

A New High-Energy Dynode Design for LC-MS

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Introduction

High energy dynodes (HED) are now commonly used to enhance the sensitivity of ion detectors by increasing the impact energy of input ions, which increases the number of emitted secondary particles. In quadrupole systems, HED's are usually designed to collect only low energy ions. However, quadrupole mass analysers used in high-mass range applications (typical in LC-MS) can produce ions with relatively high energies, while ions that emerge from an ion trap mass spectrometer can have energies of several keV. Higher energy ions produced by either of these systems may not be detected by conventional HED designs.

To achieve maximum sensitivity from a detector used in either ion trap or high massrange quadrupole systems, it is necessary to use a detector with an HED that has been designed to perform well over a wide range of input ion energies. The work presented here describes a new HED design that efficiently detects input ions with energy ranging from a few eV up to 5keV.

Design Methods

Specialized computer simulation techniques, capable of optimizing the shape of the HED for a wide ion energy range, have been used to design the optics of a new High Energy Dynode.

Over many years of design experience in ion detection and mass spectrometry, we have developed our own ion-optical design software that can accurately simulate the path of ions in electrostatic fields and the electron interactions with surfaces which are central to the operation of an electron multiplier. Continual improvement of this software has made it a very powerful tool in the design of the complex electron-optics of an electron multiplier.

This design tool has been applied to develop a new high energy dynode for use in ion traps and quadrupole mass spectrometers with high mass range.

Figure 1 shows the electron-optical design of a new detector with a very large area HED which operates at 10kV. The large-area HED can capture input ions with a very wide range of input energy. The green lines in Figure 1 represent the path of ions with low energy (5eV) which are focussed onto the upper part of the HED. The red lines represent input ions with higher energies (5keV) which are also focussed onto the bowl of the HED, but further down the bowl. The shape of the bowl of the HED is carefully designed to focus all secondary particles emitted from anywhere on its surface, to the first dynode of the amplifying part of the detector (blue lines).

The resulting HED is not a simple geometric shape, but a series of concentric surfaces, each optimized to efficiently focus the emitted secondary particles onto the first dynode of the detector.

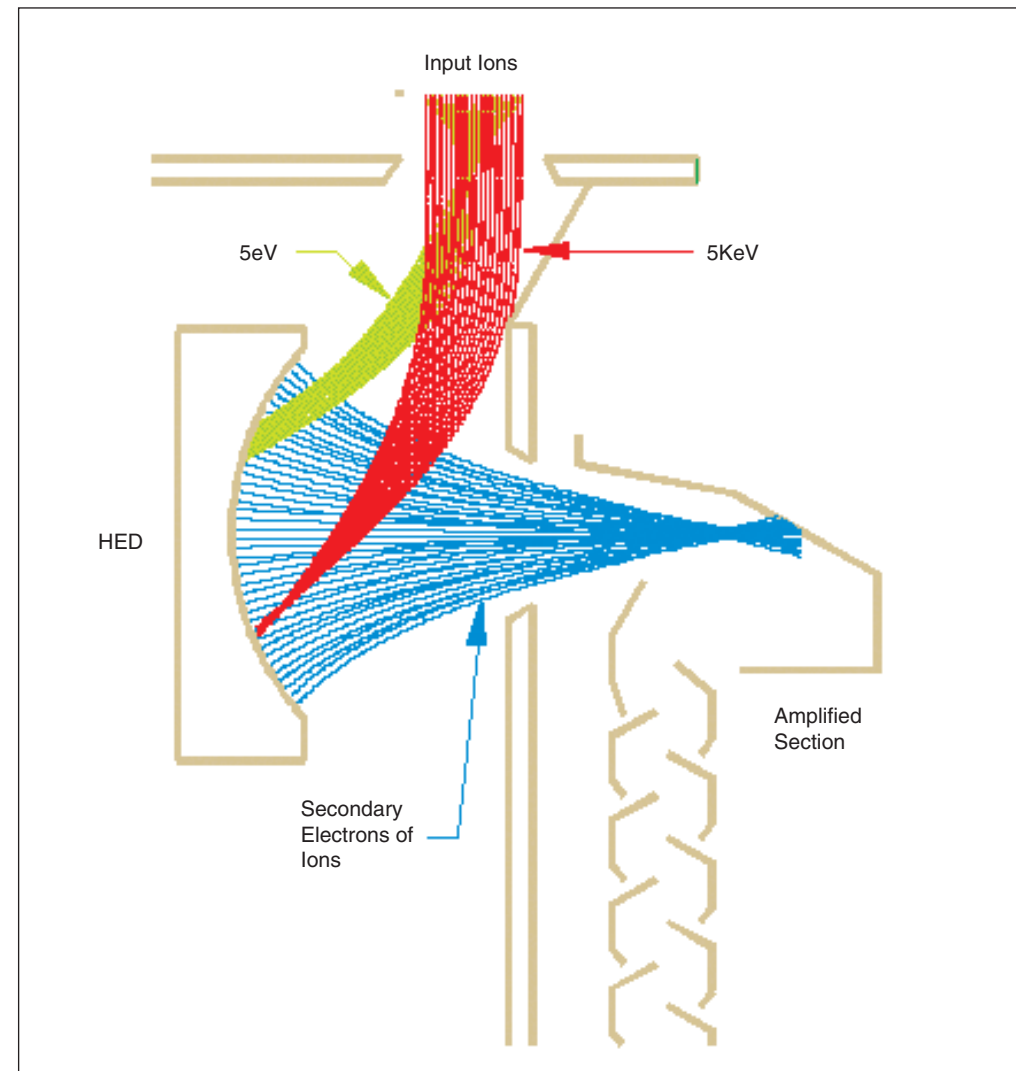


Figure 1. Electron-optics of a new detector which incorporates a 10kV large-area HED.

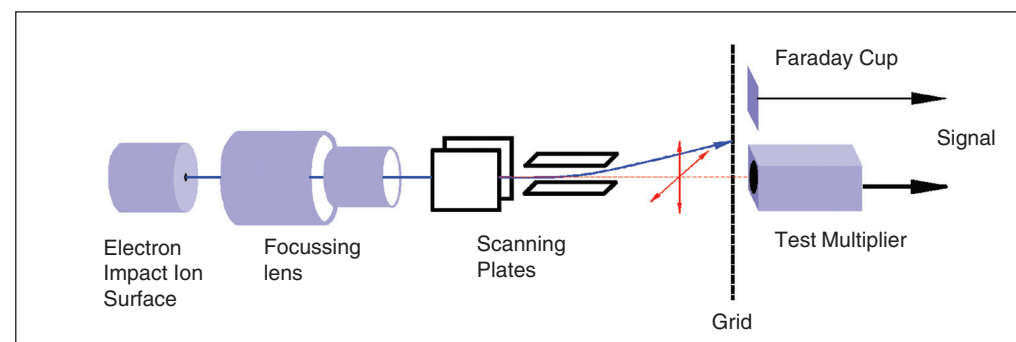


Figure 2. Experimental setup used to measure the sensitivity of the detector over its aperture and for a number of selected ion energies.

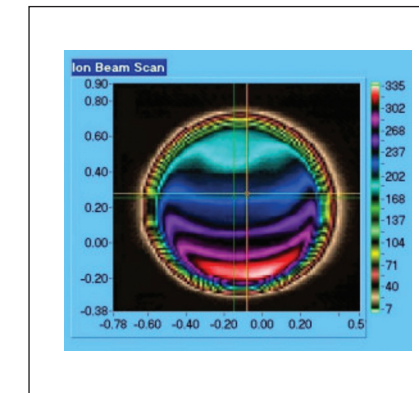


Figure 3. Experimental aperture scan of the new large-area HEDdetector using a 2mm diameter beam of 20eV input ions.

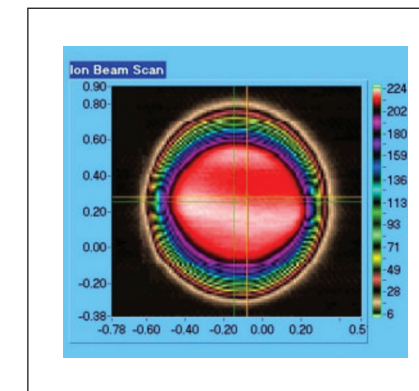


Figure 4. Experimental aperture scan of the new large-area HEDdetector using a 2mm diameter beam of 500eV input ions.

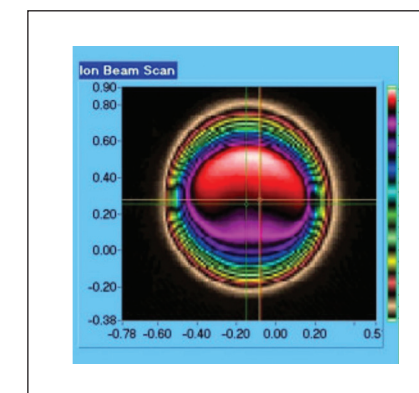


Figure 5. Experimental aperture scan of the new large-area HEDdetector using a 2mm diameter beam of 1.0keV input ions.

Experimental Performance

To measure the performance of this new HED design, an experiment was set up to scan a 2mm diameter beam of ions over the input aperture of the new detector (see Figure 2). Figures 3, 4 and 5 show the resulting aperture scans for input ions with 20eV, 500eV and 1keV energies. It can be seen from these aperture scans that the sensitivity of the detector is very uniform over the majority of the aperture, even when using input ions with very different energy. This shows the extreme tolerance of the new HED design to a broad spread of input ion energies. In the low energy case (Figure 3), the higher sensitivity seen on one side the input aperture is due to ions striking the upper part of the bowl of the HED with near grazing angle of incidence. This produces increased secondary electron emission, so a higher signal level is focused onto the first dynode of the amplifying section of the detector.

Specifications Conclusions

The performance of a newly designed large area 10kV high energy dynode multiplier has been presented. This new design efficiently collects the ions that emerge from the mass analyzer over a very wide range of energies, allowing maximum sensitivity to be achieved by the ion detection system. The data presented demonstrates the uniform sensitivity of this new HED detector over the area of the input aperture for a wide range of input ion energy. Data presented shows that the design operates efficiently for input ions with energy ranging from a few eV up to several keV, making it well suited to ion trap and high-mass quadrupole applications typical of LC-MS.

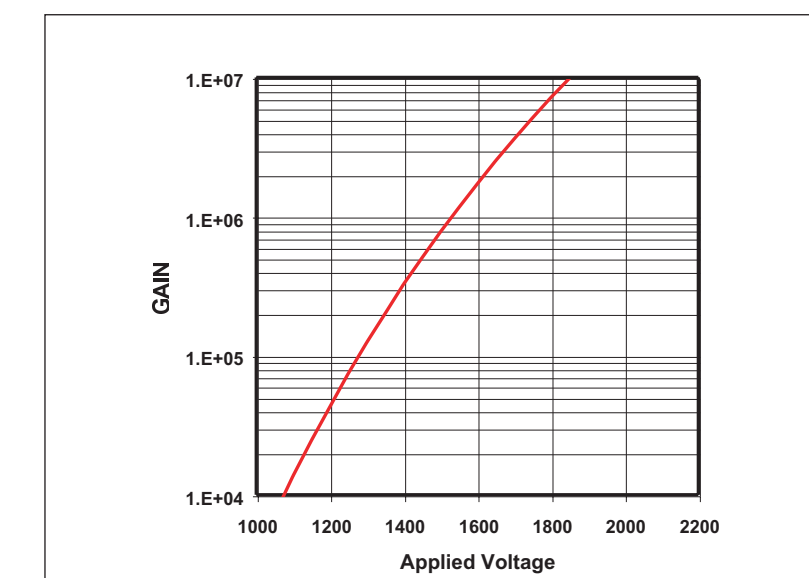


Figure 7. Gain curve of DM283 large-area HED ion detector.



Figure 8. Photograph of a DM283 large-area HED detector.

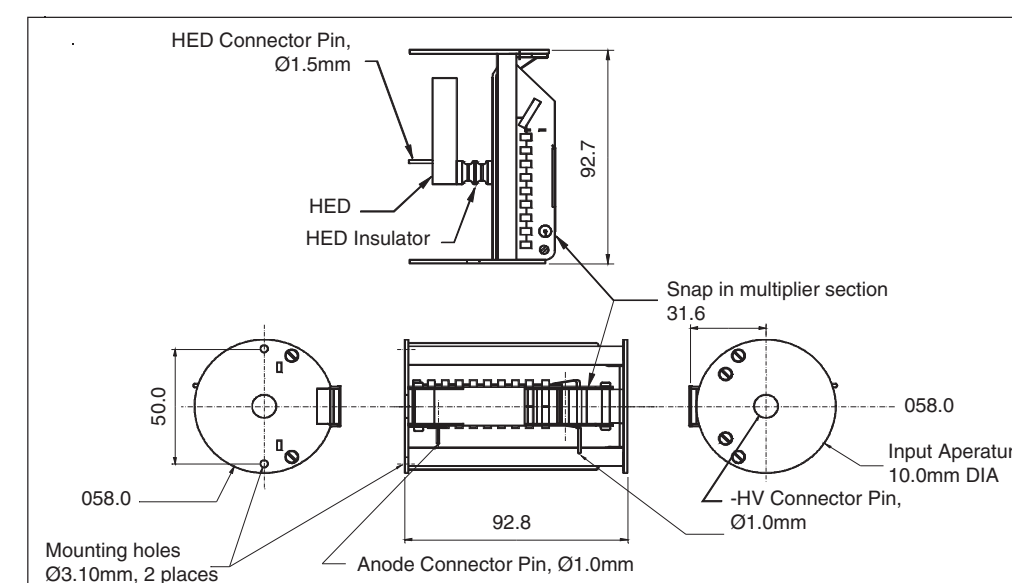


Figure 6. Mechanical specifications of DM283 large-area HED detector for ion trap and high-mass quadrupole applications.