A Low Energy Ion Beam Pepper-Pot Emittance Device

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INTRODUCTION

The transverse emittance of the ion beam at the Heidelberg Ion Therapy Center (HIT) will be measured within the Low Energy Beam Transport (LEBT) using a pepper-pot measurement system. At HIT, two ECR sources produce ions (H, He, C and O) at an energy of 8keV/u with different beam currents from about 80 µA to 2mA.The functionality and components of the pepper-pot device is reviewed as well as the final design and the choice of the scintillator. For that, results from recent beam test at the Max Planck Institute für Kernphysik at Heidelberg are presented. The material investigation was focused on inorganic doped crystal, inorganic undoped crystal, borosilicate glass and quartz glass with the following characteristics: availability, prior use in beam diagnostics, radiation hardness, fast response, spectral matching to CCD detectors

LEBT Accelerator Parameters – Project Goals

Beam Energy : 8 keV / u
Analysed DC beam current* :
- up to 2 mA for protons (H_2^+, resp. H_3^+),
- up to 200 µA for $^{12}C^{4+}$
- up to 80 µA for $^{16}O^{6+}$

Acceptance of the successive RFQ: 180 π mm mrad

*figure 1, behind the spectrometer and slit system

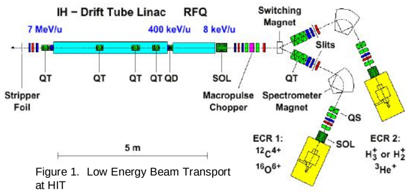


Figure 1. Low Energy Beam Transport at HIT

Pepper-pot Emittance Principle

- Shutter - > Pulsed beam
- Beam segmented by tungsten pepper- pot mask
- Beamlets drift ~15 -100 mm before producing image on screen
- CCD camera records image of light spots from behind
- Calculate emittance from spot distribution.

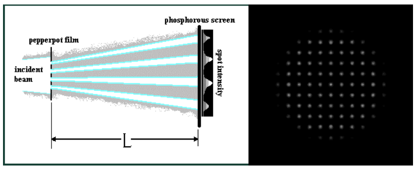


Figure 2. Pepper-pot principle [1]

Pepper-pot Emittance Components at HIT

Shutter (1)
✓ Diameter aperture: 35 mm

Movable Pepper - pot mask (2)

✓ Material : tungsten
✓ Thickness : 100 µm
✓ Hole diameter : 50 µm
✓ Pitch : 1 mm

Transparent Scintillator (3)
✓ YAG:Ce, Quartz
✓ Thickness ~0.1 mm
✓ Diameter ~80 mm

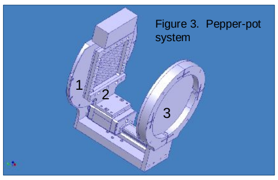


Figure 3. Pepper-pot system

Optical system

✓ CCD type : FireWire AVT Pike
✓ No. of pixels : up to 2048 * 2408
✓ Pixel size : 7.4 µm *7.4 µm

Emittance equirement

rms beam size : 35 mm
Drift Length : 10-100 mm
Resolution : 1 mrad – 5 mrad

Test for Transparent Scintillator Screen at MPI-K

Scintillator requirements :

- Transparency
- Radiation hardness (survives beam 100 nm stopping distance)
- Fast response
- High light output
- Spectral matching to CCD detectors

Tested materials :

- **Inorganic Doped Crystal** : YAG:Ce, YAP:Ce, Caf2:Eu (Crytur Ltd.) [2]
- **Inorganic Undoped Crystal** : Sapphire, YAG (Foctek Inc) [3]
- **Quartz** : Herasil 3 & 102, Infrasil 301 & 302, Suprasil 1 & 300 (Aachener Quarz-Glas Technologie Heinrich) [4]
- **Borosilicate Glass** D 263 T (Präzisions Glas & Optik) [5]

✓Ion beam parameters :

- **Ion Beam** : H2
- **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

Results:

• **Light Output :**

✓ Doped Inorganic Crystal **> > >** Undoped Inorganic Crystal **> > >** Quartz & Borosilicate glass

✓ Saturated distribution for YAG:Ce (figure 4-C), YAP:Ce, CaF2:Eu
✓ Saturated Y distr. / Non-Gaussian X distr. for others

✓ Decrease or Constant light output due to saturation of activator centers, slow decay processes (slow recombination due to trapping), or damage [6-7]

✓ Large fluctuations of L.O due to the role of very slow decay components (influence of traps), afterglow [8]

• **Repeatability :**

✓ ONLY possible for Herasil3, Infrasil 302 and Suprasil 1

✓ Due to large fluctuation of light output for all others material, no repeatability results could be completed.

Damage :

✓ Visible "blackening" : YAG:Ce (after ~2 s), YAP:Ce(~ 2 s), YAG undoped (~ 1.3 sec), sapphire(~ 550 ms)
✓ Not visible : all materials – decrease of light output : "break tooth" appearance (figure 4-C)

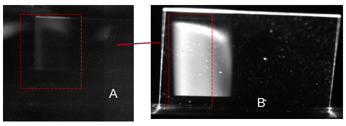
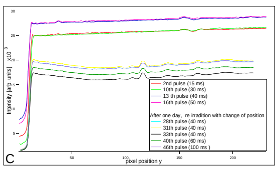
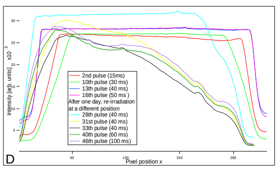


Figure 4 : The degradation of YAG:Ce (A) after a total irradiation of 2000 ms. The intensity distribution is plotted over the horizontal (C) and vertical axis (D).





CONCLUSION :

The Inorganic doped scintillators have a greater light output than the inorganic undoped scintillator and the quartz material.
However, some aspects of their scintillation behaviour (large fluctuations of their light output, non-repeatability of measurement) have not been explained satisfactorily and need further investigation.
Such effects should be investigated by studying the relationships between the beam parameters and the achieved effects.

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