

A PEPPER POT EMITTANCE DEVICE FOR 8 KEV/U LIGHT ION BEAMS – GENERAL LAYOUT AND INVESTIGATIONS ON THE SCREEN MATERIAL

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Abstract

The ion cancer therapy facility HIT in Heidelberg is producing ions (H, He, C and O) from two ECR sources at an energy of 8 keV/u with different beam currents from about 80 μ A up to 2 mA. Typical sizes for the beam in the LEBT range from are 5 – 30 mm. By using on-line emittance measurements it is possible to improve the beam quality by retuning the ion source conditions. For that, a pepper-pot measurement device is under design. In order to quantify the fast ion flux intercepted by a diagnostic ion probe, it is necessary to determine the absolute luminosity of its screen for low-energy ions. Here, Qualitative results of ion luminescence measurements are presented for candidate materials.

However, this method is really slow because the second slit has to be scanned through the range for every position of the first slit.)

With the multi-wire collector method, collector wires collect the beam particles that pass through the slit. The disadvantage of this method is that it requires an amplifier for every wire in the collector.

The Allison-type emittance scanner is faster than the multi-wire collector method but slower than the pepper – pot method.

PEPPER POT DEVICE

Location

The Pepper-Pot Scintillator Screen system should fit within the existing beam line components (vacuum boxes already used with beam diagnostics equipment like Faraday cups, profile grids and slits). The N1DK1 vacuum boxes will be equipped with a fast iris shutter, a pepper-pot mask and a scintillator screen. The N1DK2 vacuum boxes will contain a 45 degrees tilted mirror inside and a CCD camera outside. (Figure 1)

The pepper-pot principle

The pepper-pot mask, which is perpendicular to the beam and contains a regular array of identical holes, splits the beam into beamlets. The scintillator is used to create a photographic image of the beamlets with pixel intensity corresponding to the charge concentration of beam particles striking the scintillator. A CCD camera with a mirror placed at 45 degrees will record multi-shots.

Why using a pepper-pot device?

We want to measure both x-y components of the beam emittance simultaneously in one shot and to obtain data in real time. Four methods can be used and utilize a slit to select a portion of the beam for analysis. These methods are described in the following paragraphs.

The two-slit scanner method uses a second slit which can be scanned through the direction parallel to the first.

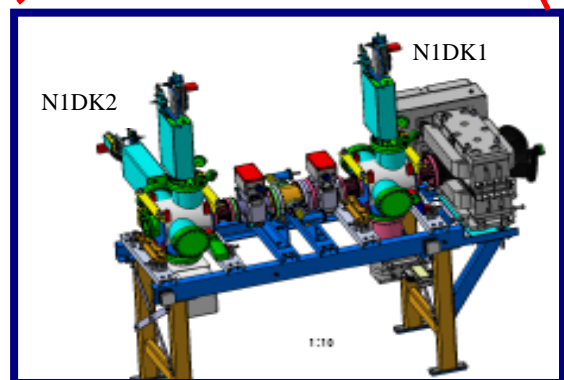
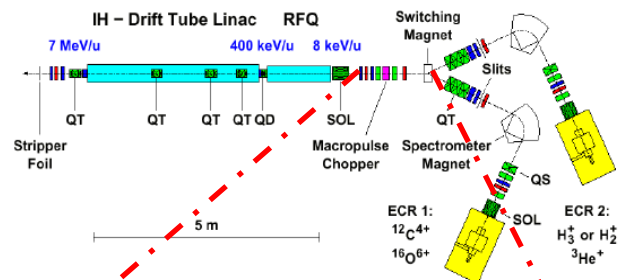


Figure 1: The Low Energy Beam Transport at HIT and the position of the Pepper-Pot Scintillator Screen device within the LEBT.

Who uses a pepper-pot device?

GS1 [1], BNL [2] and RAL [3-4] are recently developing or updating a pepper pot device. Sometimes, the use of a multi channel plate in combination with a scintillating surface has to be considered.

SCINTILLATOR

The pepper pot mask and the measurement screen will be aligned perpendicularly to the beam. The beam images will be thus produced by a transparent scintillator and will be captured by a suitable CCD camera.

Properties

The materials, selected because of their availability, radiation hardness, fast response, prior use in beam diagnostics, or spectral matching to detectors (CCDs) are:

- Inorganic Doped Crystal : YAG:Ce, and also YAP:Ce
- Inorganic Undoped Crystal : Sapphire, YAG
- Quartz and Borosilicate glass : Herasil 3 & 102, Infrasil 301 & 302, Suprasil 1 & 300 , D 263 T

One of the most important properties of fused quartz is its extremely low coefficient of expansion: 5.5×10^{-7} mm $^{\circ}\text{C}$. Its coefficient is 1/34 that of copper and only 1/7 of borosilicate glass. This makes the material particularly useful for applications which require minimum sensitivity to thermal changes.

Experiment at the Max Planck Institute - Heidelberg

These tests were made on the first week of November 2009. During these runs, the scintillator plate was placed in the beam path at a 45 degree angle and CCD camera was recording 15 frames per second. Three scintillators could be placed on a holder and be tested with the same conditions in one machine run.

The Ion Beam parameters used in this experiment are the following:

- 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

Each material is irradiated with 3 macro pulses of 15 ms, 20 ms, ...until 500 ms (or less if the light output intensity became constant) with a frequency of 1 Hz. At the end of the test a total irradiation time of 1.5 sec to 2 sec have been applied to each material.

The measurements made with H ions having energies of ≈ 8 keV / u. Qualitative results are summarized and used to estimate light output, degradation, low time delay which are then compared with known published values.

The ion beam is first passing through a collimation entrance slits. Once the beam is tuned into the Faraday cup and a beam current measurement is acquired, the chopper is released and the beam travels down to the screen material situated in front of the Faraday Cup.

Three samples to be irradiated reside on a sample holder driven by a manual actuator. The target is heated to below the melting point by the beam energy.

The resultant ions were then accelerated towards the probe before passing through a collimation entrance slits. In this way flux up to 3×10^{13} pps for protons was achieved.

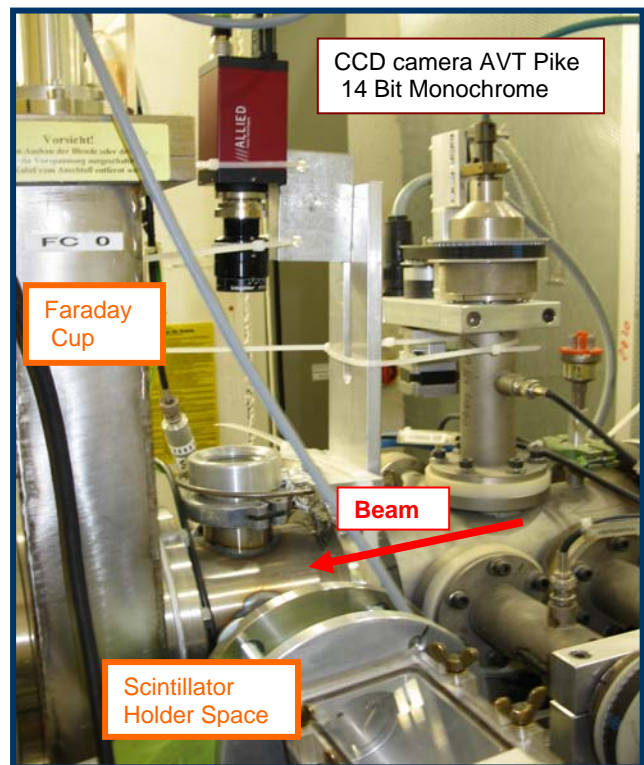


Figure 2: Ion Beam-Material Irradiation Test Setup at the Max- Planck Institute in Heidelberg.

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

The Inorganic doped scintillators have a greater light output than the inorganic undoped scintillator and the quartz material. However, the undoped scintillators show constant light output intensity with respect to the beam pulse whereas quartz and inorganic doped scintillators shows an increase in the light output intensity with the increase of the beam pulse.

As a qualitative result, slighter damage with quartz material has been revealed. Only quantitative analysis will give us more details.

Influence of doping – comparison between YAG:Ce and YAG undoped

As envisaged, the light output of the doped scintillator is superior and increases with the beam pulses. That's not the case with undoped scintillators.

Degradation Effect: damage visible with a 10 nA current

The video of the degradation of YAG:Ce shows a small beam current of 10 pA which have been used to reveal the blackening of the materials. However, a standard microscope doesn't show any damage (burning bubbles, changes in colour ...)

The damage of the undoped YAG (Figure 3) shows that after 1.3 seconds of total irradiation time the undoped material cannot be used anymore. Only a small part of the material scintillates, a big part (corresponding to the irradiated beam width of the previous day) doesn't scintillate at all. This material should be analyzed with care since undoped YAG should be stronger through radiation than YAG:Ce.

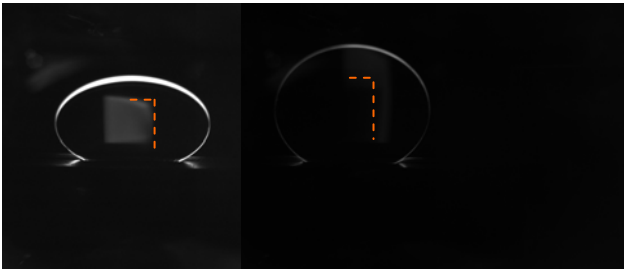


Figure 3: Degradation Effects of undoped YAG after an irradiation time of 1.3 seconds.

CONCLUSION

Inorganic Doped and quartz material are qualitatively good candidates. Of concern is the damage at the surface giving rise to stresses that could result in atomic mixing in the collision cascade. A model is needed in this area to better understand the beam target interaction and its effects on the target.

In order to find solutions such as the choice of the target, quantitative investigations on all materials should be performed.

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