A Simple Image Intensifier Prepared for the Transport of Nano–Ampere keV Ion Beams*

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We introduce our handmade image intensifier for visualizing the beam profiles of accelerated ion beams having energy and current in the order of keV and nano-amperes, respectively. The simple image intensifier comprising stainless steel meshes and a fluorescent screen has been used for the transport of mm-size ion beams. The intensifier is easy to install in the beamline of a vacuum setup, because it is designed to attach on a conflat flange of ICF70. We have used the image intensifier to observe the beam profiles of the ion beams transported from the ion source to an ultra-high vacuum chamber. Through the use of the image intensifier, bright images were obtained, and it was concluded that the intensifier is useful for observing the profiles of the beams having current densities greater than 0.1 nA mm⁻².

1. Introduction

We have previously studied the surface morphologies of electron-irradiated alkali halides via surface channeling of MeV proton beams1–4). To investigate the surface morphologies of various sample species, we employed a keV-proton beam using a facile apparatus.

We developed an experimental apparatus for measuring keV-ion beams scattered from the surface. An electron-gun-equipped ultra-high vacuum (UHV) chamber along with a differential pumping-system chamber and an existing high vacuum (HV) chamber were linearly connected to an RF ion-source. We designed a beam visualizing system, i.e., an image intensifier, and installed it in the beam-transport line extending from the RF ion-source to the UHV chamber. The observation of beam profile, including information such as size, shape, and intensity distribution, is important for the adjustment of a beam transportation system.

In this paper, we introduce a laboratory-constructed simple image intensifier. Generally, a fluorescent screen is used to view the beam profile for MeV ions. However, for keV ions, it is difficult to observe the shape of the beam profile using a fluorescent screen because the intensity of the light emitted is weak. Note that for typical ion-beam transport systems, the current density (nA mm⁻²) is too high for the use of an image intensifier assembled with a micro-channel plate. Therefore, we designed an image intensifier comprising stainless steel (SUS) meshes and a fluorescent screen. The intensifier is designed such that it cannot easily be damaged by the beam and is simple to assemble on a conflat flange of ICF70. The development of technologies for high-speed computing, large personal computer (PC) memories, and processing software to project data from a digital camera that looks dark fluorescence may assist this work.

Note that Mase et al. mounted various devices on a conflat flange of ICF70 and reported the advantage of these devices5–7).

2. Experimental Setup and Apparatus

2.1 Experimental Apparatus

Figure 1 shows a schematic of the experimental setup. The main part of the experimental setup has been described elsewhere; thus, only the parts modified for this experiment are mentioned here.

The ion beam from an RF ion-source is transported to the UHV chamber via the HV and differential pumping system chambers. The laboratory-constructed image intensifiers are set along the line extending from the RF-ion source to the UHV chamber. One of the image intensifiers (A) is set upstream of the HV chamber and the other (B) in the differential pumping system chamber, as shown in Fig. 1. A set of X-Y slits is placed between these intensifiers. The base pressure of this system is approximately 10⁻⁸ Pa at the HV chamber, 10⁻⁵ Pa at the differential pumping system chamber, and 10⁻⁷ Pa at the UHV chamber.

2.2 Construction of the image intensifier

The image intensifier comprises triple stainless steel meshes (758051; Nilaco Inc., Japan; SUS304, 50 meshes/inch) and a fluorescent screen. The meshes and the screen are isolated on doughnut-shaped alumina ceramic frames. Figure 2 shows a schematic and the construction of the image intensifier. The ion beam is inclined at an angle of 45° for the first stainless steel mesh. The emitted secondary electrons from the stainless steel mesh are accelerated to other stainless steel meshes, which are held at a potential of $P_1$ and $P_2$ kV, as shown in Fig. 2. These secondary electrons hit a glass plate coated with the fluorescent material (#974727; Nilaco Inc., Japan). We checked and monitored the fluorescence from the opposite side of the fluorescent material by the naked eye and a digital camera (EOS 60D; Canon Inc., Japan). The camera was connected to a PC and a number of images of the luminous intensity distribution appearing on the screen were taken. The exposure time for each image was 30 seconds. The camera was covered with a blackout curtain to prevent the entrance of any...
ambient light. The intensity distribution map was plotted by adding up the blue RGB values of each individual pixel using these images.

3. Results of beam profile observation

The ion beams from the RF ion-source contained H\(^+\), H\(_2\)\(^+\), H\(_3\)\(^+\), and residual gas ions. The accelerating potential for the ions was 15 kV. The Wien filter was used to analyze the ions. Figure 3 shows typical beam currents of the H\(^+\), H\(_2\)\(^+\), H\(_3\)\(^+\) and residual gas ions, which were measured in the HV chamber. Although they are of a nano-ampere (nA) order, the magnitude of the current because of H\(^+\) ions is the least.

Beam profiles were measured using our image intensifier. Figure 4 shows examples of images obtained for the secondary electrons, with \(P_1=0\) kV and \(P_2=2\) kV. The visible lattice-like pattern is due to the shadow of the last mesh (the one accelerated to \(P_2\) kV). The shapes and sizes of all ion beams were almost similar, which reflect the shape defined by the set of X–Y slits. The number of images for adding up the blue RGB values of H\(^+\) was 20 and that of the other ions were 10. The fluorescence by all ions, except the H\(^+\), could be seen by the naked eye and on the PC screen. The fluorescence by H\(^+\) ions could barely be seen on the PC screen. For comparison, Fig. 4(c) shows the images of H\(^+\), H\(_2\)\(^+\), and H\(_3\)\(^+\) profiles obtained using only a fluorescent screen. The screen is made of fluorescent material on a stainless steel plate and is viewed from its front side. This fluorescence is too weak to be seen by the naked eye. In the intensity distributions for H\(_2\)\(^+\) and H\(_3\)\(^+\), 10 images are composed, respectively. However, the shadow created by the slit is clearly seen on the intensity distribution for H\(_3\)\(^+\). In the case of H\(^+\) beams, 30 or more images are needed for a clear image to be observed.

Figure 5 shows typical H\(_3\)\(^+\)-beam images and horizon-
Fig. 4  Beam images of $\text{H}^+$, $\text{H}_2^+$, $\text{H}_3^+$, and residual gas ions obtained by the image intensifiers. (a) Image intensifier A. (b) Image intensifier B. (c) Image obtained by a simple fluorescent screen set at the wrong side up on the image intensifier A.

Fig. 5  Typical $\text{H}_3^+$ beam profiles. Beam images and the horizontal-section profile are shown, obtained by image intensifier A and B.

Fig. 6  An example of the use of the image intensifier for beam profile monitoring according to deflection of the beam. The beam was deflected without changing its form.
To check the beam position-adjustment property of the image-intensifier, an alignment coil and an electrostatic deflector were used at the HV chamber. The alignment coil was used for horizontal deflection and the deflector was for vertical deflection of the ion beam. Because there is no obstruction between the deflectors and the image intensifier, the beam can be deflected such that it passes through to the intensifier. We have confirmed that the beam was deflected without changing its form, as shown Fig. 6, for the horizontal and vertical deflections.

Although the H\(^+\)-ion species was used for the surface morphology measurement, it cannot be concluded that the required beam position-adjustment property has been obtained for the ion presently. The fluorescence for H\(^+\) ions can barely be visible on the PC screen. A clear image for the ion beam with low current density could be obtained if a highly efficient mesh of secondary electron emission is used.

### 4. Conclusion

We devised a simple image intensifier and observed the beam profiles of H\(^+\), H\(_2^+\), and H\(_3^+\). The advantages of our image intensifier are as follows:

- Visualization of the profiles of the keV ion beams having a current density of 0.1 nA mm\(^{-2}\) is possible.
- Structure is simple and can be easily assembled.
- Because the device is very compact, it is easy to install it into the beam line of a vacuum setup.

Our laboratory-constructed image intensifier facilitated the transportation of the ion beam. Further, the obtained images of the beam profiles for various ions were bright. However, the images for the 15 keV H\(^+\) ion are intensified by 3–4 times at the most. It cannot be presently concluded that the required beam position-adjustment property for H\(^+\) ion has been obtained. Improvement is needed to get a clear image that can be seen by the naked eye for ion beams with a low current density.

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