A PORTABLE UNIVERSAL HAZARDOUS GAS DETECTOR

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ABSTRACT

Experimental work on the Miniature Mass Spectrometer (MMS) at JPL has resulted in a "table top" configuration with a CCD detector that has demonstrated a detection limit of 50 parts per billion. The CCD detector operates at ambient temperature.

Intelligent Ion, Inc., a commercial instrument developer, has taken out a license on the JPL technology and has built a prototype using a Faraday Cup Array detector as a placeholder detector. The prototype instrument was tested at Kennedy Space Center and demonstrated detection limits in the parts per million range. The test results are presented as well as detailed photographs of the prototype instrument.

A presentation of the MMS was made to an expert review panel for "On-Board Environmental Monitoring Systems for the International Space Station (ISS)." The scores obtained by the MMS system are presented.

The prototype instrument will be retro fitted with a CCD array detector in August 2004 and will again be tested at KSC. The instrument is expected to show a detection level for hydrazines of 10 ppb and a detection level for solvents below 10 ppb.The expectations are based on raw data from the first batch of CCD's that was tested.

INTRODUCTION

JPL has conducted studies on the safety aspects of fueling spacecraft in highbay environments with Hydrazine type fuels (1, 2). One topic was the potential replacement of SCAPE suits with less-restrictive Splash type suits while maintaining safety. It was apparent that a portable sensitive Hydrazine detector with instant response was needed for such a change to be feasible.

A primary need in this area is a portable instrument that can measure the regulatory limit of 10 parts per billion of Hydrazine type fuels in highbay environments with instant response. Such an instrument is not available today.

JPL carried out a survey of potential new instrument concepts (3). The survey identified a Miniature Mass Spectrometer (MMS) as a viable candidate for development to meet the requirements of portability, 10 ppb detection limits, instant response, low maintenance and reasonable cost.

A Miniature GC/MS was developed by Mahadeva Sinha at JPL (4). The Gas Chromatograph (GC) part does not provide an instant response, as it takes time for a sample to absorb on and desorb from the GC column material. Therefore the GC part of the instrument can be dropped to obtain an instant response. It was decided to further develop the MMS to improve the detection limits to below 10 parts per billion.

The MMS is a focal plane mass spectrometer and was miniaturized by using new materials for the magnet and by the use of a photon array detector, utilizing a linear array charge-coupled device (CCD). The MMS is projected to meet 10 ppb sensitivity. One reason for the improved sensitivity is the use of the CCD detector as the noise levels on such detectors are very low. Another reason for improved sensitivity is it's non-scanning operation: the instrument looks at all compounds continuously. Thus the signal for a given compound can be integrated over time, from 1 to 10 seconds, to arrive at a more accurate signal.
The MMS can be used as a portable, instant response instrument for many applications. As such, it has the potential to be a Universal Hazardous Gas Detector.

GOALS AND OBJECTIVES

The Jet Propulsion Laboratory (JPL), Kennedy Space Center (KSC) and Johnson Space Center (JSC) signed a Memorandum Of Understanding (MOU) to jointly develop and build a prototype Miniature Mass Spectrometer (MMS). The MOU refers to the interests and unique capabilities of the partners. The various partner tasks have been assigned as follows:

- JPLL -Overall Lead Center. Design and build the MMS.
- KSC -Perform preliminary and comprehensive performance tests.
- JSC -Requirements documentation. Space qualification.

The goals of the task are to develop a

- MMS for Hydrazine detection that is:

–capable of detecting a minimum of 10ppb in air
–is portable
–has an immediate response
–has an acceptable cost
–has low maintenance

and to develop

- a MMS that has the potential to be used in various applications as a Universal Hazardous Gas Detector.

PROTOTYPE INSTRUMENT TEST RESULTS

Development work at JPL in FY 03 on the MMS technology improved the detection limit to 50 ppb in the "table top" unit at JPL, using an experimental CCD detector.

A Caltech patent was issued on the JPL new technology and Intelligent Ion, Inc, an instrument developer, was licensed to develop the new technology for commercial applications.
Intelligent Ion then built a prototype instrument with a placeholder detector (Faraday Cup Array) instead of the CCD detector while the latter is being manufactured.

The prototype Instrument of Intelligent Ion with the Faraday Cup Array Detector was tested at KSC with the following results

Compound	Concentration Detected (ppm)	Matrix	Signal/noise	Detection limit (ppm)
Acetone	2100	Air	27	12
Toluene	3	Air	66	0.13
MMH	110	Air/Nitrogen	103	7.0
Hz	600	Nitrogen	80	26
UDMH	20	Nitrogen	16	1.3

The detection limits were calculated for a minimum signal at 3x standard deviation.
As indicated, the detection limits are of the order of several ppm. It is expected that the detection limits will be improved by three orders of magnitude when the Faraday Cup Array detector will be replaced with the CCD detector. This prediction is based on the data obtained with the first lot of manufactured CCD's.
Three orders of magnitude improvement should bring the detection limit below 10 parts per billion, one of the goals of this task.

JPL has placed an order for a prototype MMS instrument with the new CCD detector with Intelligent Ion Inc. for a projected delivery time of July 30, 2004.

The unit will then be demonstrated and tested shortly afterwards at KSC.

JSC will conduct a review of the purchased prototype to assess the use of the instrument in space applications.

APPLICATIONS

The potential applications of immediate concern to NASA are:

- Detection of Hydrazine type fuels in a high bay environment during fuel transfers at the 10 ppb level with instant response
- Detection of gases like Hydrogen, Helium, Oxygen, Argon etc. in propellant loading environments and on the Mobile Launch Platform
- Detection of Hydrogen and/or Oxygen in the Aft Section of the Shuttle during launch
- Detection of UDMH, MMH, Ammonia and NTO in the Airlock of the Shuttle and the ISS
- Detection of trace chemicals in the cabin atmosphere of the Shuttle and the ISS

NASA issued a Request for Information (RFI) for On-Board Environmental Monitoring Systems for the International Space Station (ISS). In response, JPL/Intelligent Ion made a presentation to an Expert Review Panel (October 2003 at South Shore Harbour, TX) proposing the Miniature Mass Spectrometer as a candidate.
The following scores were obtained for the MMS system:

–Operation in Spacecraft Environment	13/14
–Instrument Characteristics	19/22
–System Characteristics	11/12
–Compounds	17.5/20
–Instrument Maintainability	8.5/9

As the system obtained excellent evaluations, we plan to work with Intelligent Ion,Inc to respond to an RFP in this area when it issues, possibly in FY 05.

PLANNED FUTURE WORK

The planned work for this task in FY 05 consists of the following subtasks:
1.The second generation CCD will be evaluated by instrument performance tests at KSC. These tests will be followed by tests in the Mass Spectrometry Lab to evaluate the instrument as a HUMS replacement on the Mobile Launch Platform.
2.JSC will continue earlier work on an engineering evaluation of the instrument to establish the requirements for an Engineering Design Unit upgrade of the instrument.
3.JPL will carry out the JSC recommendations to upgrade the instrument. This will include upgrades in the electronics, the mechanical parts and replacing the aluminum case with a stainless steel case.
4.After completion of the upgrades, the instrument will be tested at KSC.
5.Selected environmental tests will be carried out at JSC

6.After the environmental tests the instrument performance will be verified at KSC.
7.The various potential customers will be contacted from time to time to keep them up to date about progress and to find opportunities for future field/flight tests.
8.An RFP for the ISS cabin monitor may be issued during this FY. JPL/Intelligent Ion plan to make a joint proposal to use the prototype MMS with a GC attachment in the ISS.

REFERENCES

(1) Houseman, John and. Patzold, J. D., **" A Comparison of Two Different Approaches to Hydrazine Loading of Spacecraft, the Use of SCAPE and Alternate Approaches"**, Proceedings of the JANNAF 17th Safety and Environmental Protection Subcommittee Meeting, JANNAF, San Diego, CA, (April 1999).

(2) Brown, Pamela R., Houseman, John, Patzold, Jack D., **Progress Report on "Safe Universal Hydrazine Loading Cart"**, JPL D-16320-1, (September 2000).

(3) Houseman, John, C. R. Webster and Brown, Pamela R., **"Hydrazine Detection with a Tunable Diode Laser Spectrometer",** Proceedings of the JANNAF 17th Safety and Environmental Protection Subcommittee Meeting, JANNAF, San Diego, CA, (April 1999).

(4) Houseman, John and Sinha, M., P.,**"A Miniature Mass Spectrometer for Hydrazine Detection",** Proceedings of the JANNAF 20th Safety and Environmental Protection Subcommittee Meeting", JANNAF, Charlottesville, VA, (March 2003).

Figure 1 Operation of MMS

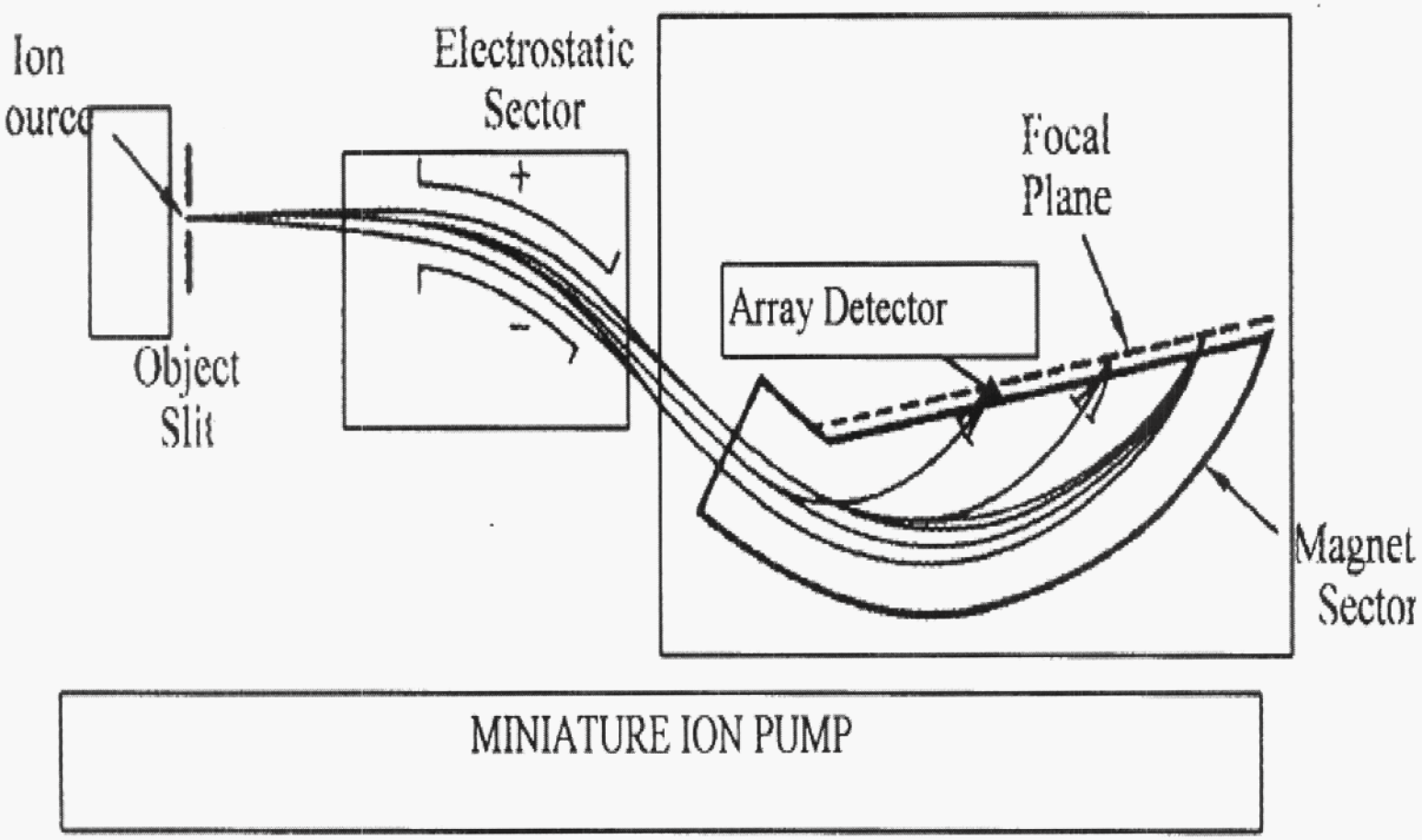

Figure 2 JPL Table-top Research Instrument

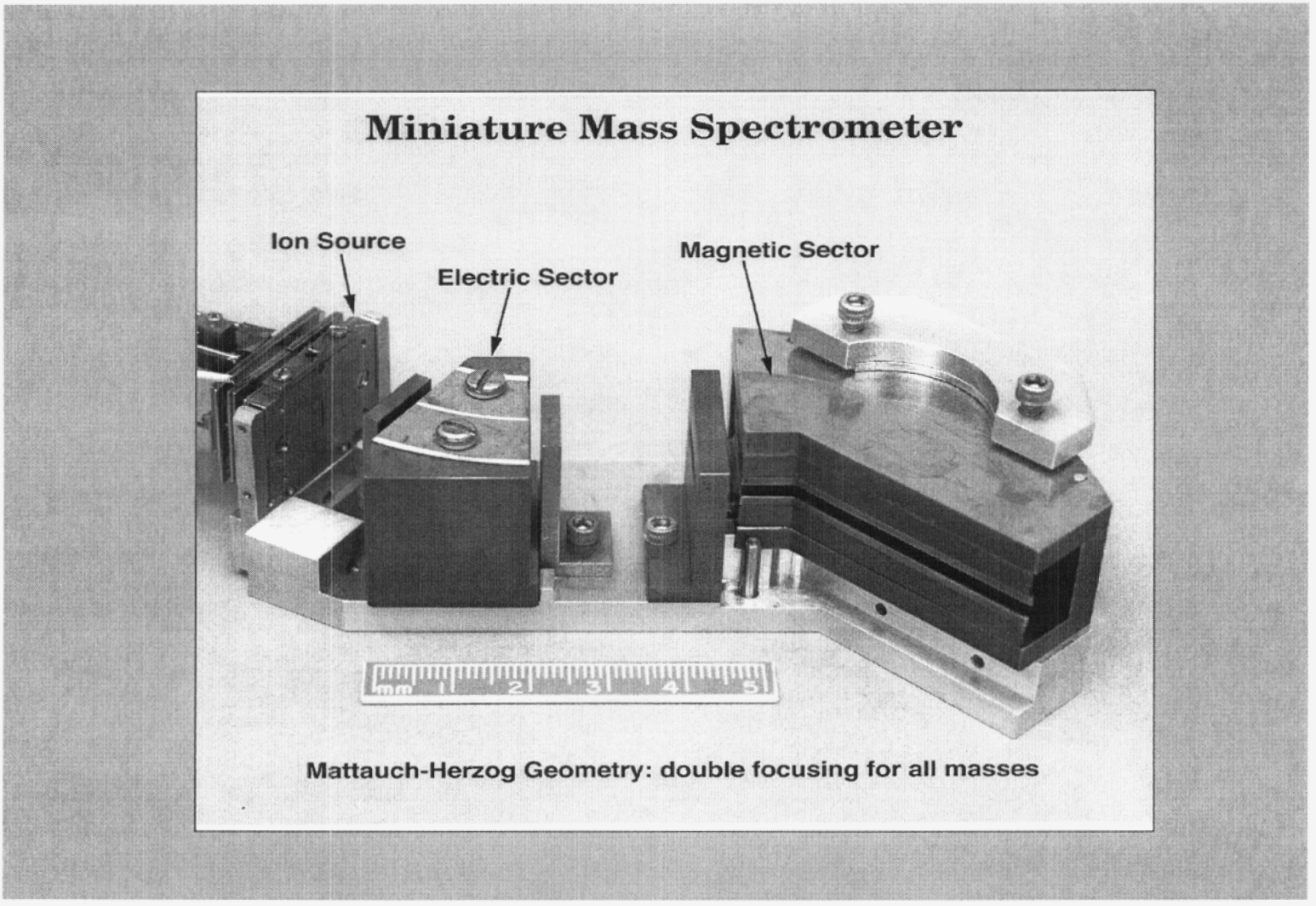

Figure 3 Array Detector

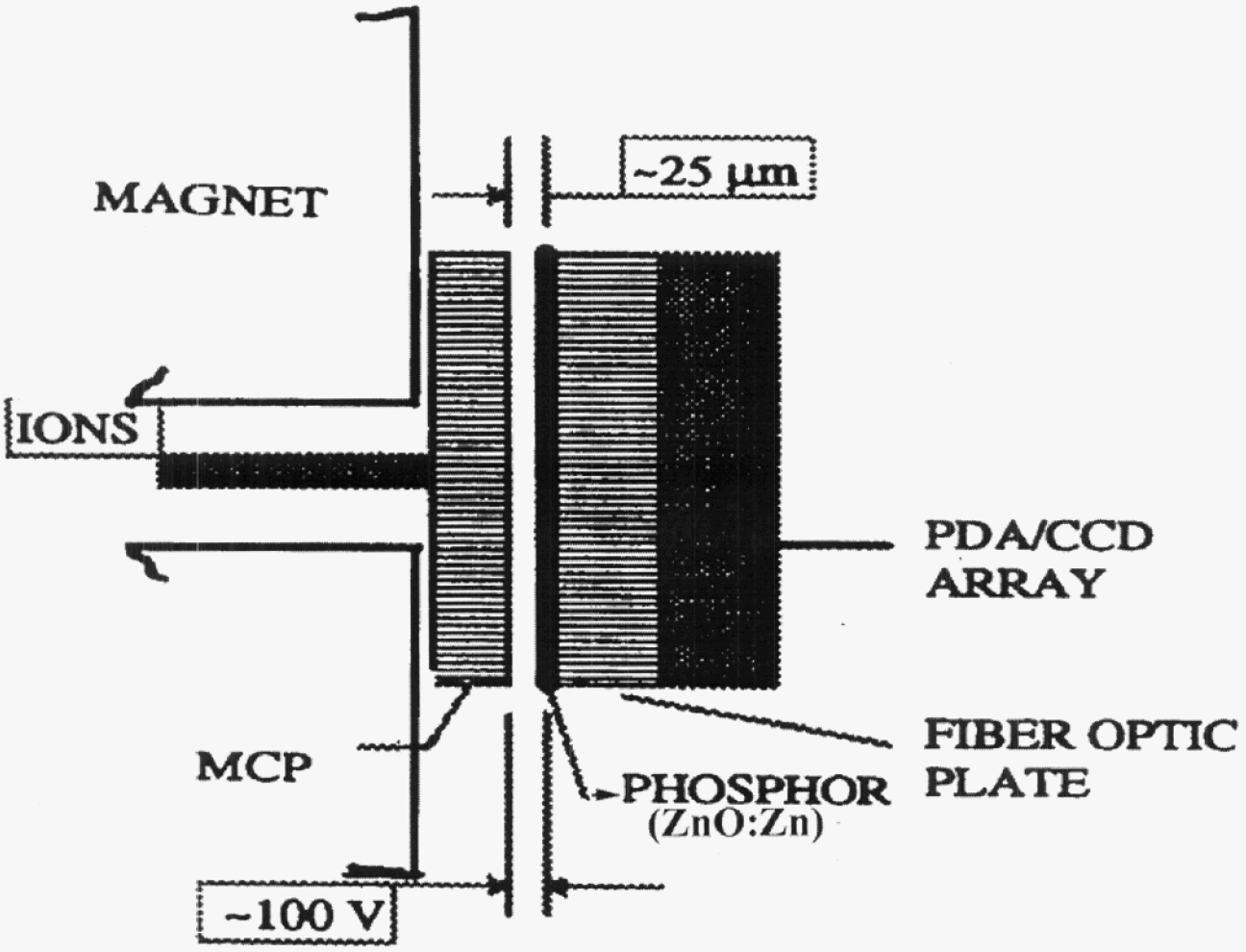

Figure 4 MMS Operating in Bell Jar

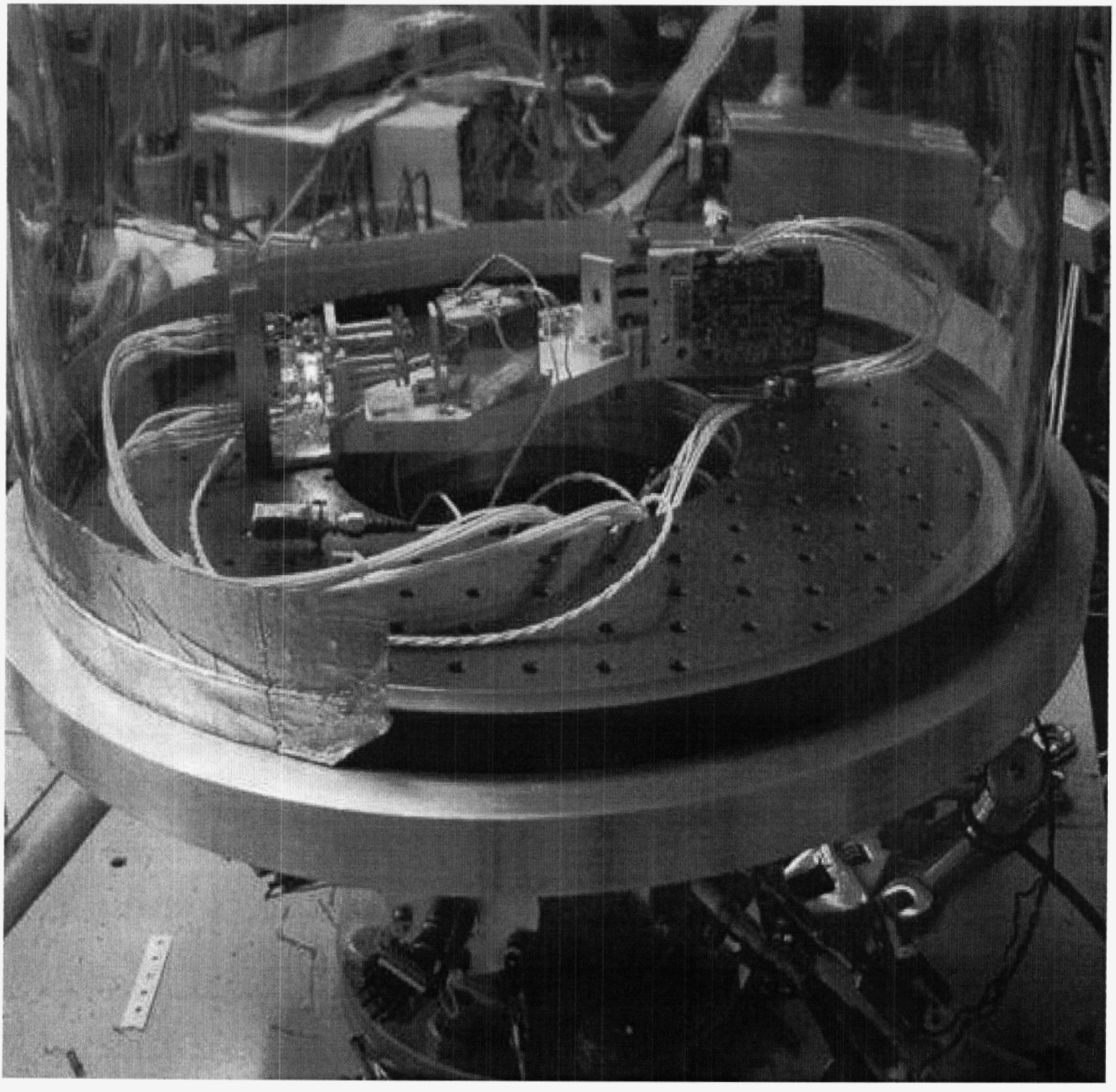

Figure 5 Current Version of the Prototype Miniature Mass Spectrometer

Intelligent Ion, Inc.

Dimensions:
11”H x 8.5”W x 20”D

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