A pepper pot emittance device for 8 kev/u light ion beams

Heidelberg Ion-Beam Therapy Centre

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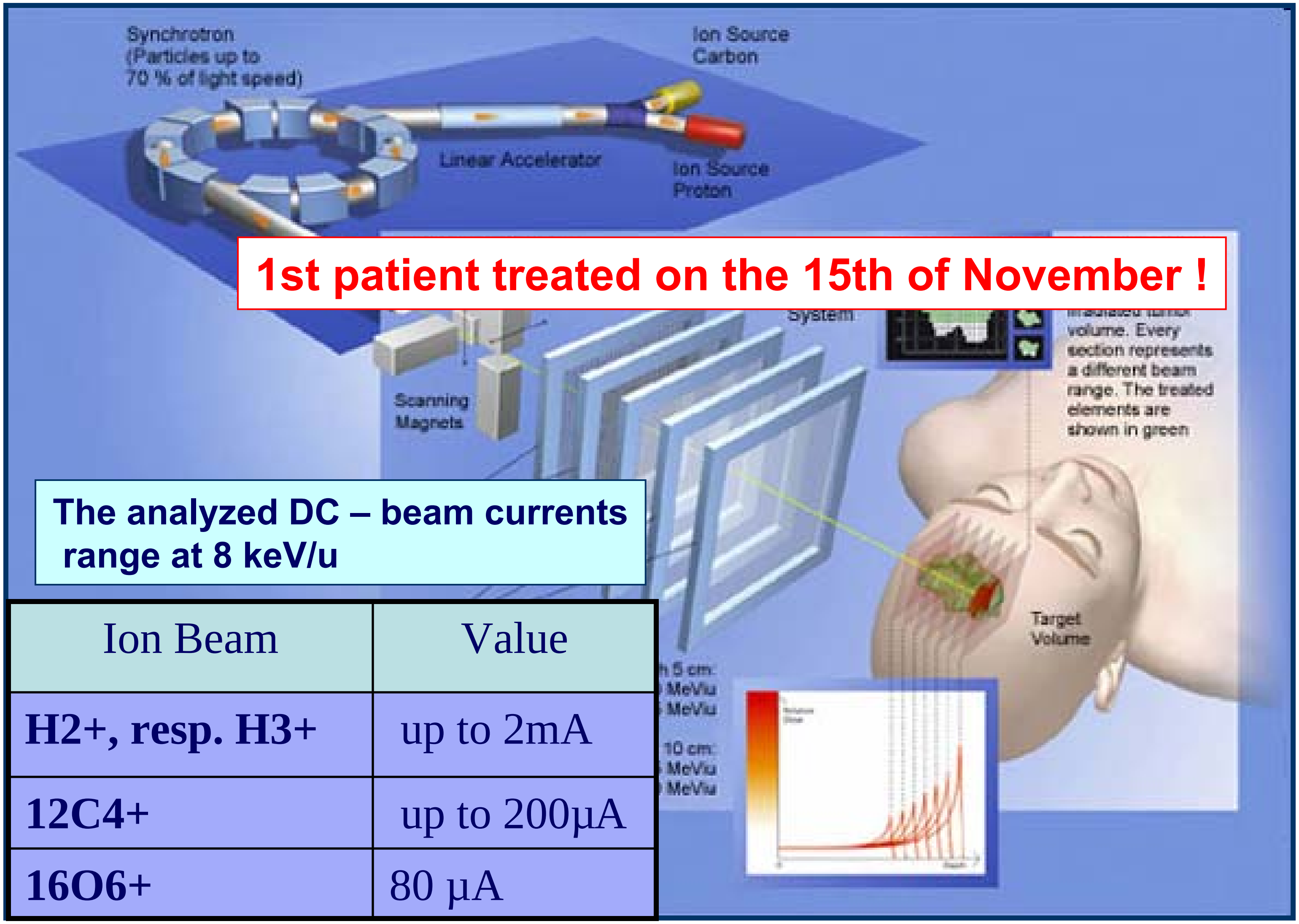
25-26/11/2009 Workshop on 'Low Curret, low Energy Beam Diagnostics'

Outline

- Introduction:
  - Heidelberg Ion Beam Therapy Center (opened since 02/11/2009)
  - Pepper Pot Screen Scintillator device at HIT
  - Why a Pepper Pot ?
  - Who uses a Pepper Pot ?
- Objectives : Find the perfect scintillator material for this device
- Responsibilities:
  - List of adequate materials
  - Experimental Setup
  - Experimental Results
- Conclusion

HIT facility

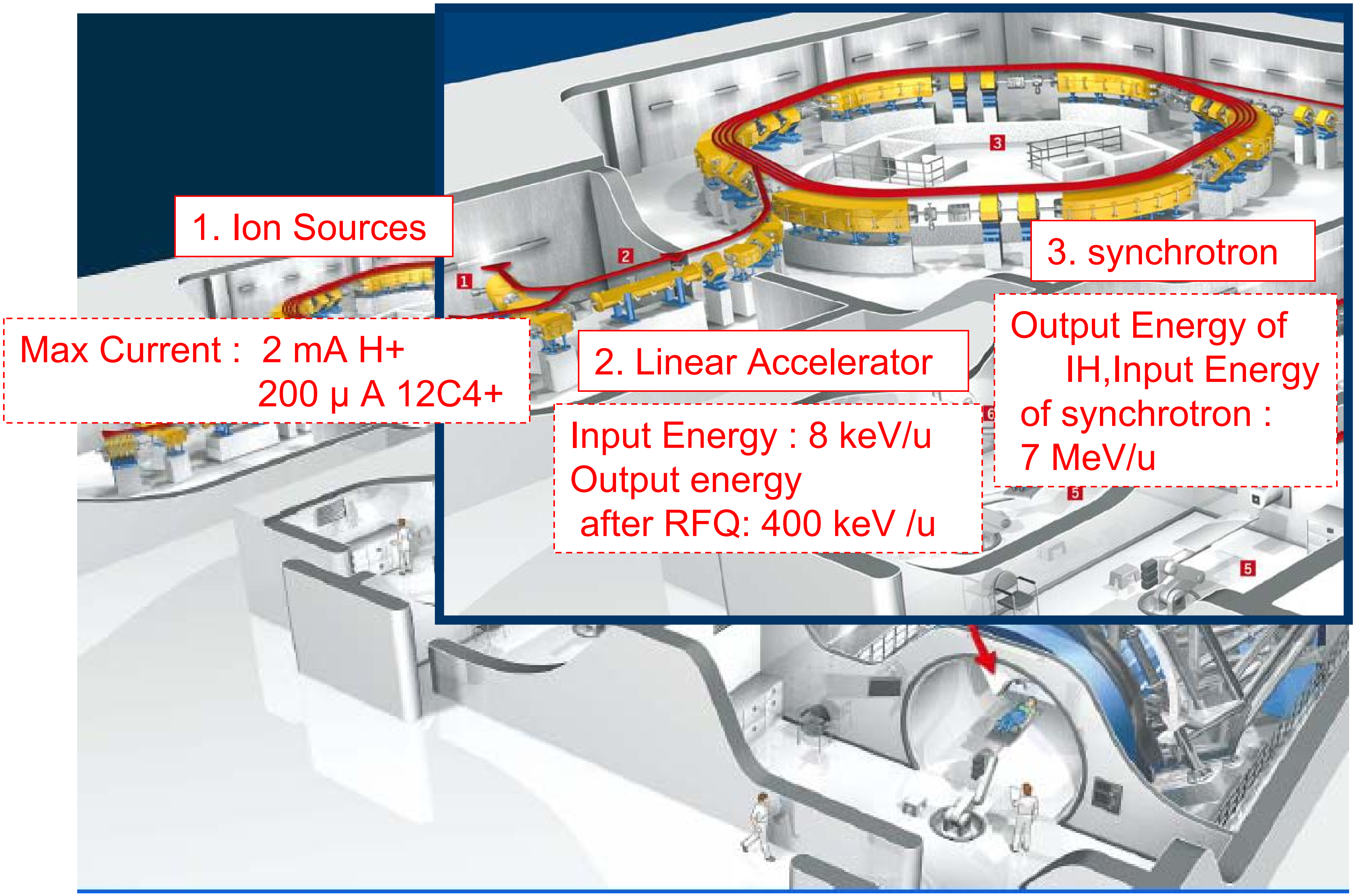


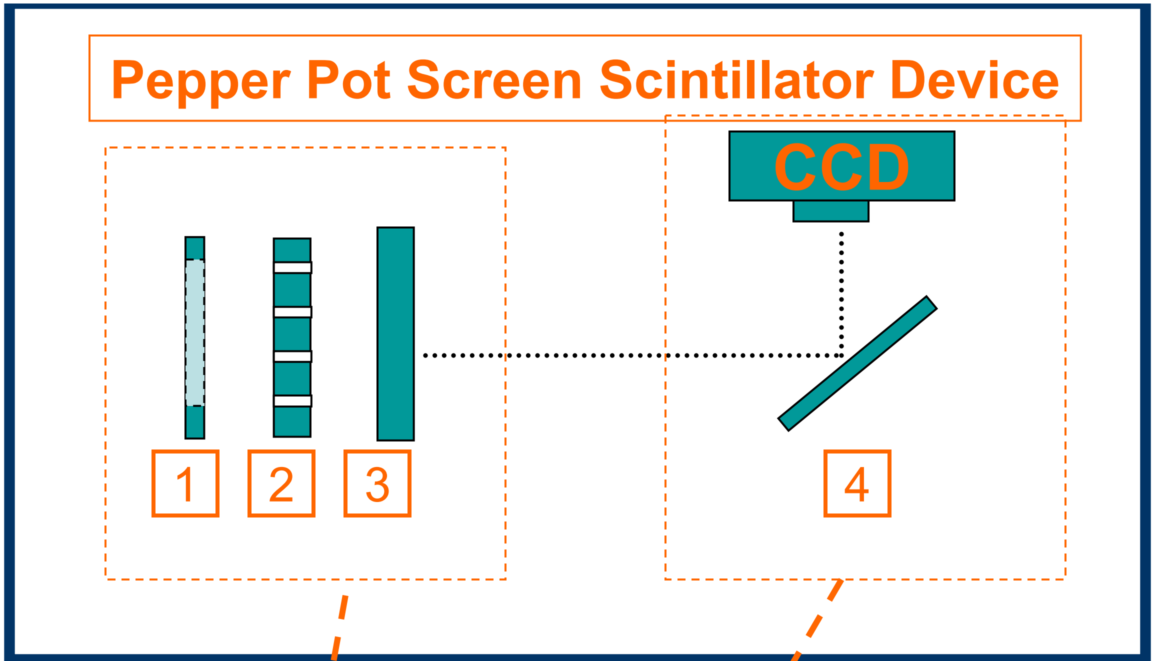
1st patient treated on the 15th of November !

The analyzed DC – beam currents range at 8 keV/u

Ion Beam	Value
H2+, resp. H3+	up to 2mA
12C4+	up to 200µA
16O6+	80 µA

Accelerator at HIT



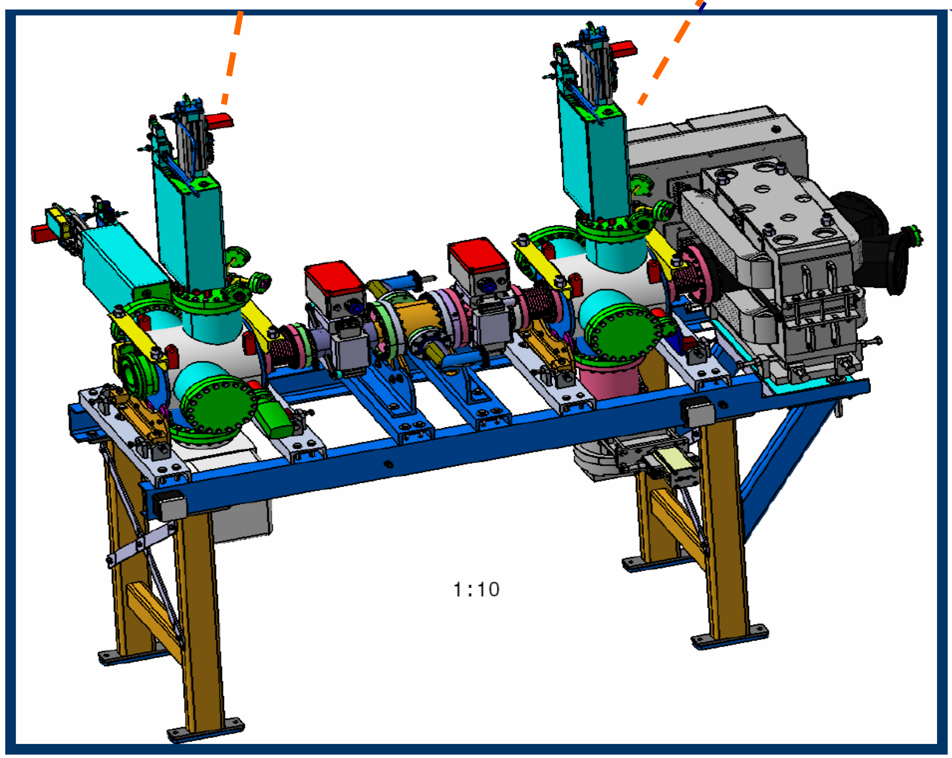


1. Iris Shutter

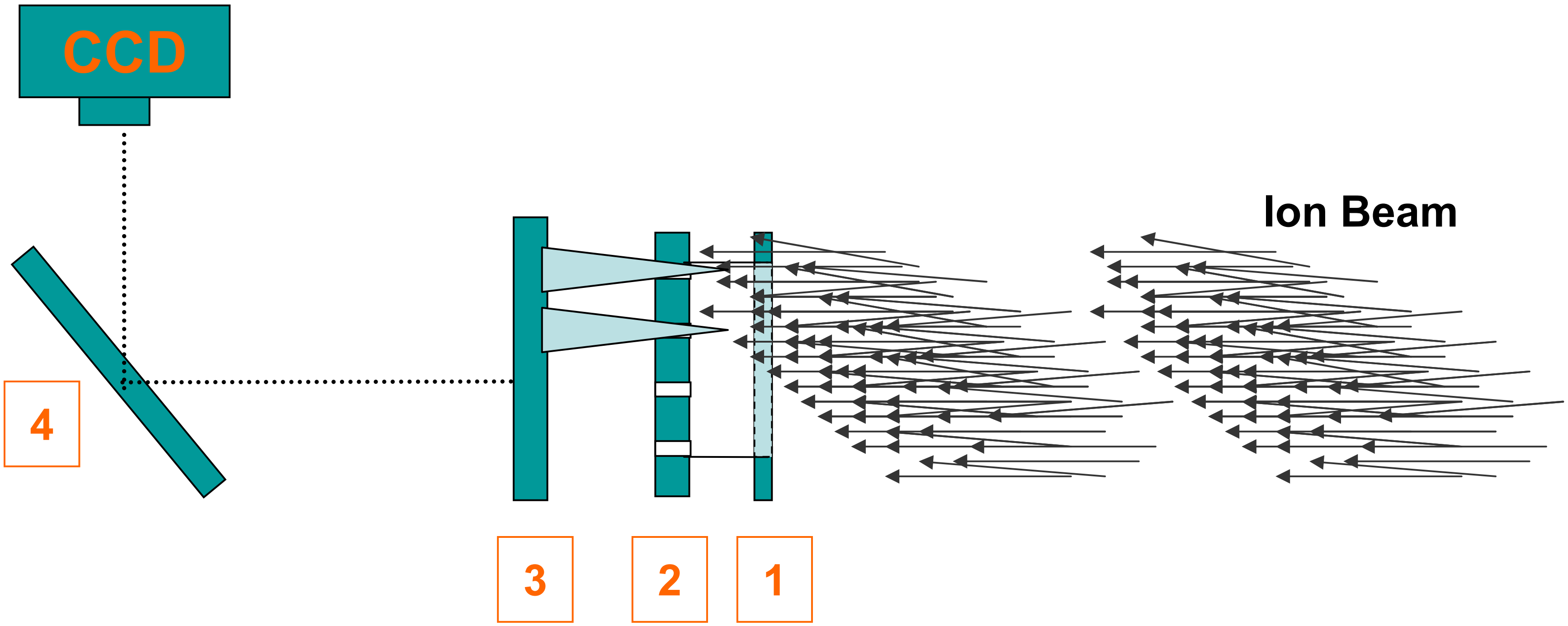
2. Pepper-pot Mask (parallel collimator)

3. Scintillator Screen

4. Mirror + CCD camera



Pepper Pot Device – A Fast Imaging device



Allow to create an image that portrays the distribution of particles in the beam

Why using a Pepper Pot Device ?

• Replaced traditional wire /slit scanners (destruction due to thermal strain)

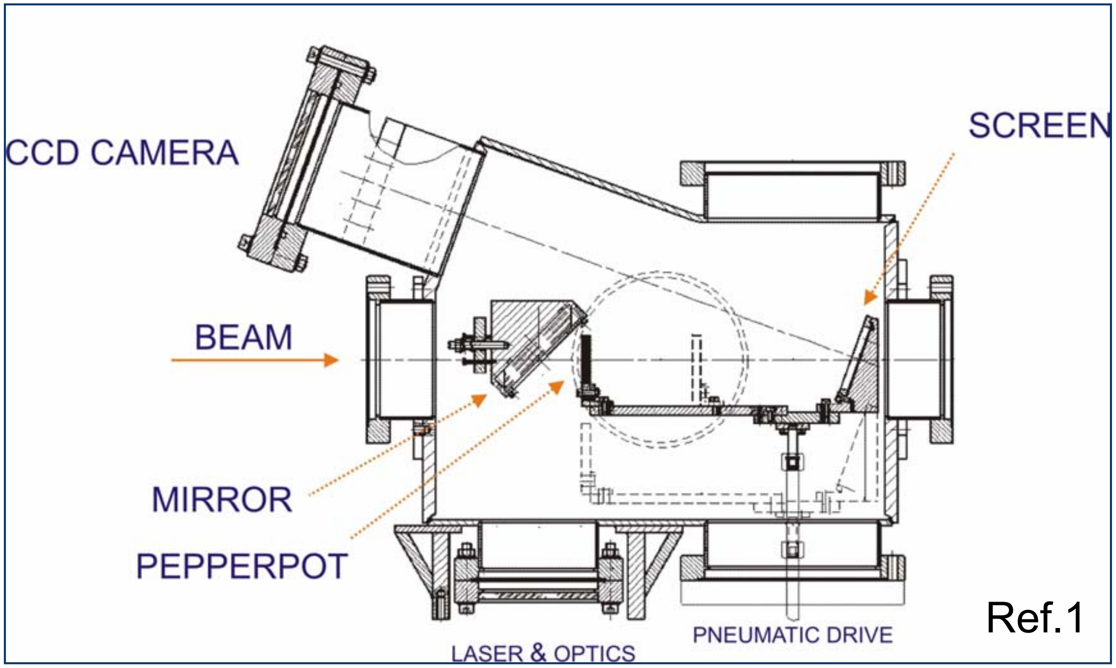
• Want to measure both x-y components of the beam emittance simultaneously <u>in one shot</u> and <u>data obtained in real time</u>

→ uses a slit to select a portion of the beam for analysis

	Advantages / Disadvantages
Two-slit scanner :	slow
Multiwire collector :	Faster than two slits method but need amplifier for each wire
Allison-type scanner :	**slower than pepper pot**
Pepper- Pot :	**fast, need “adequate“ scintillator**

Pepper pot set-up at GSI in 1999

- The beam energy measurable with this device120 keV/u to 1.44 MeV /u
- Pepper pot plate: 15x15 0.1 mm ϕ holes, 2.5 mm distance
  → sensitive area of 45x45 mm2
- Al2O3 screen; Distance plate to screen adjustable: 15 – 25 cm
- Chamber interior totally blackened
- Calibration parallel laser beam



Ref.1

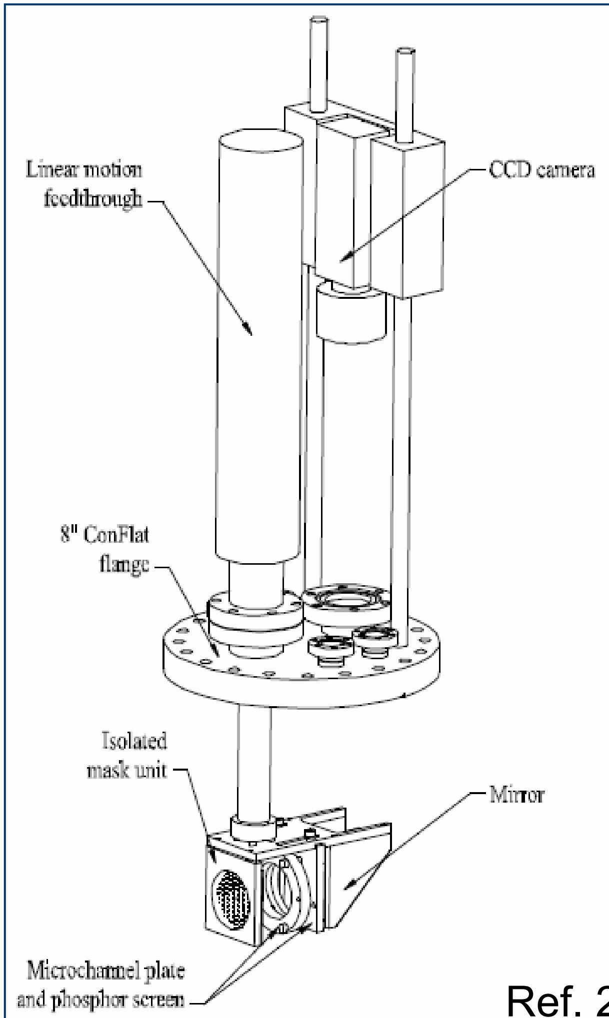
Pepper pot set-up at BNL, similar to GSI development

- Measures emittance of beams with particle enegies from **several kev/u to several hundred kev/u**

- **Tungsten pp mask** 100 µm thickness foil with 100 µm diameter holes spaced 2 mm apart from each other

- **Tungsten foil sandwiched** between two 0.5 mm thick copper plates with 0.5 mm diameter holes (mechanical strength and conducts the heat away)

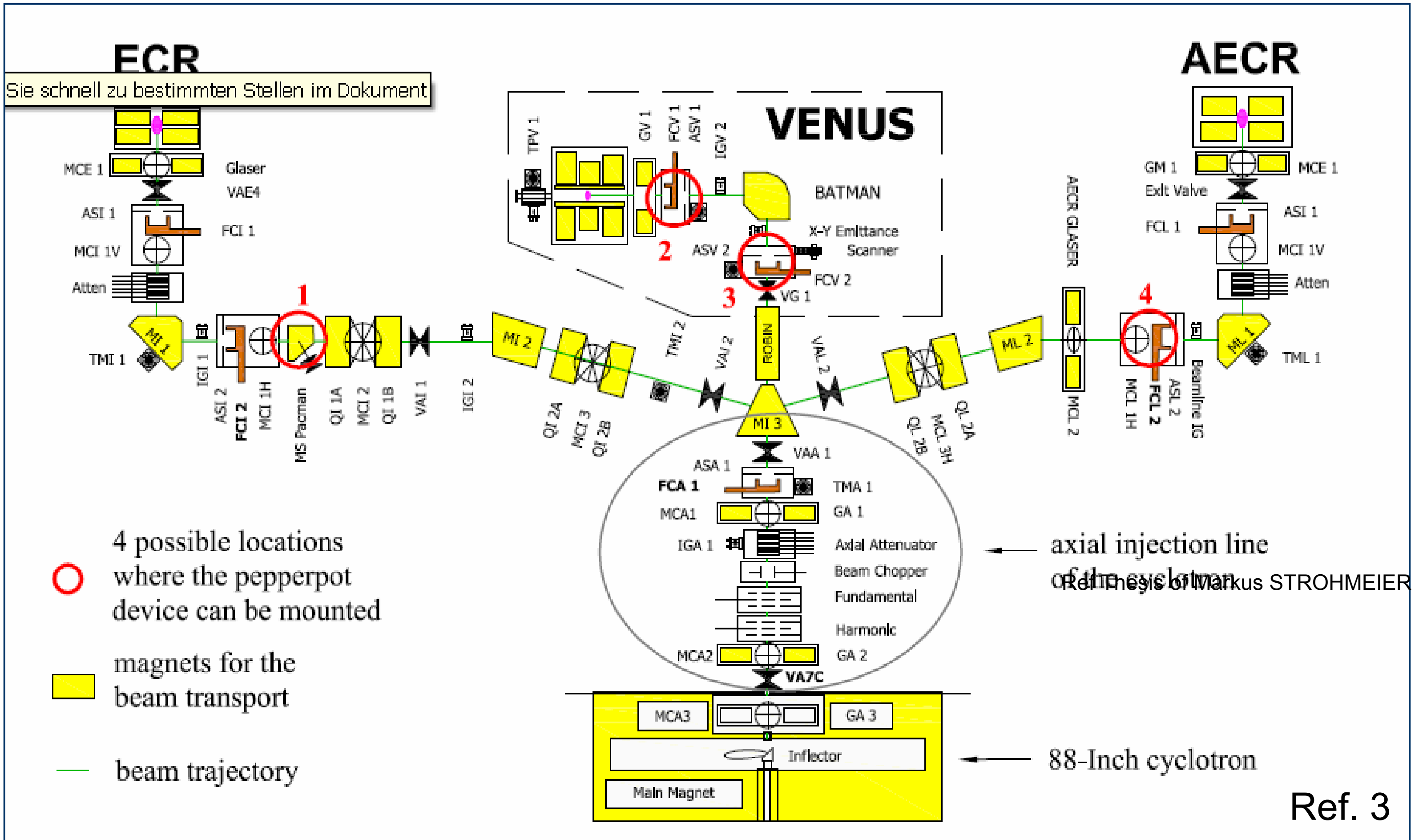
- Distance between the MCP and the pp Mask is adjustable (5-50 mm)



Ref. 2

Pepper pot set-up at Berkeley

Protons and other light ions are available at **high intensities 10 -20 µA** up to an energy of **55 MeV** (Protons), **65 Mev** (Deuterons) ; **135 MeV** (3He) and **14 Mev** (4He)

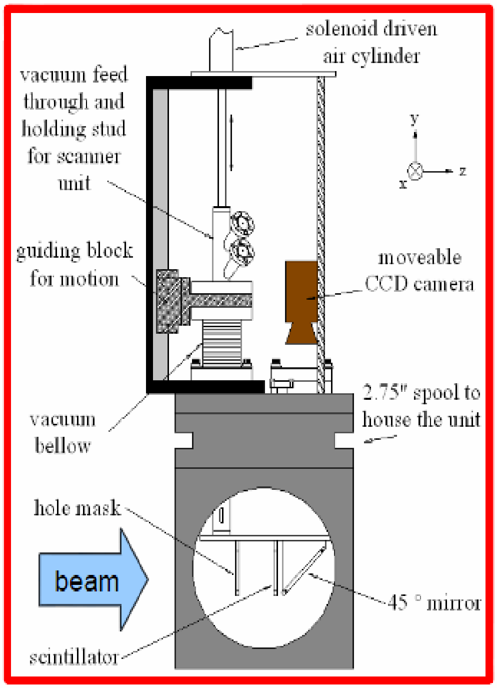


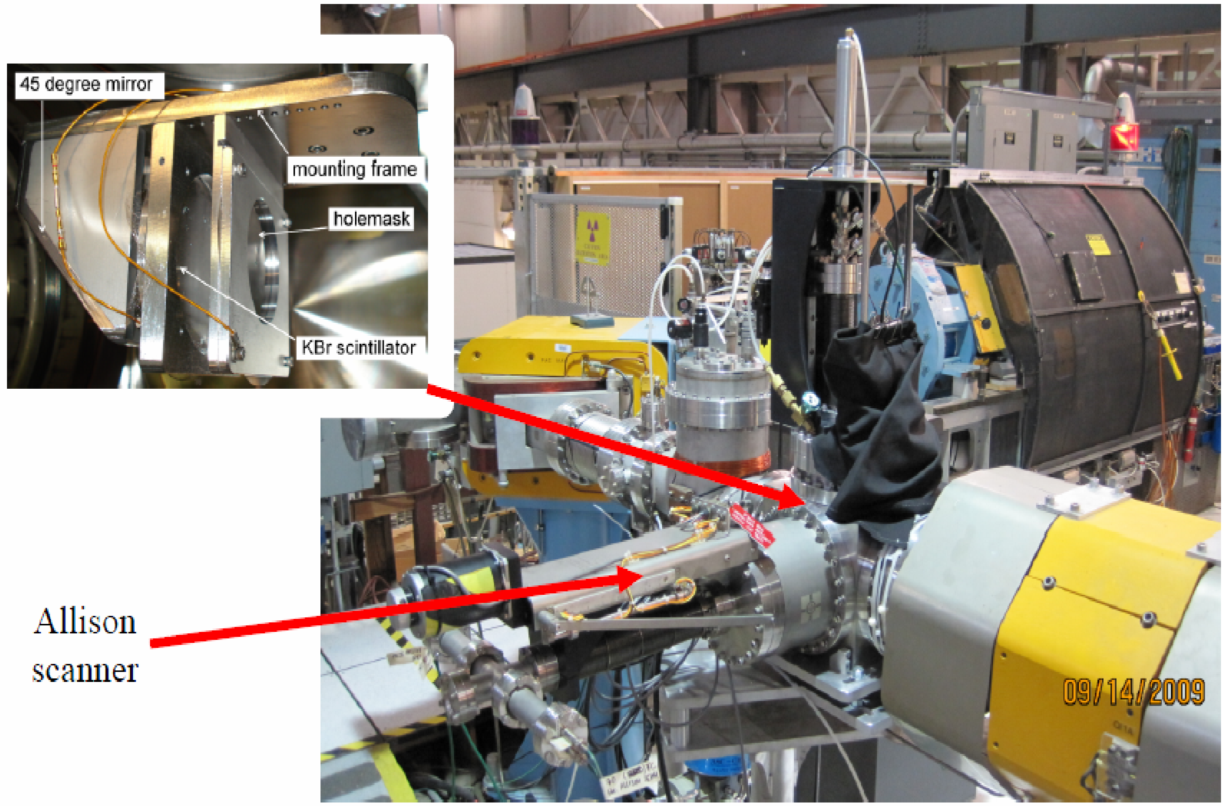
Ref. Thesis of Markus STROHMEIER

Ref. 3

Compare Pepper pot and Allison scanner

Experimental Setup

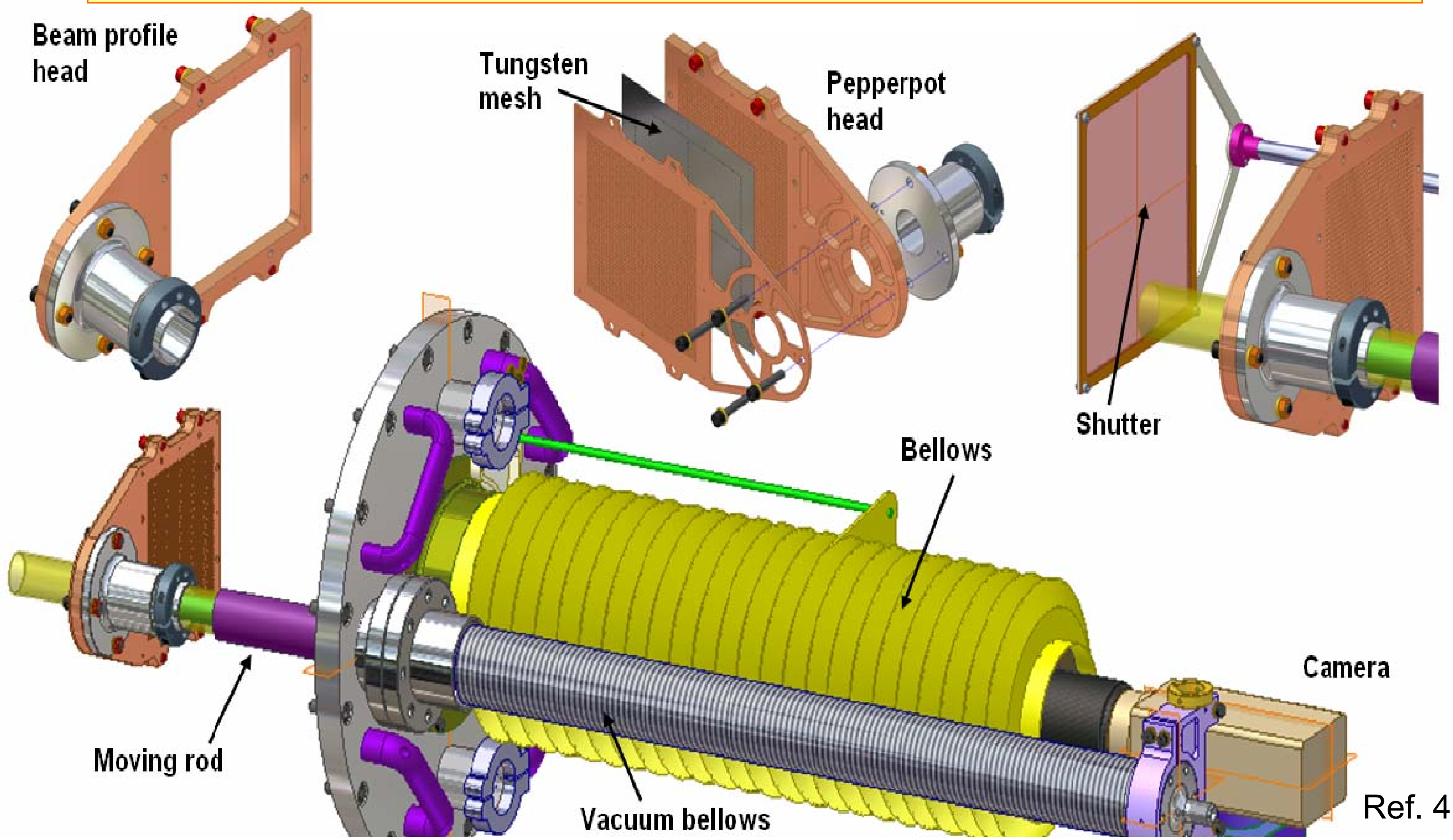




The Pepper-pot scanner and Allison type scanner are located at the same z position of the LBNL ECR beam line

Pepper pot set-up at RAL (UK)

H- ions, 60 mA, 2ms, 50 pps chopped beam 35 keV (total acc potential constant), 30 mm radius, emittance up to 1 π mm mrad



Ref. 4

Pepper pot set-up at RAL

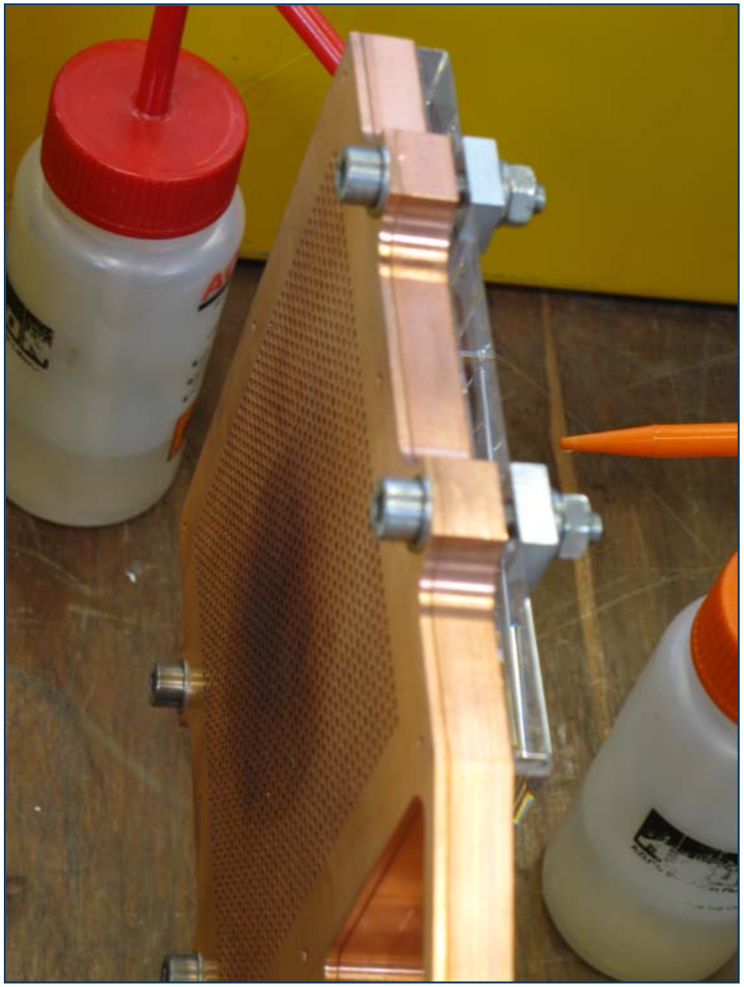
- **Tungsten sandwiched between 2mm/10mm** copper support plates, 2mm diam holes

- **Tungsten**: 100 μm thick with 50μm holes diameter on 3 mm pitch in 41x41 array

- **Quartz scintillator** 10 mm from tungsten

- **Angular resolution** 6.5 mrad

- Calibration by eye from calibration markings around support structure

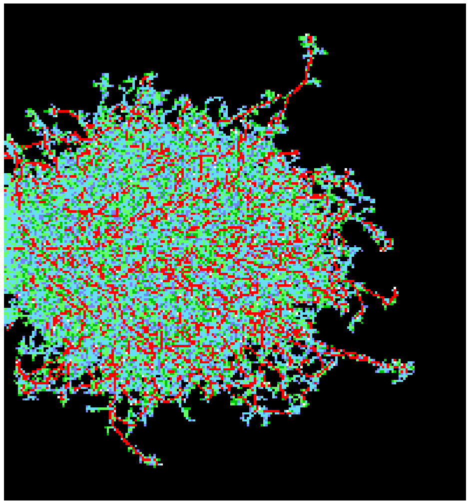


Properties of Material

- Low density since low penetration depth
- High thermal conductivity
- Low surface roughness
- Transparent

Type	Material	Manufacturer
Inorganic Doped	YAG:Ce, CaF2:Eu, YAP:Ce	Crytur
Inorganic Undoped	Sapphire, YAG	Focteck
Quartz	Herasil 3 & 102, Infrasil 301 & 302, Suprasil 1 & 300	Aachener Quarz-Glas Technologie Heinrich
Glass	D 263 T	Präzisions Glas & Optik

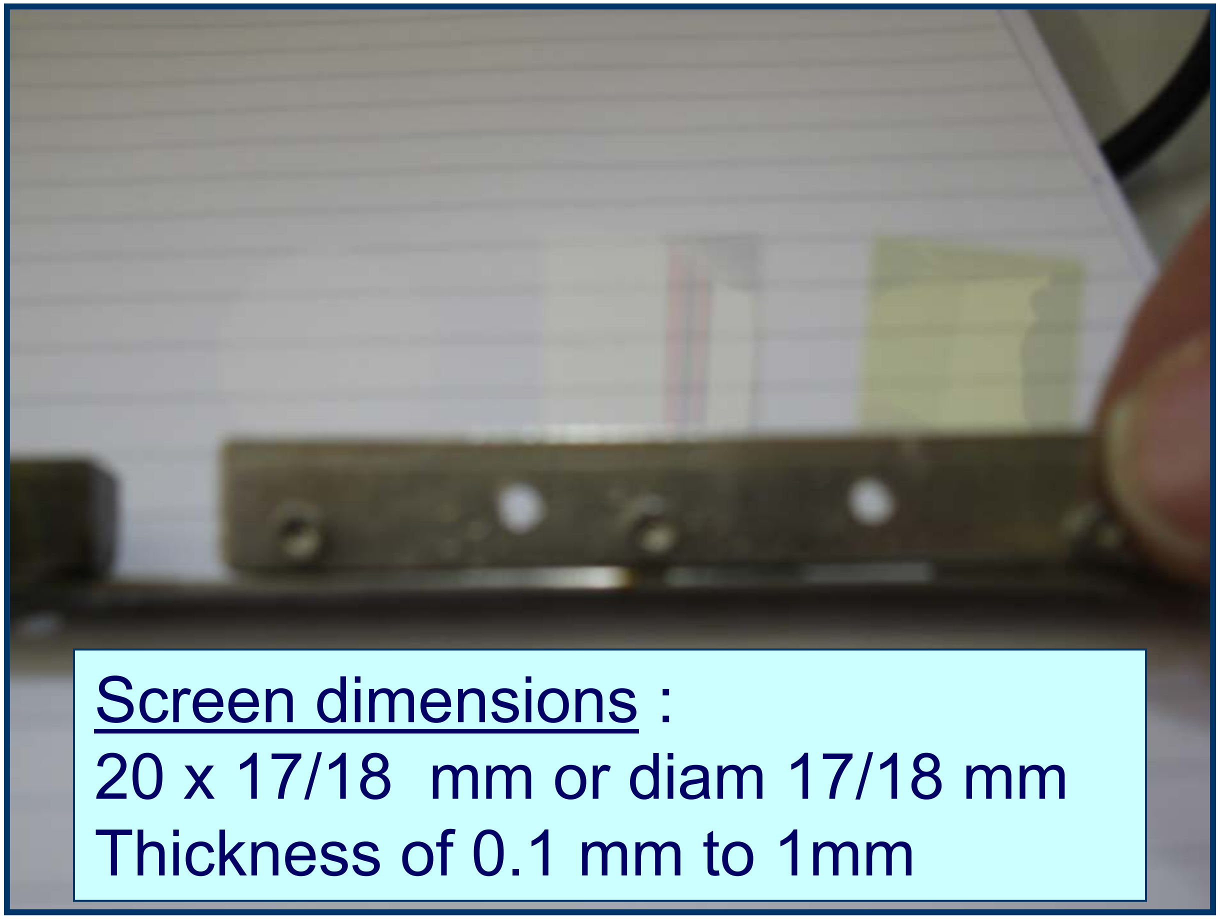
Depth vs. Y axis



TRIM Simulation Carbon Ion (8keV/u) Into SiO2. The longitudinal range and straggle is 282 Å and 133 Å respectively.

Ion Beam-Material Irradiation Test @ Max Planck Institute (Heidelberg)

Investigate 3 scintillators materials in one machine run



Screen dimensions :
20 x 17/18 mm or diam 17/18 mm
Thickness of 0.1 mm to 1mm

Ion Beam-Material Irradiation Test Parameters (MPI)

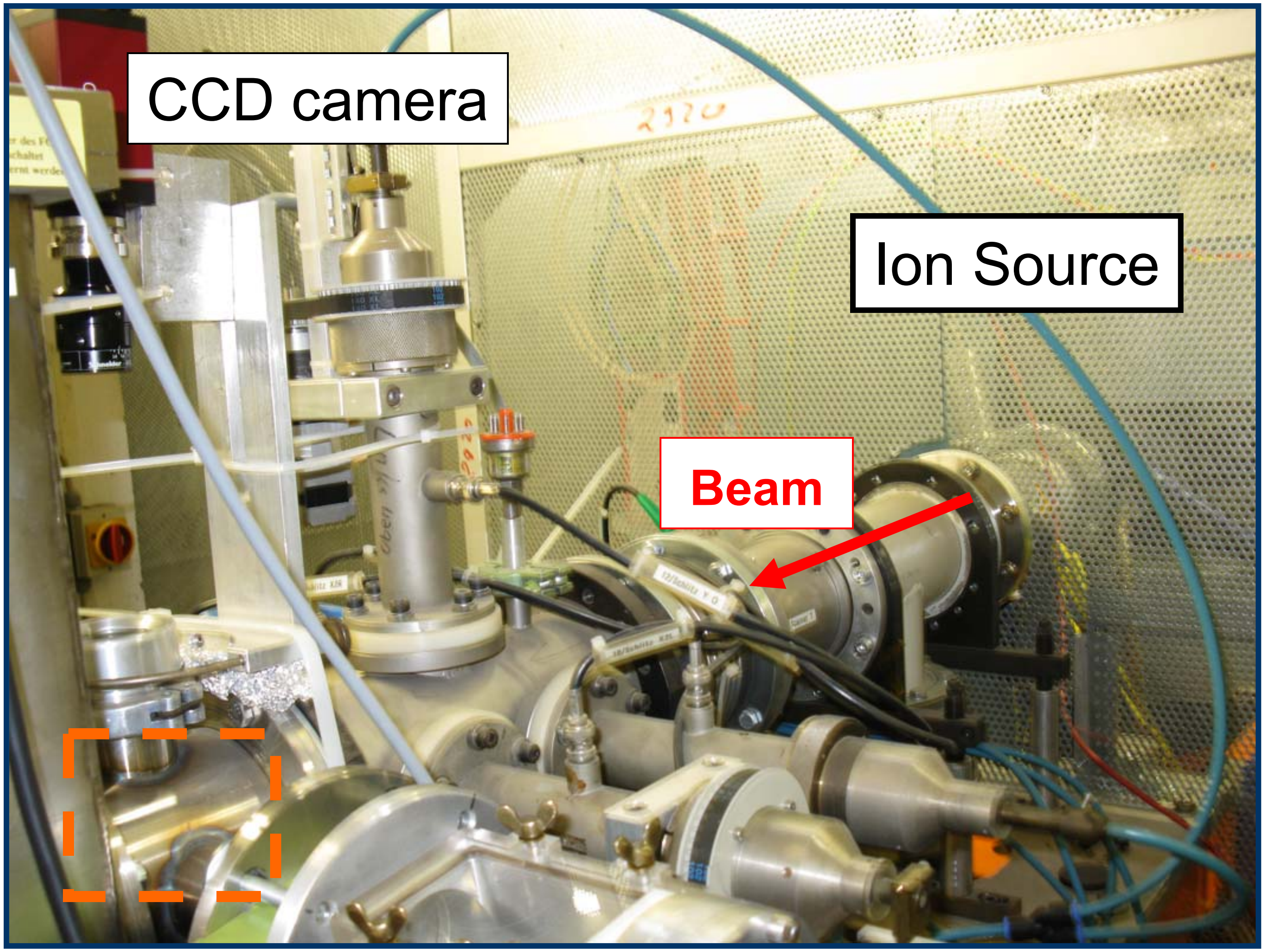
Ion Beam Characteristics :

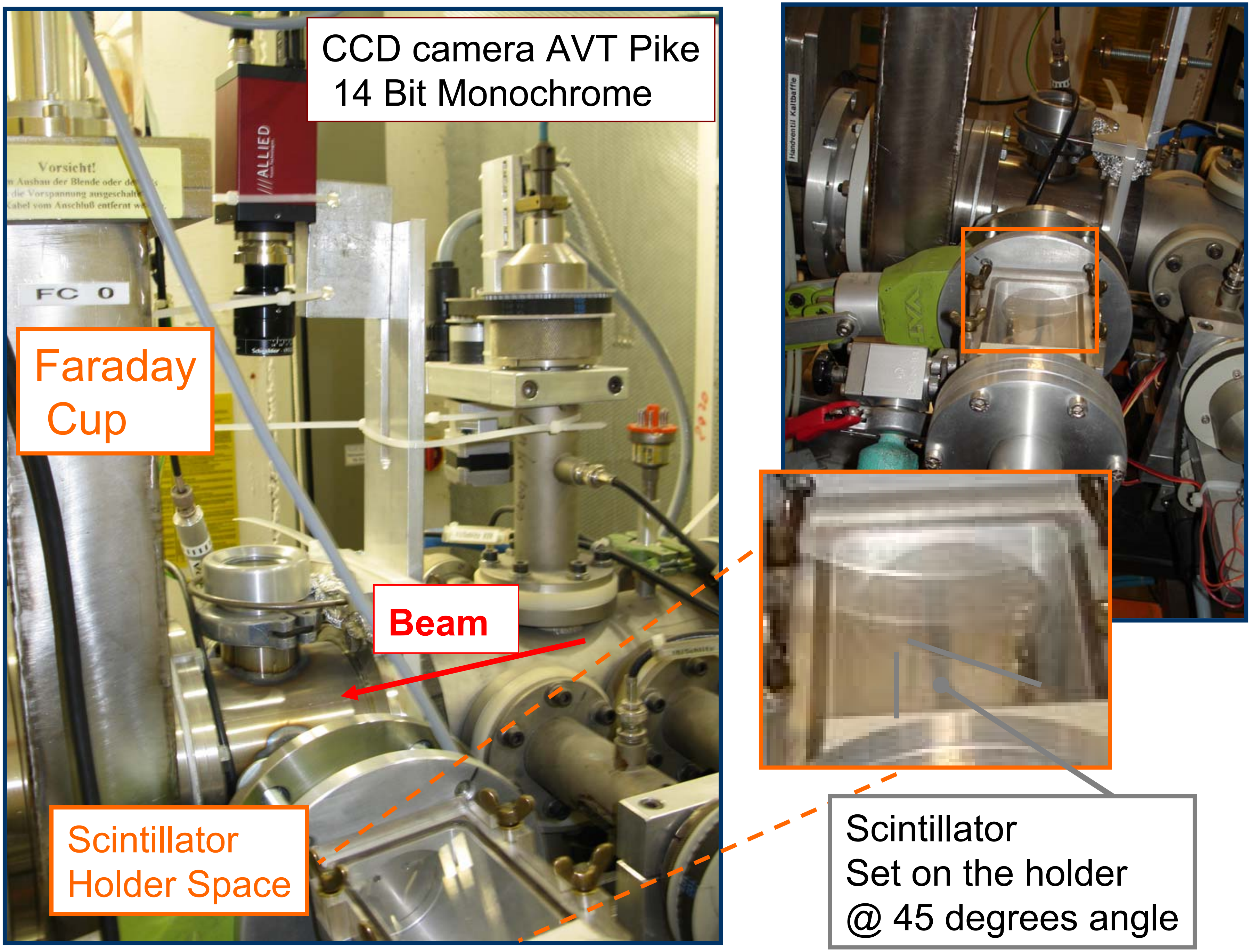
Energy : 8 KeV/u
Beam Current : 10 μ A
Particles per pulse : 9.4*10^11– 3*10^13

Variable Pulse Length : 15 ms – 500 ms
Frequency : 1 Hz
3 Macro Pulses of each beam pulse

A total irradiation time of 1.5 sec to 2 sec have been applied to each material

Ion Beam-Material Irradiation Test Setup (MPI)




CCD camera AVT Pike
14 Bit Monochrome
Faraday Cup
Beam
Scintillator Holder Space
Scintillator
Set on the holder
@ 45 degrees angle
FC 0
Vorsicht!
ALLIED

First Qualitative Results

- Summary of the first results between Inorganic doped/undoped and Quartz/Glass

- Example of YAG:Ce and YAG undoped :

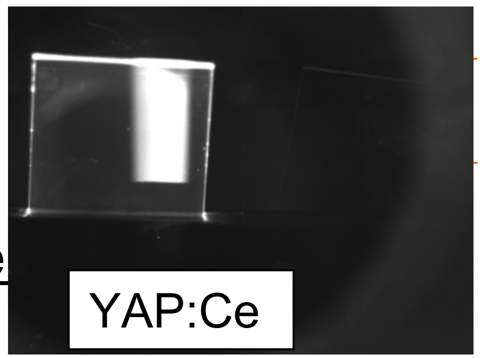
  - Influence of doping
  - Degradation Effect : damage visible with a 10 nA current.

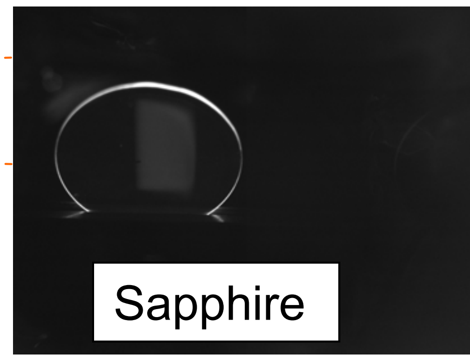
Summary : All Materials

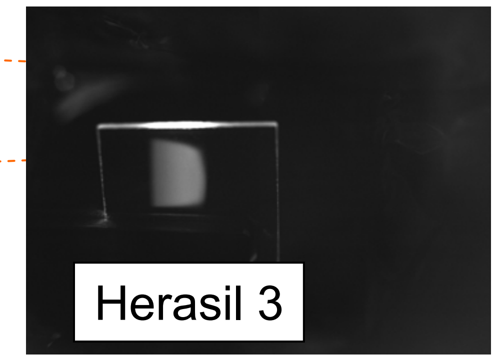
	Inorganic doped Crystals	Inorganic undoped Crystals	Quartz/Glass
Light Output :	+++ (high & ↑)	+ (moderate & →)	++ (moderate & ↑)

Damage :

Low Time De







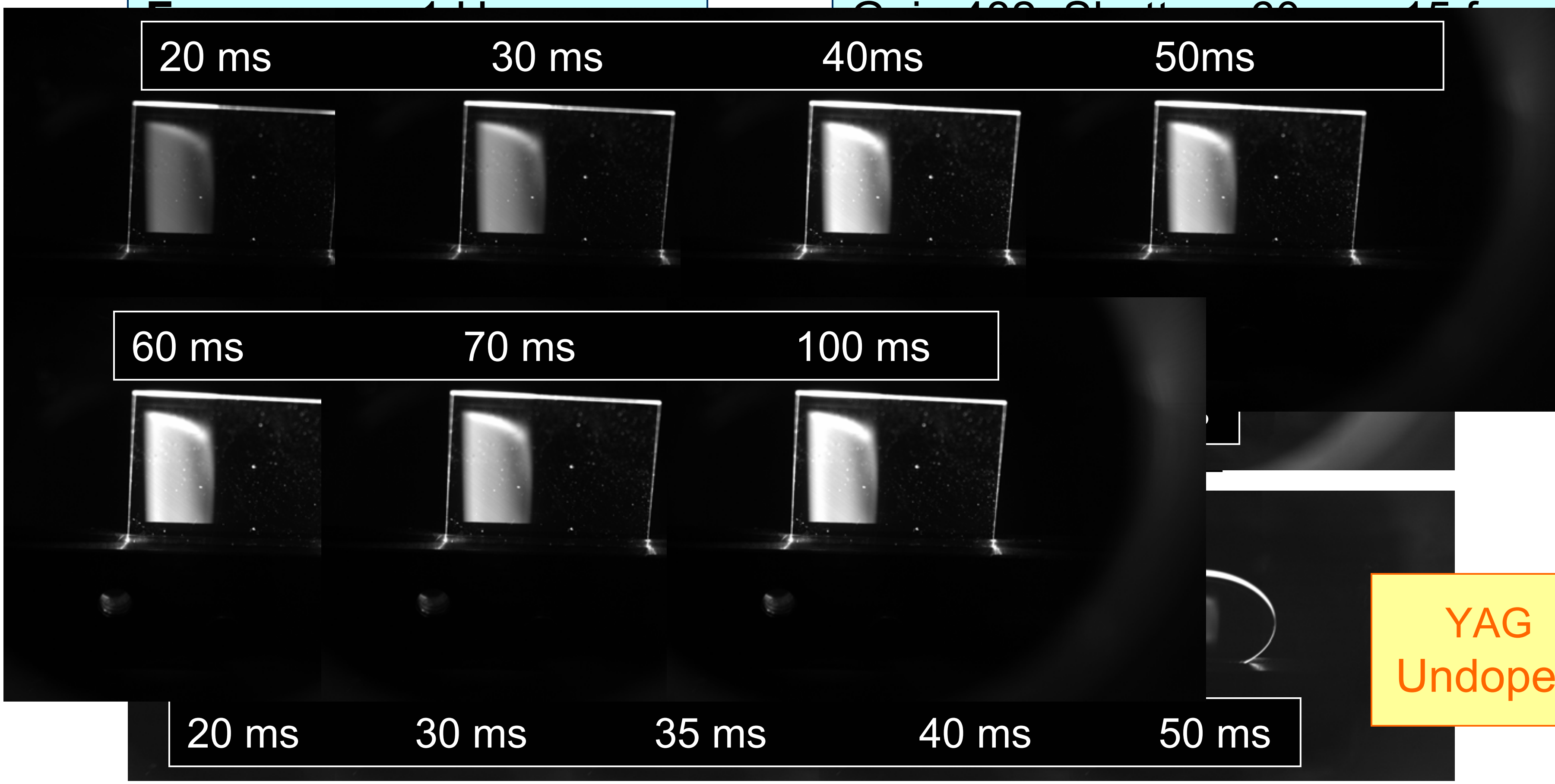
Reproducibility :	+++	++	+++

Quantitative Analysis should be performed

Influence of doping : YAG:Ce and Undoped YAG

Min Pulse Length : 15 ms

CCD Parameters : Brightness = 197

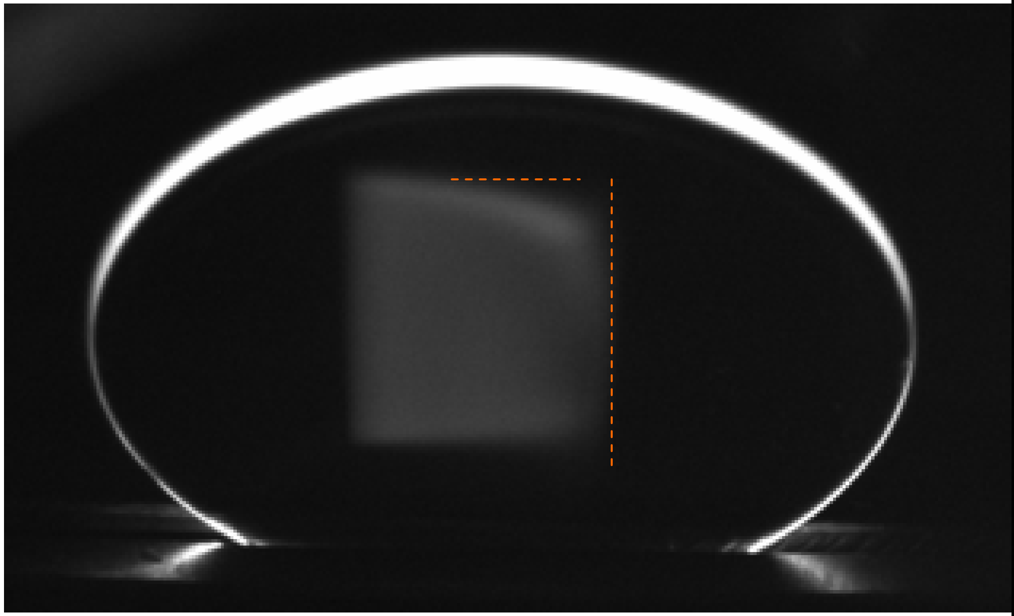


YAG Undoped

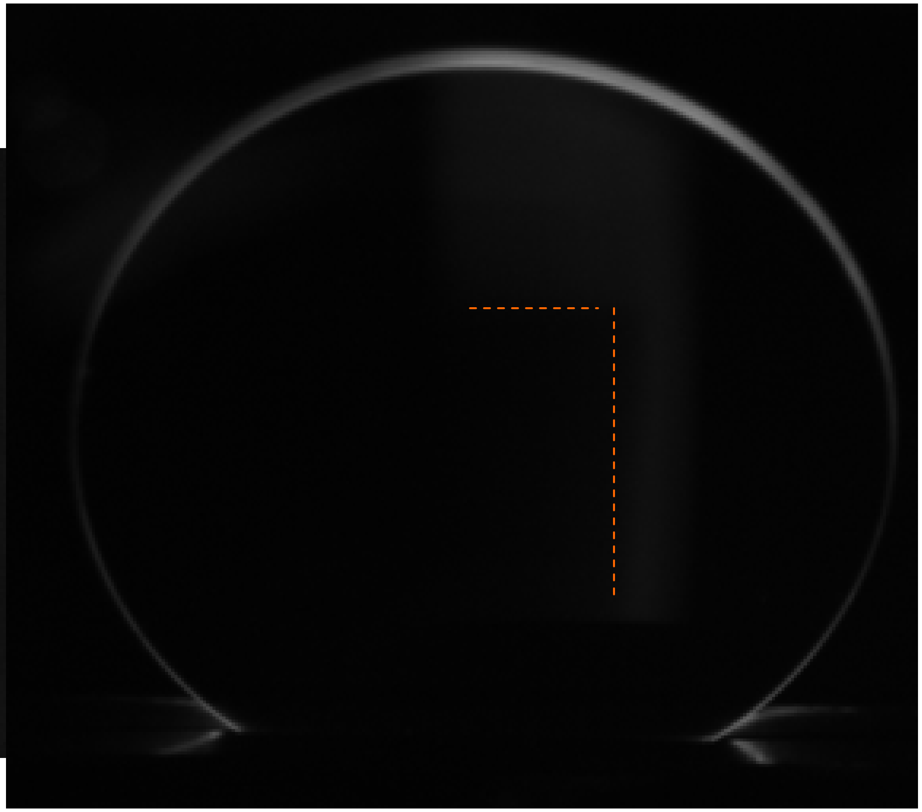
Degradation Effects : YAG:Ce within a irradiation time of 1.3 sec

Degradation Effects : YAG Undoped within a irradiation time of 1.3 sec

2nd Macro pulse of 50 ms pulse



One day later, 1st Macro pulse of 50 ms pulse



What has to be done ...

- Quantitative Investigations on all materials

    - Light yield and profile width
    - Degradation of surface

- In Depth Analysis and Theoretical description of the observed damage effects

Conclusion

- Really Good Candidates : Quartz and Glass
- Good Candidates : Doped Crystals

- A lot to be done and

- Future Test with a Pepper Pot mask ...

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References

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2. Poster - Development of a pepper-pot device to determine the emittance of an ion beam generated by an ECR ion source - Markus Strohmeier
3. Presentation DIPAC ’07– Simon JOLLY
4. The Front End Test Stand High Performance H- Ion Source at RAL – D.Faircloth et al.