Target Fabrication at the Rutherford Appleton Laboratory

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Science & Technology Facilities Council
Central Laser Facility

Experimental validation programme needed

- Absorption and energy transfer to the fast electron beam
- Divergence and collimation – novel techniques
- Phase control
- Hydrodynamics and mixing and tamping of the Au cone
- Fast electron transport in dense deuterium plasmas
- Transition from the Ohmic to drag-heating regimes
- Collective Stopping
- Whole beam self-focusing
- Colour and Z scaling
- Proton / ion driven FI scaling experiments
- Two stream instability – ion heating
- Hole boring
- Alternative geometries (get rid of the cone!!!)

Overview

- The CLF and Target Fabrication at RAL - Why do we exist?
- What do we produce?
- Delivery
- Facilities
    - Thin film coating
    - Micro-assembly
    - Micro-engineering
    - MEMS
    - Characterisation
- Target Development
- Future Challenges

The Central Laser Facility – Target Fabrication

- CLF is an operations driven facility running 2 High Power Lasers - Vulcan and Astra - for the (mainly UK and EU) academic community.
- The main function of the group is to provide on-site support for the experiments on these facilities.
- The two high power lasers operate into 5 experimental areas. The Target Fabrication Group co-ordinates the target delivery to all of these areas.
- Carry out production of complex 2D and 3D microstructures for standard experiments and high repetition rate systems such as Astra Gemini.
- More recently support on a contract basis through Rutherford Optics or through LaserLab agreements for delivery of targets materials for external experiments (LULI, AWE)

Target Fabrication at RAL – Why are we here?

1. To make targets - At present Target Fabrication Group produces ~98% of all solid microtargets shot at RAL. (~3000 pa, ~150 types pa.)
2. Knowledge - Knowing how to make high specification objects of sub-mm size is the whole reason for the Target Fabrication community. The RAL group has a broad scope of fabrication skills and techniques
3. Experience - Approximately 25 years of experience in managing and delivering targets for a wide range of experiments.

Most Importantly

The Group is available to enable rapid changes to be made to target geometries and compositions during an experimental campaign, often on a day-to-day basis.

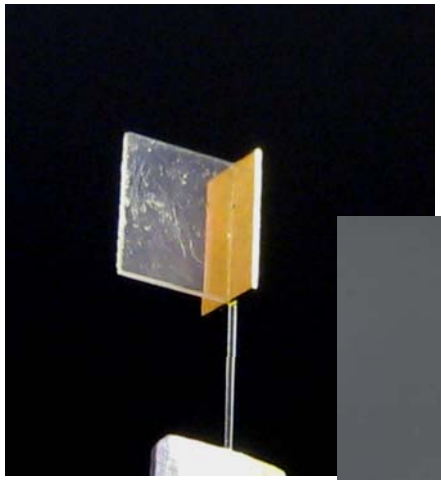
Its on-site presence at the RAL enables experimental groups to make decision on target manufacture based on data from the current experimental campaign, or even on their last shot. This 'just in time' capability coupled with a programme of long term target delivery makes the target fabrication laboratory a major reason why experimental groups use the facilities at RAL time and again.

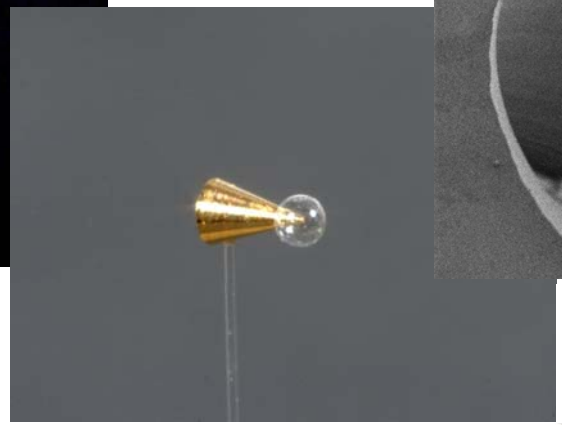
'This flexibility often can change an experimental campaign from just achieving the goals to providing exciting results pushing forward scientific knowledge'

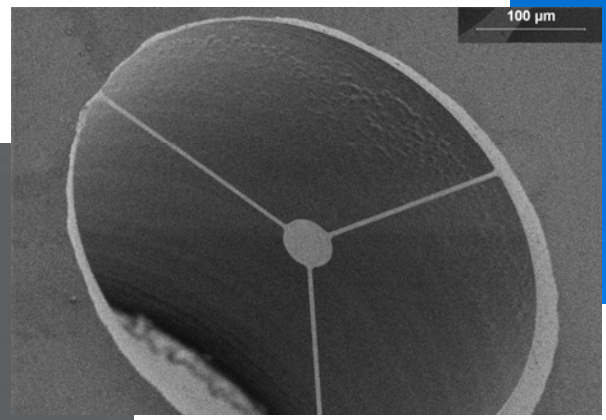
What targets do we produce?

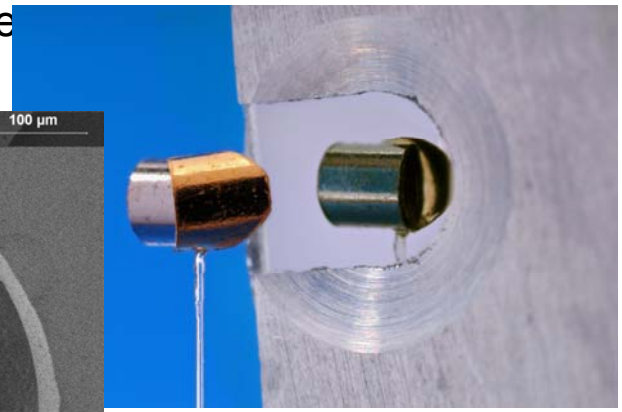
Range of Targets Produced

- Vulcan Target Area East
    - X-ray laser targets, Crystal shock targets and complex backlighters
- Vulcan Target Area West
    - Proton probing targets, proton focussing, buried layer targets, x-pinch targets, XRTS targets.
- Vulcan Petawatt Target Area
    - Thin foil proton production targets, proton generation and focussing, AFI cone targets and buried laye targets. Fast ignition studies.



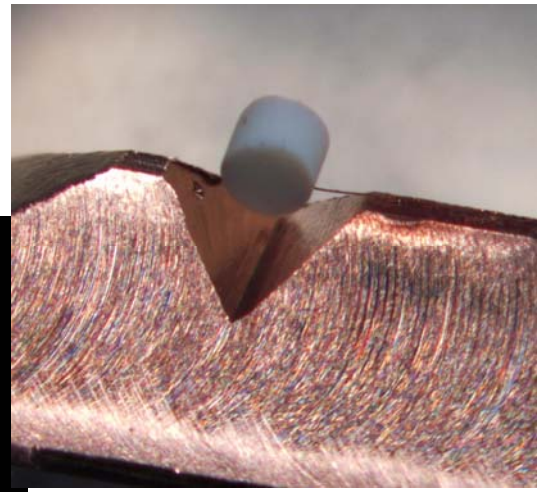


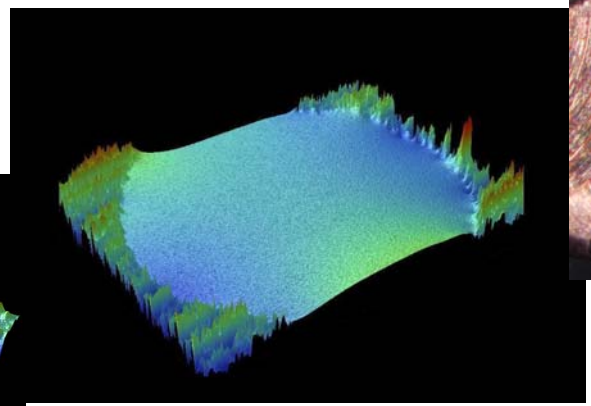


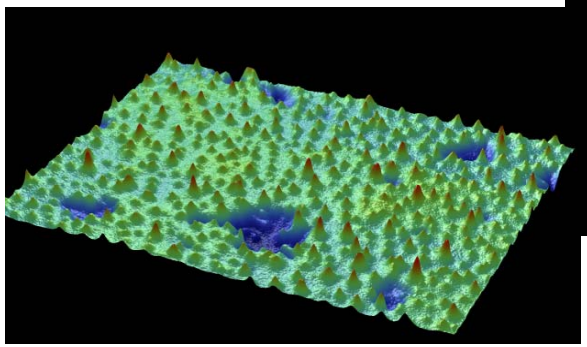


Range of Targets Produced

- Astra Target Area 2
    - High order harmonic generation targets, Ion acceleration targets, astrophysics targets, micro-dots, high absorption targets, spectroscopy targets.
- Astra Target Area 3 (Gemini)
    - High rep rate targets, tapes, raster targets, thin foils, microdots, proton focussing.
- Lasers for Science Facility
- Laser Operations







Operational Delivery

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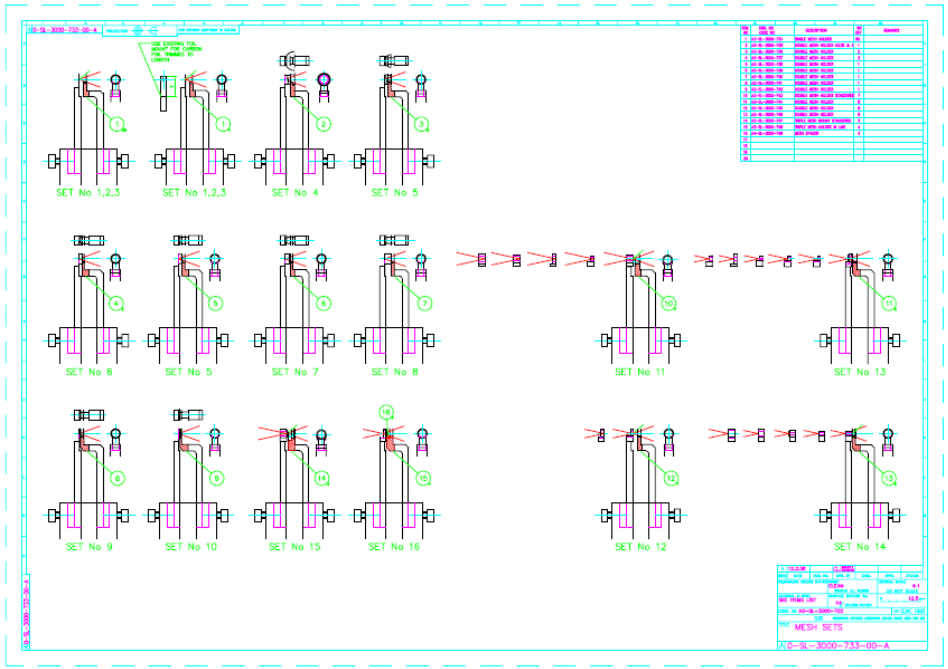
Operational Delivery of Targets

Experimental campaigns do not consist of one experiment with one target design and with one goal

- Groups consisting of a investigators from a number of different institutions
- Each group with its own target requirements
- Constantly changing demands through out the experiment.



Different target types are often small variation on a standard target that often require a lot of planning and work to integrate.

Operational Delivery of Targets

The Central Laser Facility and the Target Fabrication Group manage the delivery of targets through a number of activities.

Support provided includes:-

•Pre-experimental planning and consultation with PI's to discuss feasibility

•Target design and integration assisted by experienced design engineers.

•Manufacture of micro-target components (films, micro-machined parts etc..)

•Precision Micro-assembly by dedicated experienced fabricators

•Precise and thorough characterisation of targets.

Throughout the experimental campaign close collaboration between target fabrication staff and experimental groups enables the delivery of high quality high specification targets on time.

What facilities are available?

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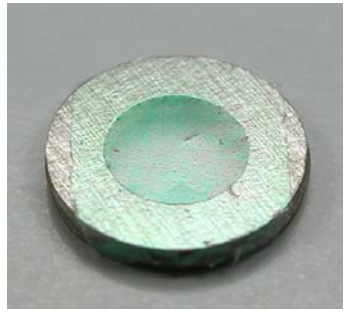
Capabilities - Thin Film Coating

A dedicated thin-film coating laboratory provides a solid base of coating capabilities which services the production needs for high rep-rate target delivery as well as providing good research and development facilities to investigate new target technologies.

Plastic Coating

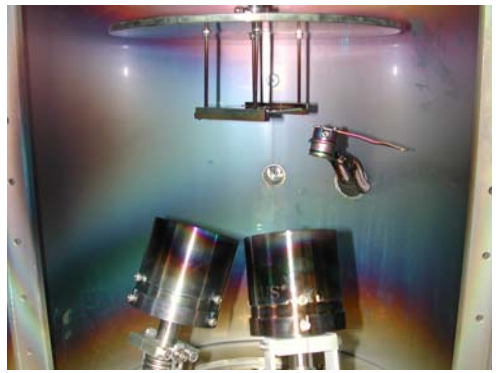


• Parylene films available in the range 0.05 - 25.0 µm.

Spin Coating

• Spin-coating of plastic such as SU-8 onto wafers or glass slides.

Sputtering



• One RF and two DC power supplies enabling co-deposits.

Thermal Evaporation

• Standard Thermal Evaporation for fast turn-around production of thin films for high rep rate targets, filters, plasma mirrors and thin trace layers on targets

Electron Beam Deposition

• Layered foils for AFI targets – 25um layered coating

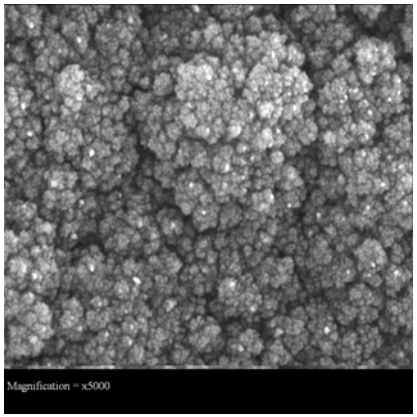
Capabilities - Thin Film Coating

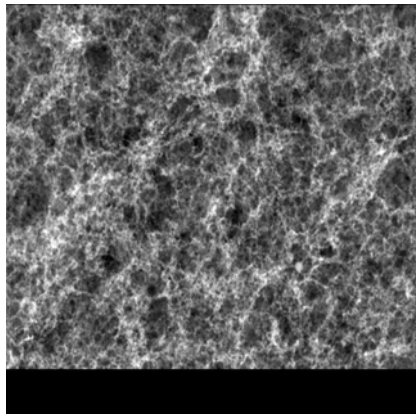
Low-Density Coatings

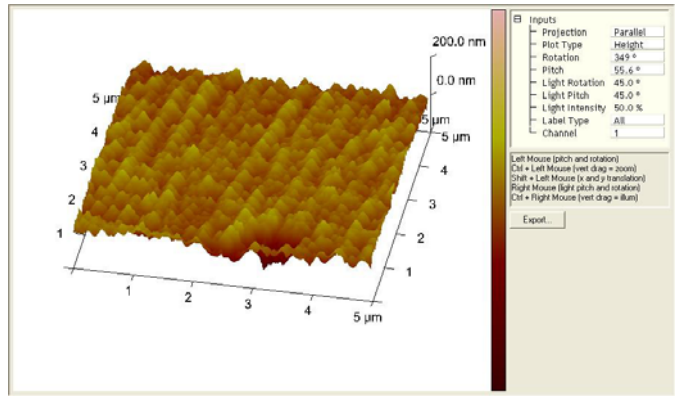
- ‘Low Density Metallic’ coatings and ‘fluffy’ photocathode production.
- Mass flow controlled to give enhanced structure control
- Materials include – Al, Cu, Au, Ti, CsI, KBr.

Structured (GLAD Coatings)

- Glancing angle deposition causes microstructures through shadowing





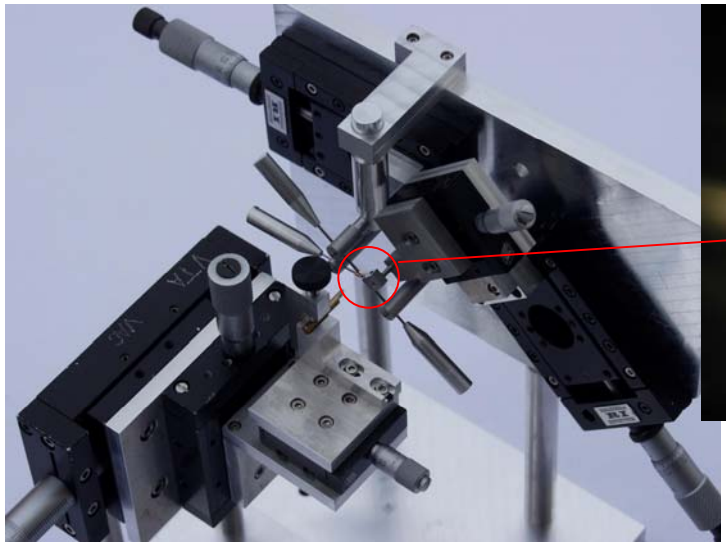


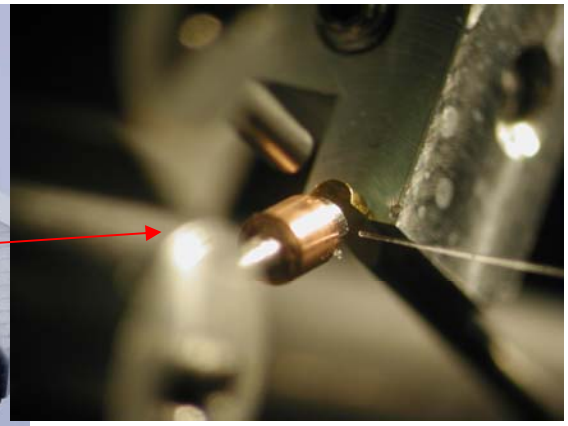
Capabilities – Micro-Assembly

Two fully trained time fabricators to enable the group to be able to respond to daily changes in target design geometry.

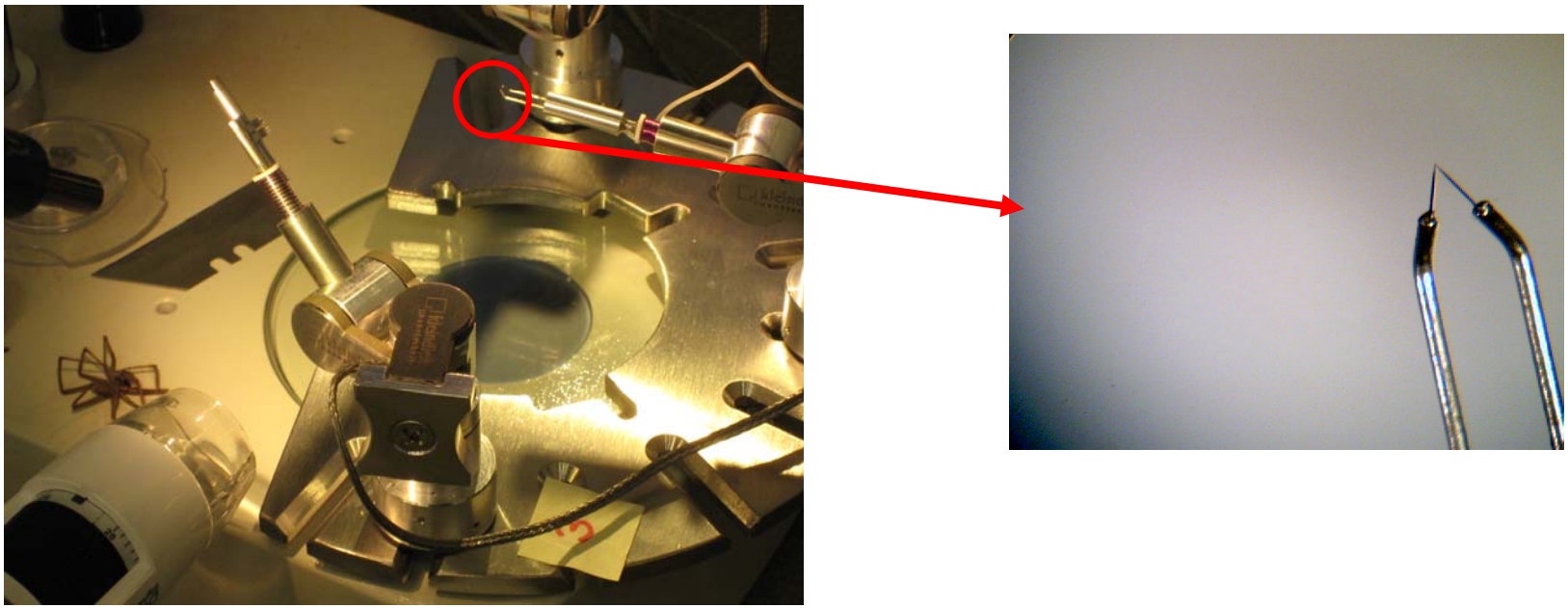
Extensive expertise in the process of micro-fabrication at the sub-mm level and an understanding of the problems that this poses.

Bespoke jig design for the more complex 3D targets to ensure high repeatability of results and ultra precise assembly.





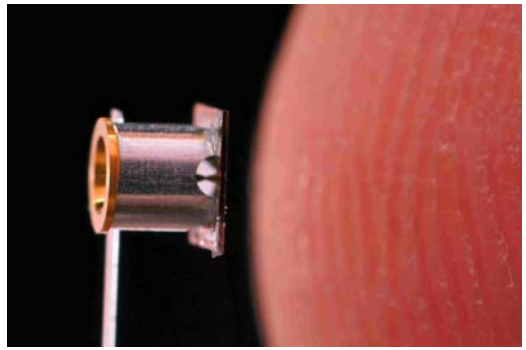
Case Studies – Robotic Micro-Assembly

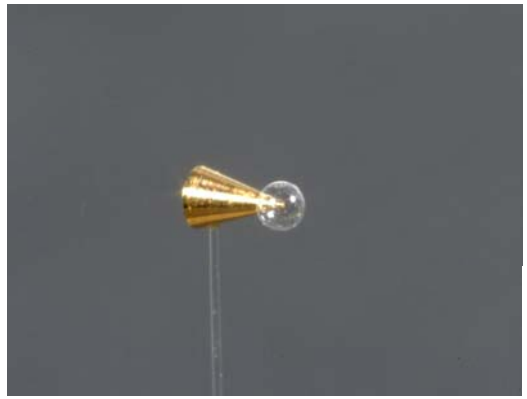


Nano-positioning robotic assembly robots, programmed to produce large numbers of simple targets. The technology can be up-scaled to produce an automated production line, delivering assembly, bonding, metrology and delivery.

Capabilities – High Precision Micro-engineering

The Precision Development Facility of SSTD has extensive capability in precision micromachining, particularly with two HAAS and one KERN CNC micro milling machines. The PDF also has experience in producing specialist prototypes of targets at short notice.





In support of Target Fabrication PDF provides:-

•Micromachining / Microcomponent manufacture

•Bespoke high precision assembly jigs

•Specialist Electroplating

An ongoing programme of development is helping to solve problems such as mass production of cones and target delivery for high rep rate laser systems.

Recent successful projects include:-

•Mass production trials for holhraums and cones

•Automated mass production of x-ray backlighter targets

•Mass production of embedded disk targets

•X-ray collimator targets

•Stepped targets

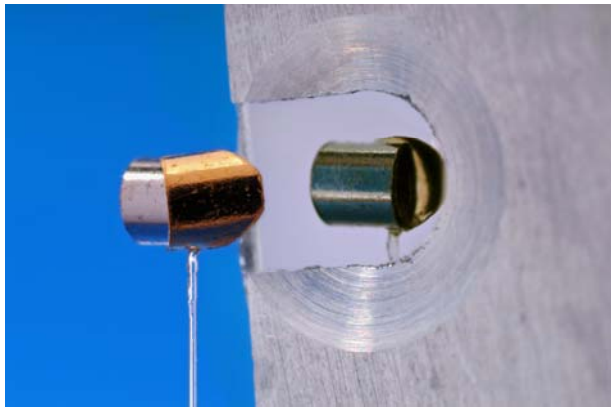
Case Studies – Micromachining

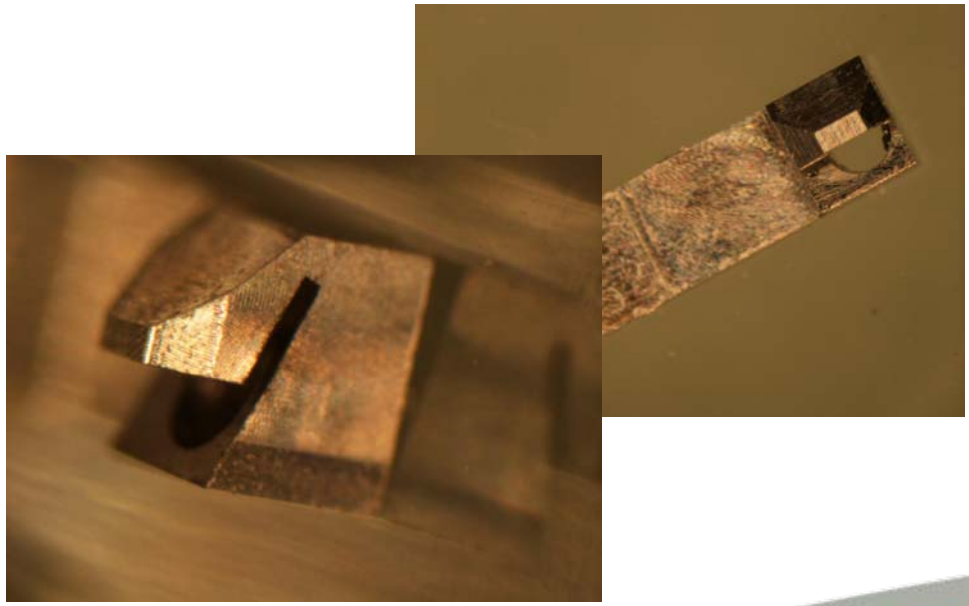
Automated production of x-ray backlighter targets.

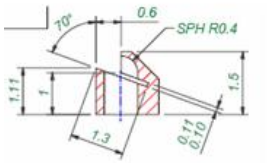
•Large numbers of high specification targets in short timescales

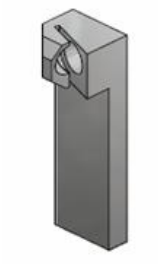
•Joint Target Fabrication/Micromachining project to produce x-ray backlighter targets using novel machining methods.

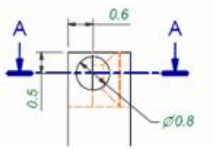
•5 axis machining on a Kerns CNC Micro-mill enabled single element targets to be made in a fully automated process.











Capabilities – MEMS Manufacture

The Target Fabrication Group works closely with the Central Microstructure Facility with its considerable experience and is also developing in-house techniques for the wafer-based manufacture of MEMS devices, especially high aspect ratio structures.

Processing steps can typically include:-

•Photolithographic or e-beam mask production

•Deep reactive ion etching

•Wet processing

These process allow the production of large numbers of high specification targets that could not possibly be produced in other ways.

Examples include

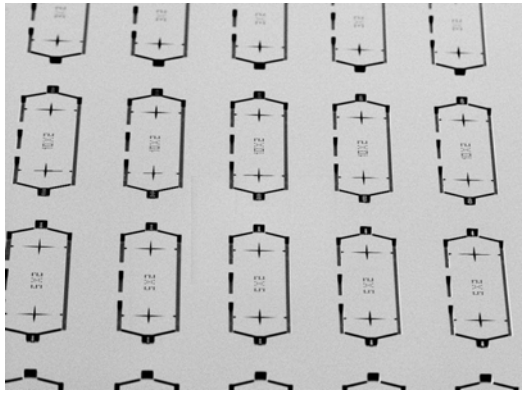
•Disk based targetry is being developed for use on the high rep-rate Astra Gemini system

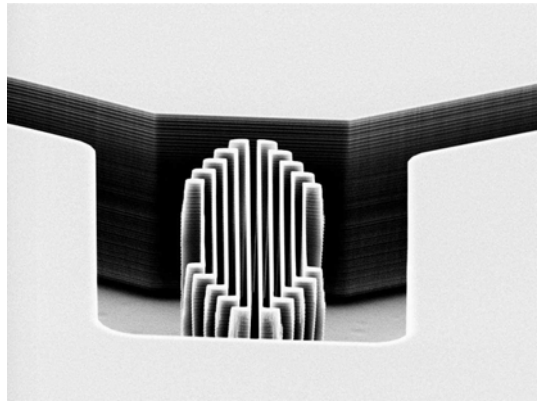
•Mass production for LIBRA ion source grant

Case Studies – MEMS Manufacture

A number of Target Fabrication/Central Microstructure Facility projects have been successfully delivered to provide high specification high aspect ratio targets.

Vane Targets – 2um thick Si vanes with 2um spacing dimensions 80um long x 40um high

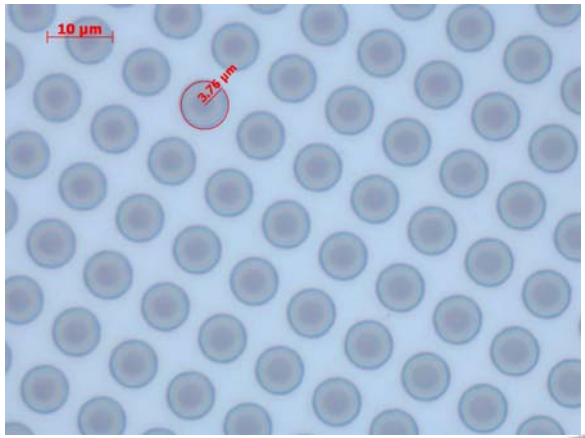




Plastic Disc Micro-targets - 7.5 um diameter, 1 um thick.

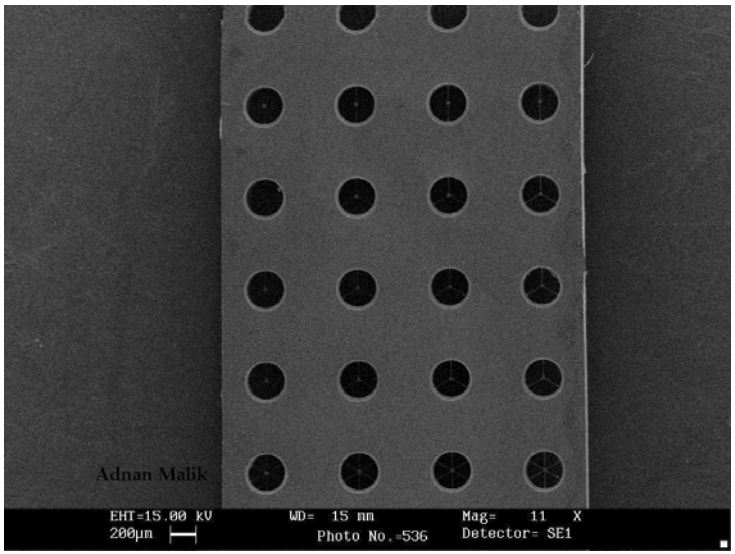
Fabricated on Si wafer substrate, released chemically.

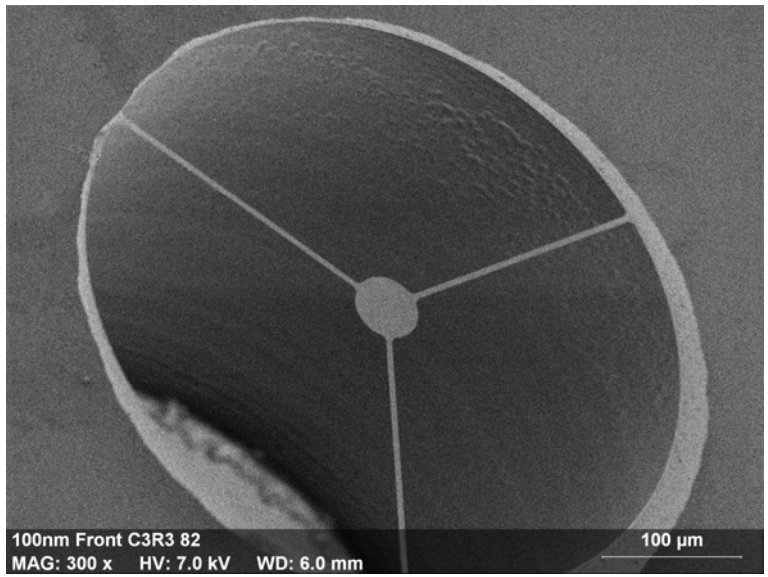
Many thousands produced in one batch.

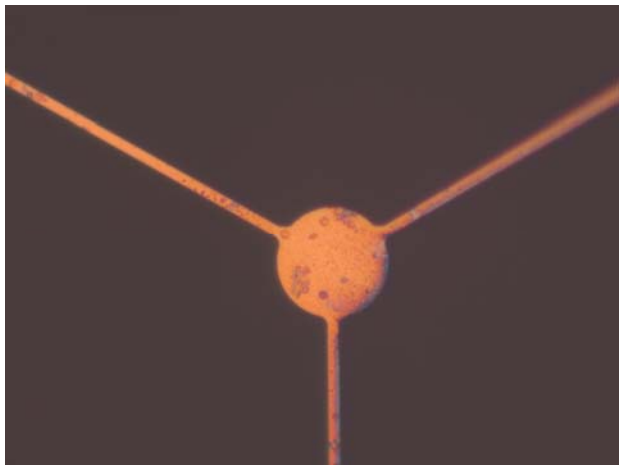


Case Studies – MEMS Manufacture

Ultra-thin membrane targets - 32um diameter, 40nm thick SiN membranes supported on 1µm wide, 40nm thick arms over hole etched through 400µm thick Si.







Capabilities – Characterisation

Large scale investment into characterisation equipment has led to the Target Fabrication laboratory having an extensive suite of instruments that are specifically geared towards characterisation of high power laser targets.

Facilities include:-

•High specification optical microscopes with advanced contrast techniques

•Co-ordinate measuring microscope with laser scan system

•SEM with EDX, Backscatter detection, 3D image capture and surface reconstruction and measurement

•Wyko white light interferometer with advanced film analysis software.

•Surface profiling systems for thin film measurements and surface characterisation.

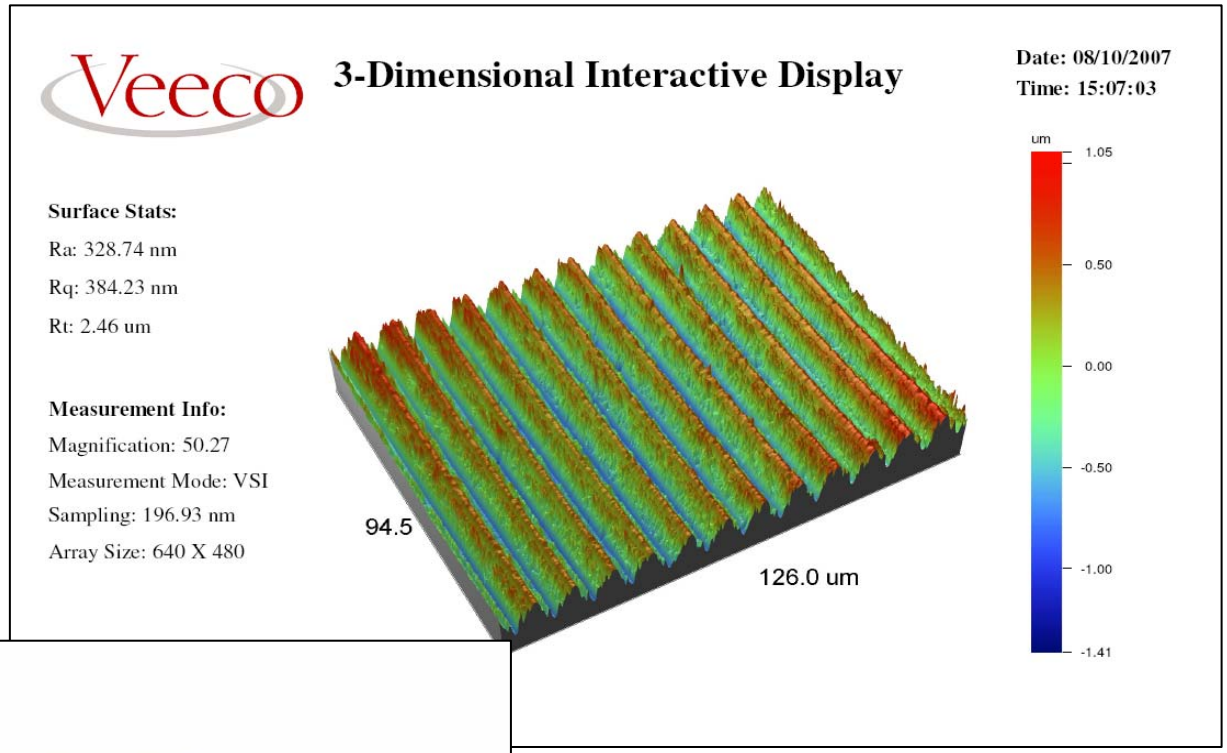
Access to other equipment including

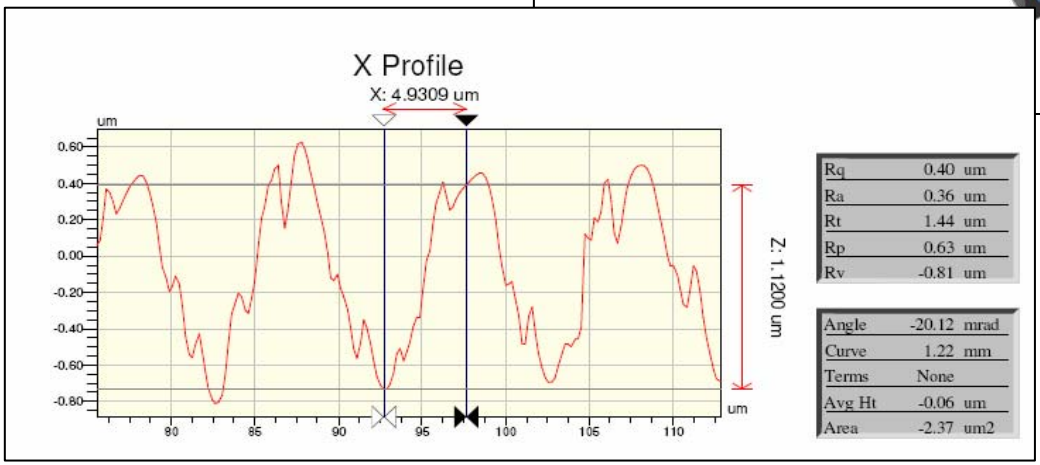
•AFM systems

•X-ray defractometer

Capabilities – White Light Interferometry

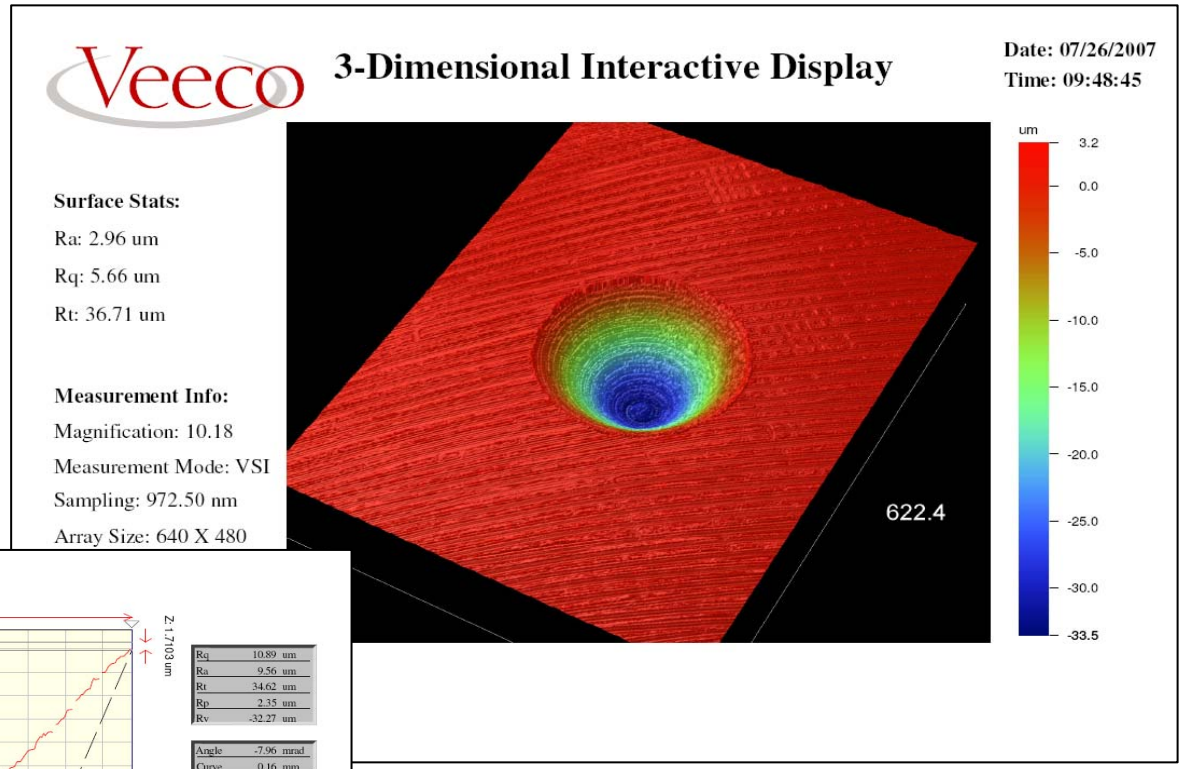
Micro-groove targets

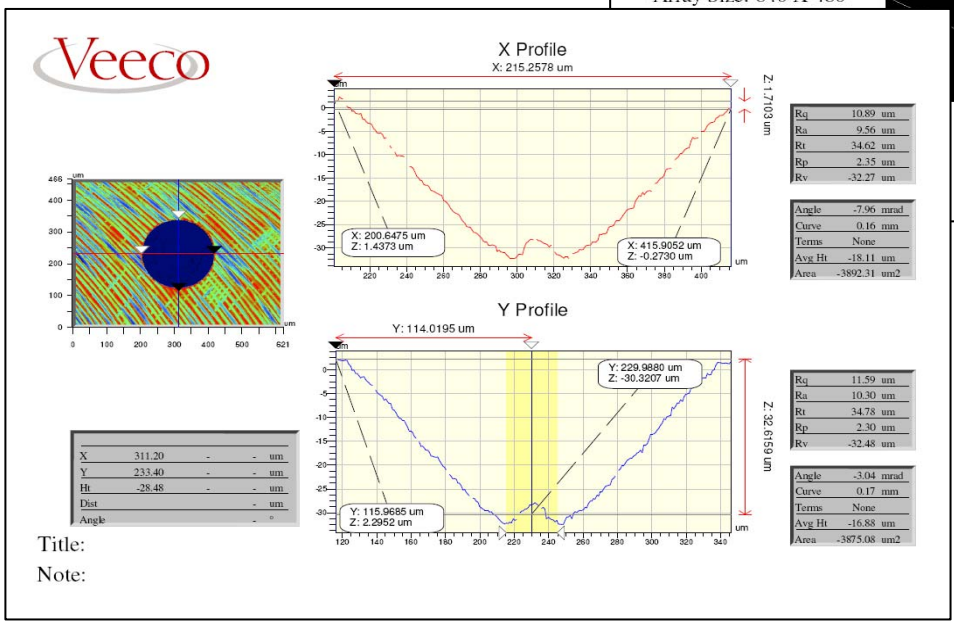




Capabilities – White Light Interferometry

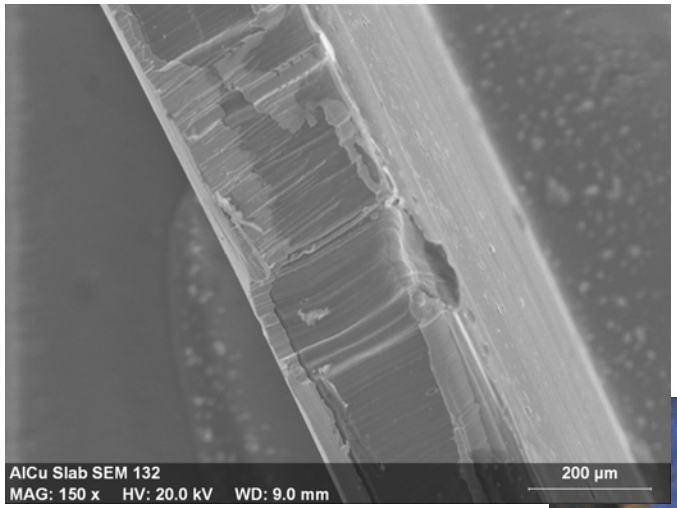
Micro-machined dimples



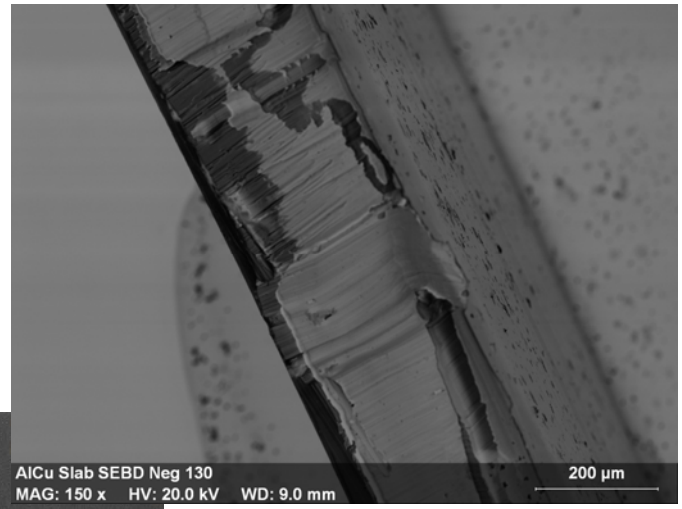


Capabilities – SEM Analysis

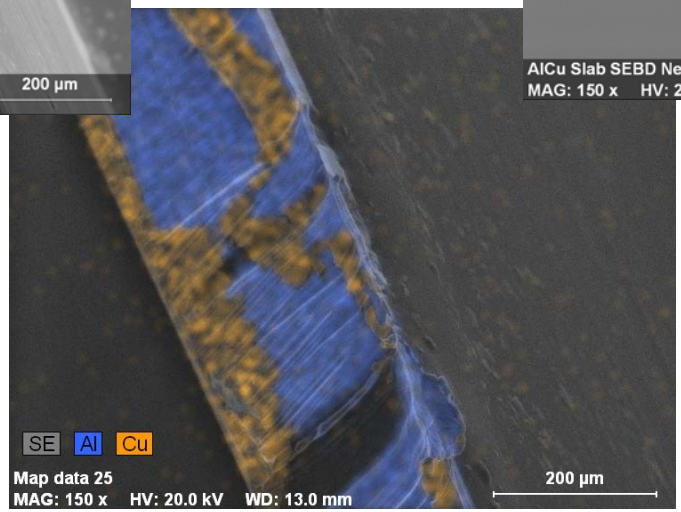
Thick metallic coating analysis – Rapid characterisation of coating processes can be carried out to improve target fabrication techniques.



SEM Image



Backscattered electron image



Elemental analysis of sample with mapping

High Rep Rate Facilities

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Short Term Delivery – Nanopositioner Wheel

Nanoposition wheel driving one or more discs populated (around edge?) with targets.

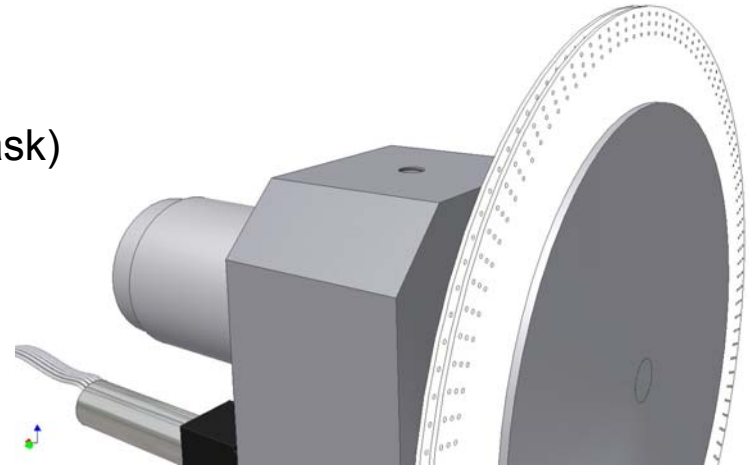
Discs can be made using

•Micromachining

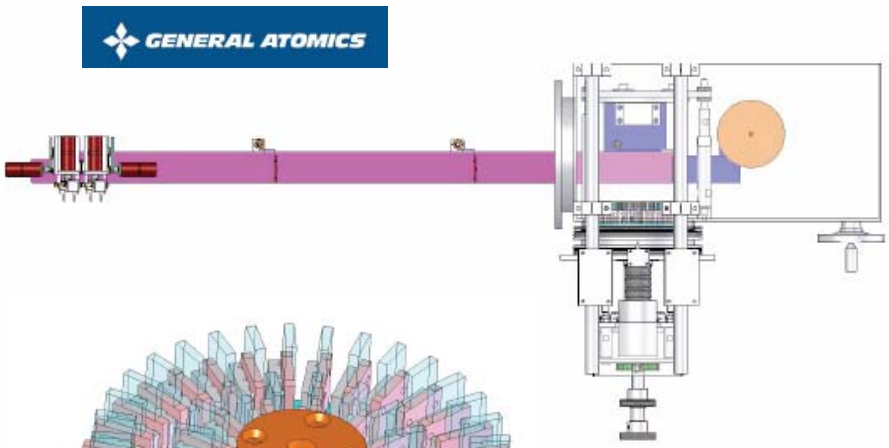
•Wafer-based techniques

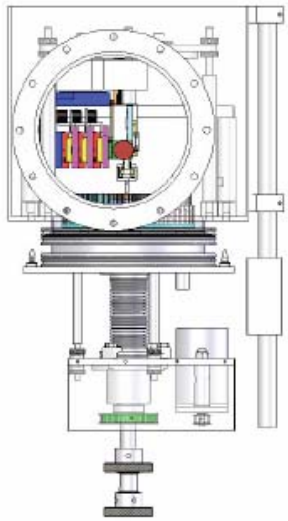
•Chemical etching

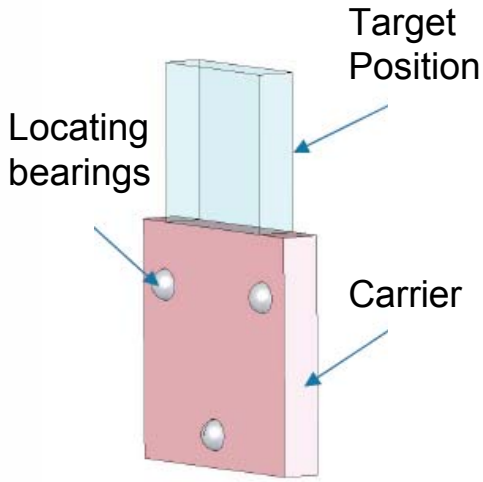
All of these in combination with (through-mask) coating or electroplating.

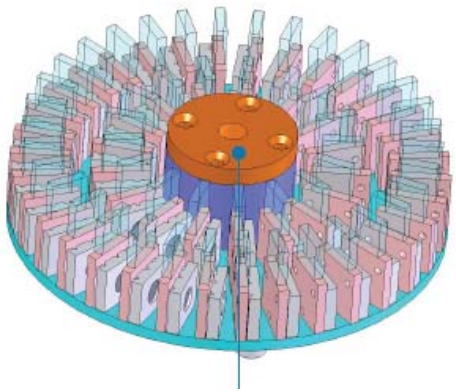


Delivery – Target Inserter









51 Position
Carousel

Telescopic cable reel arm with gripper to position target holder. Targets stored and picked from a carousel with 51 positions.

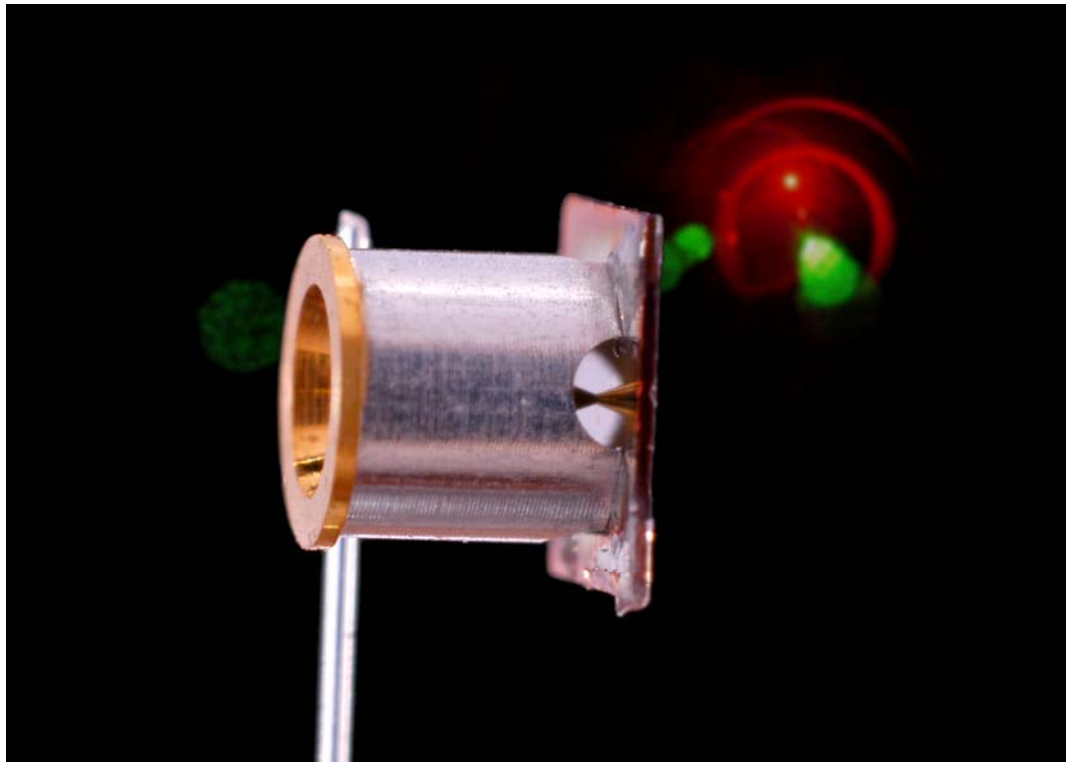
Hexapod on target positioner and metrology station

Future Challenges

- Current target numbers are reaching 3000 pa, of 150 different types.
- Astra Gemini will inflate this number to 10's thousands with single experiments capable of shooting ~1000 targets.
- Delivery to this and other high rep rate laser systems will require the integration of
  - Automated target fabrication
  - Automated characterisation of target parameters
  - Delivery of these targets precisely and in a manner that is adaptable to a number of different target types and geometries
  - Data handling, 1000's of targets generate huge amounts of data.

Conclusion

- Developed over 25 years, with a large investment in recent years and continued research and development in emerging target fabrication technologies the target fabrication laboratory at RAL is one of the world leaders in experimental support and micro-target fabrication.



Target Fabrication

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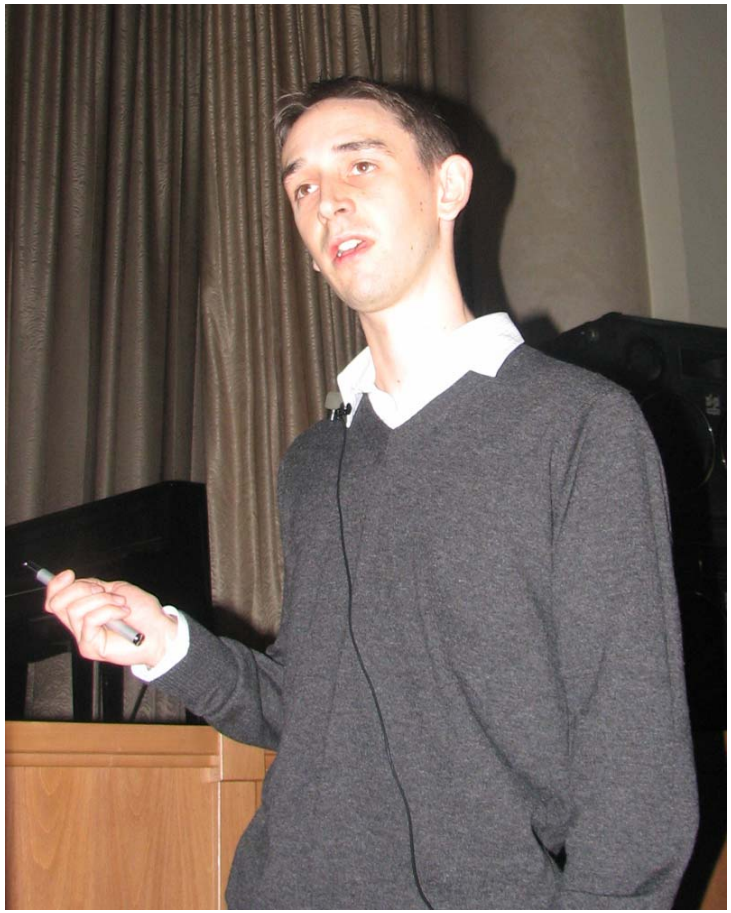

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