Unclassified

The Study of Shock Physics in single crystal Tantalum. A Target Fabrication Challenge.

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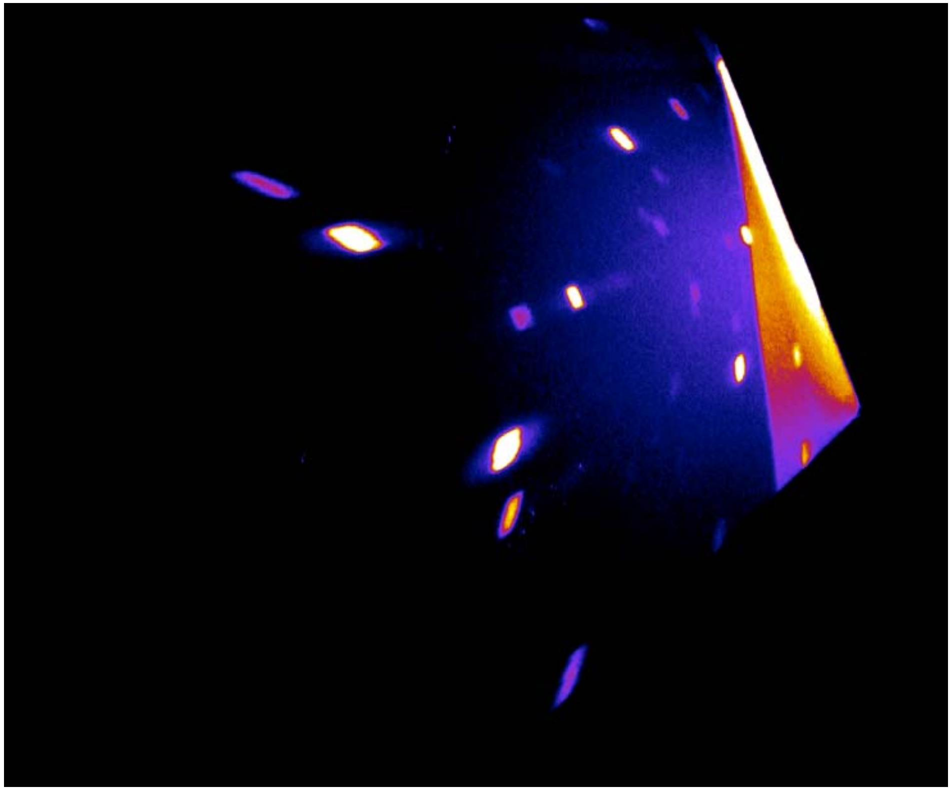
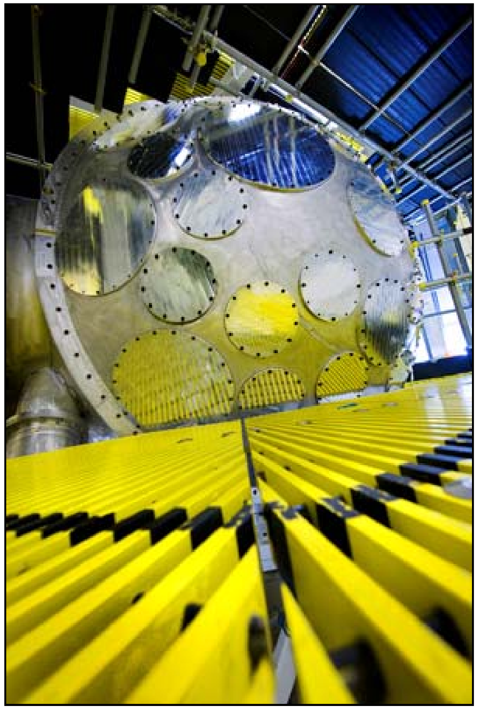


Overview

- General Introduction
- Introduction to the Laue Campaign
- Experimental Principle
- The Target
- The Components
- The Construction
- Conclusion

Introduction

- AWE Target Fabrication Group supports plasma physics experiments fielded on a number of laser systems around the world, which will soon include AWE’s flagship Orion Laser.

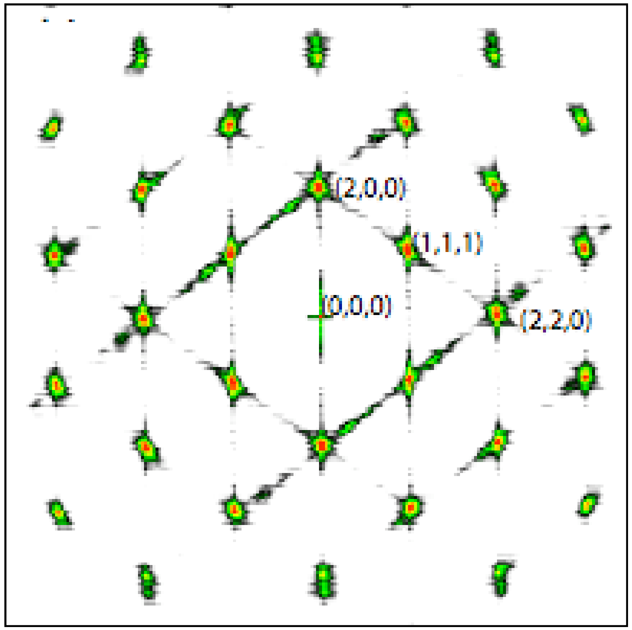


Background

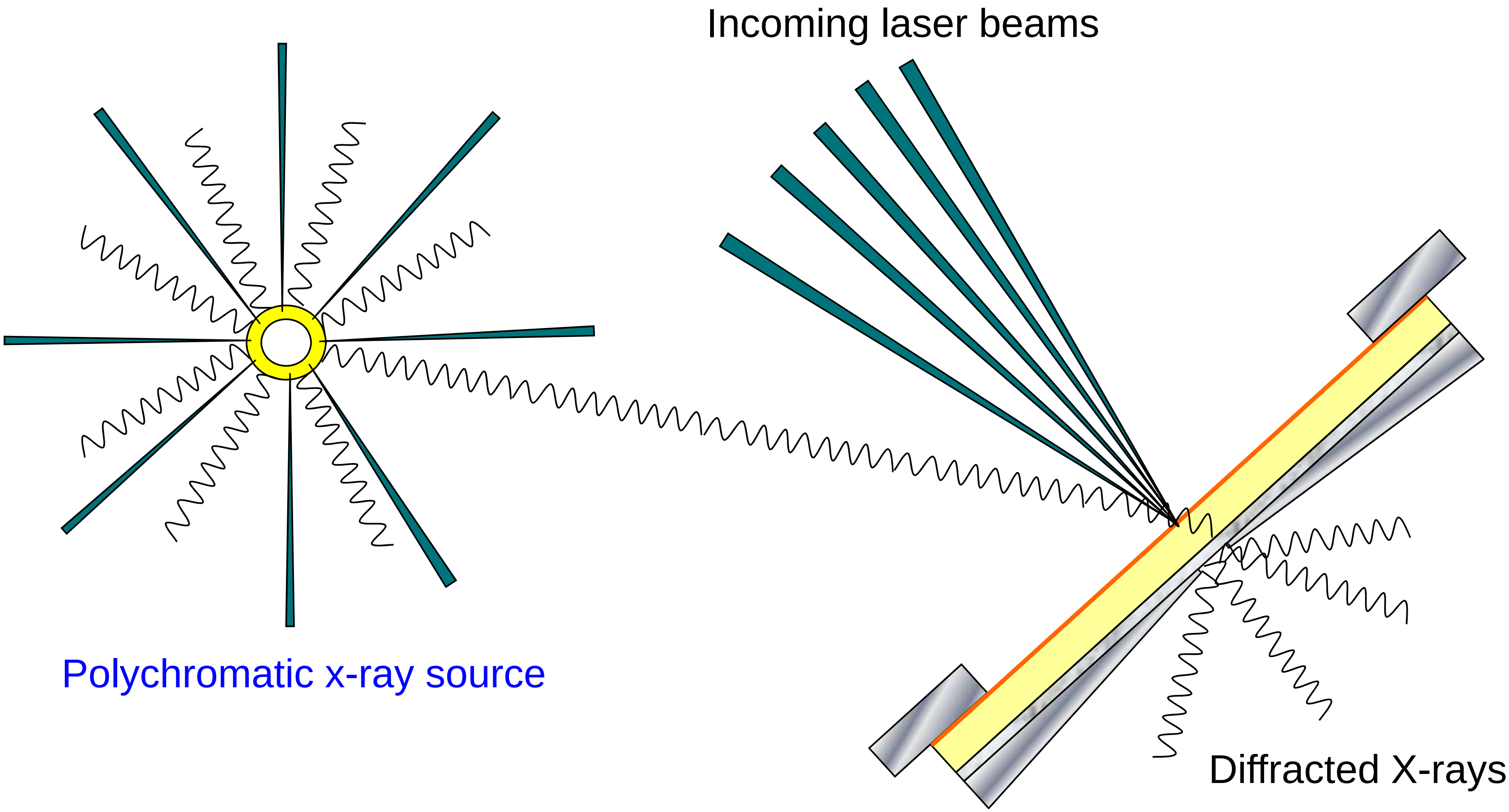
- Most laser targets need an element of:
  - Procurement,
  - R&D, manufacture,
  - Assembly and
  - Characterisation.
- What can seem like a straight forward target to the experimentalist can in fact prove quite a challenge to the fabricators.

Laue Experimental Aim

- To investigate dislocation densities in a shocked single crystal using the x-ray Laue diffraction technique.
- High rate dynamic loading in a metallic single crystal is expected to produce very large dislocation densities which should be revealed by a broadening of the spots in the Laue diffraction pattern.

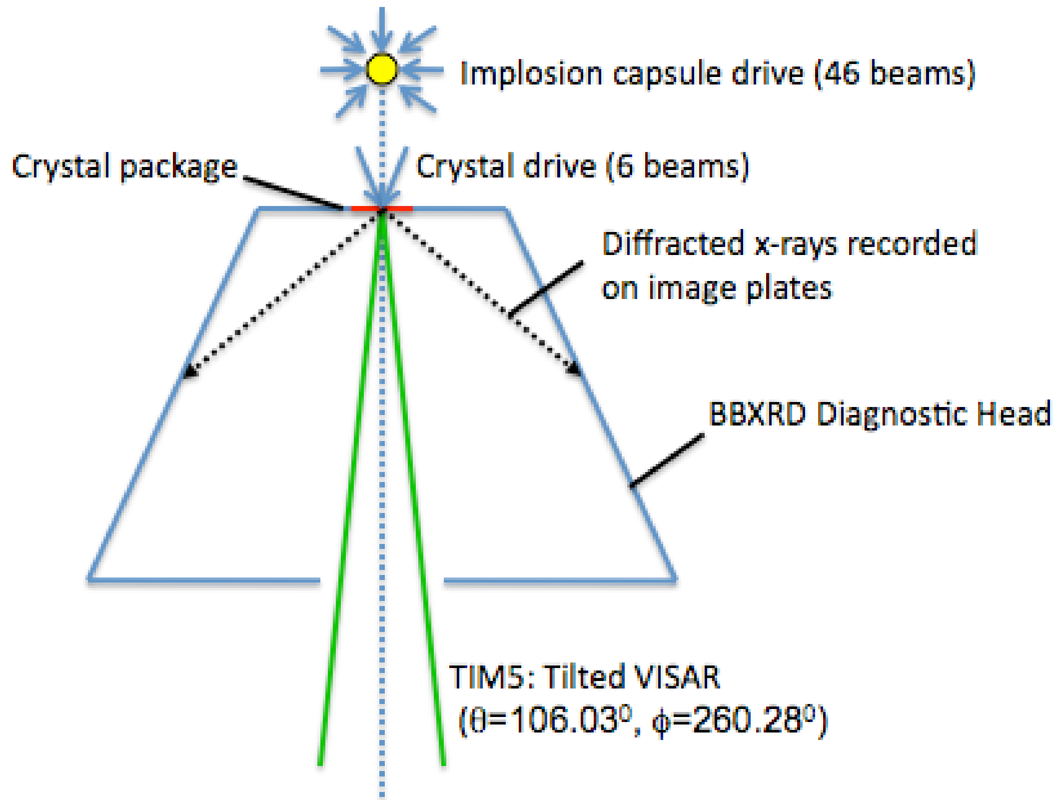


The Principle

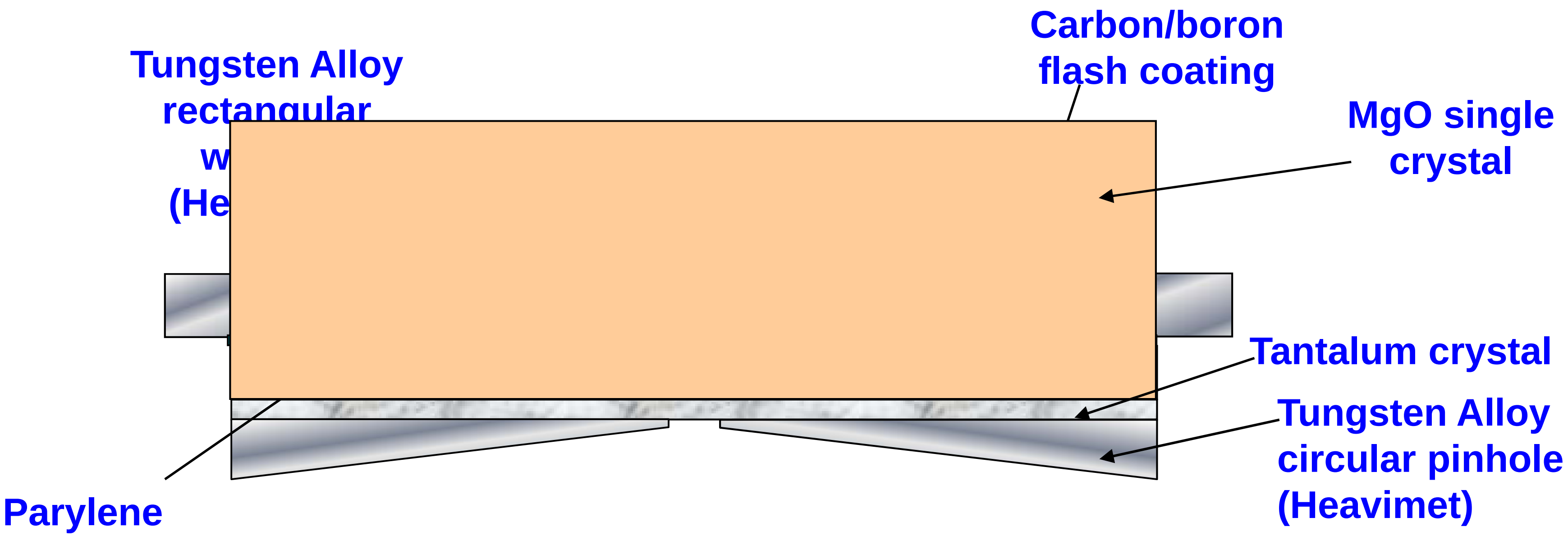


Experimental set up

- Target sits in a broad band x-ray camera.
- Camera has x-ray sensitive film on the inside to collect diffracted x-rays.



The Target



Tungsten Alloy
rectangular
Carbon/boron
flash coating
MgO single
crystal
Tantalum crystal
Tungsten Alloy
circular pinhole
(Heavimet)
Parylene

Construction – first thoughts

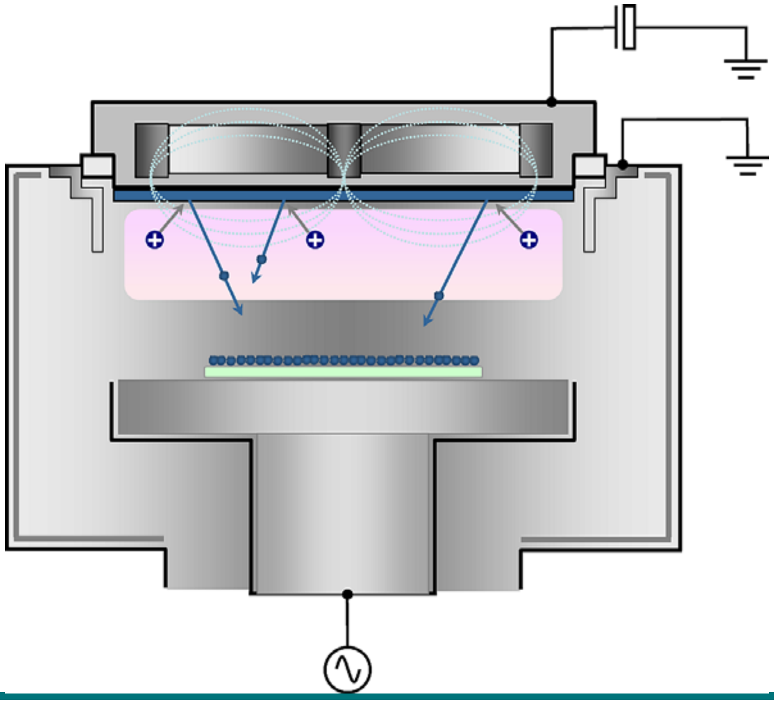
- Simple!
- Order a piece of single crystal foil and a pinhole.
- Glue them together.
- Coat it.
- Attach it to a washer and
- Shoot a laser at it.
- Unfortunately its not that simple.

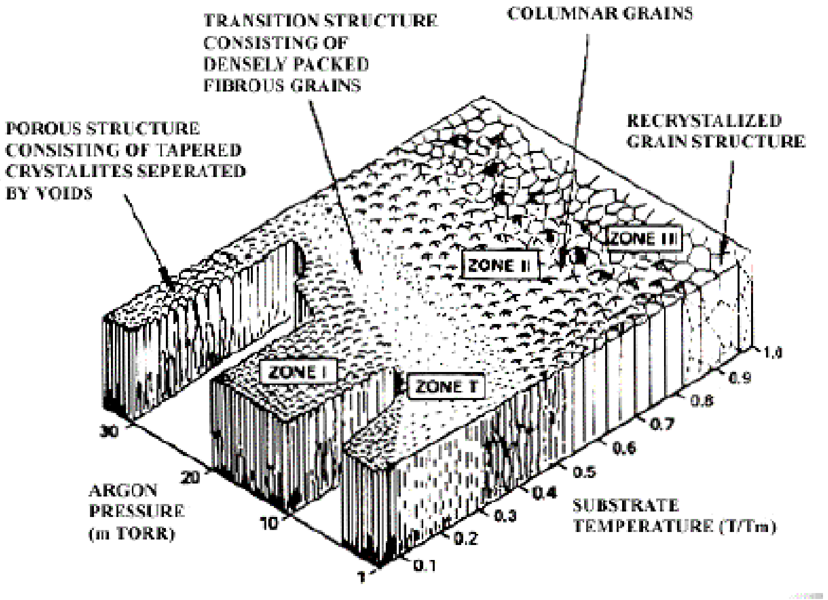
To begin with, there are the parts.

- Ta single crystal foils (on MgO).
- Heavimet circular pin holes.
- Adhesive.
- Heavimet rectangular washers.
- Parylene ablator.
- Boron/carbon reflector.
- CH capsules.
  - Chemicals and lab apparatus.

Single crystal tantalum foils

- Physically vapour deposited utilising an effect known as eptiaxy.



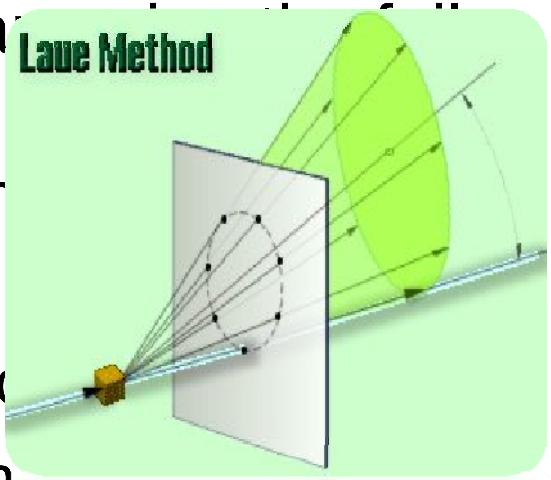


Single crystal tantalum foils

- Challenge:
  - Only one known source in the world available for producing this type of Ta foil.
  - Only one source of single crystal MgO (must be sourced from China).
  - This creates supply/time issues.

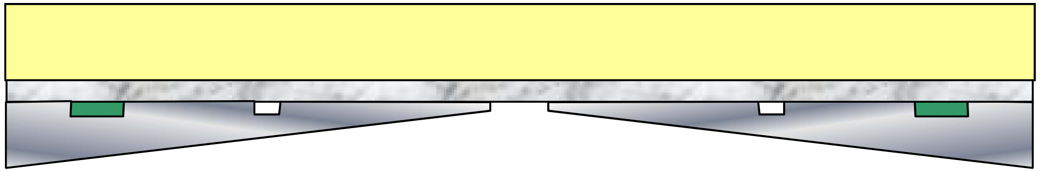
Single crystal MgO Substrate

- Ideally need to cut MgO without da
  How?
- Must remove the MgO from the tar
- Note
  - free standing Ta foils liable to defe
  - Ta foils need x-ray characterisation.



Pinholes

- Precision machined from Heavimet alloy.
- First challenge, finding a supplier who can supply, machine and characterise the parts.
- Centre must be 100 microns +/-10 microns. Angle needs to be 170 degrees.
- Need an adhesive well and over-flow reservoir to prevent glue wicking into central hole.

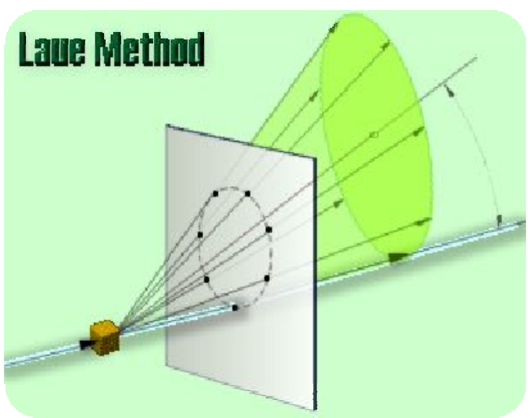


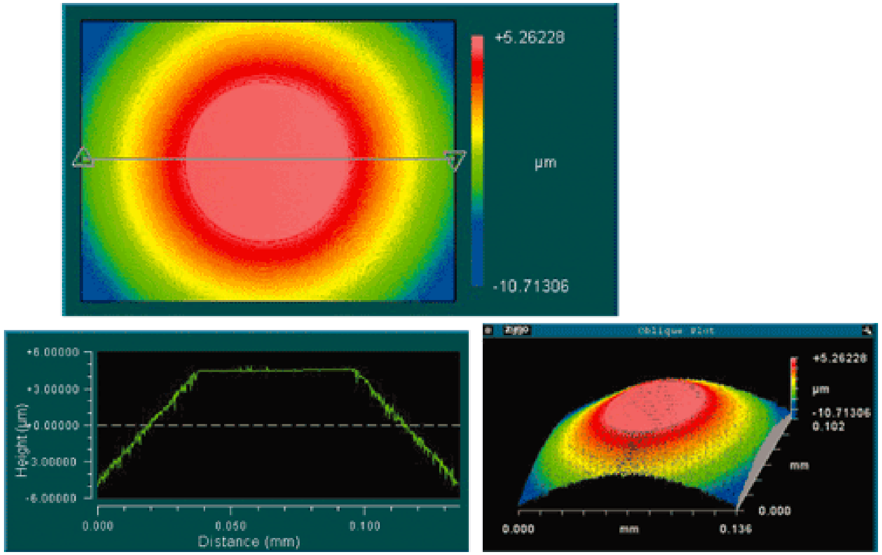
Adhesives

- Used to bond MgO backed tantalum foil to Heavimet pinhole.
- MgO removed using conc acid at elevated temperature.
- Compatibility trials are needed as no specific adhesive is manufactured for these conditions.
- Still have other usual adhesive challenges, curing wicking, sticking etc.

Characterisation

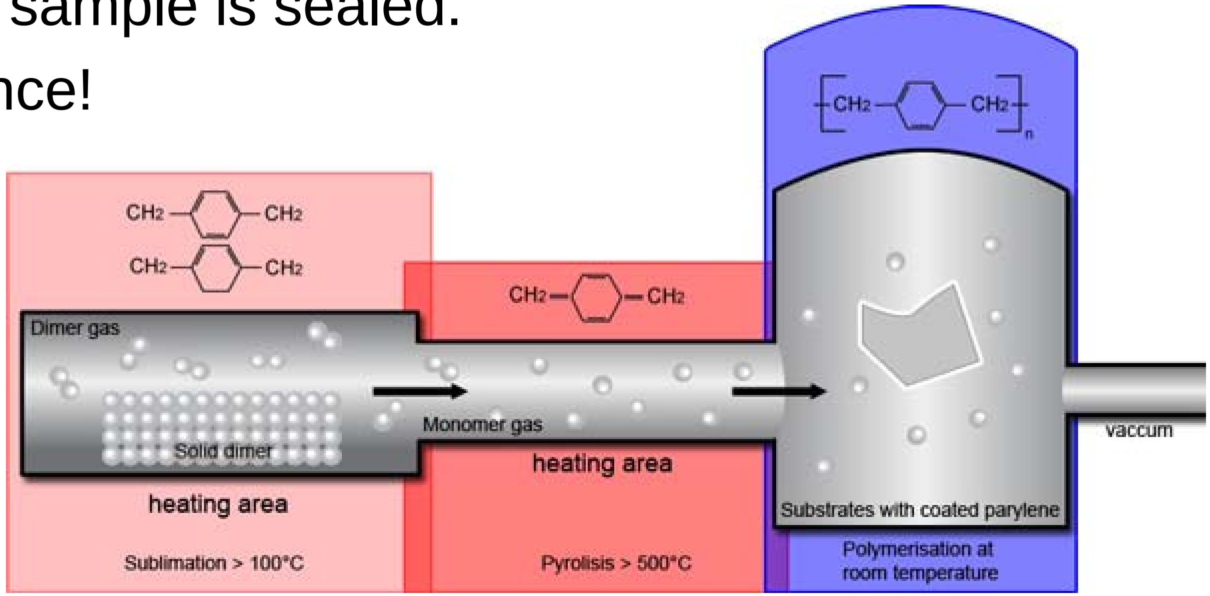
- Foils need to be assessed at each stage to check for damage to the foil (damage = increased defect density)
  - Laue diffraction
  - Flatness





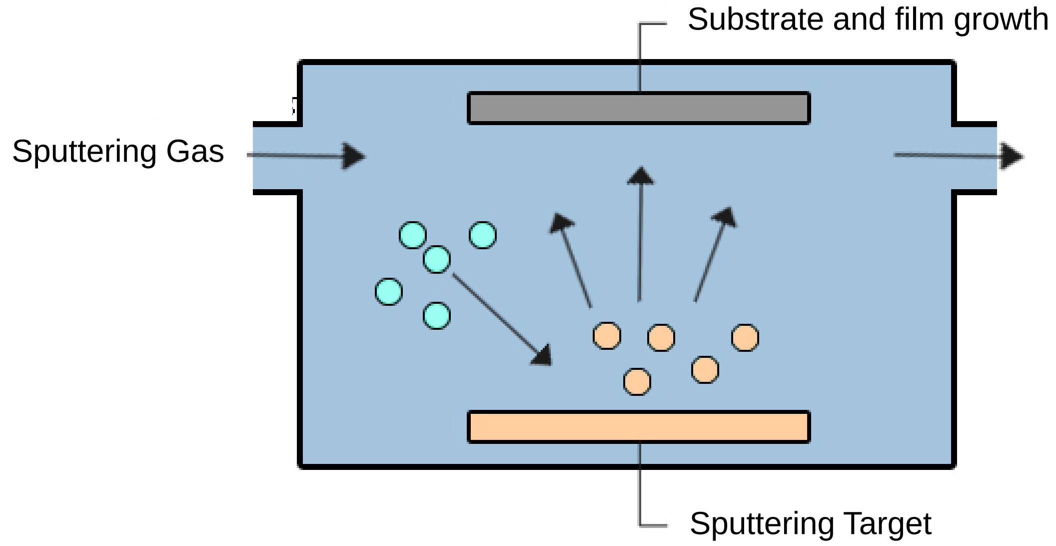
Parylene Coating (and characterisation)

- Parylene coating gets everywhere!
- Need 20 microns (2 days) on one the tantalum foil side and nothing on the reverse.
  - Need to ensure sample is sealed.
  - No second chance!



Carbon overcoat

- Less difficult as a line of sight coating process using sputter coating.
- Also only 500nm required.
- But still needs characterisation.



Assembly

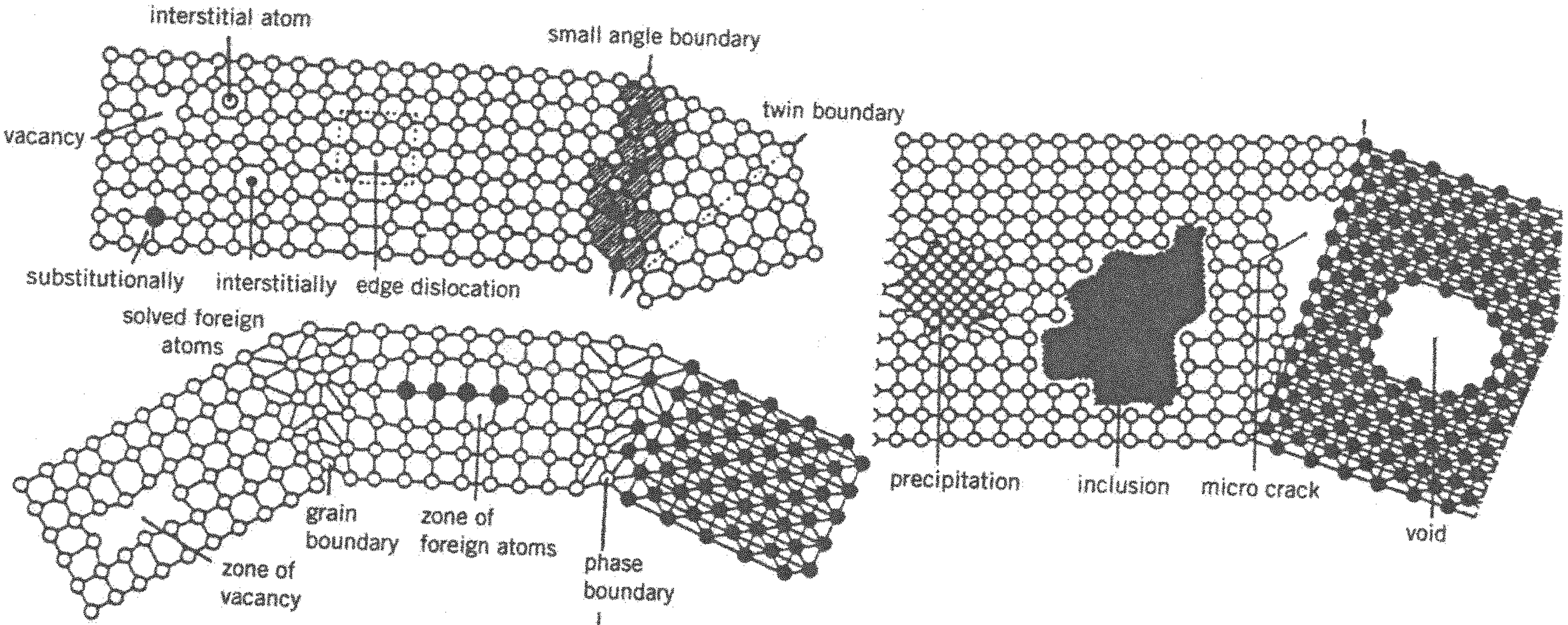
- Finally, the bonded, coated and characterised foil needs to be mounted into a washer in the correct orientation.
- Transported safely to the US.
- Then all the experimental timing issues begin.

Conclusion

- Even before you get to Donald Rumfelt's 'unknown unknowns' there are plenty of 'known knowns' and 'known unknowns' to keep us all very busy.

Thankyou

Crystal Defects

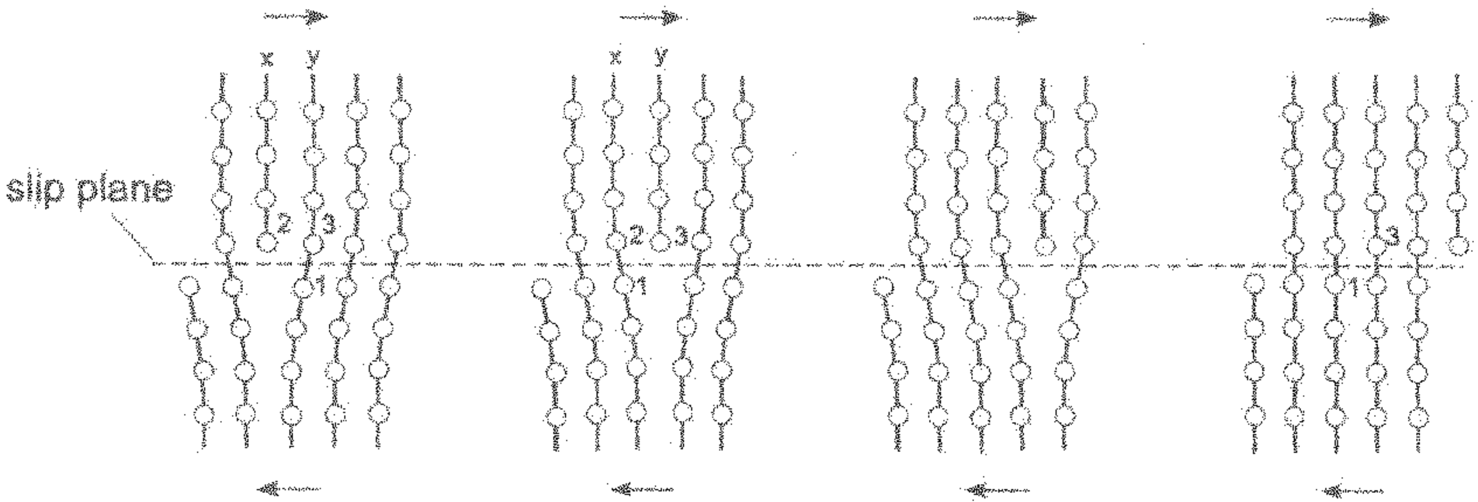


• Generation, growth and propagation of defects in crystalline materials play important role in determining macroscopic material properties such as strength

• Purpose of diffraction experiments is to gain insight into material microstructure (particularly defect density) under dynamic loading conditions

• Complements strength measurements made by comparing 2D continuum simulations with experiments looking at Rayleigh-Taylor growth in solid samples (described later).

Dislocation Dynamics and Strength



• Dislocations are the fundamental carriers of plastic deformation

• Their density and velocity (mobility) determine dε/dt and strength

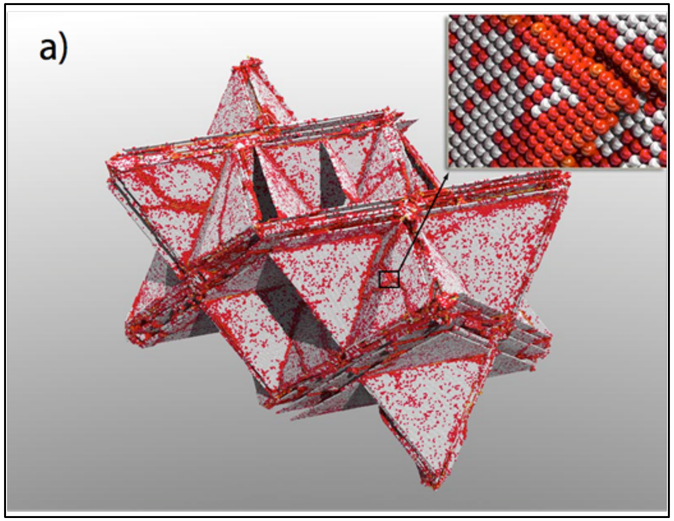
• Dislocation mobility determined by interactions with other defects encountered as dislocation glides through crystal (other dislocations, point defects, grain boundaries, etc).

• Described by Orowan's equation:

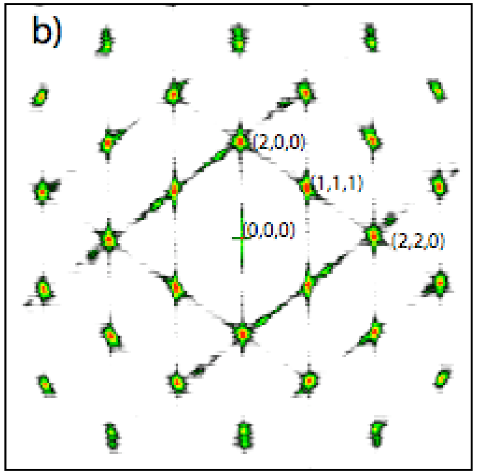
Where $d\varepsilon/dt$ = plastic strain rate, ρ_m = dislocation density,
b = Burger's vector, v_d = average dislocation velocity

Scientific objective – Make an in situ measurement of defect density and structure in dynamically compressed single crystal materials

- The structural response of a material to deformation is controlled by the formation and motion of defects
- In dynamic situation the predicted dislocation density is predicted to be orders of magnitude higher then observed in recovering
- By looking at the diffuse scattering around Laue diffraction spots using a broadband x-ray source can be used to determine density and structure

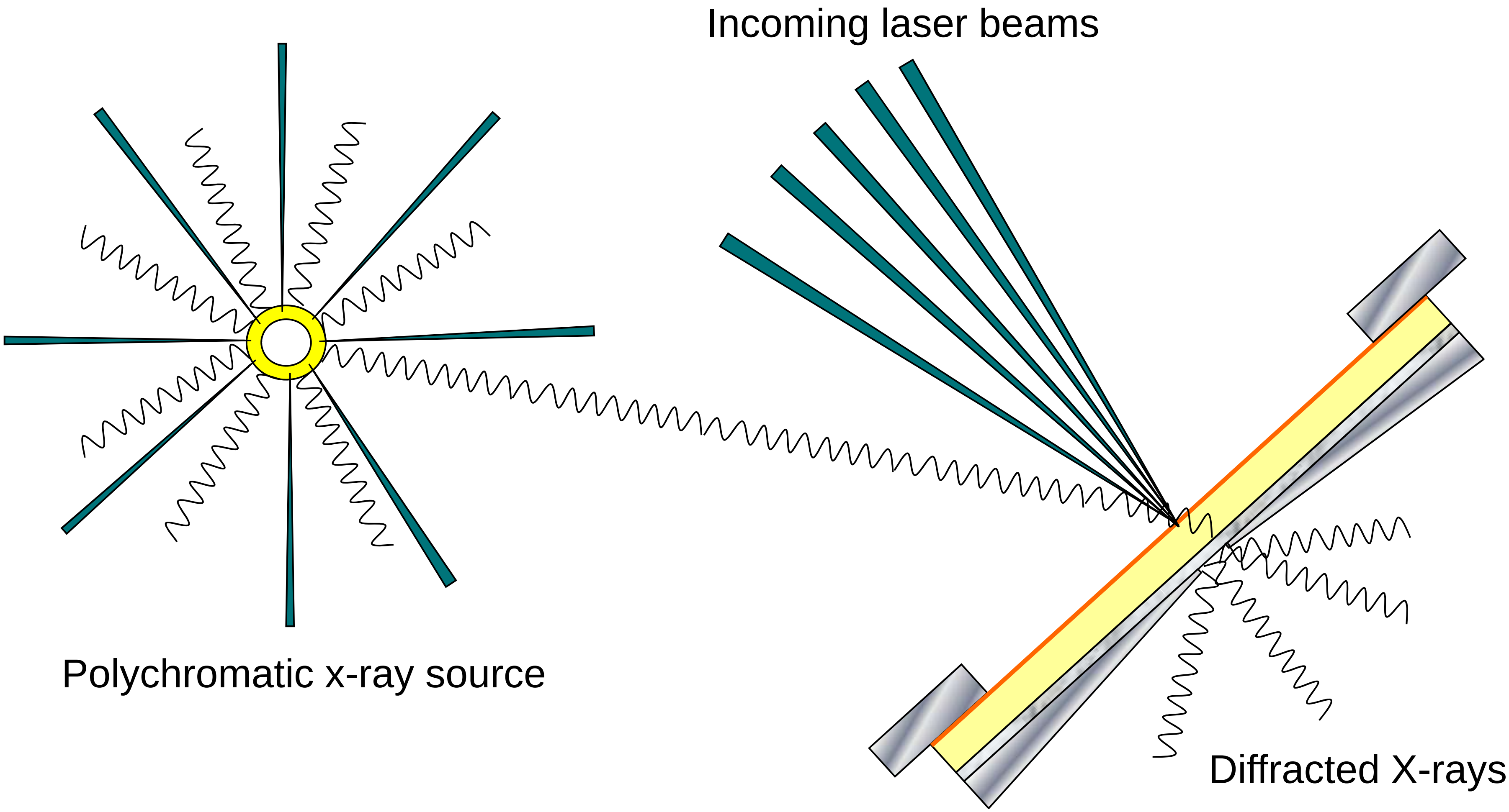


Real space image of defects



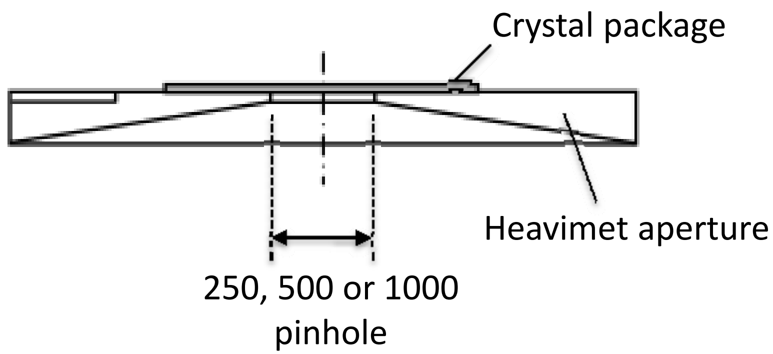
Broadening of Diffraction spots due to defects

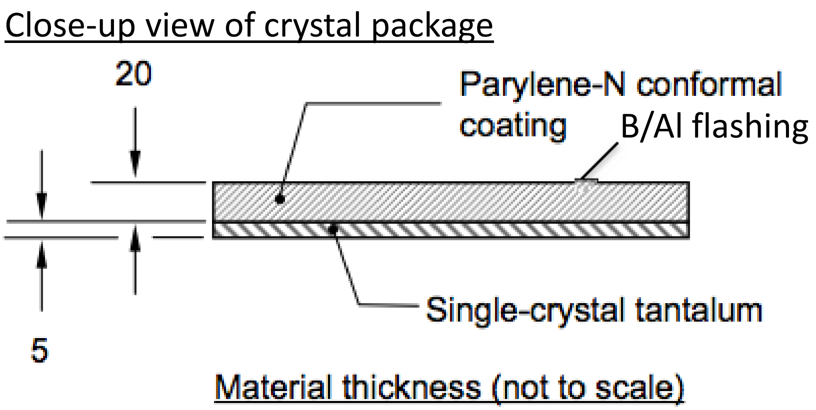
Timing!


Incoming laser beams
Polychromatic x-ray source
Diffracted X-rays

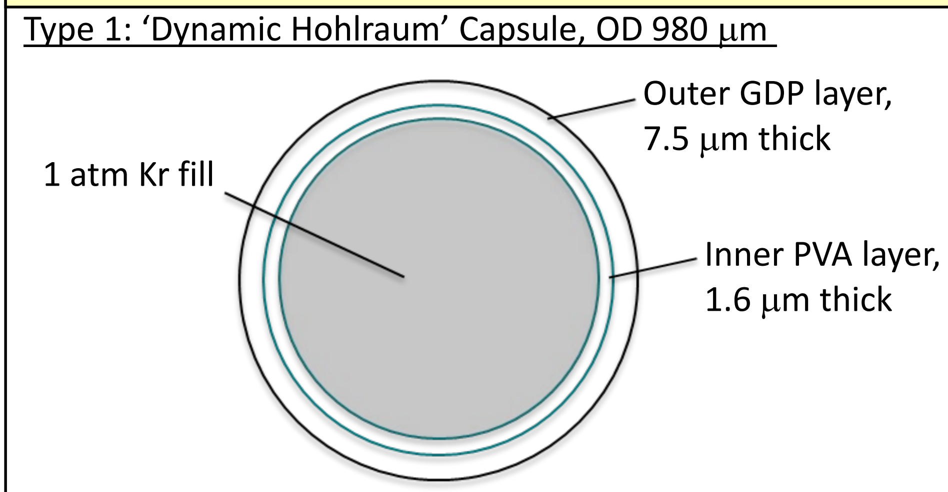
Target and Backlighter

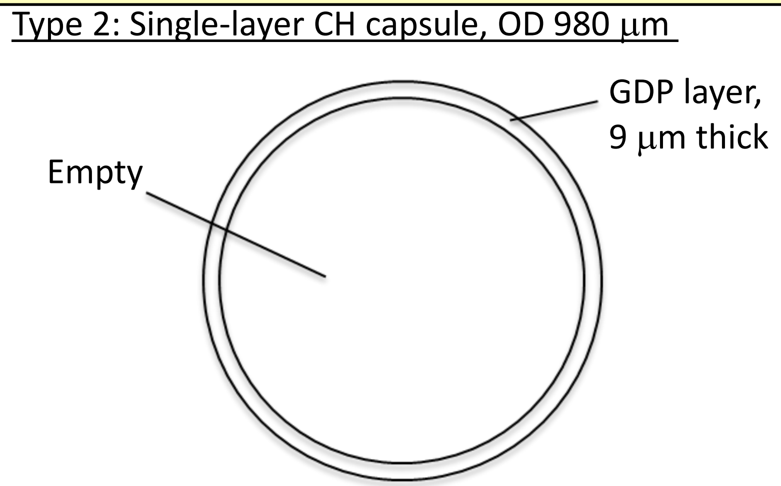
BBXRD-mounted target (dimensions in μm)

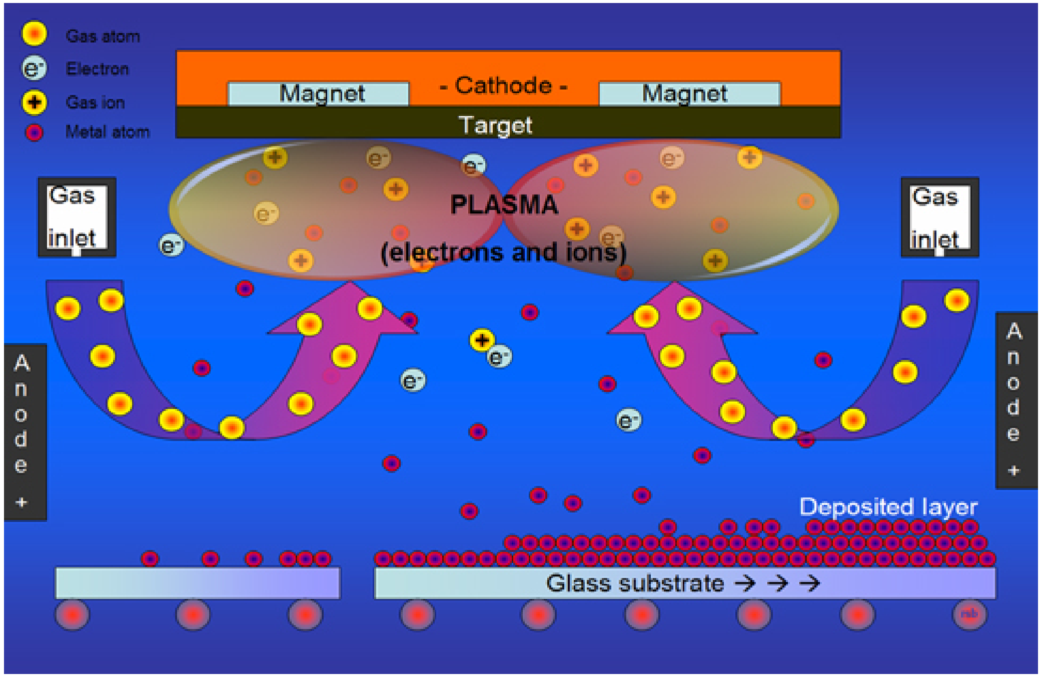




Implosion Backlighters (not drawn to scale)







Gas atom
Electron
Gas ion
Metal atom
- Cathode -
Magnet
Magnet
Target
PLASMA
(electrons and ions)
Gas
inlet
Gas
inlet
Anode +
Anode +
Deposited layer
Glass substrate → → →