

# OBSERVATION OF A H-BEAM AT THE CERN LINAC 4 TEST STAND USING A PEPPER-POT\*

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## Abstract

Pepper-pot based transverse emittance measurement has the advantage of providing a fast (single shot) measurement with a relatively simple hardware. We report on the installation of a pepper-pot at the CERN Linac4 test stand.

## LINAC4 TEST STAND

Linac4 [1] is a new H- accelerator being built at CERN, for the injection of a 160 MeV beam into the existing PS Booster (PSB). It will replace the aging Linac2, and allow the accumulation of a higher brightness beam in the PSB, due to a reduction in the space charge tune shift at injection energy.

In order to test the critical components at the low energy end of Linac4 (source, RFQ and fast chopper system) a test stand is being constructed, which will in the future be moved to the Linac4 tunnel. The source has already been built [2] and is in its beam commissioning phase.

## PEPPER-POT BASED TRANSVERSE EMITTANCE MEASUREMENT

The pepper-pot technique is used to measure the transverse emittance of particle beams. It consists of a plate with an array of holes (like a pepper-pot). When a beam much larger than the holes impinges on the plate it is split in several beamlets. A screen located further downstream allows to measure the divergence of each beamlet. As the position of these beamlets is already known the position-divergence product of the beam can be calculated and hence the emittance. This allows a fast (single shot) measurement of the area occupied by the beam in the phase-space and hence of its transverse emittance. Further details can be found in references [3, 4].

## PEPPER-POT ASSEMBLY

An overview of the pepper-pot assembly used for the experiment described in this paper is shown on figure 1. The pepper-pot is made of a thin ( $50\mu\text{m}$ ) plate of stainless steel in which holes have been etched. In order to check that the scattering of the protons on the holes was negligible the amount of material around some of the holes was reduced by etching a larger concentric hole half-way through the plate as shown on figure 2. The through holes have a diameter of  $500\mu\text{m}$  whereas the larger holes have a diameter of

1mm. Holes are placed regularly on the plate with a 2mm spacing over a 80mm by 80mm area. Near the centre of the plate two rows and two columns of holes have not been etched to make it easier to find the centre of the plate.

The pepper-pot plate is mounted on a screen holder capable of holding a round screen with a diameter of 100mm. Two different types of screen were used during the tests: a fused silica uncoated screen and a P43 coated silica disk with a 50nm aluminium overcoat. Spacers were used to keep the pepper-pot plate 10mm away from the screen.

The screen holder is attached to two 45 degree wedges that hold a mirror. The wedges are mounted on a long rod connected to a single-acting pneumatic actuator. A DN150CF flange is used to mount the assembly on the vacuum cross at the exit of the source. A camera is mounted on the same flange so that it is right above the mirror, viewing the screen.

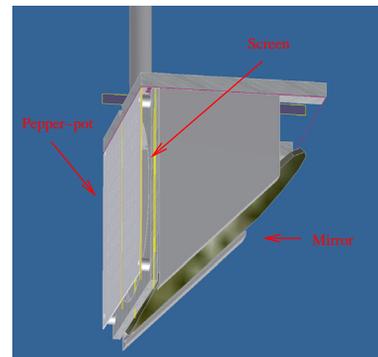


Figure 1: Pepper-pot assembly.

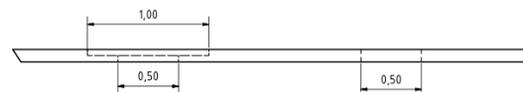


Figure 2: Transverse view of the holes as etched in the stainless steel plate (dimensions in mm).

## OBSERVATION

### Screens

The first observations were made using the fused silica screen. A pattern reproducing the shape of the pepper-pot's holes was observed on the screen, however it was noted that

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this was also visible when the source RF was fired, generating Plasma, but the extraction high voltage was turned off (and thus no beam was extracted). Hence the observations with this screen were dominated by the light emitted by the plasma and not by the actual light emitted by the screen when it is hit by the protons.

The fused silica transparent screen was then replaced by a screen coated with P43. An image observed with the P43 screen is shown in figure 3. In this image three different types of spots (corresponding to different types of beams) can be seen.

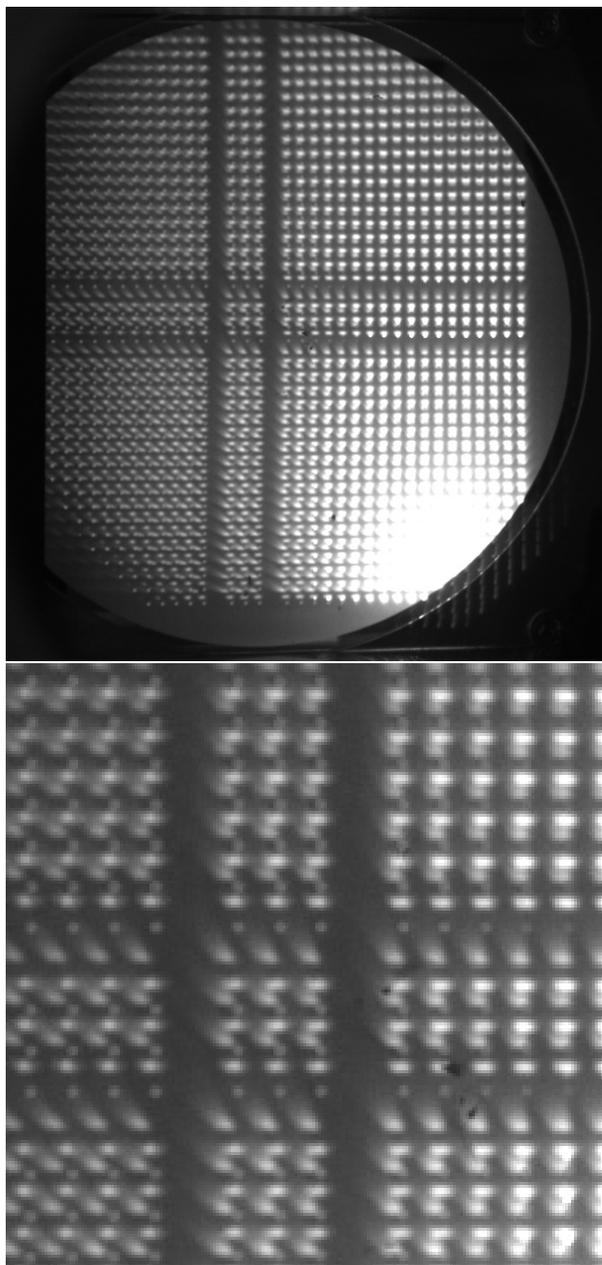


Figure 3: Image observed with the P43 screen (top) with a close-up zoom of the central section (bottom). The presence of three different type of spots can clearly be seen.

### *Effect of a deflecting magnet*

To investigate the origin of the different types of spots a deflecting dipole magnet was installed between the source and the pepper-pot. The effect of this magnet on the beam when the current in the magnet was varied from  $-8\text{A}$  to  $+8\text{A}$  (corresponding to an average field of  $8\text{mT}$ ) is shown on figure 4. A large square aperture can be seen on some of these pictures. The position of this aperture is highly correlated with the current, indicating that it corresponds to the electrons passing the aperture. It can clearly be seen that two types of spots observed on the image move significantly when the current is increased whereas the third type of spot does not move. This indicates that these spots also corresponds to electrons from the source, coextracted with the  $\text{H}^-$  ions, but not removed by a selecting spectrometer. The presence of electrons requires further investigation from the source.

### *Effect of the High Voltage*

A similar study was done by reducing the voltage applied between the electrodes of the source from  $38\text{ kV}$  to  $31\text{ kV}$ . This is shown on figure 5. It can be seen that the electron signal becomes more important at higher voltage, when the electrons gain a higher energy and thus a higher magnetic rigidity.

### *Scattering*

A comparison of holes with different material thickness does not show any spot size difference (see for example the magnified images of figures 3 and 4). Hence it can be assumed that the effect of the scattering in the mask was negligible.

### *Damages after beam exposure*

After about 10 hours of beam exposure (with the source delivering  $400\mu\text{s}$  long beam pulses, spaced by  $1.2\text{ s}$  with a typical intensity of  $20\text{ mA}$ ) the device was dismantled. Clear burn marks were seen on the rear side of the P43 screen (i.e. by looking through the silica substrate) although there was no indication of damage on the side on which the beam impinged on the screen (see figure 6). The damage displayed the same pattern as the mask (with one mark per mask hole), and was quite evenly distributed over the whole screen (in particular the damage was no worse in the region where the electron beam was strongest).

These burn marks may have strongly contributed to the unusual patterns seen within the spots observed on the P43 screen. Deformation was also seen on the mask.

## CONCLUSION

A pepper-pot and screen were installed after the source on the Linac4 test stand. The images show the presence of electrons in the beam, which should have been suppressed by a magnetic filter after the source. This information will

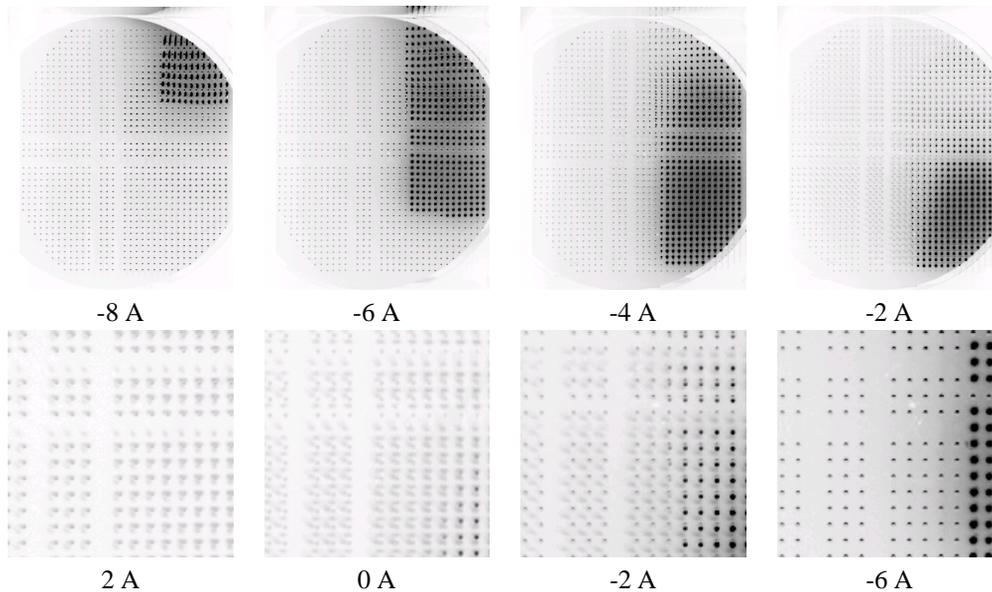


Figure 4: Top row: Variation of the pepper-pot pattern observed on the screen as a function of the magnetic field applied. Bottom row: Zoom for selected current values. On these pictures dark means more intense light.

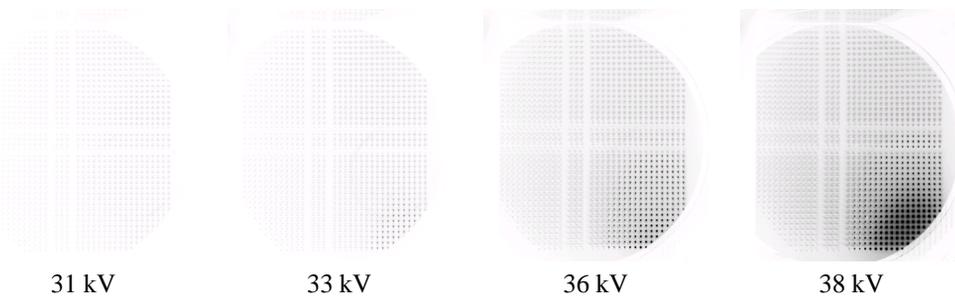


Figure 5: Variation of the pepper-pot pattern observed on the screen as a function of the extraction voltage of the source. On these pictures dark means more intense light.

be of use for the continued development of the source. No effect due to scattering of the ion beam in the channels could be observed.

To extract a value for the emittance, the screen would have to be replaced by a screen with a more resistant substrate and the mask modified.

## REFERENCES

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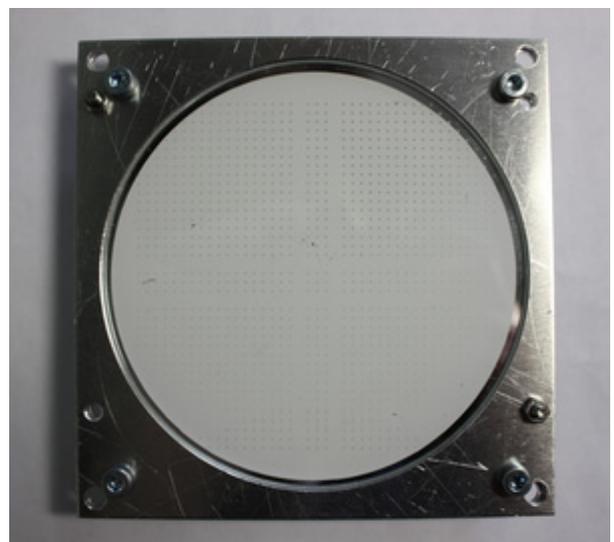


Figure 6: The P43 screen after several hours of exposure to the H- beam. Burns marks reproducing the pepper-pot pattern can clearly be seen on the rear face (shown above).