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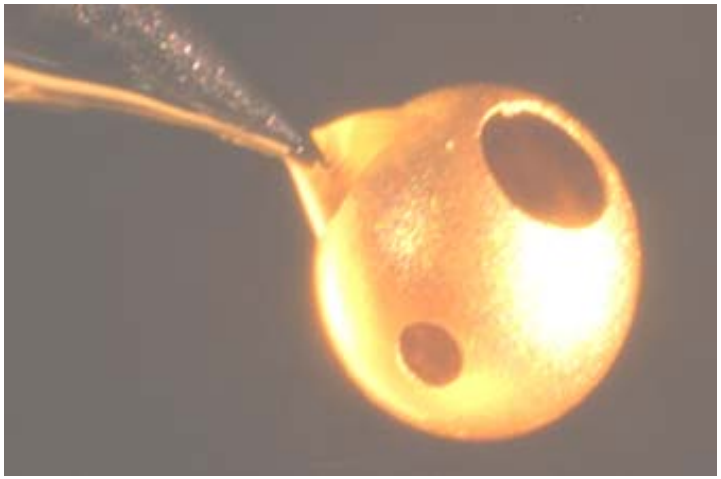
Target Fabrication Capabilities at TUD with a focus on Thin Cryogenic Deuterium Targets



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Detector- & Target Laboratory

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Outline

TECHNISCHE UNIVERSITÄT DARMSTADT

- Detector- & Target Laboratory
  Institute for Nuclear Physics, Darmstadt University

- 3D-Targets for high intensity / high energy laser experiments
  - photolithography, electroplating, etching – hohlraum targets
  - laser machining, precision micro-machining, micro-moulding

- Thin Cryogenic Deuterium Targets
  - Applications, e.g. pump-probe experiments
  - Target production
  - Metrology

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Target Laboratory – Mission

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- Small scale university facility
- Focus on development of target manufacturing techniques
- Focus on development of preparation & delivery techniques
  - Pre-alignment
  - Target insertion at the experiment
  - Target alignment techniques at the experiment
  - Target support (minimal mass of supporting structure, …)
- Targets for high energy density laser experiments
  => single use targets
- Which manufacturing techniques are amenable to medium (~50) or high (>100) number production?

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Target Laboratory – Equipment

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- 30m^2 laboratory workspace
  - Production of cryogenic hydrogen & deuterium targets
  - Gas monitoring & gas extraction system
- 40m^2 + 20m^2 laboratory workspace
  - Grinding, polishing, press
  - Diamond Wafer saw
  - Film thickness measurement by means of alpha-particle energy loss rating (Americium 241)
  - Precision micro machining (CNC-lathe)
  - Storage
- 30m^2 laser laboratory to be commissioned for
  - fs-laser machining and
  - 3D-lithography by fs-two-photon polymerisation

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Target Laboratory – Equipment

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- 100 m^2 clean laboratory workspace
  - Air condition; humidity control, air filter system
  - Flow boxes (<1000) for micro assembly, bonding, UV-curing, etc.
  - Flow Boxes (<1000) with fume extraction for wet chemical processing (including hydrofluoric acid) and for electroplating (Cu, Au, Ni)
  - Purification plant, providing ultra pure water
  - Equipment to handle acids, chemicals, etc.
  - Plasma cleaner / reactive ion etching; process gases like oxygen, nitrogen, argon
  - Two thermal evaporation plants
  - Photolithography: Mask imaging and proximity exposure @365nm
  - Spin coater (up to 6'' wafer or 5'' square substrates)
  - Precision micro welding
  - Nanosecond laser machining
  - …

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3D-Targets for Laser Experiments

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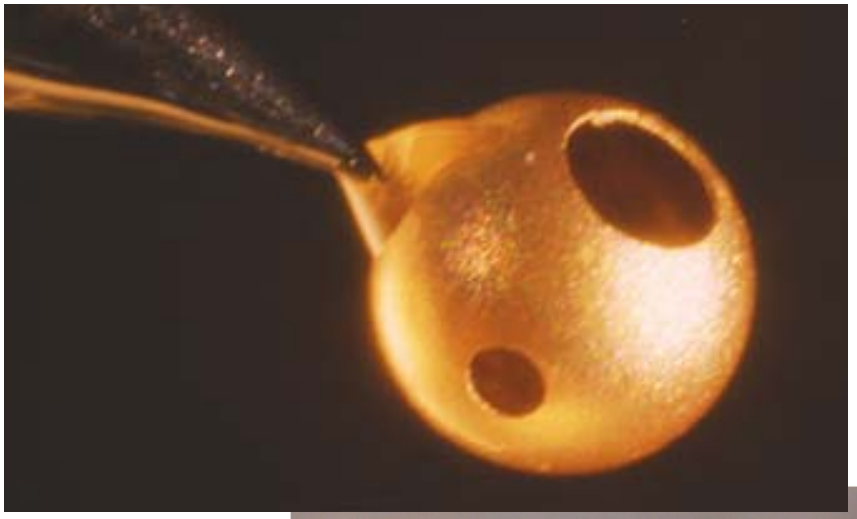
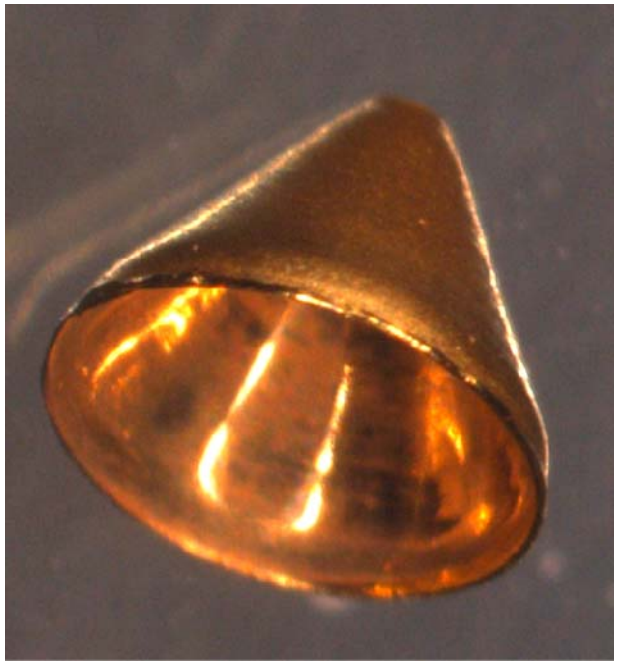
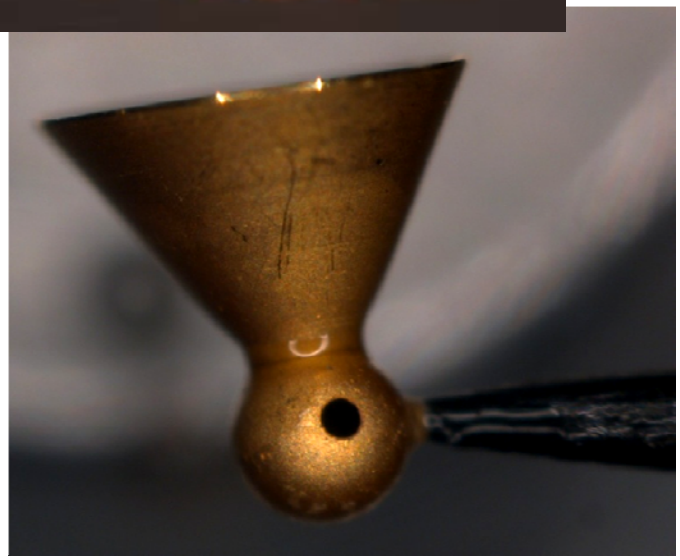


sphere:
Ø 750µm
ports:
Ø 150µm
Ø 350µm
wall:
d=10µm





Cone:
Ø 350µm & Ø 2000µm

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Hohlraum manufacturing

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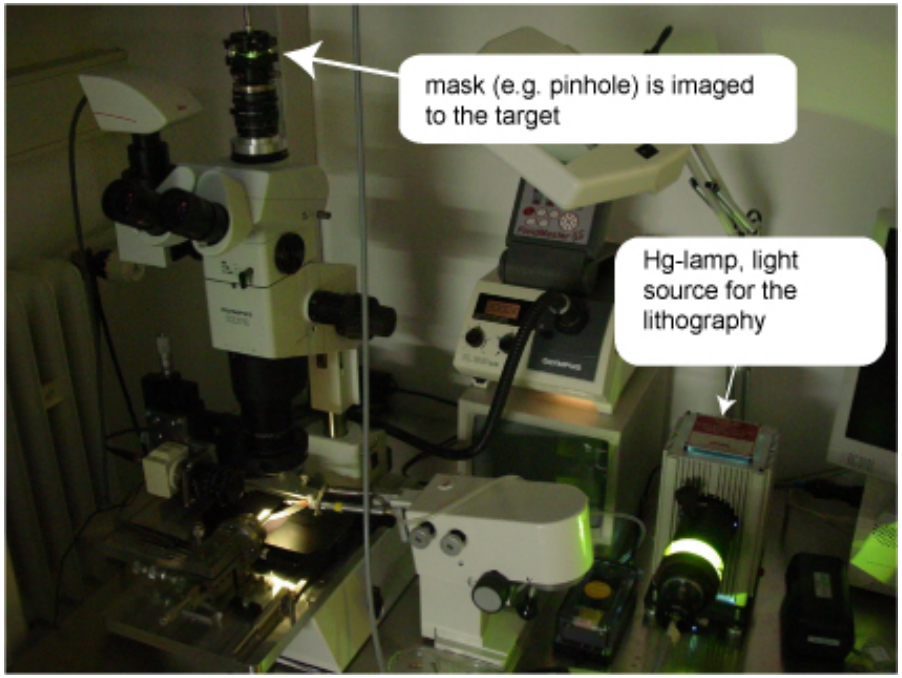
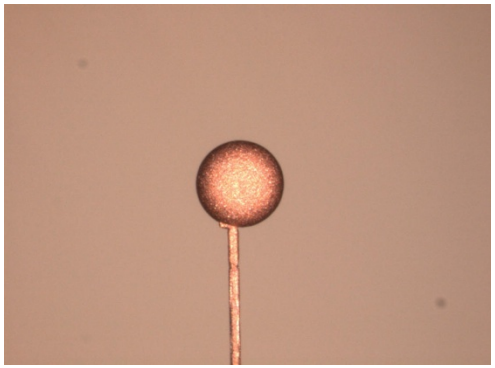
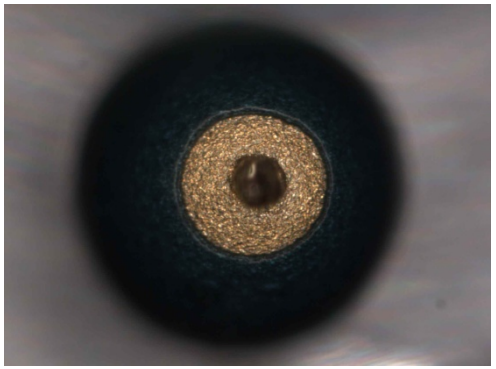
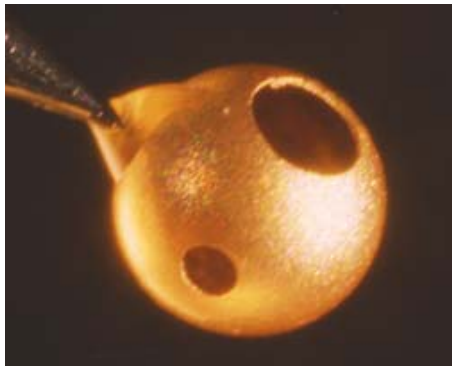


- Positive form,
  e.g. bras or stainless steel ball
- Contact the ball with a 50µm wire
- Cleaning procedure
- Electroplate
- Apply the 3D positive photo resist
- Expose, e.g. laser entrance hole
- Etch the gold
- Etch the massive brass body







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Hemi-Spheres for Proton acceleration

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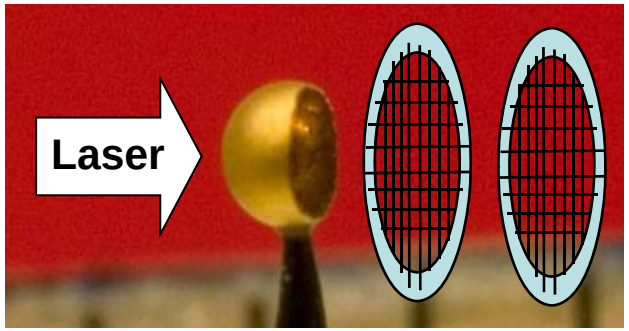
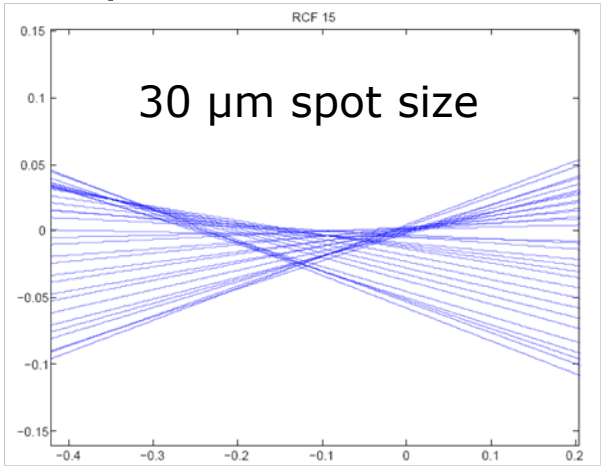
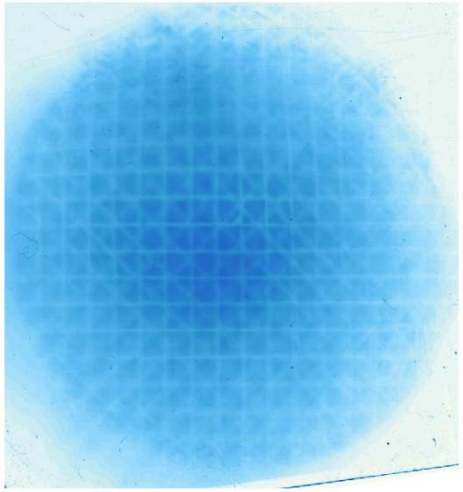
- Sphere diameter 600µm
- Au wall thickness 10µm
- Mounted on steel needle
- Well defined distance to jig (supports two meshes)
- Various grid sizes available

Proton focussing with hemi-spheres







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How to section the ball?

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Grinding & Polishing

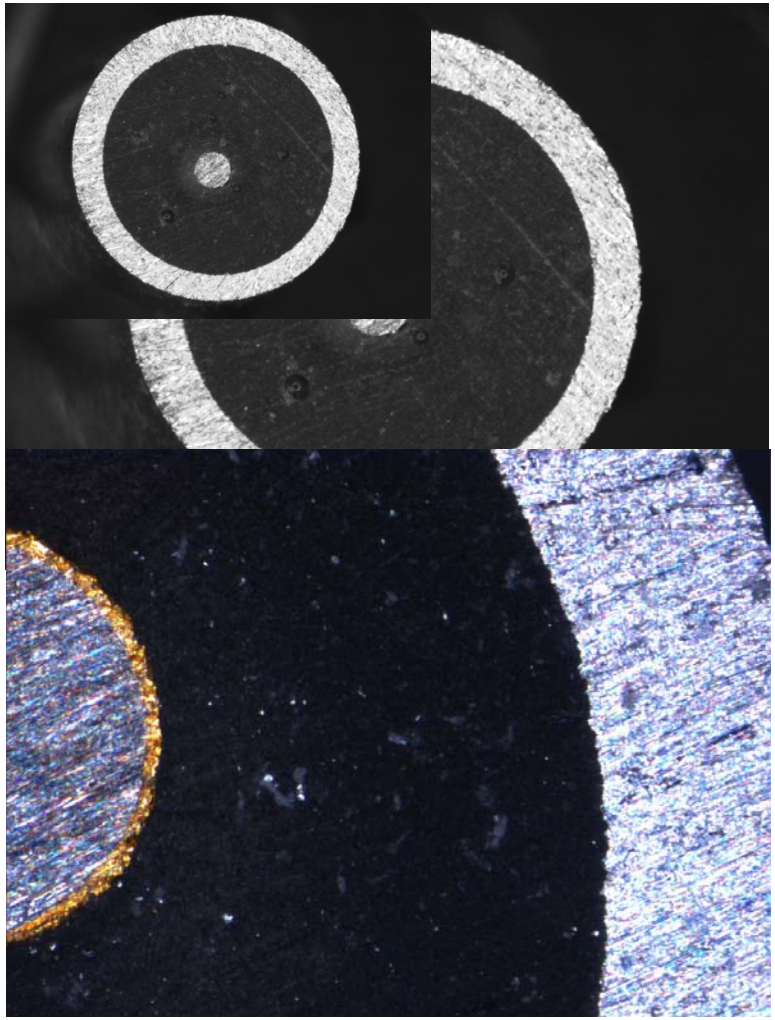
- Electroplated steel ball
- Embedded in glue
- Supported by steel tube

Typical Target Specs

- Ball: Ø400µm-Ø750µm
- Au/Cu wall: 3µm-25µm

Remove glue in acetone

Remove steel in HCl



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Mass limited ball scraper targets

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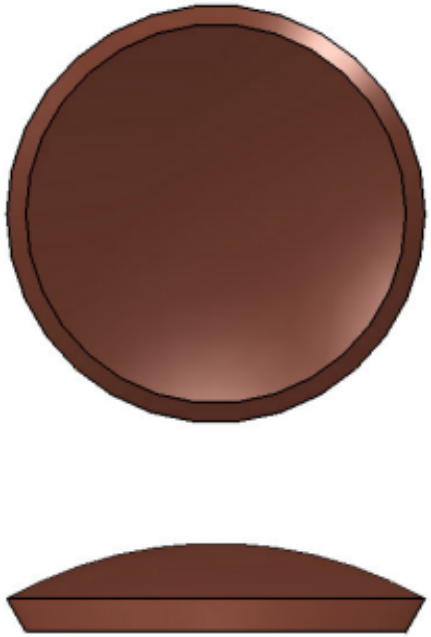
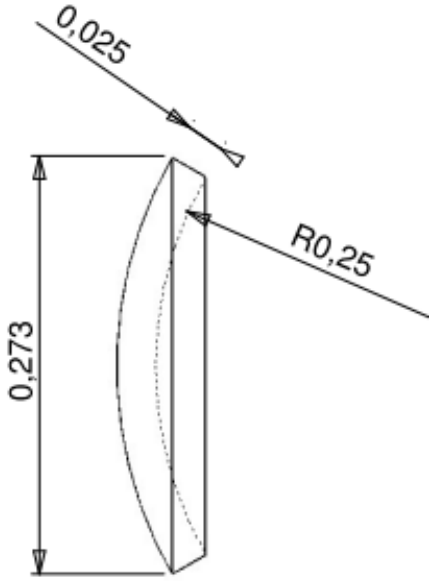
Limited mass of target & supporting strut enhances the proton acceleration mechanism

- Grinding & polishing doesn't work any more
- Target size comparable to laser focus diameter
- Handling gets tricky
- Target alignment gets tricky
- How to contact / support the target?





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Mass limited ball scraper targets

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Prepare the ball target

- Electrically contact the steel ball
- Electroplate, e.g. Au / Cu

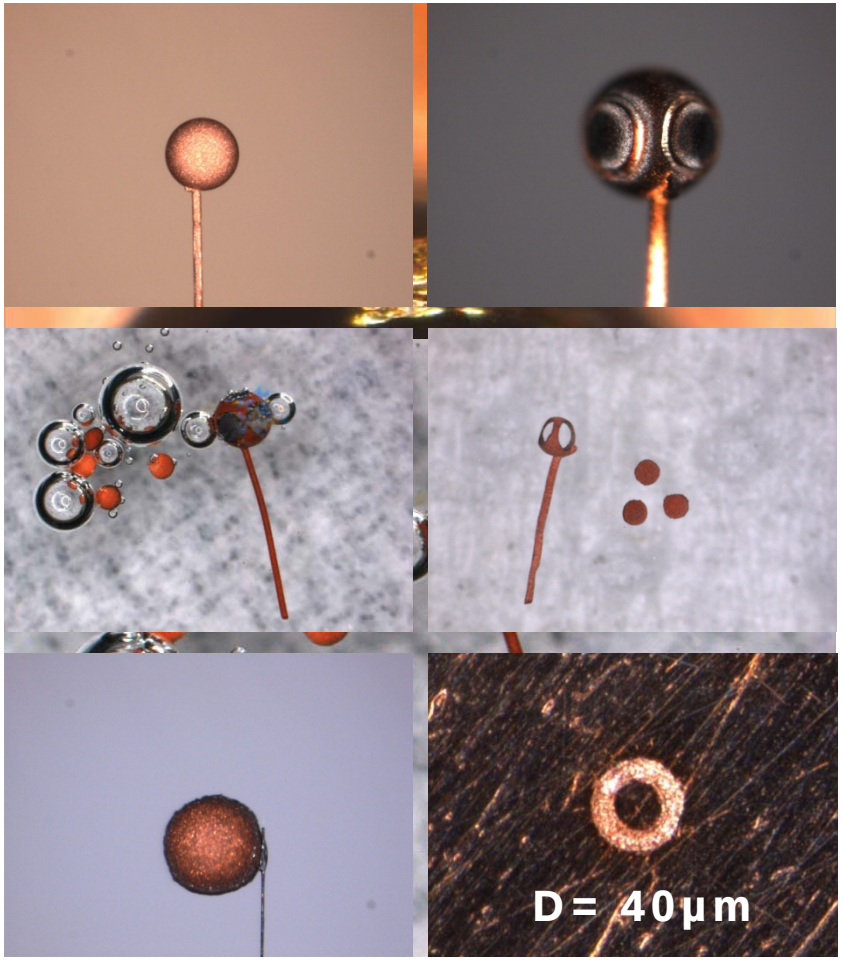
Nanosecond laser machining

- 25µm copper layer on steel ball
- Melting effects …

Acid party pool

Target support

- Glue to 7µm carbon fibre
- Target diameter is 220µm



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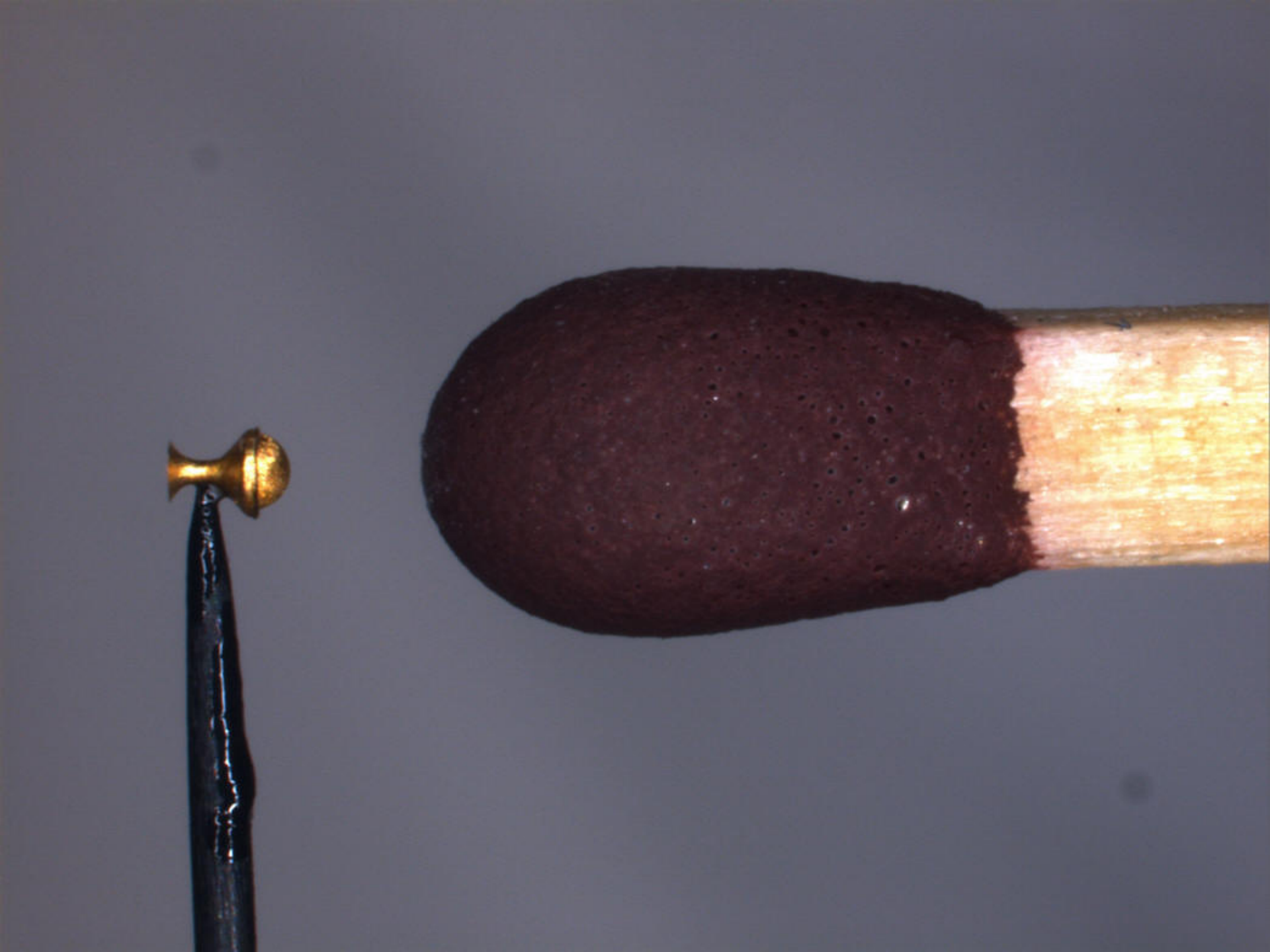

How to shape the proton beam

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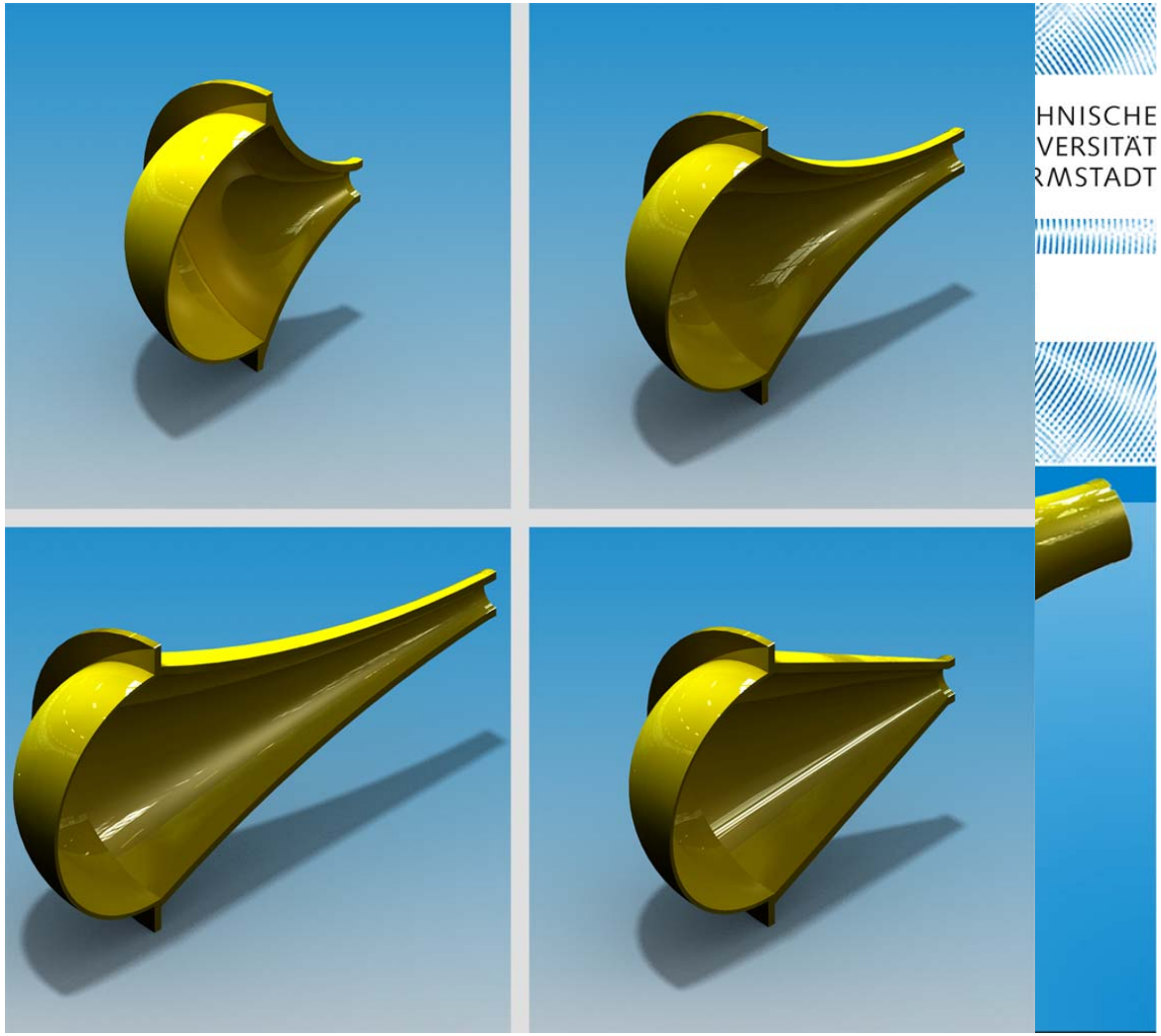

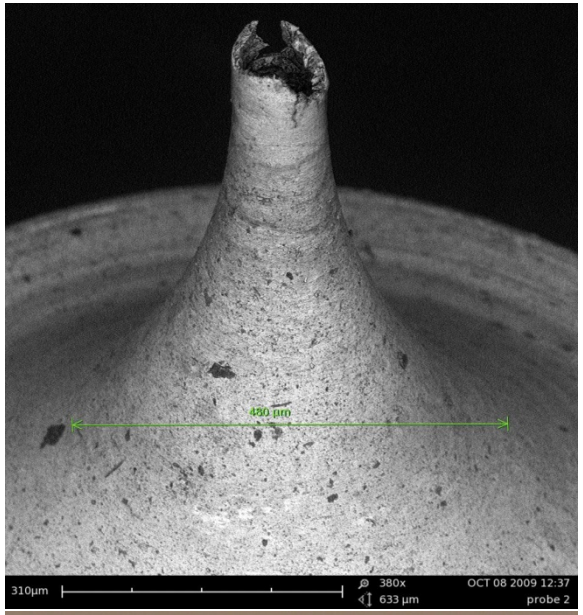

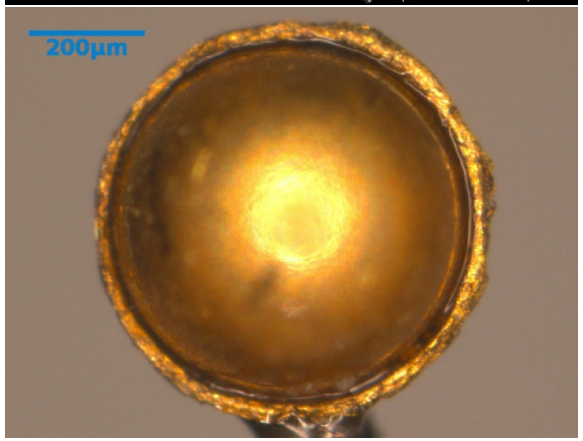

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Precision micro machining

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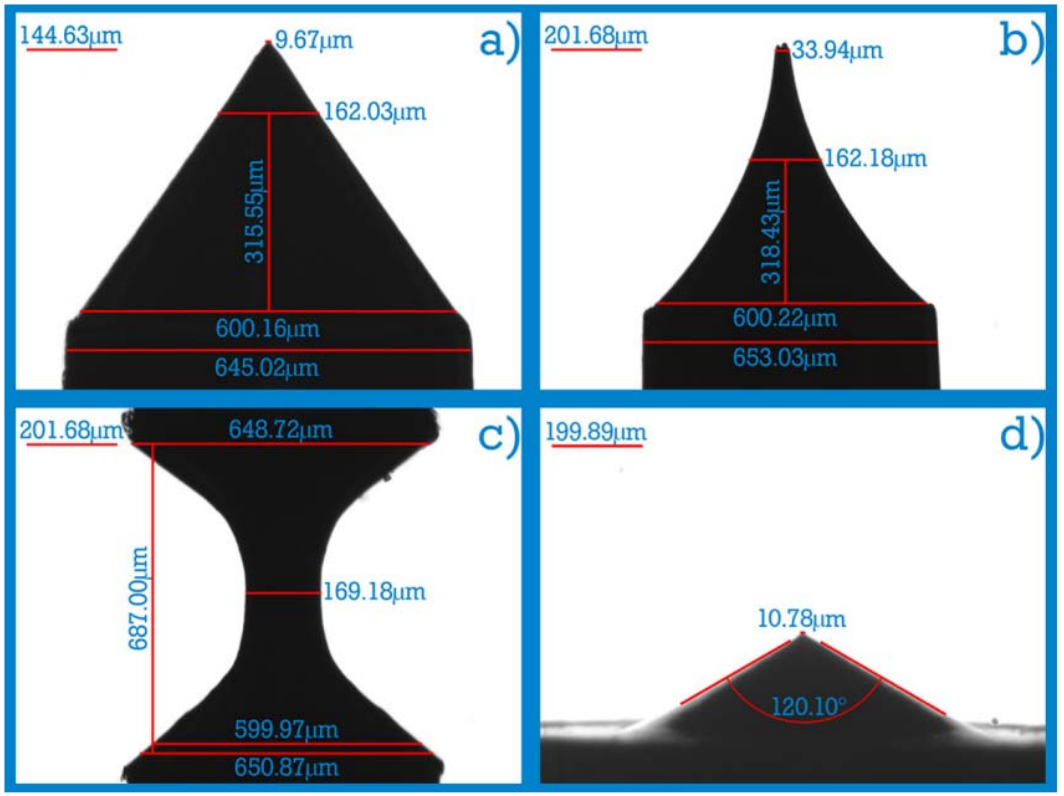
CNC-lathe

- 3-Achsis high precision motorized stage to move the tool
- Various different tools, e.g. diamond blades …
- Optical metrology at the lath:
  Imaging system with micron resolution and large field of view



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Confocal image & lineout of a 160° cone

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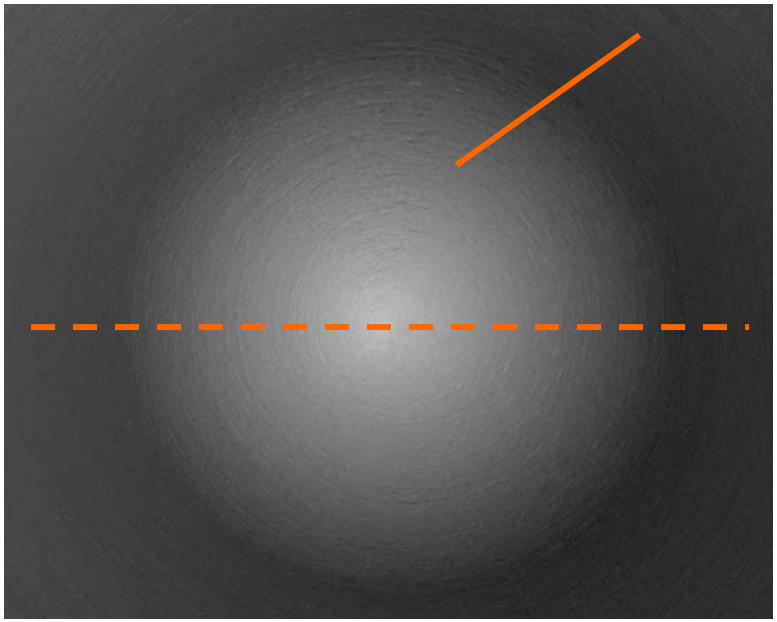
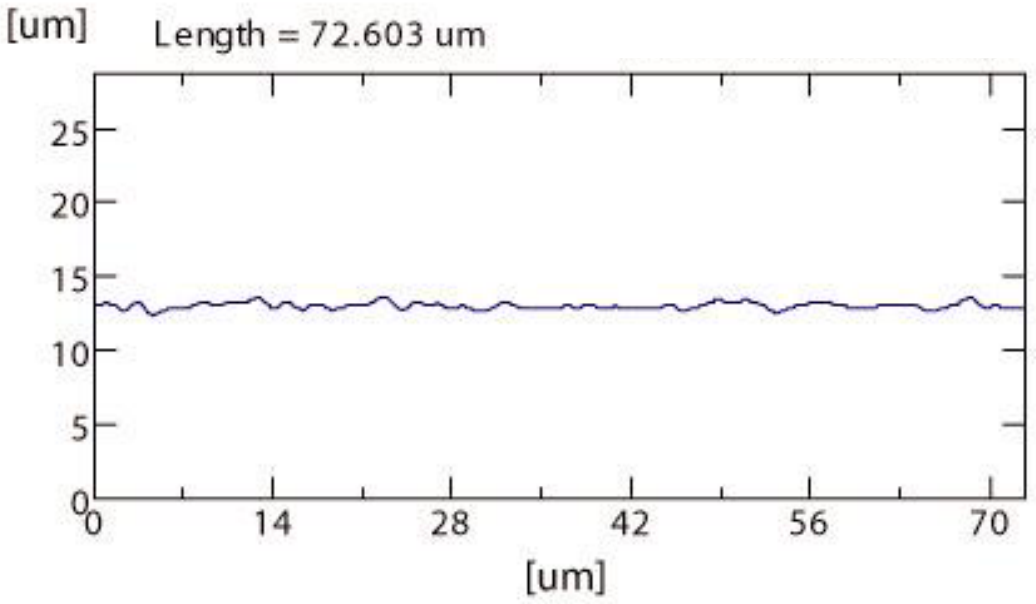
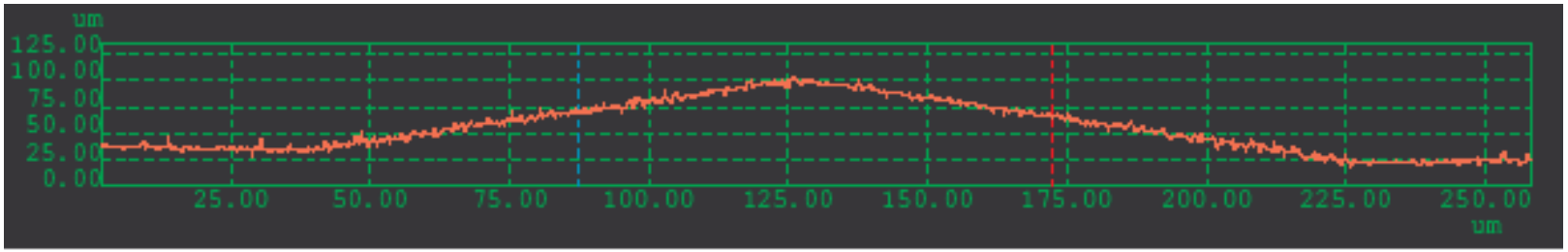
Confocal z-image (1µm resolution)







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Cone Targets

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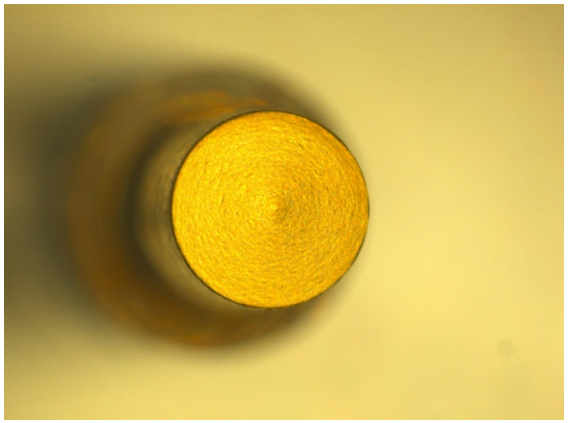
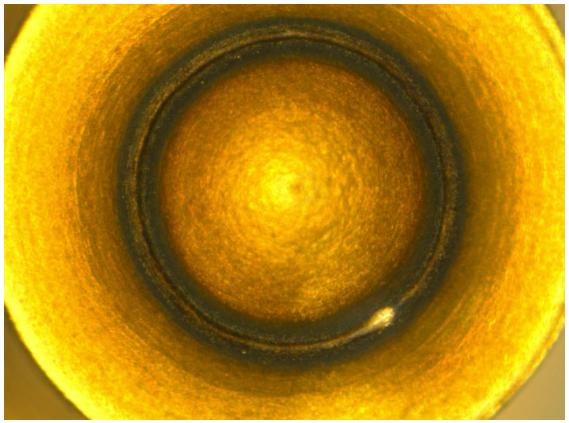
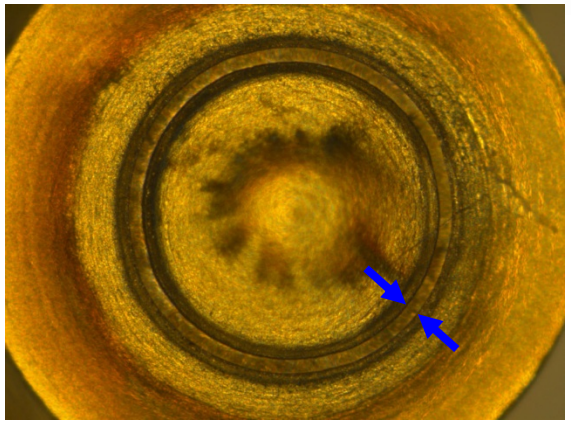
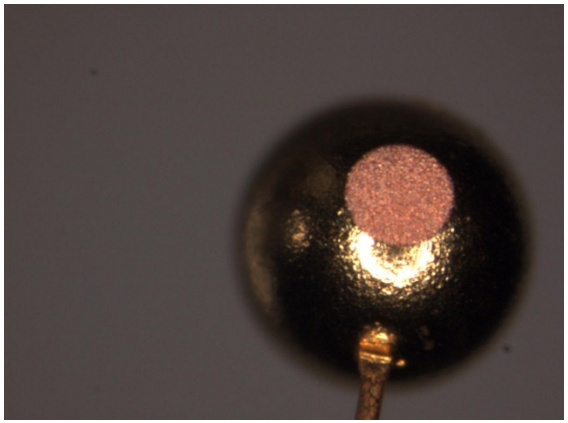


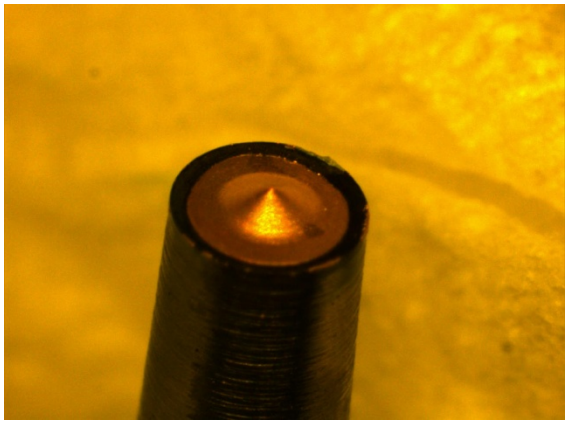


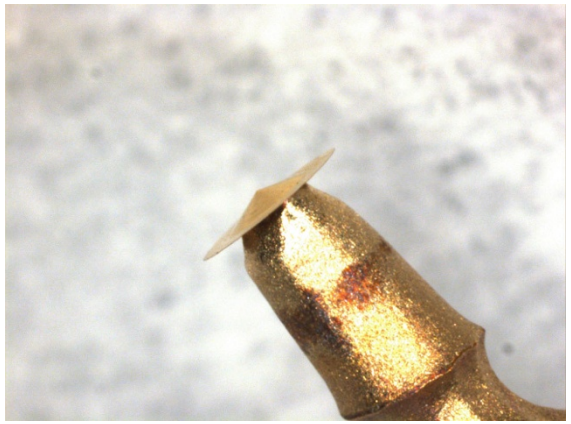


Partially etched

Line width: 40µm







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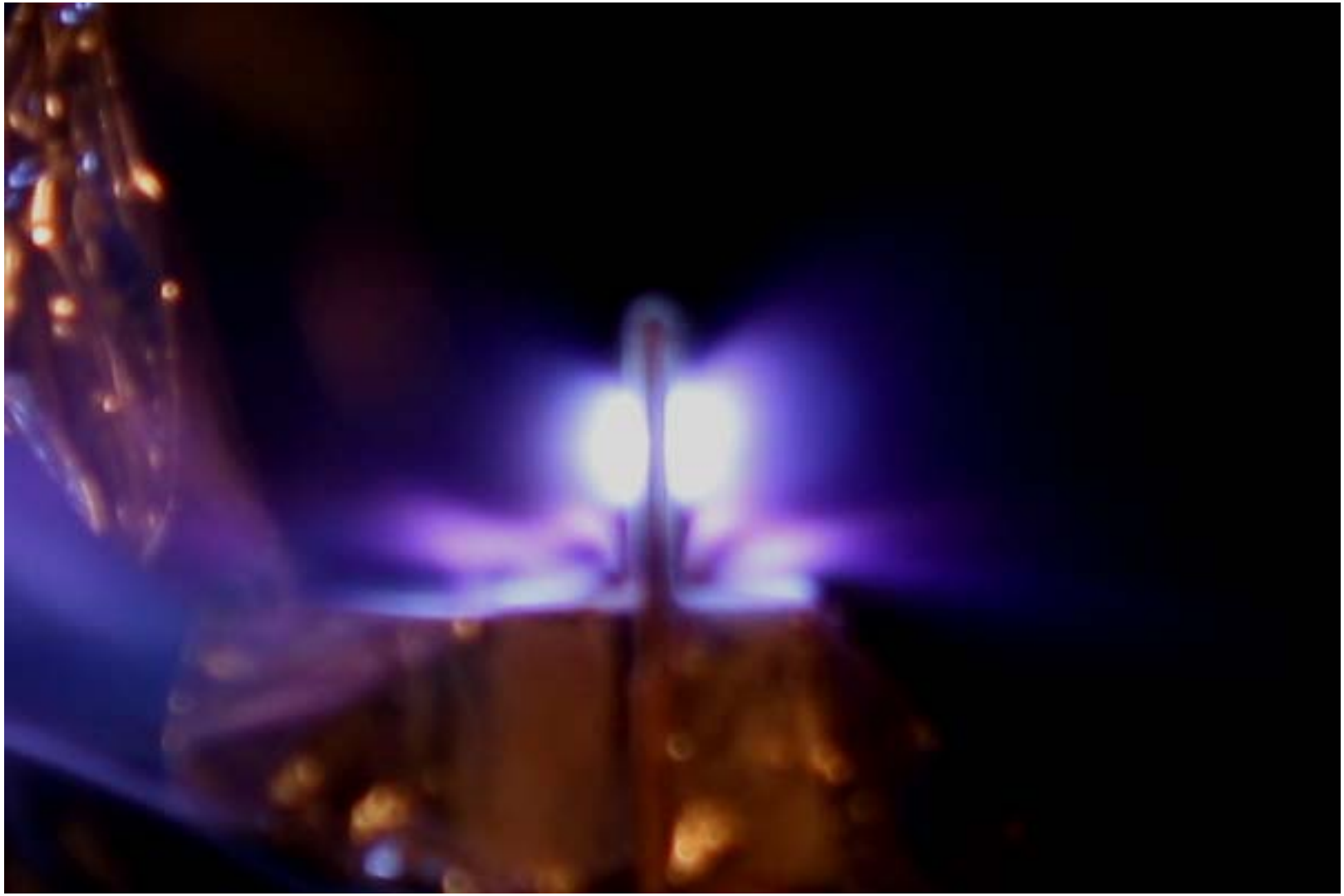
Cryogenic Targets



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Cryogenic Target Development at TUD

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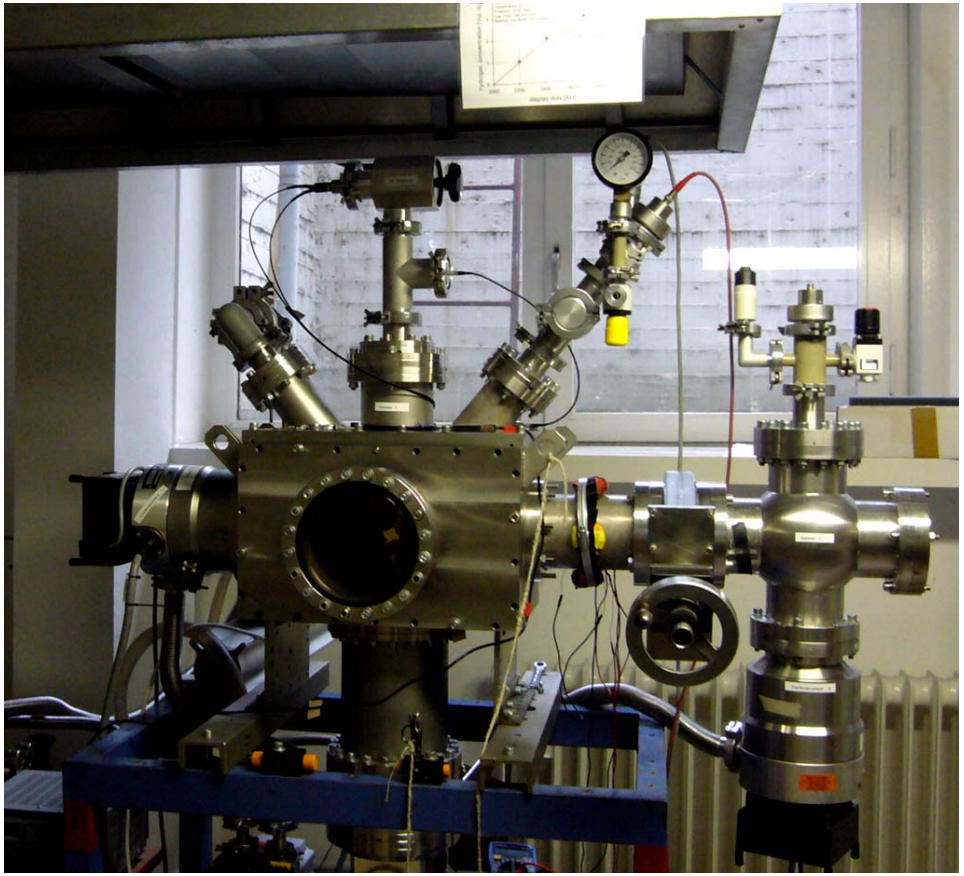

- Vacuum chamber
- Cool head
- Constant pressure gas delivery system
- Gas precooling with liquid nitrogen
- Motorized growth chamber
- Electron gun with focussing and steering magnets

Versatile and flexible test rig for R&D work.

Equipment can easily be moved to different experiments, e.g. to GSI

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Cryogenic Nitrogen Target

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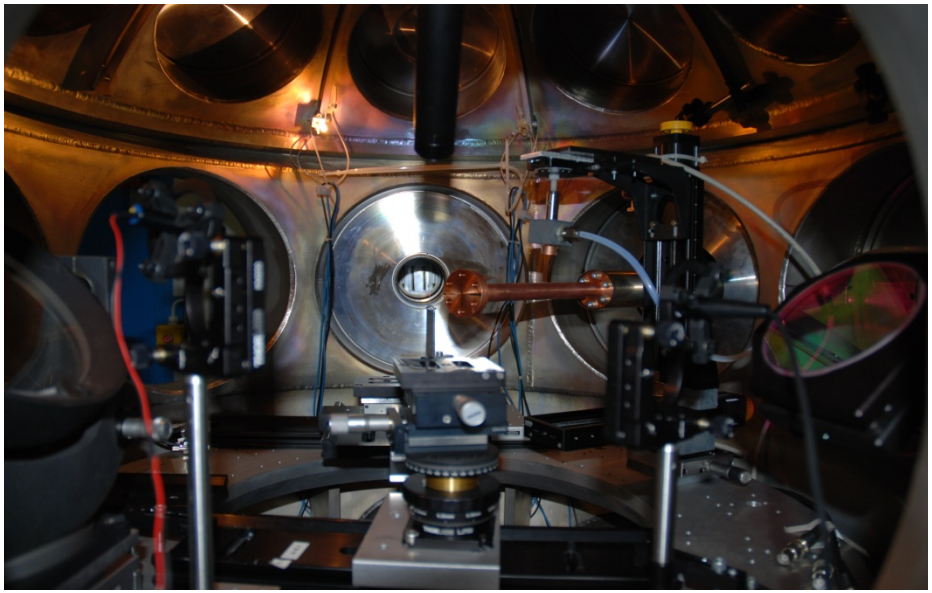

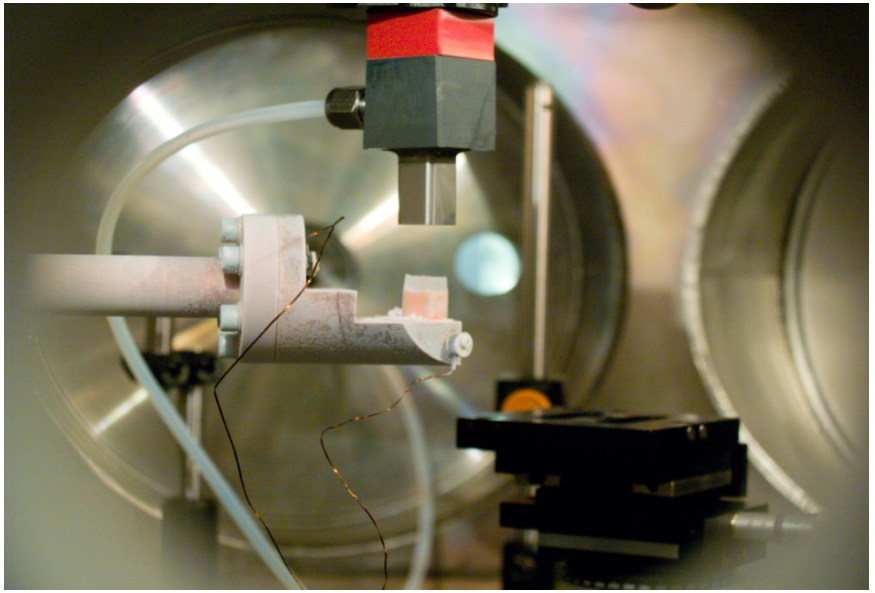

- Target setup integrated into the accelerator beam line at GSI
- Remotely controllable growth process, e.g. motorized growth chamber, gas pressure control, etc.
- External cool head; Vacuum Chamber diameter: 1m
  cold finger extension required gas precooling system

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Pump-Probe Experiment

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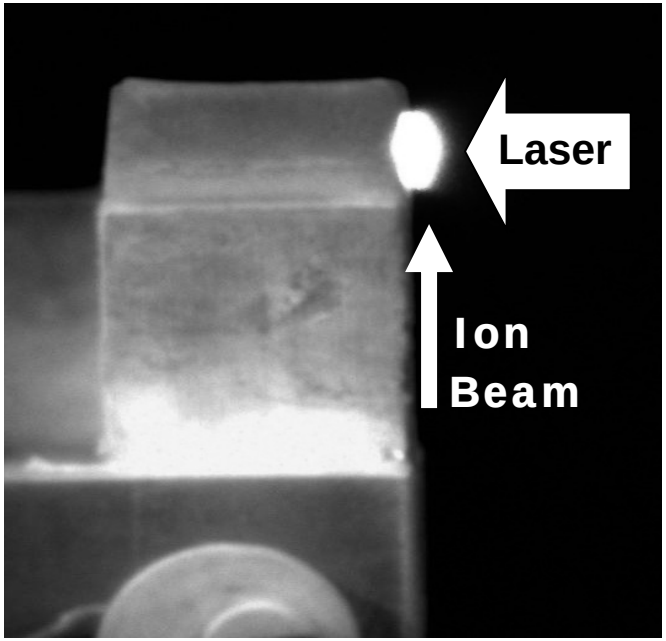

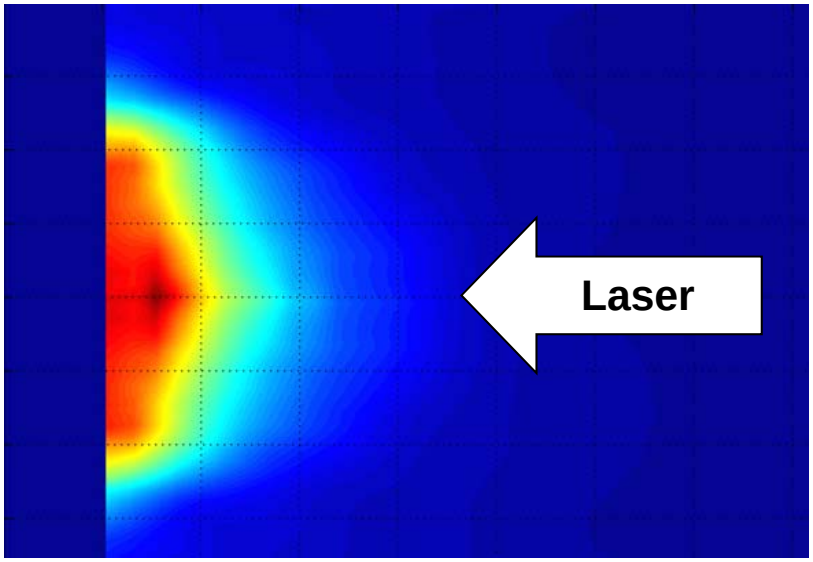

Plasma diagnostic: Interferometry

Solid nitrogen target:

- Dimensions: 10x10x0.4mm
- Growth time: 20 min
- Growth pressure: 300mbar
- Temperature: 10K

Unfavourable setup:

- spatially inhomogeneous plasma
- temporally inhomogeneous plasma

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Thin Cryogenic Deuterium Target

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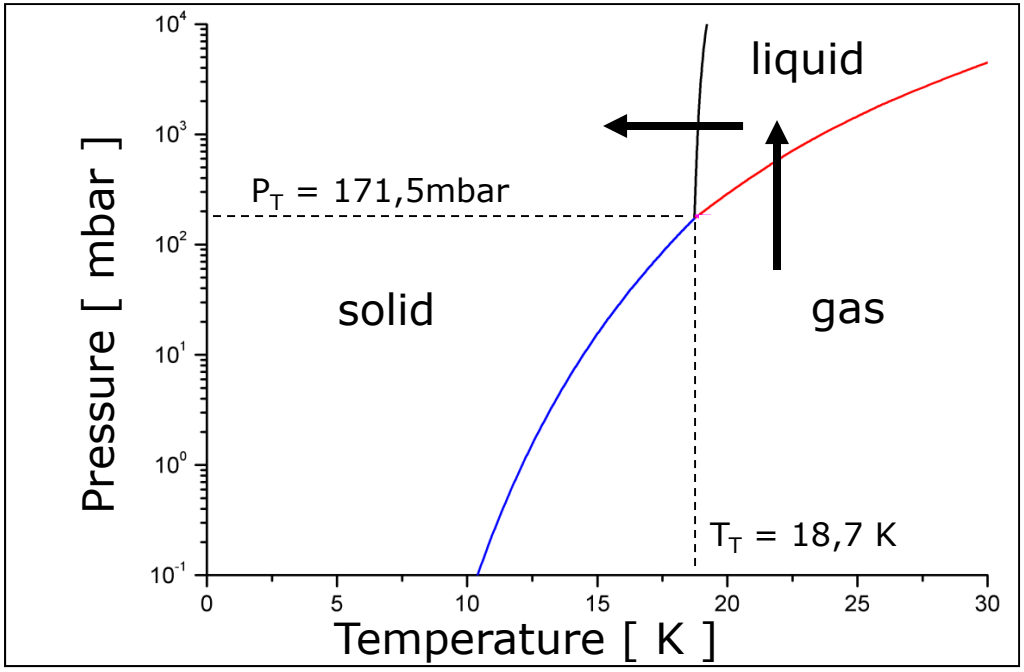
- Initial target thickness is about a millimetre
- Initial target shape is determined by the geometry of the growth chamber and supporting foil
- Thickness is reduced by thermal evaporation



Deuterium:

P_T = 171,5mbar

T_T = 18,7K

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Thin Membrane Target Mount

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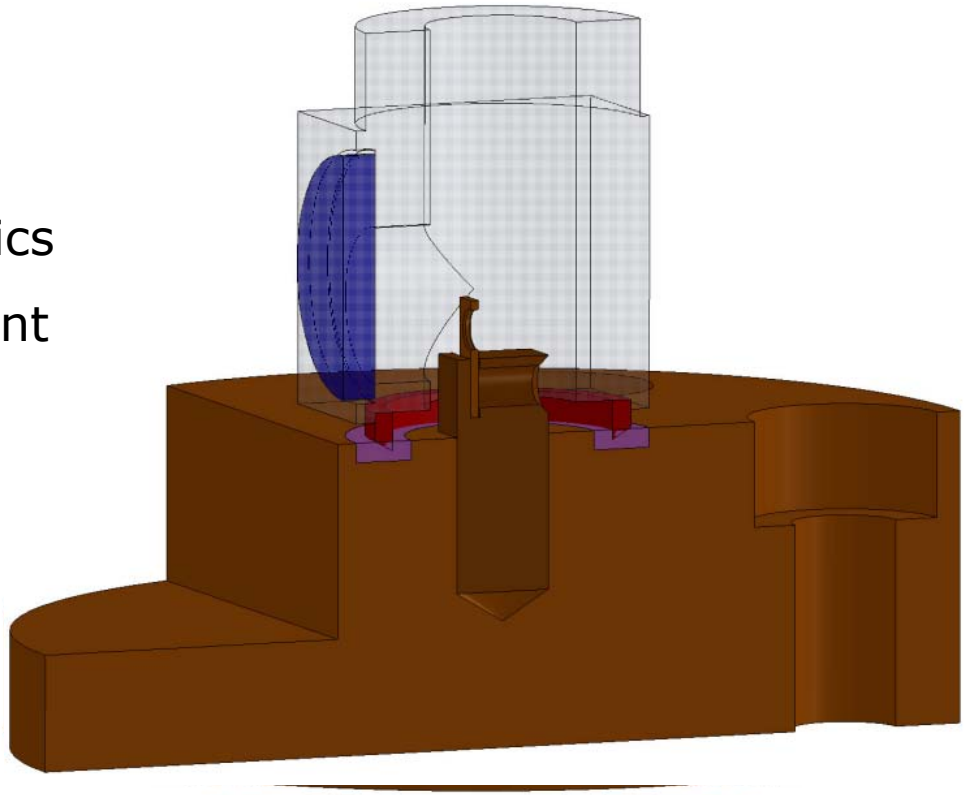
- Cool head
- Growth chamber
- Deuterium gas supply
- Window for optical diagnostics
- Interchangeable target mount
- Indium seal



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Target Thickness Measurement

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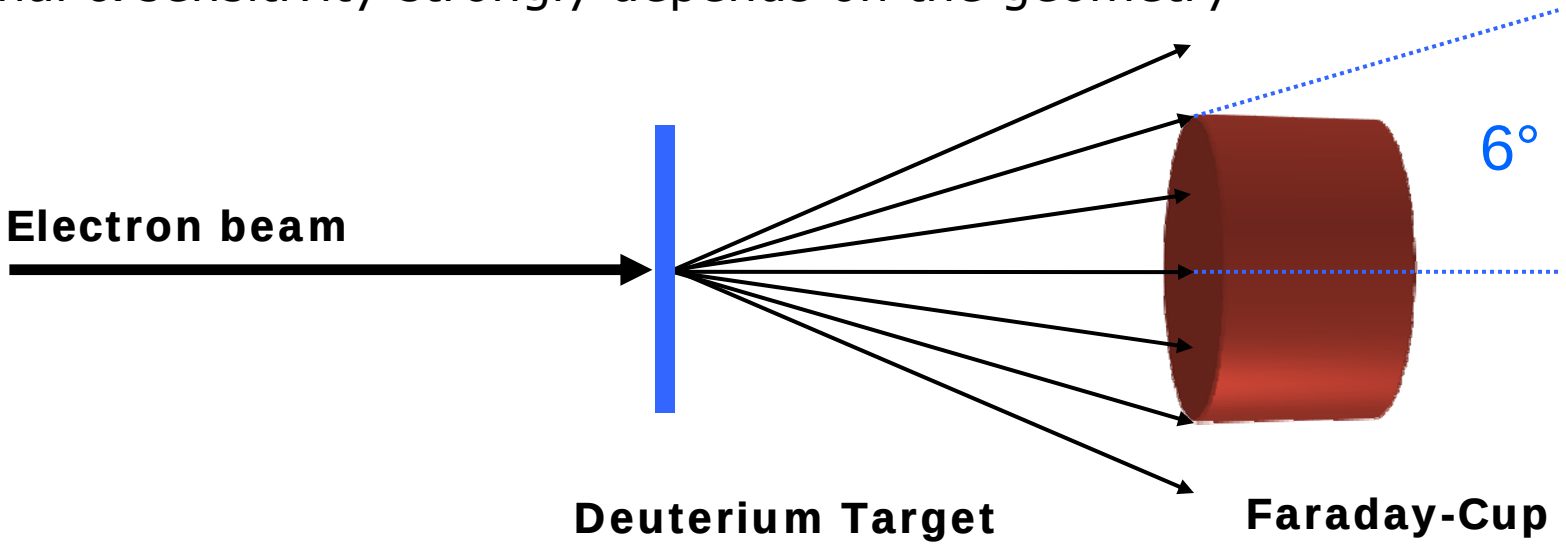
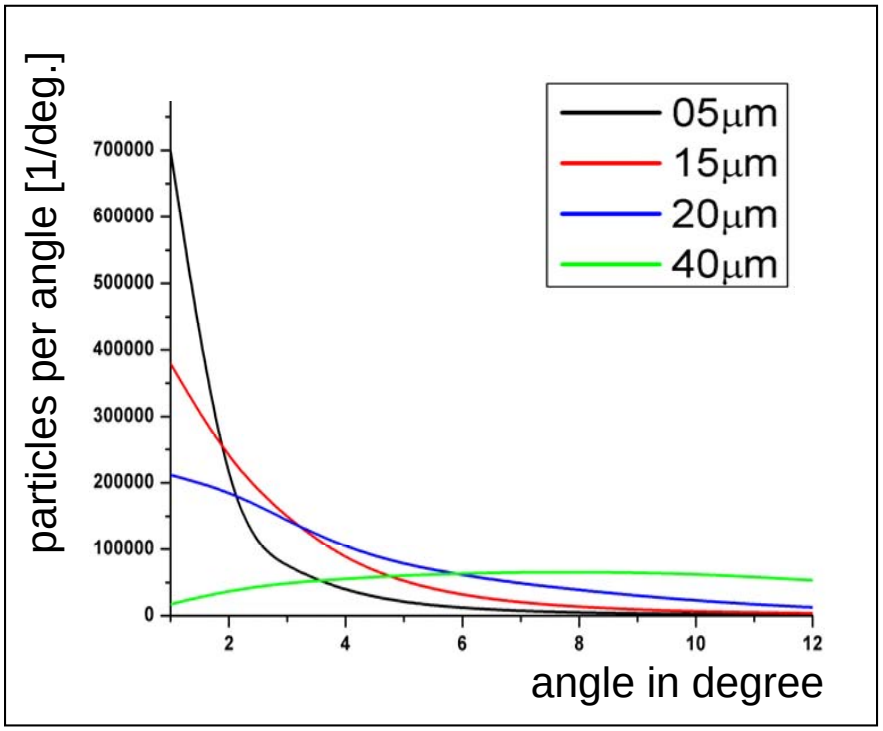
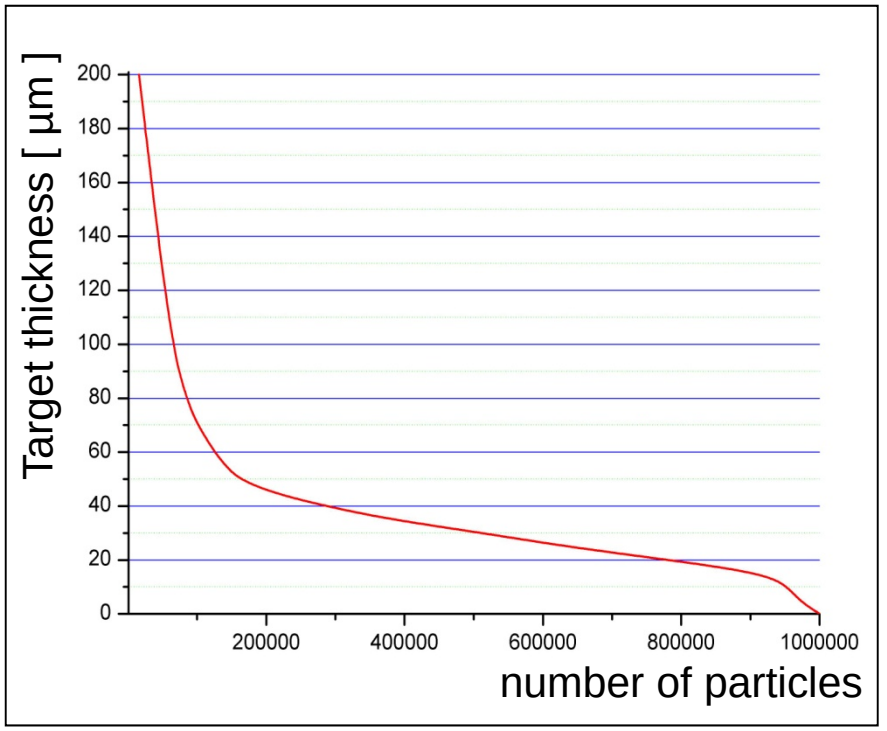
- Electron beam: 14kV, 5µA, 2mm diameter
- Detect the current with a simple Faraday-Cup
- Measured current correlates with the amount of scattering in the target
- Signal & sensitivity strongly depends on the geometry



- The experimentally measured amount of scattering has to be compared to a calculated (Geant4) amount of scattering for a certain target thickness

Simulated particle distribution





- Deuterium target
- With 6° opening angle

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Target Thickness Measurement

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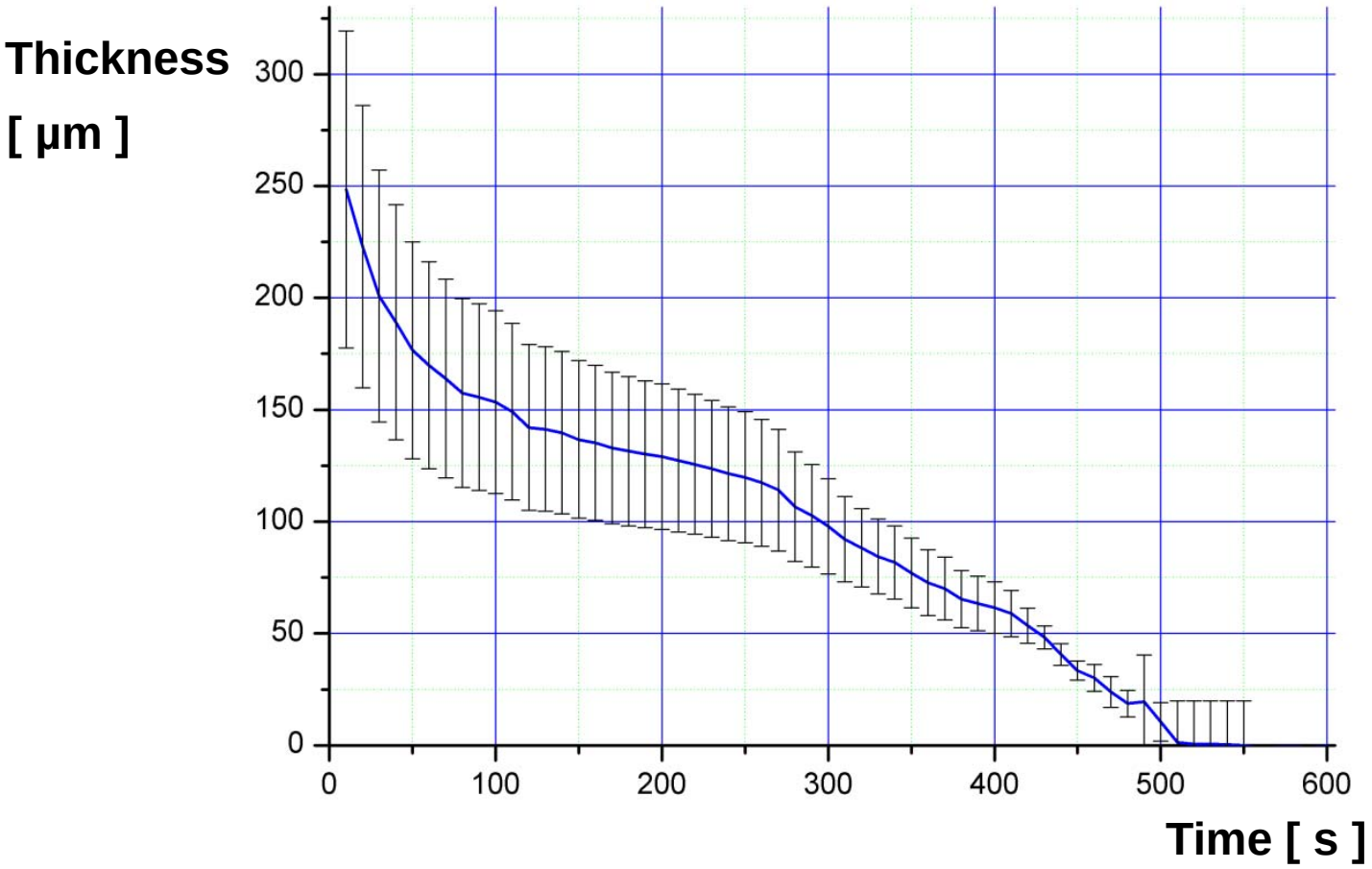

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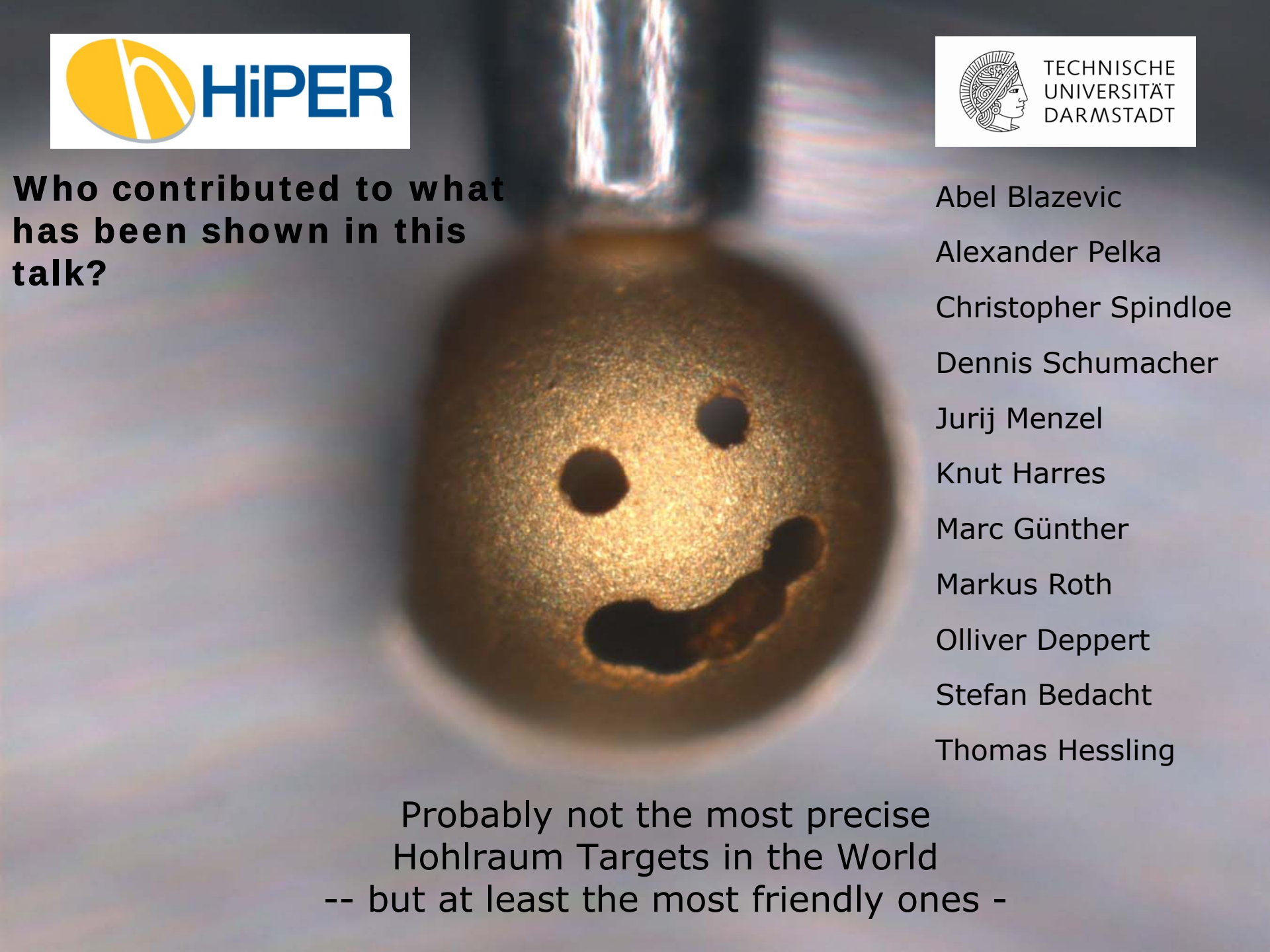

Who contributed to what has been shown in this talk?

Abel Blazevic

Alexander Pelka

Christopher Spindloe

Dennis Schumacher

Jurij Menzel

Knut Harres

Marc Günther

Markus Roth

Olliver Deppert

Stefan Bedacht

Thomas Hessling

Probably not the most precise
Hohlraum Targets in the World
-- but at least the most friendly ones -