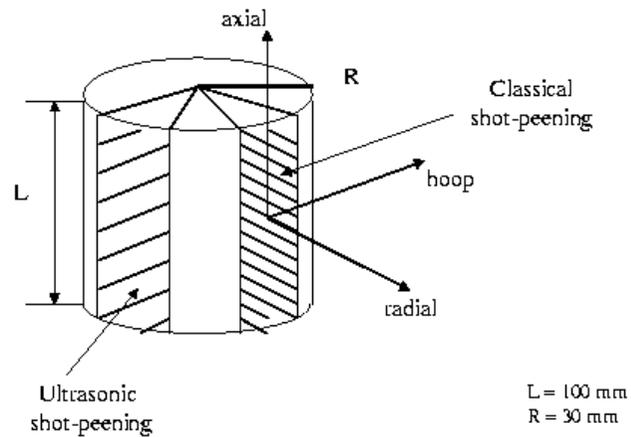
Shot peening



Laser shot peening



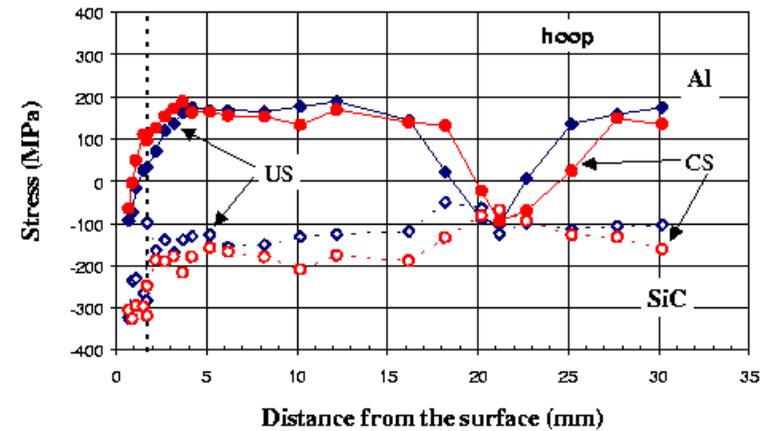
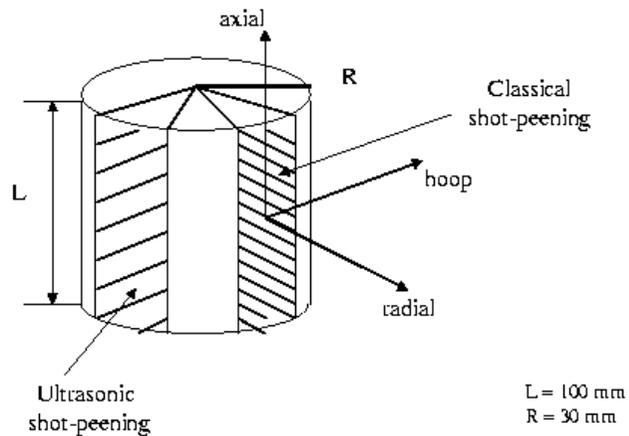
Shot peening



Shot peening of an Al-SiC whisker reinforced composite

D Reirant and J Lu, University of Troyes, France

Shot peening



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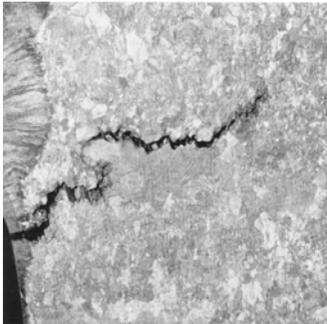
Heat treatment of welds





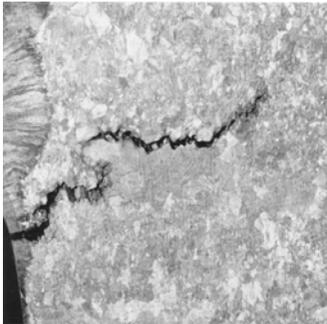
Re-heat cracking in advanced gas cooled reactors

Safety: structural integrity assessment



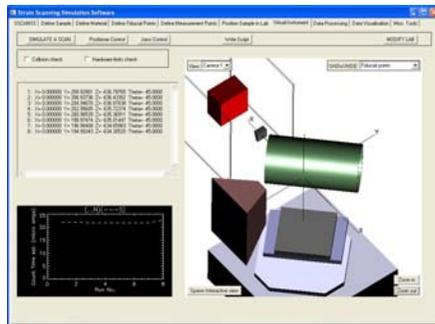
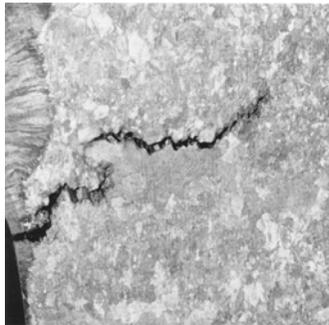
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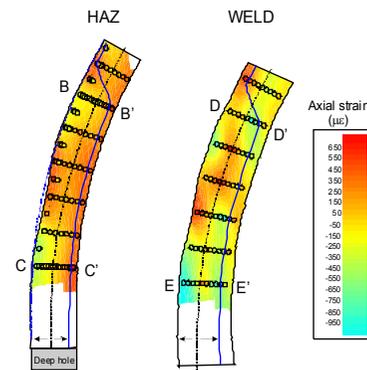
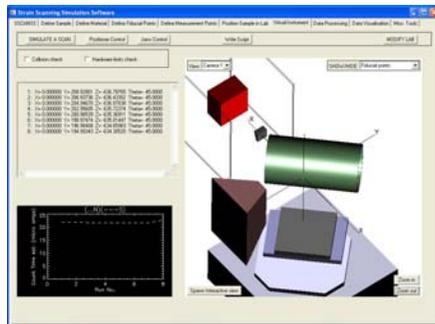
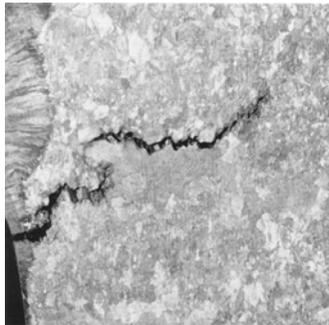
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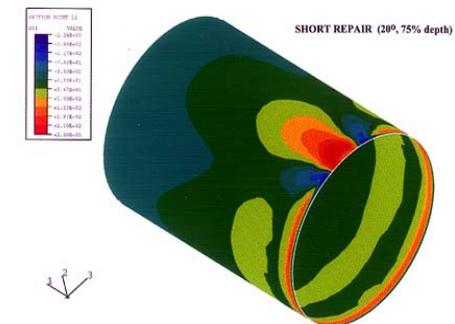
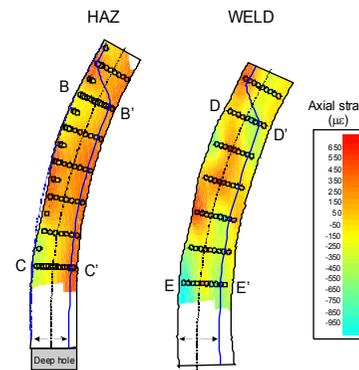
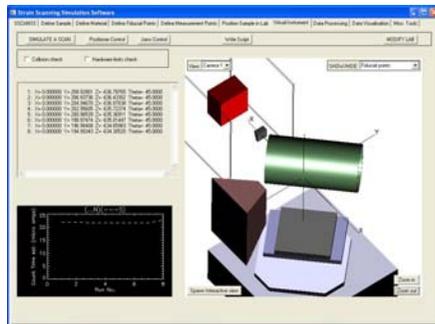
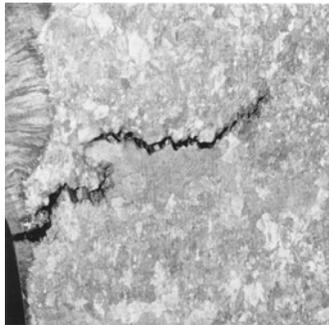
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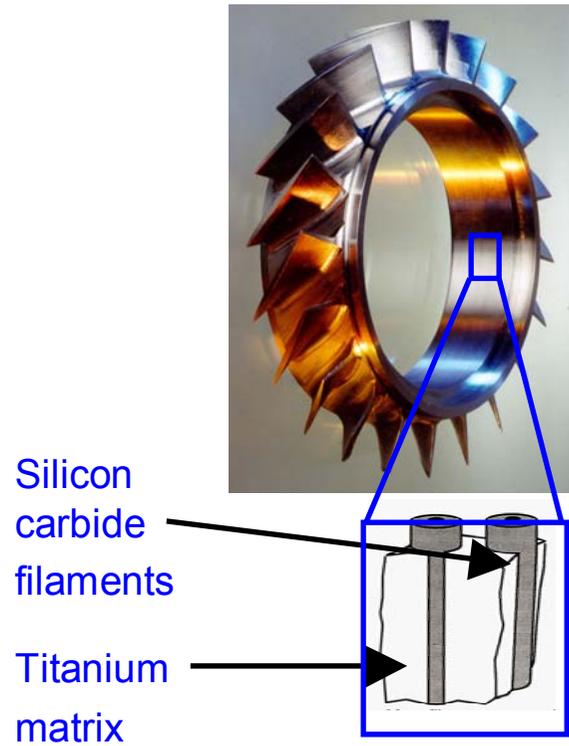
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Re-heat cracking in advanced gas cooled reactors

Safety: structural integrity assessment

'Bling' – Bladed ring

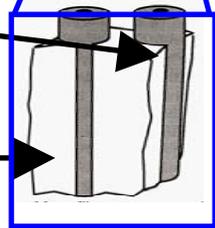


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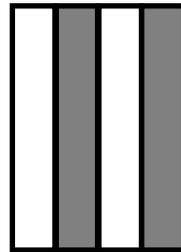


Silicon carbide filaments

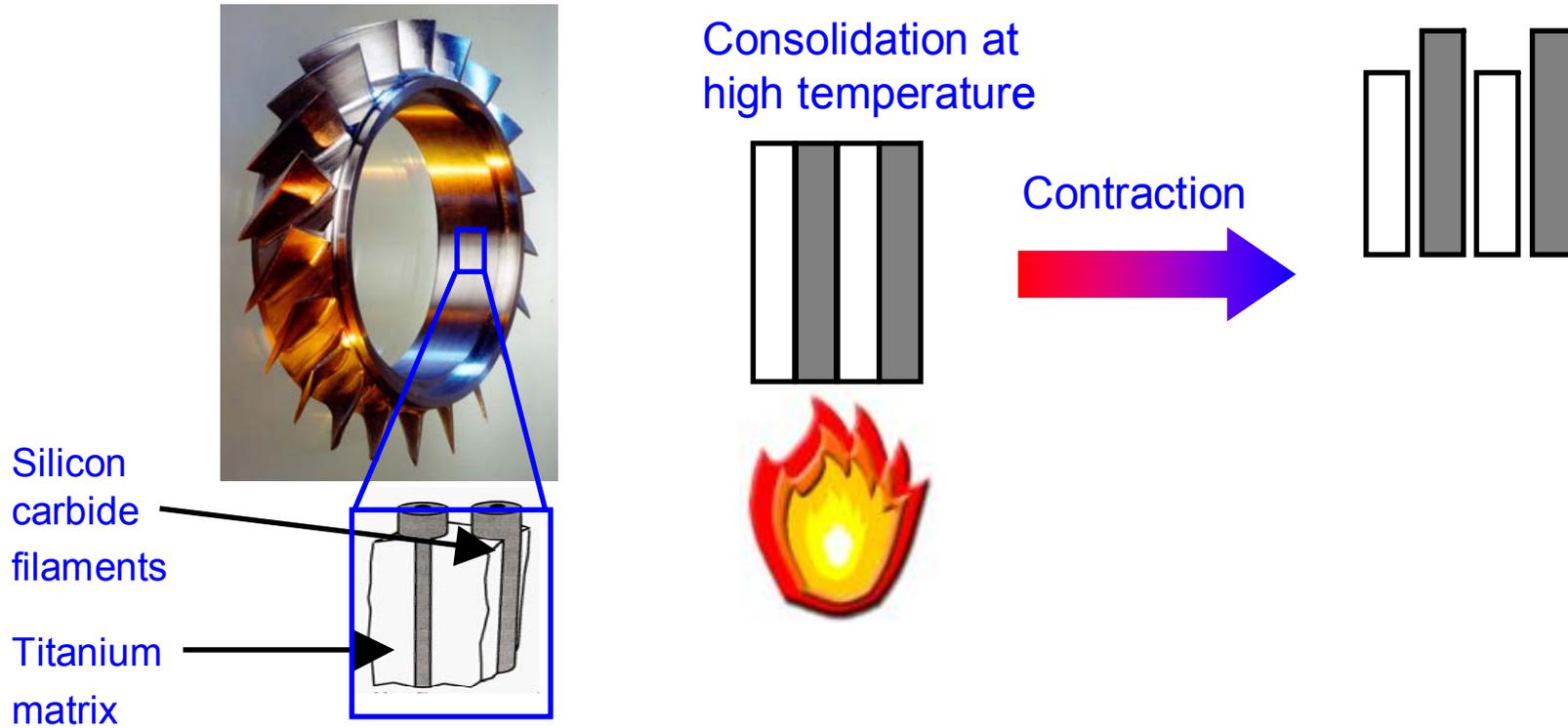
Titanium matrix



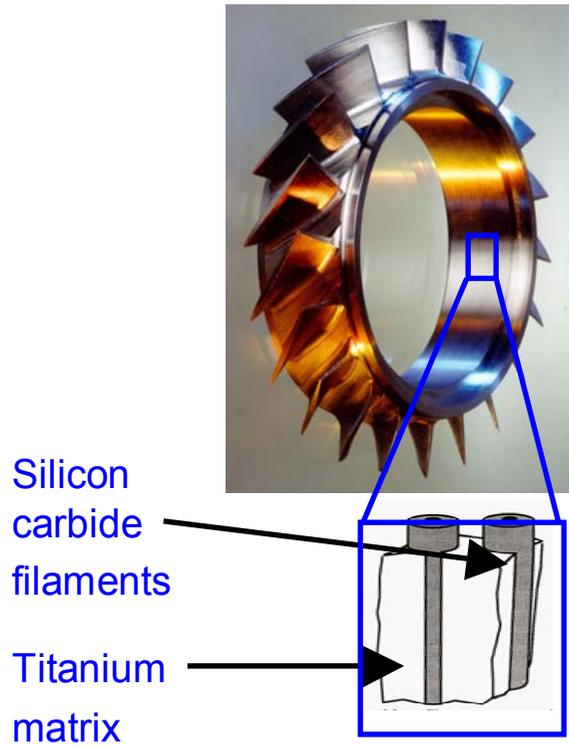
Consolidation at high temperature



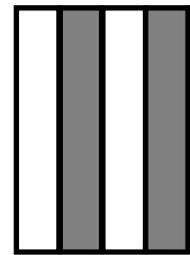
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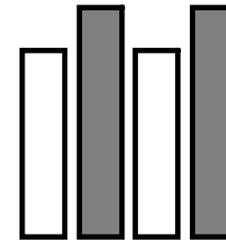
'Bling' – Bladed ring



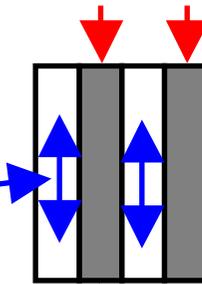
Consolidation at high temperature



Contraction



Tension



Compression

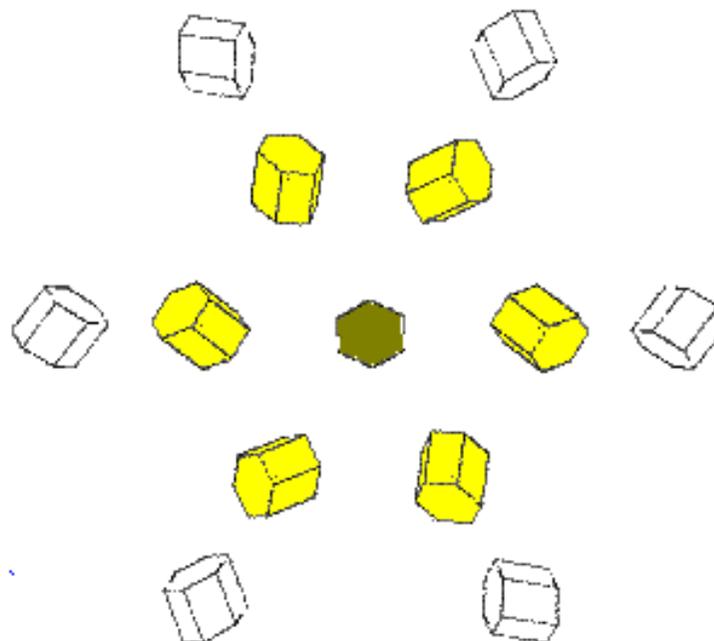
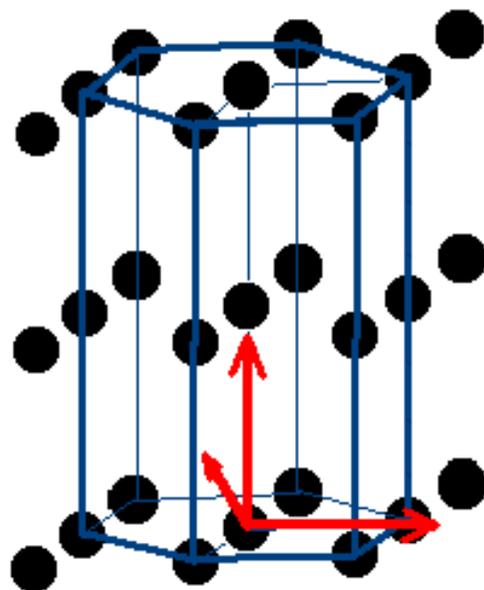


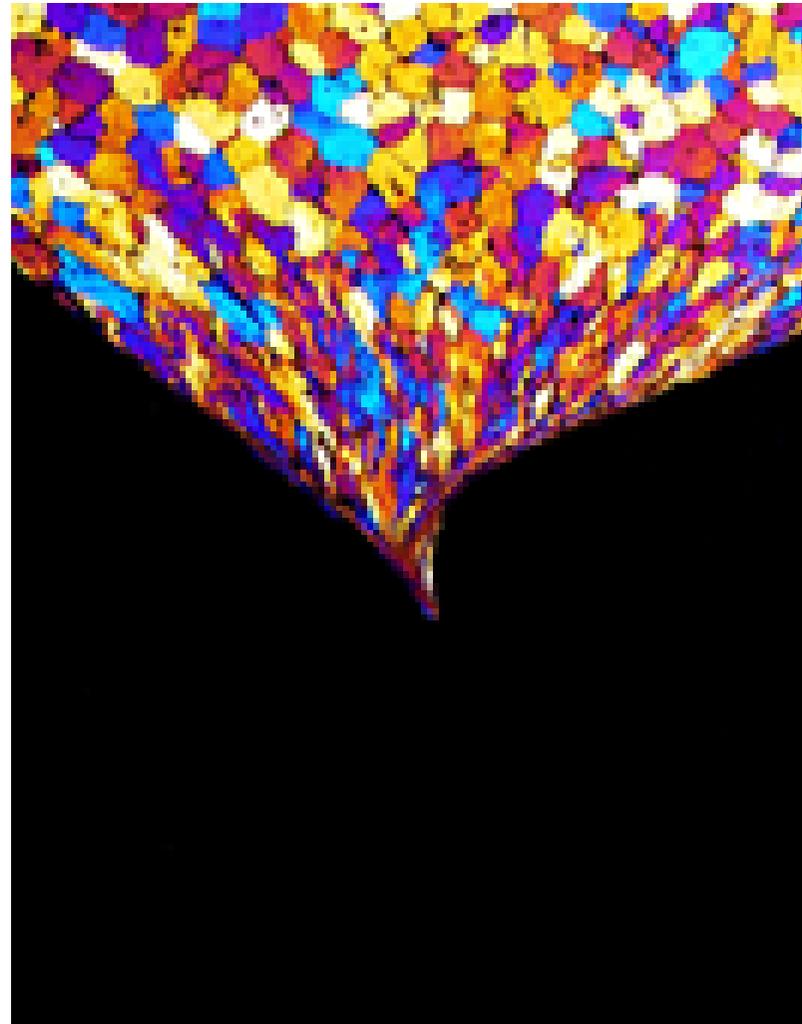
'Bling' – Bladed ring





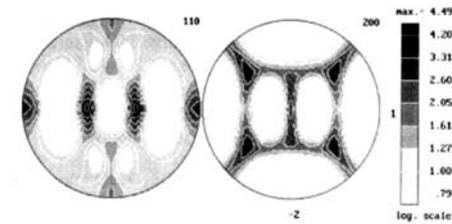
How thin you can make the can depends on the texture
(size and orientation of crystallites)
in the original metal ingot



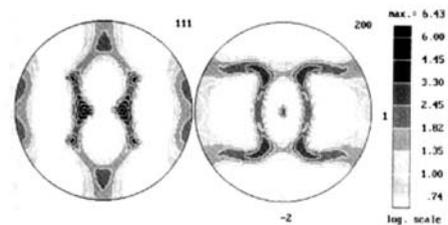




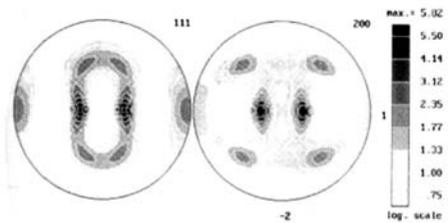
Measure the
intensity of a
diffraction peak
as a function of
the orientation of
the sample.



Steel



Cu

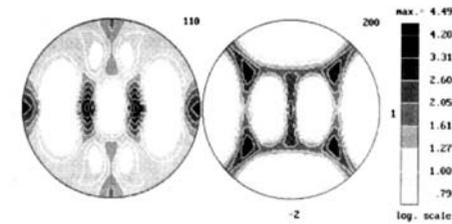


Ni

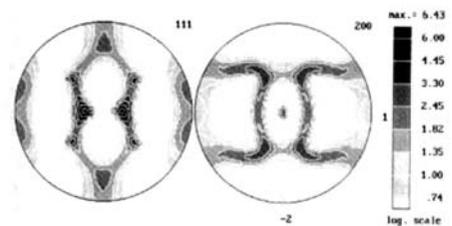
M Cernik and D Neov
Physica B 2000 276-278 894

Measure the intensity of a diffraction peak as a function of the orientation of the sample.

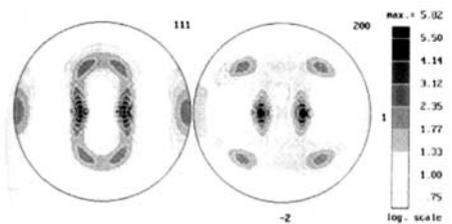
Texture pole figures



Steel



Cu



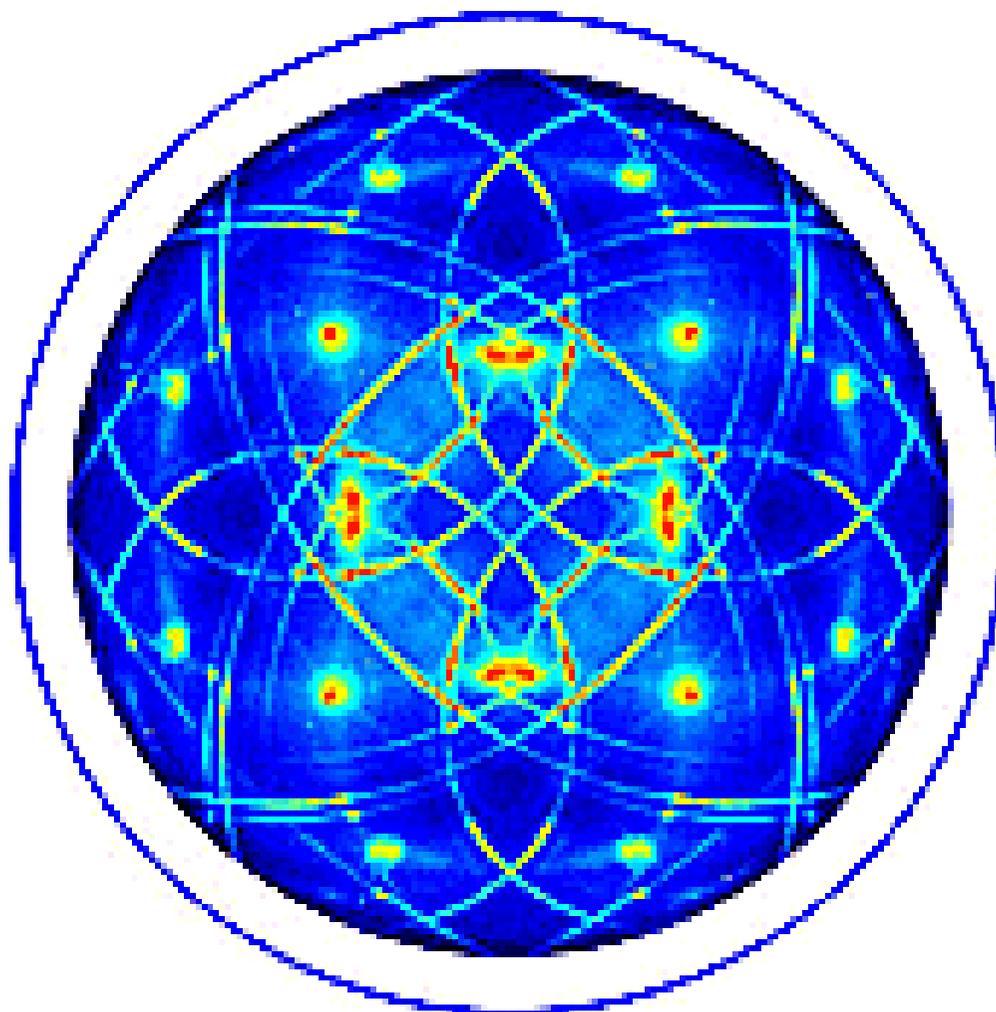
Ni

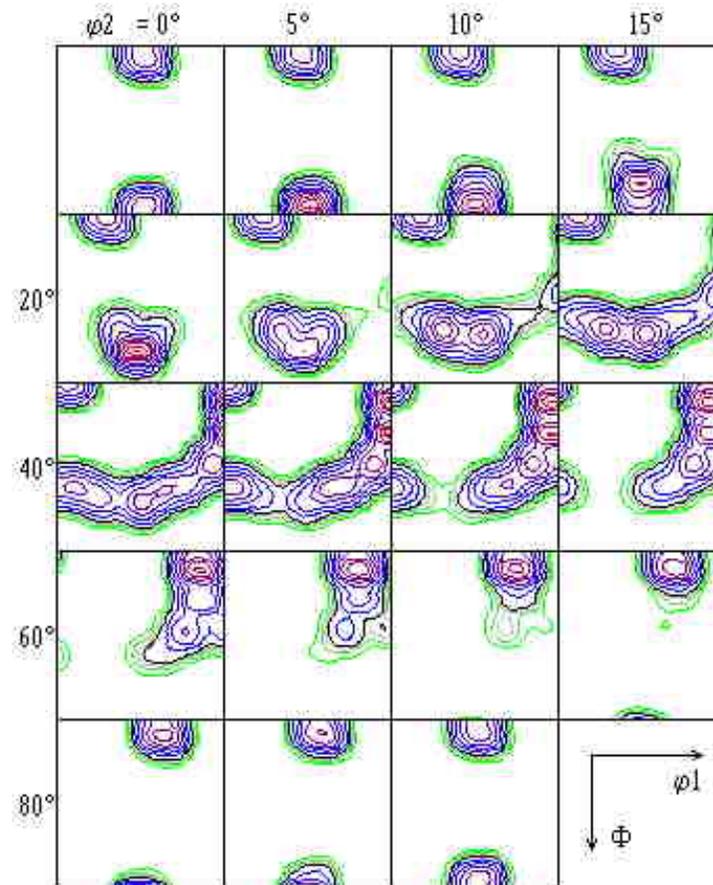
M Cernik and D Neov
Physica B 2000 276-278 894

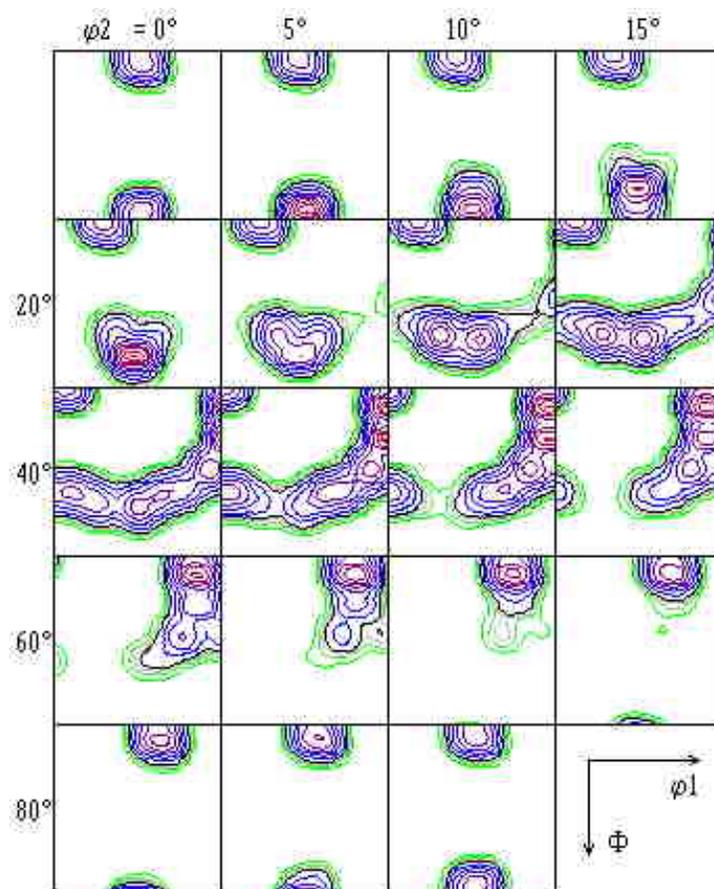
Measure the intensity of a diffraction peak as a function of the orientation of the sample.

Derive the crystallite orientation distribution function (ODF)

Texture pole figures







Orientation Distribution Function (ODF)





The sheep broke its leg.



Bone is a composite of oriented collagen fibres and hydroxyapatite crystals.

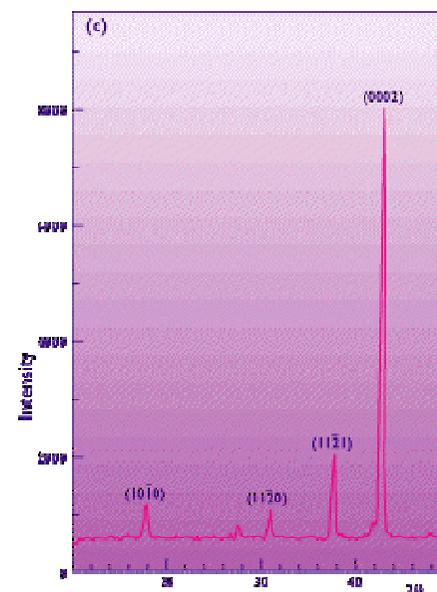
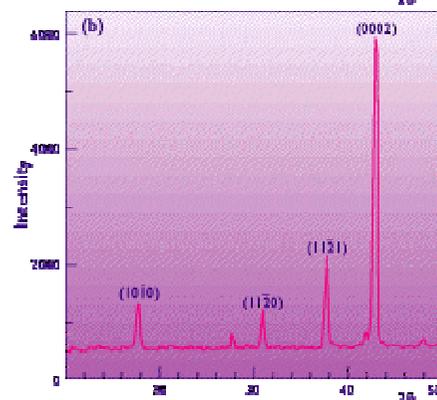
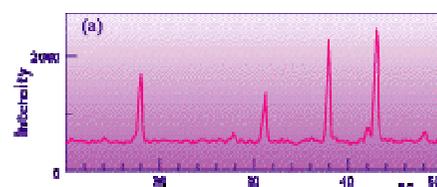
The crystal orientation is related to the directions of the stresses which the bones need to withstand.

Bone is a composite of oriented collagen fibres and hydroxyapatite crystals.

The crystal orientation is related to the directions of the stresses which the bones need to withstand.

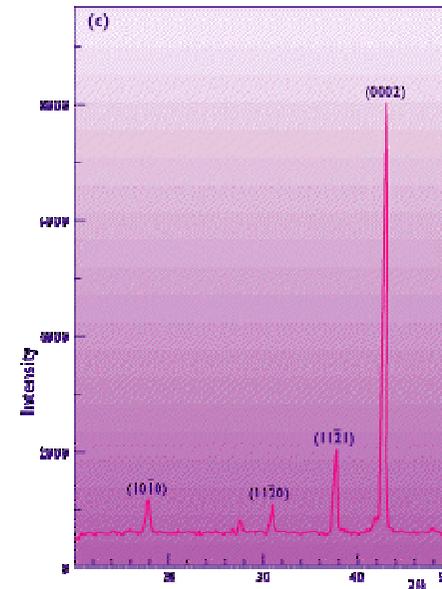
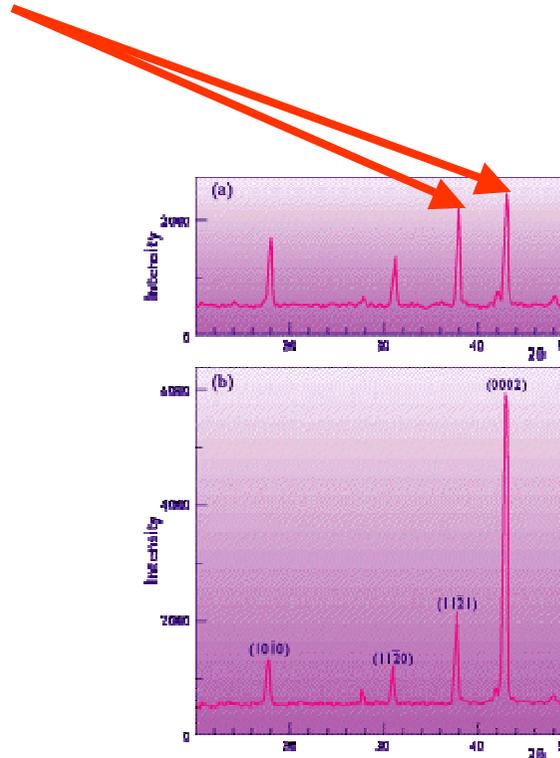
After a break the collagen grows back fast. The crystalline material takes longer.

3 months later ...



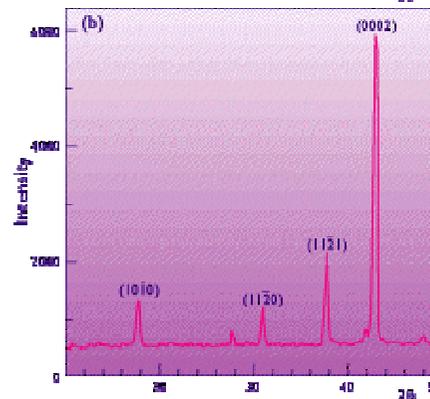
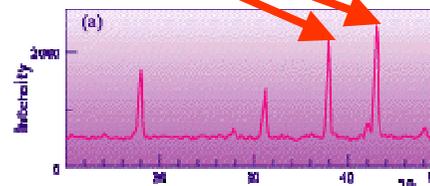
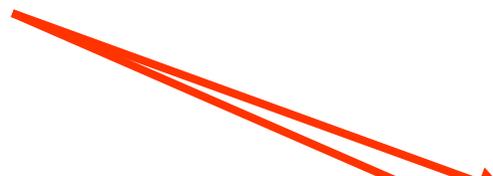
G. Bacon and P. Convert

At the fracture
(weak bone)

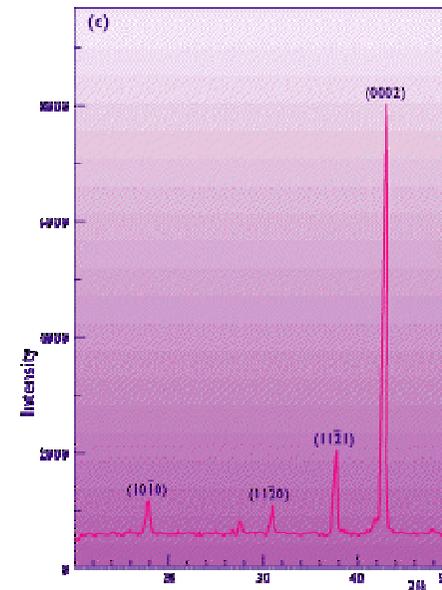


G. Bacon and P. Convert

At the fracture
(weak bone)



1 mm away →



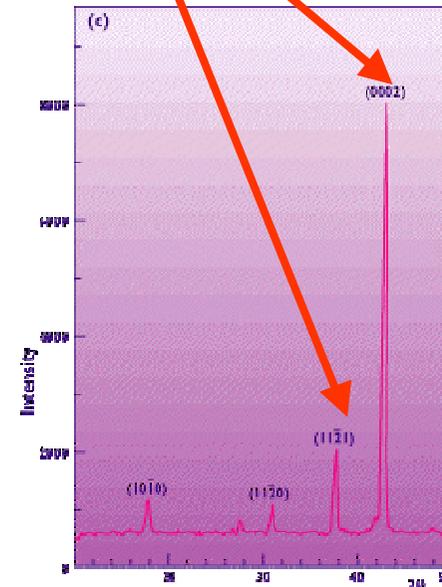
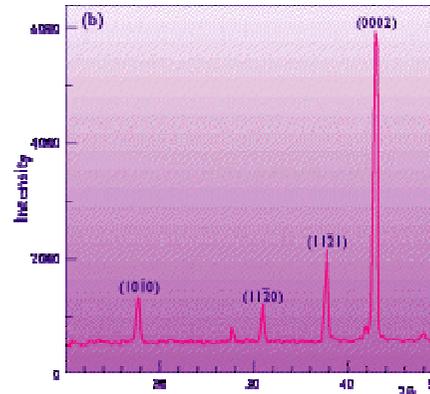
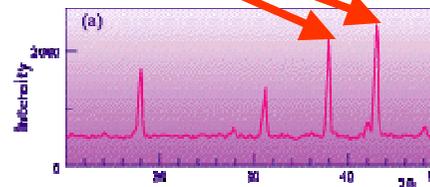
G. Bacon and P. Convert

At the fracture
(weak bone)

2 mm away
(stronger bone)

1 mm away

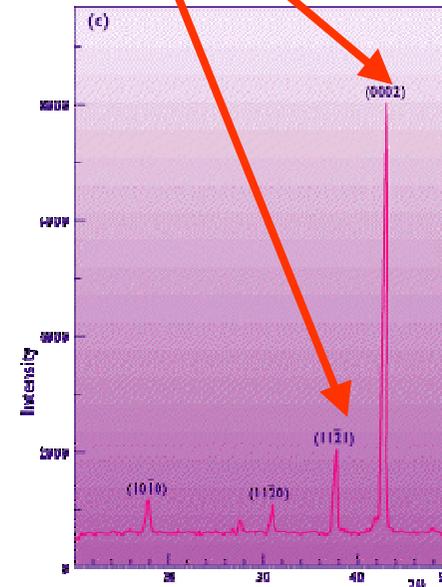
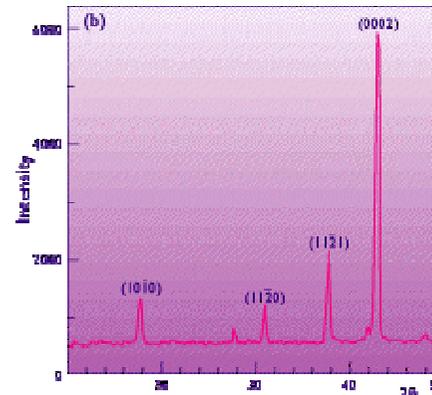
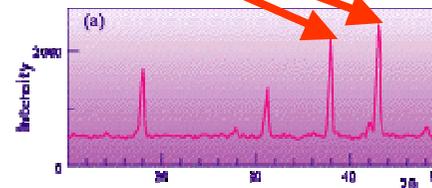
G. Bacon and P. Convert

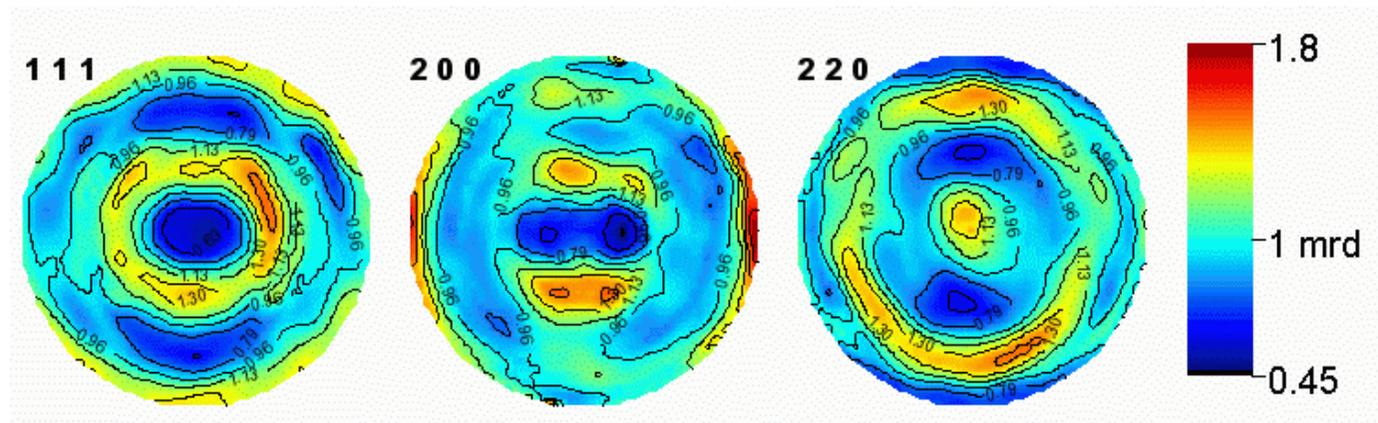
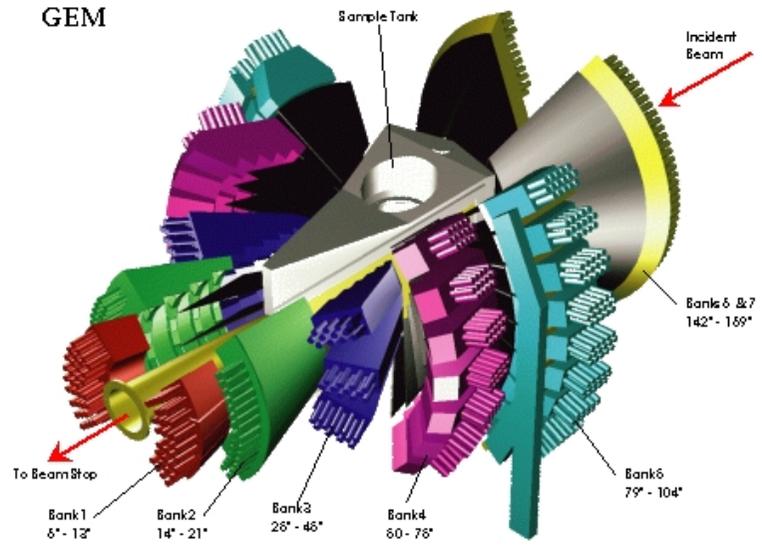


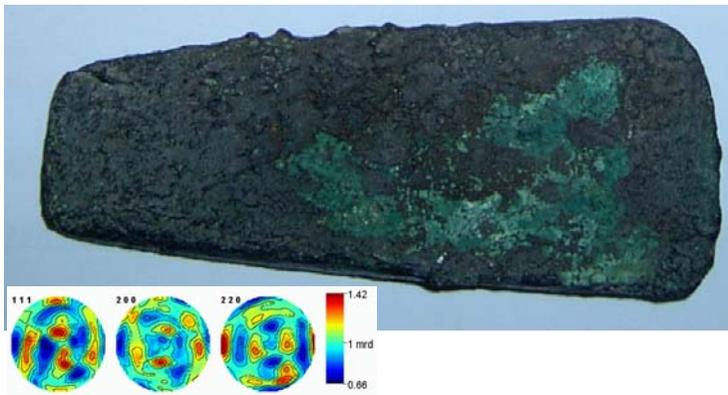
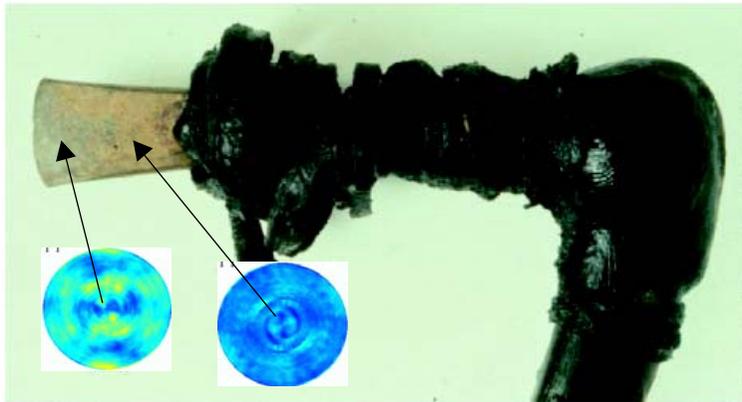
At the fracture
(weak bone)

2 mm away
(stronger bone)

George Bacon

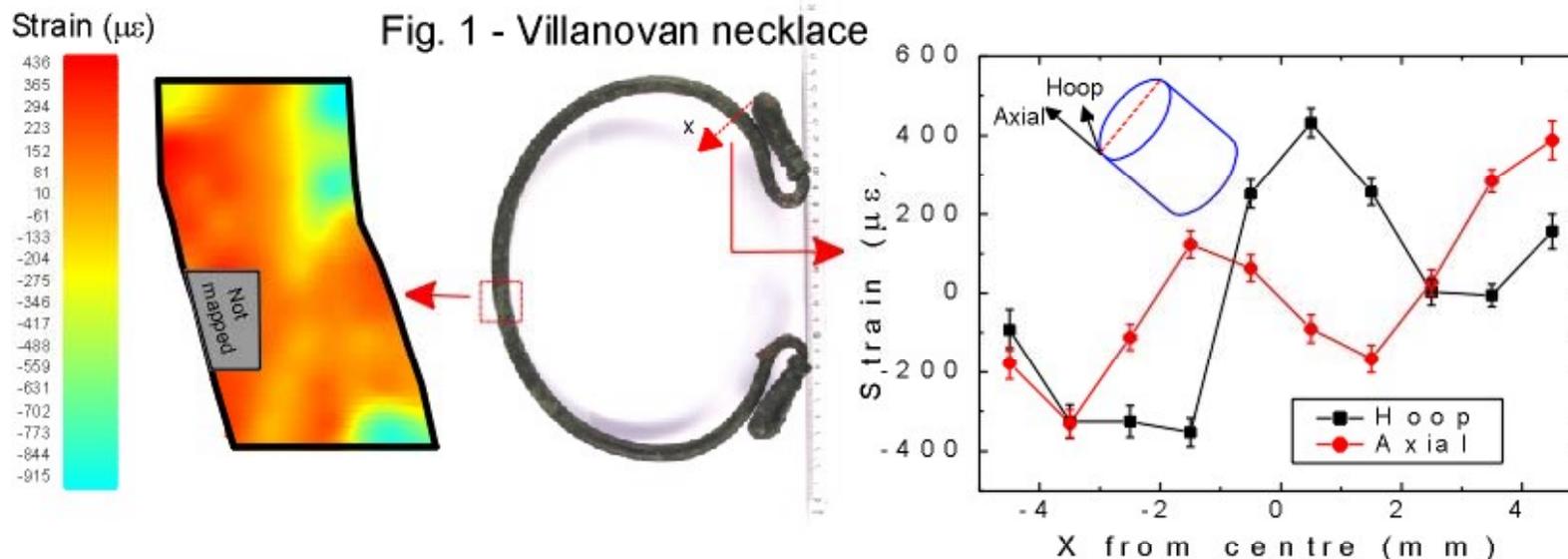






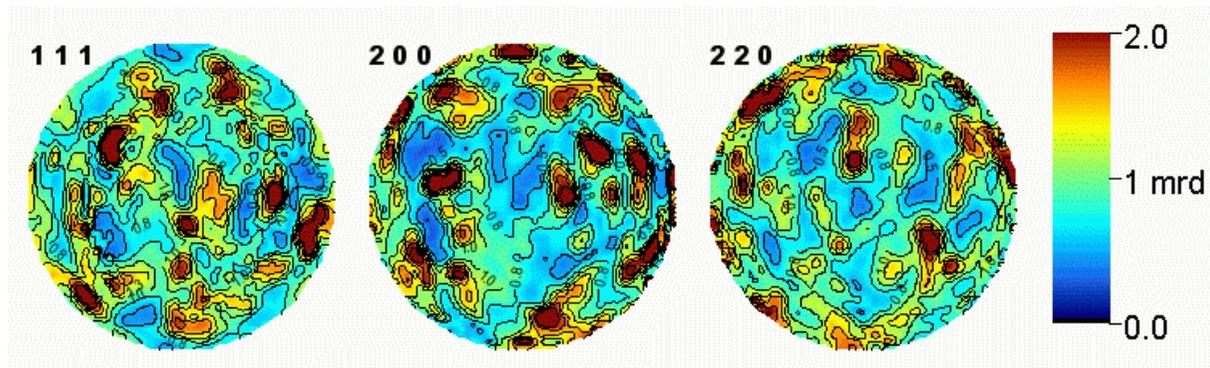
Cultural Heritage

- Early Iron Age bronze objects (1000-1100BC) from Villanovan and Celtic civilizations
- Research program on ancient manufacturing processes (S.Siano, Firenze)
- Difficult to identify non-destructively cold-worked and/or annealed from as-cast specimens
- Cold working processes leave characteristic fingerprints





Bronze statuette from the National Archaeological Museum of Florence





Stress, strain, texture and some other things ...

Robert McGreevy

*ISIS Facility,
CCLRC Rutherford Appleton Laboratory,
Chilton, Didcot, OX11 0QX, UK.*





