

ION DETECTORS FOR MASS SPECTROSCOPY



HAMAMATSU

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Introduction

Recently, progress in mass spectroscopy (MS) techniques such as GC-MS and LC-MS has been increasing remarkably. This makes mass spectroscopy more useful as analytical equipment in a variety of fields including environment, industry and medical applications. To come up with this trend, ion detectors such as channel electron multipliers, electron multipliers and microchannel plates have also been improved in various technical respects.

We have poured our advanced photonics technologies and experiences to research into "more ideal ion detectors" for mass spectroscopy, and have developed "positive ion detectors" that are completely new and innovative in terms of long service life, high sensitivity and ease of use. We have especially focused our research work on GC-MS and LC-MS positive ion detectors. As a result, we now offer 2 types of positive ion detectors that are respectively designed to enhance the features of GC-MS and LC-MS.

GC-MS and LC-MS Positive Ion Detectors R5150-60 and R5150-70



Left: R5150-70, Right: R5150-60 (Flange is Option)

Optimized ion and electron trajectories

The R5150-60 and R5150-70 were designed to have optimized ion and electron trajectories. To ensure a high S/N ratio during measurements of even minute amounts of a sample, a special 3D simulation technique was used to design these detectors. Based on simulation results, the conversion dynode and electron multiplier positions and shapes were precisely designed and assembled to achieve high sensitivity that exceeds a detection efficiency of 90%.

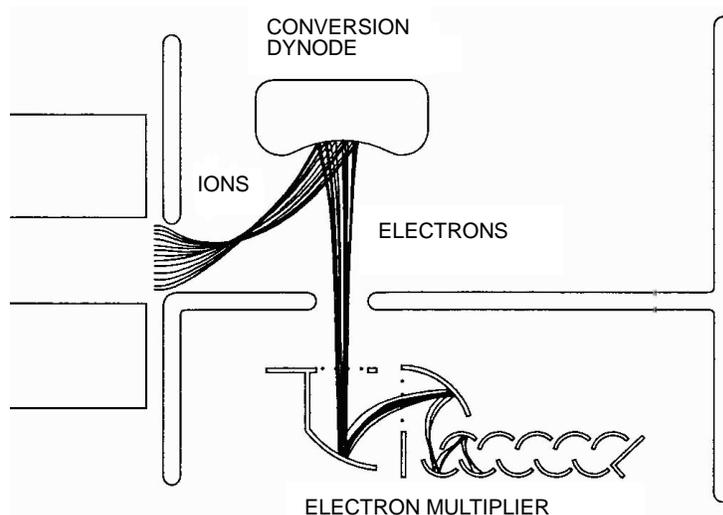


Figure 1: Ion and electron trajectories

Figure 1 shows the ion and electron trajectories in the R5150-60 and R5150-70 ion detectors. Positive ions emitted from the Q-pole are focused by the electron lens, which is formed by a conversion dynode applied with a high negative voltage, and accelerated onto the conversion dynode. When ions strike the conversion dynode, electrons are released from the surface of the conversion dynode by the input energy of the positive ions and then guided into the electron multiplier where electrons are multiplied with high sensitivity.

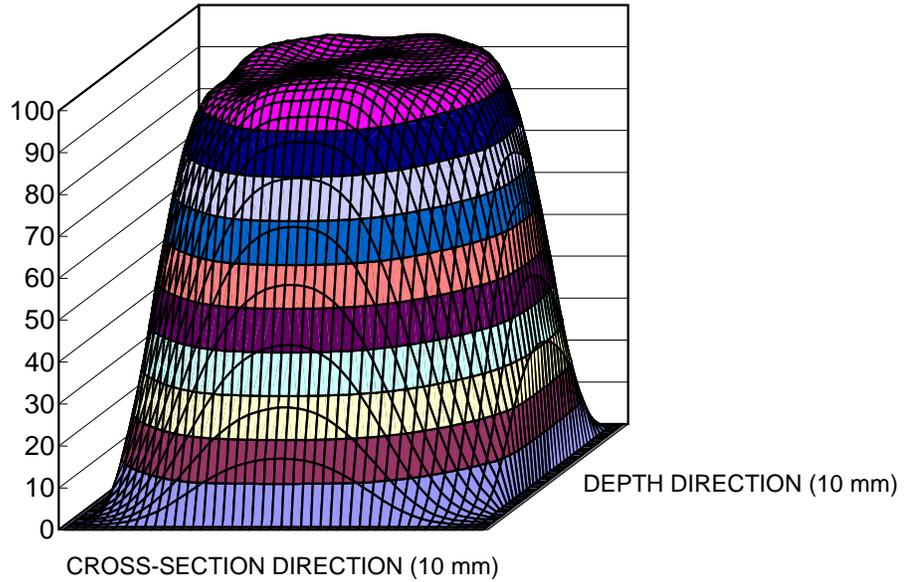


Figure 2: Spatial uniformity of positive ions landing on conversion dynode

To detect minute amounts of positive ions with high sensitivity, positive ions emitted from the Q-pole must be efficiently guided onto the conversion dynode. Special 3D simulation was used to efficiently focus and detect all positive ions even if they enter from different positions of the ion beam input aperture. As Figure 2 shows, R5150-60 and R5150-70 ion detectors provide good spatial uniformity for the positive ions landing on the conversion dynode. This excellent uniformity ensures high detection efficiency which is an essential factor in detecting small amounts of positive ions.

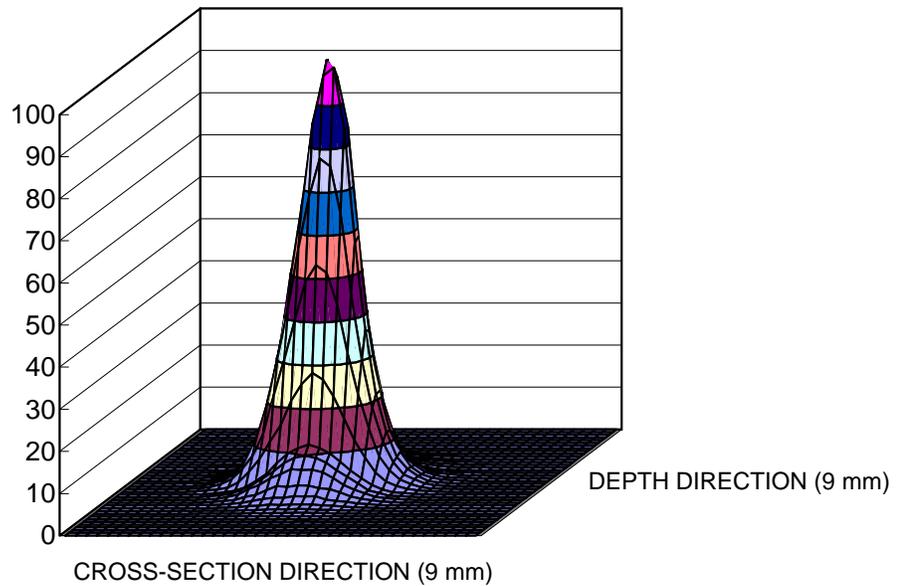


Figure 3: Electrons efficiently focused onto the first stage of electron multiplier

Another important factor for detecting minute amounts of positive ions with high sensitivity is high multiplication of electrons that are released from the conversion dynode. As shown in Figure 3, our special 3D simulation also allows designing an optimum electron lens by a precise combination of the conversion dynode applied at a high negative voltage and the high-sensitivity electron multiplier, so that electrons released from the conversion dynode are efficiently focused onto the electron multiplier. This means that the electrons land on the first stage of the electron multiplier in the form of “pin-point”. This “pin-point” landing of electrons delivers high sensitivity when detecting positive ions.

Unprecedented high sensitivity

Greatly high sensitivity was achieved by an electrode design that allows applying a high voltage to a conversion dynode to increase the input ion energy. Sensitivity was further enhanced by using optimized ion and electron trajectories to achieve a peak intensity even when detecting only small amounts of a sample. The R5150-60 and R5150-70 are also designed to minimize detection of noise components generated from the ion source, so the base line noise level has now shrunk to an acceptable level.

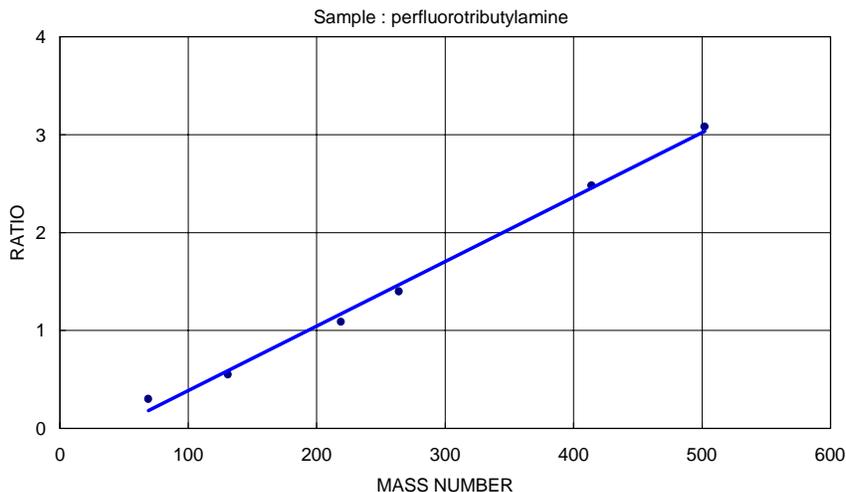


Figure 4: Mass sensitivity improvement in conversion dynode

Figure 4 shows the ratio of the signal level obtained with the R5150-60 (or R5150-70) versus the signal level obtained with a conventional electron multiplier, using perfluorotributylamine as a sample. Providing the R5150-60 (or R5150-70) with a conversion dynode clearly delivers a higher signal level than conventional electron multipliers, especially on the high mass number side.

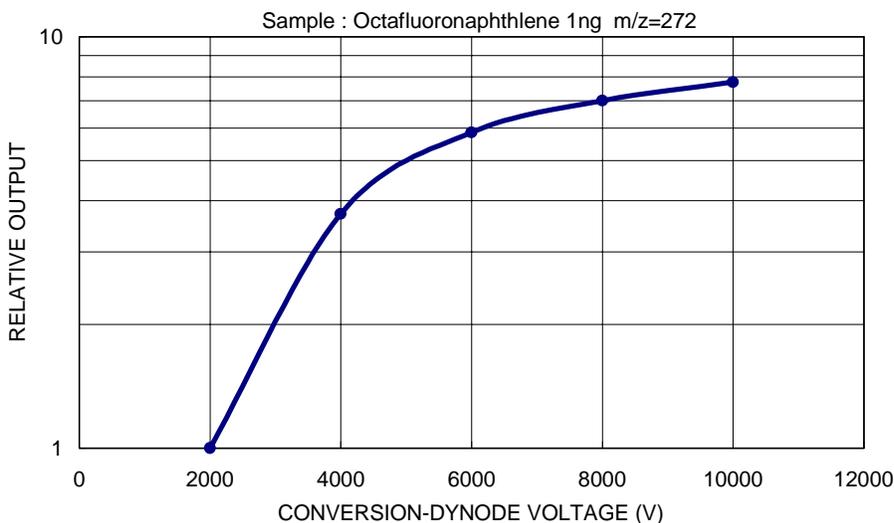


Figure 5: Relative output vs. conversion dynode voltage

As can be seen from Figure 5, the output signal level rises as the conversion dynode voltage is increased. This is because increasing the conversion dynode voltage enhances the collection efficiency of positive ions emitted from the Q-pole and also the ion-to-electron conversion efficiency at the conversion dynode. We recommend operating the R5150-60 and R5150-70 at around -7 kV.

Experimental Parameters

Column: HP5
 ID: 30 m x ϕ 0.32
 Film Thickness: 0.25 μ m
 Initial Temp.: 60°C, 2 min.
 Program Rate: 10°C/min.
 Final Temp.: 300°C, 5 min.
 Injection Temp.: 200°C
 Injection Volume: 1 μ l
 Interface Temp.: 250°C
 Ion Source: EI
 Ion Source Temp.: 140°C
 Scan m/z: 50 to 300
 Scan Time: 500 ms
 Conversion Dynode Voltage: -10 kV
 Electron Multiplier Voltage: -1.3 kV

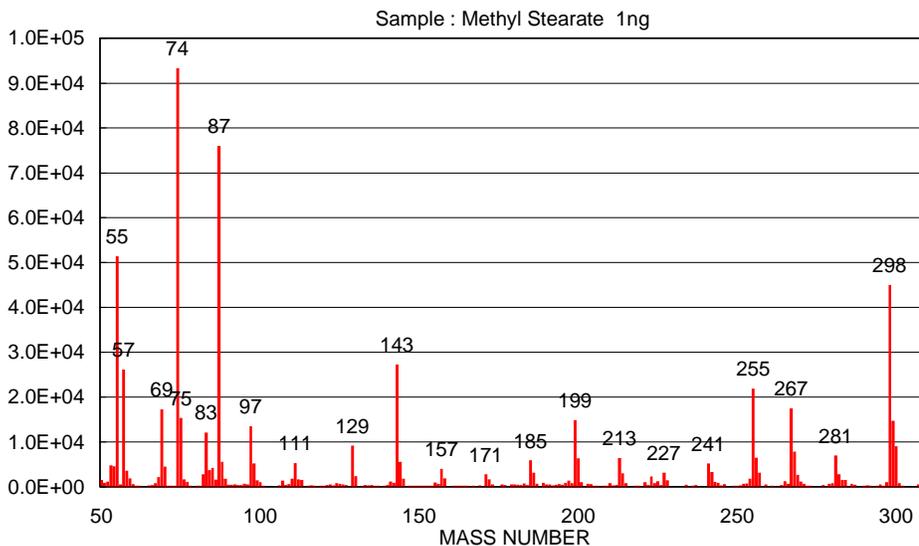
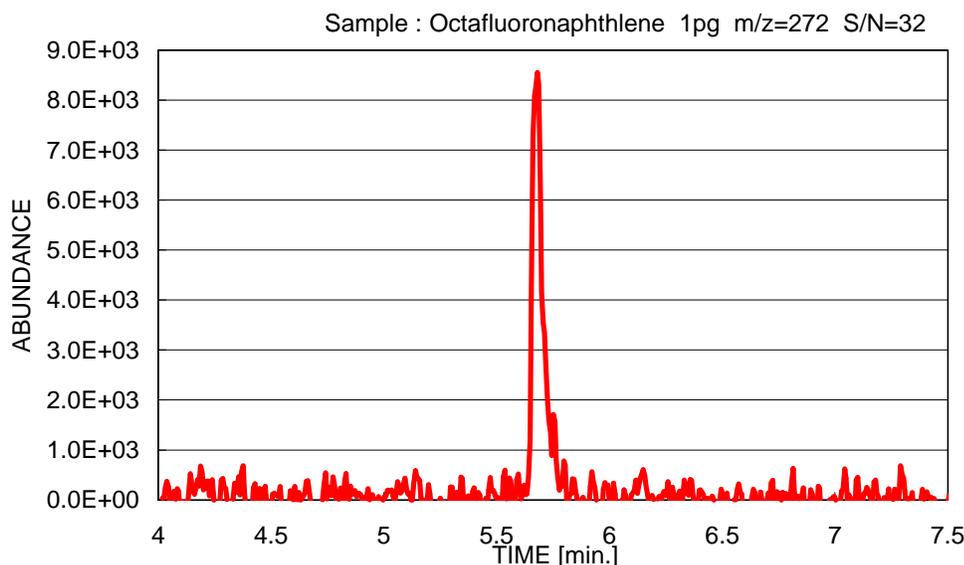


Figure 6: Mass spectrum of methyl stearate



Experimental Parameters

Column: HP5
 ID: 30 m x ϕ 0.32
 Film Thickness: 0.25 μ m
 Initial Temp.: 70°C, 2 min.
 Program Rate: 30°C/min.
 Final Temp.: 300°C, 5 min.
 Injection Temp.: 250°C
 Injection Volume: 1 μ l
 Interface Temp.: 250°C
 Ion Source: EI
 Ion Source Temp.: 150°C
 Scan m/z: 50 to 300
 Scan Time: 500 ms
 Conversion Dynode Voltage: -10 kV
 Electron Multiplier Voltage: -1.3 kV

Figure 7: Sensitivity of octafluoronaphthlene 1pg

Since the R5150-60 and R5150-70 are designed by use of special 3D simulation to optimize the ion and electron trajectories, positive ions emitted from the Q-pole can be detected with great reliability. A high-intensity molecular ion peak can also be obtained by applying a high negative voltage to the conversion dynode. This enables measurement of minute amounts of a sample down to 1 pg with a high S/N ratio.

Simple and easy replacement of electron multiplier

The electron multiplier section, which gradually deteriorates with operation, can be easily replaced. A metal cover is attached to the electron multiplier section to prevent accidental damage to or unwanted contact with wiring during replacement work. This cover allows easy replacement of the electron multiplier which gradually deteriorates with continued operation.



Specifications

Parameter	R5150-60	R5150-70
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Conversion Dynode

Maximum Operating Vacuum Level	Below 1×10^{-2} Pa	
Maximum Supply Voltage (DC)	-10000 V	-7000 V

Electron Multiplier

Maximum Operating Vacuum Level	Below 1×10^{-2} Pa
Maximum Multiplication at 1500 V	1×10^5
Maximum Operating Multiplication	1×10^8
Maximum Supply Voltage (DC)	-3000V
Total Built-in Resistor Value	Approx. 18.5 M Ω
Number of Dynode Stages	14

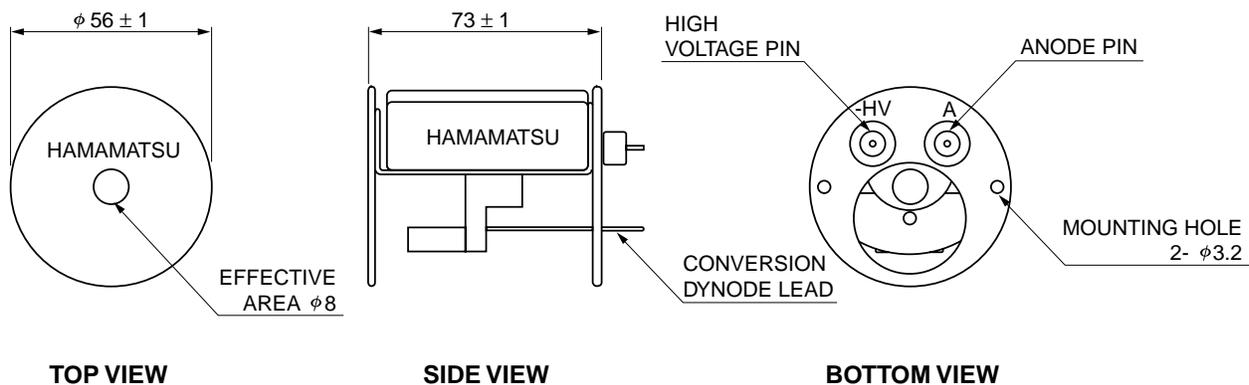


Figure 8: R5150-60 Dimensional Outlines (Unit: mm)

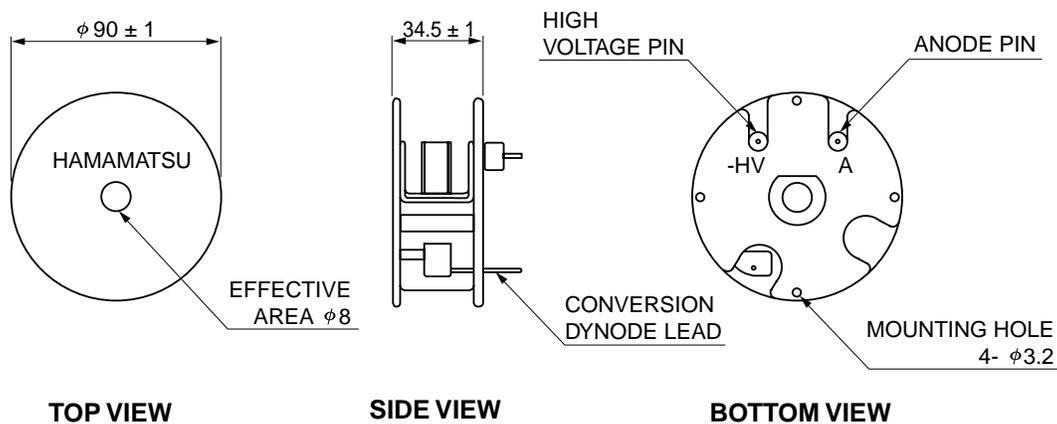


Figure 9: R5150-70 Dimensional Outlines (Unit: mm)

The R5150-60 and R5150-70 are standard types of Hamamatsu R5150 series ion detectors using a conversion dynode. We welcome any special requests you may have for modifying the R5150 series ion detectors to match applications on your mass spectrometer.

LC-MS Positive Ion Detector H8285



Longer service life, yet high sensitivity

Ion detector service life depends greatly on output current magnitude and ambient conditions. In particular, the service life of ion detectors tends to drastically shorten when used in LC-MS. The H8285 ion detector was specially designed to eliminate this problem of short service life, making it ideal for LC-MS applications. The H8285 has a conversion dynode that efficiently converts input ions into electrons. These electrons are then guided to strike the phosphor surface where they are converted into light. This light is then detected and amplified by a photomultiplier tube with a unique vacuum envelope. These design features ensure that the H8285 ion detector will have a long service life.

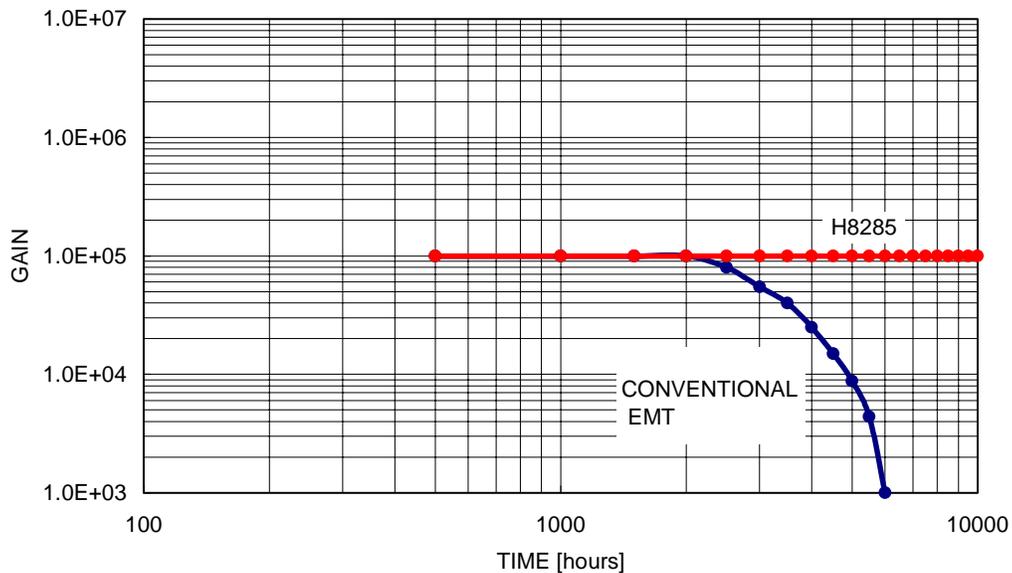


Figure 10: Life Characteristics

Optimized ion and electron trajectories for efficient electron-to-light conversion

The H8285 was designed to have optimized ion and electron trajectories. To obtain a high S/N ratio when measuring even minute amounts of a sample, a special 3D simulation technique was used to design the H8285. Based on the simulation results, the conversion dynode and phosphor screen positions and shapes were precisely designed and assembled to ensure efficient electron-to-light conversion.

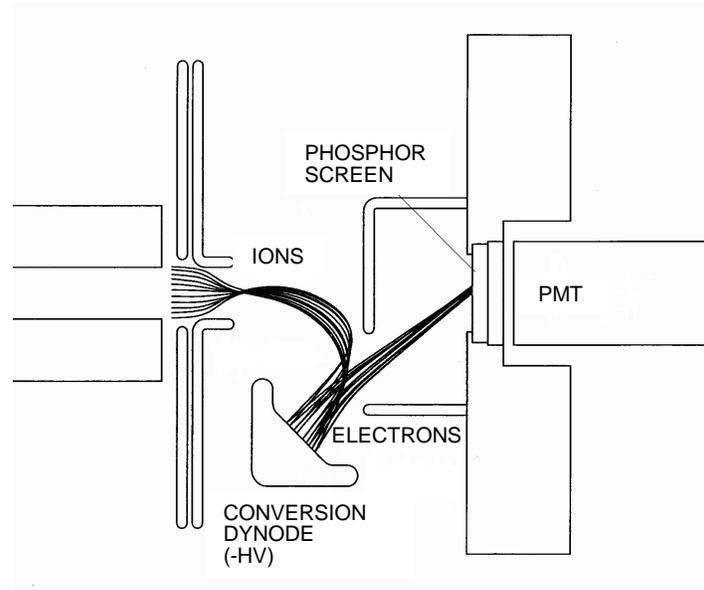


Figure 11: Ion and Electron Trajectories

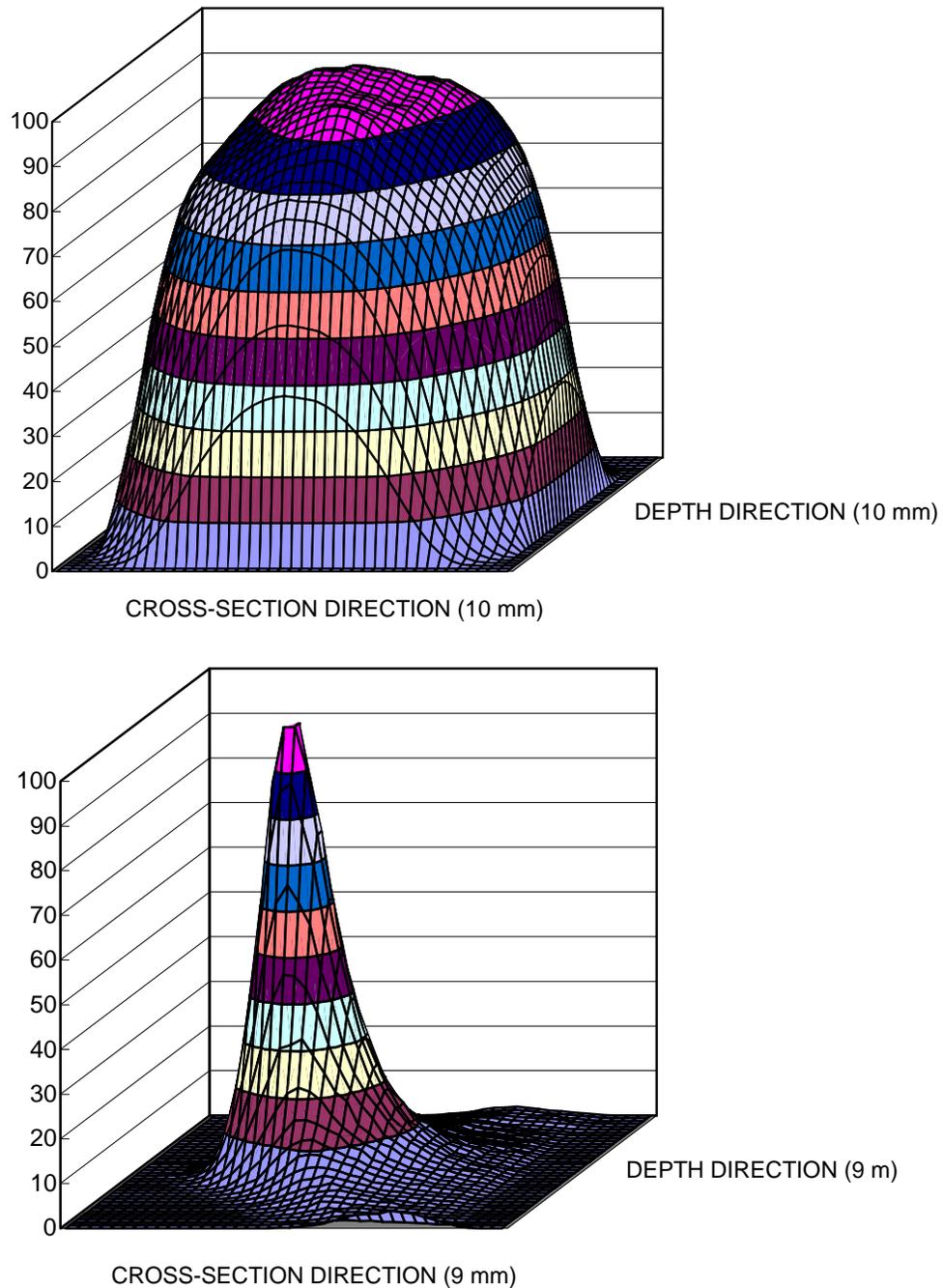


Figure 12: Spatial uniformity on the conversion dynode and phosphor screen

To detect minute amounts of positive ions with high sensitivity using the H8285, it is necessary to guide positive ions emitted from the Q-pole efficiently onto the conversion dynode and also onto the phosphor screen. The H8285 was designed by using special 3D simulation so that almost all positive ions entering from the ion beam aperture are guided onto the conversion dynode and electrons released from the conversion dynode are then accelerated to strike the phosphor screen in the form of a “pin-point”.

Unprecedented high sensitivity

Greatly improved sensitivity was achieved especially for high mass numbers thanks to an electrode design that allows applying a high voltage to a conversion dynode to increase the input ion energy. Sensitivity was further enhanced by using optimized ion and electron trajectories to achieve a peak intensity even when detecting only small amounts of a sample.

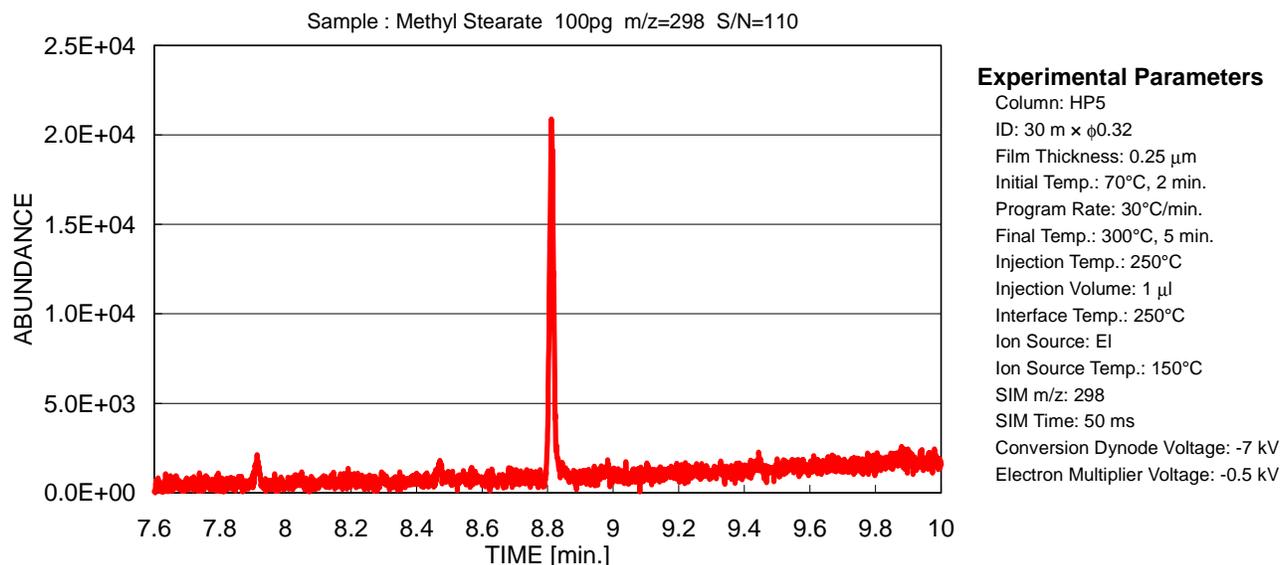


Figure 13: Sensitivity of methyl stearate 100 pg

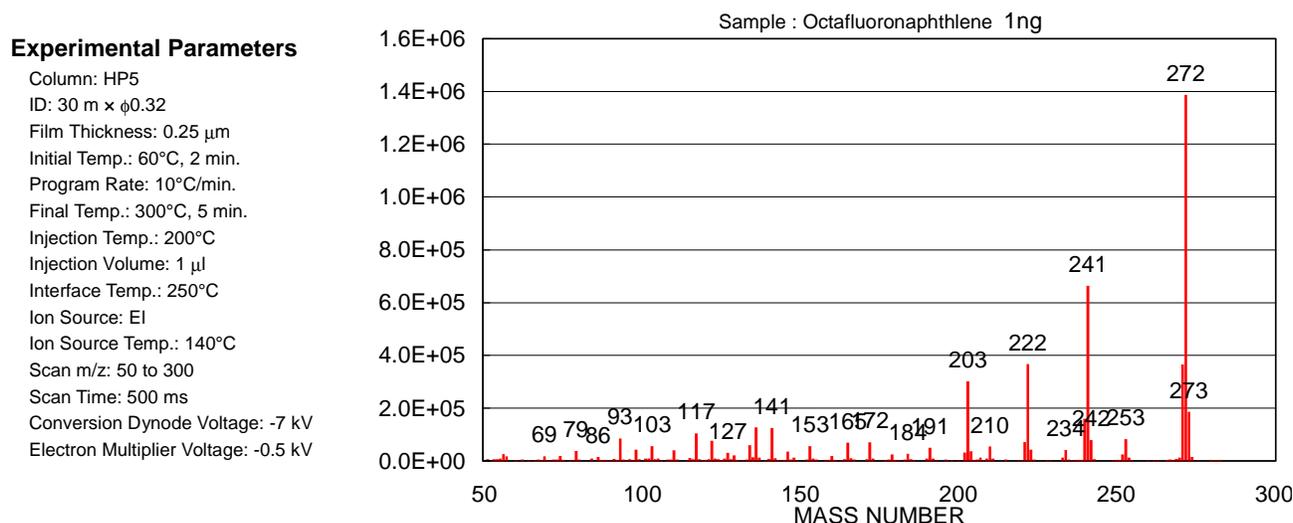


Figure 14 : Mass spectrum of octafluoronaphthlene 1 ng

We evaluated our special 3D detector design by using actual GC mass spectroscopic techniques . The data obtained was a good match with the simulation results as shown in Figures 13 and 14. This proves that the H8285 ion detector delivers high performance as an ion detector in LC-MS applications.

Easy-to-use vacuum flange assembly

The H8285 has a vacuum flange on which a conversion dynode, phosphor screen and photomultiplier are mounted in the optimized arrangement. This eliminates troublesome positioning alignments. The H8285 easily attaches to equipment to allow high sensitivity measurements.

Specifications

Conversion Dynode

Maximum Operating Vacuum Level	Below 1×10^{-2} Pa
Maximum Supply Voltage (DC)	-7000 V

Photomultiplier

Averaged Maximum Output Current	25 μ A at -1000 V
Maximum Supply Voltage (DC)	-1000 V
Total Built-in Resistor Value	Approx. 2 M Ω

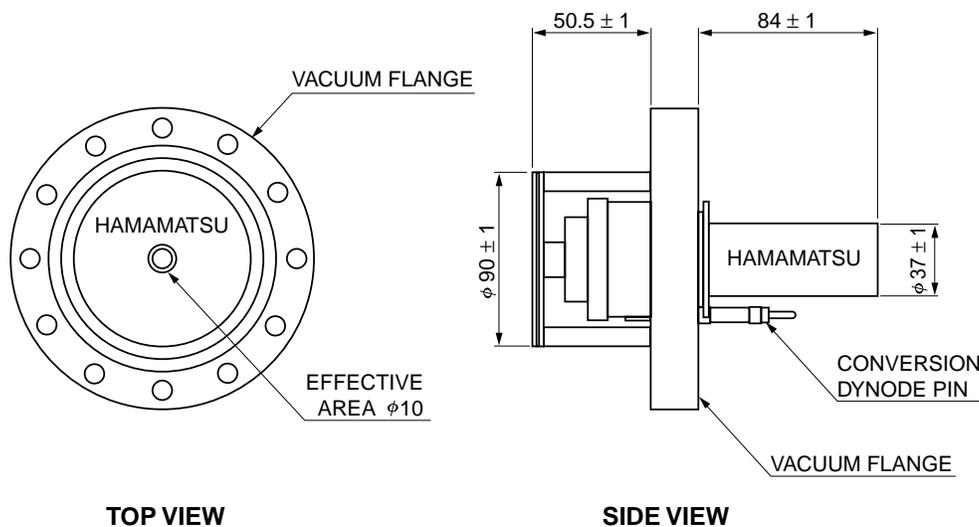


Figure 15: H8285 Dimensional Outlines (Unit: mm)

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