BURLE
ELECTRO-OPTICS

Performance Characteristics of Detectors Operated in Harsh Environments

The HEMS 2005 Conference
Poster Paper

Raymond F. Cochran, Bruce N. Laprade,
Richard Prunier, Lenny Erickson
and William Dunn
BURLE Electro-Optics Inc

Introduction

BURLE ELECTRO-OPTICS

- Mass Spectrometers are a valuable tool for use in demanding applications such as drug discovery, semiconductor manufacturing and food processing. The unique capability of a mass spectrometer to identify minute amounts of unknown materials sets this instrument apart from almost all others.

- The typical Mass Spectrometer has three key components: The ionization source, the mass filter and the detector.

Discussion

BURLE ELECTRO-OPTICS

- Homeland security requirements are now driving the development of field portable instruments that can provide laboratory grade analysis.
- In order to reduce the size, weight and power consumption of a portable mass spectrometer, it is often necessary to deviate from the normal operating environment inside the vacuum system.

Discussion

BURLE ELECTRO-OPTICS

- Operation of High Gain Ion Detectors has traditionally required a vacuum of 10^{-6} Torr or better

- Vacuum systems capable of this performance are large, heavy, costly and consume large amounts of power

- Use of High Gain, Low Noise Detectors that Operate at milli-Torr pressures will permit use of simple, low cost and much lighter weight vacuum systems

Discussion

BURLE
ELECTRO-OPTICS

- The ideal field portable mass spectrometer must:
  - Be small and light weight
  - Operate at milli-Torr pressures or higher
  - Produce high gain and maintain low noise while operating at elevated pressures
  - Exhibit long detector lifetime at elevated pressure
  - Must withstand periodic venting to atmosphere
  - Should tolerate storage at atmospheric pressure

Objective

- The objective of this project was to characterize the performance of various high gain electron multipliers operating at elevated pressures

There are 4 main types of Electron Multipliers:

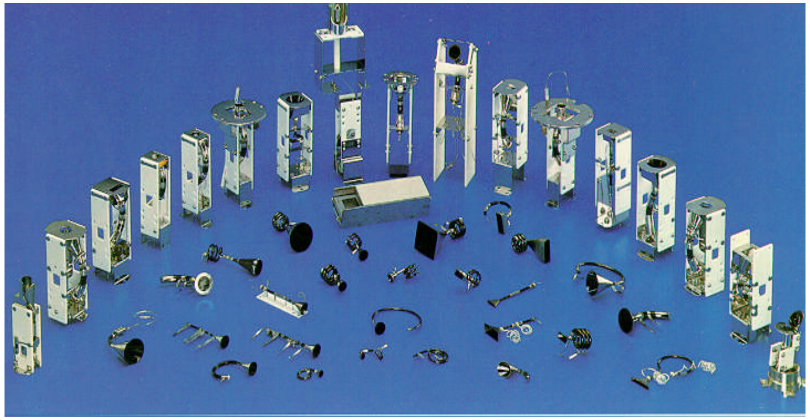
- Single Channel Electron Multipliers (CEMs) (Channeltron®)

-Spiraltron™ CEM Technology

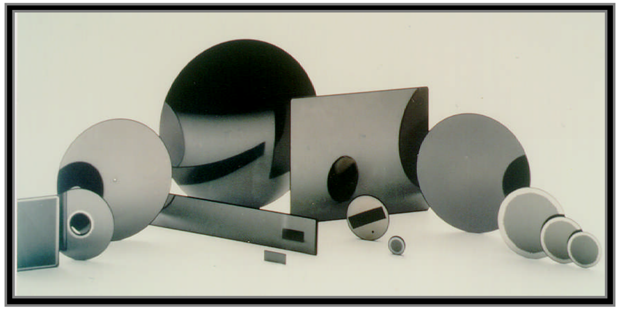
- Microchannel Plate based Detectors

-Discrete Dynode Multipliers

Various Types of Electron Multipliers

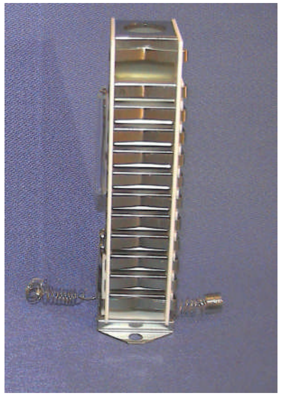


Single Channel Electron Multipliers



Microchannel Plates

Magnum® 6-Channel Multipliers
using Spiraltron™ Technology



Discrete Dynode

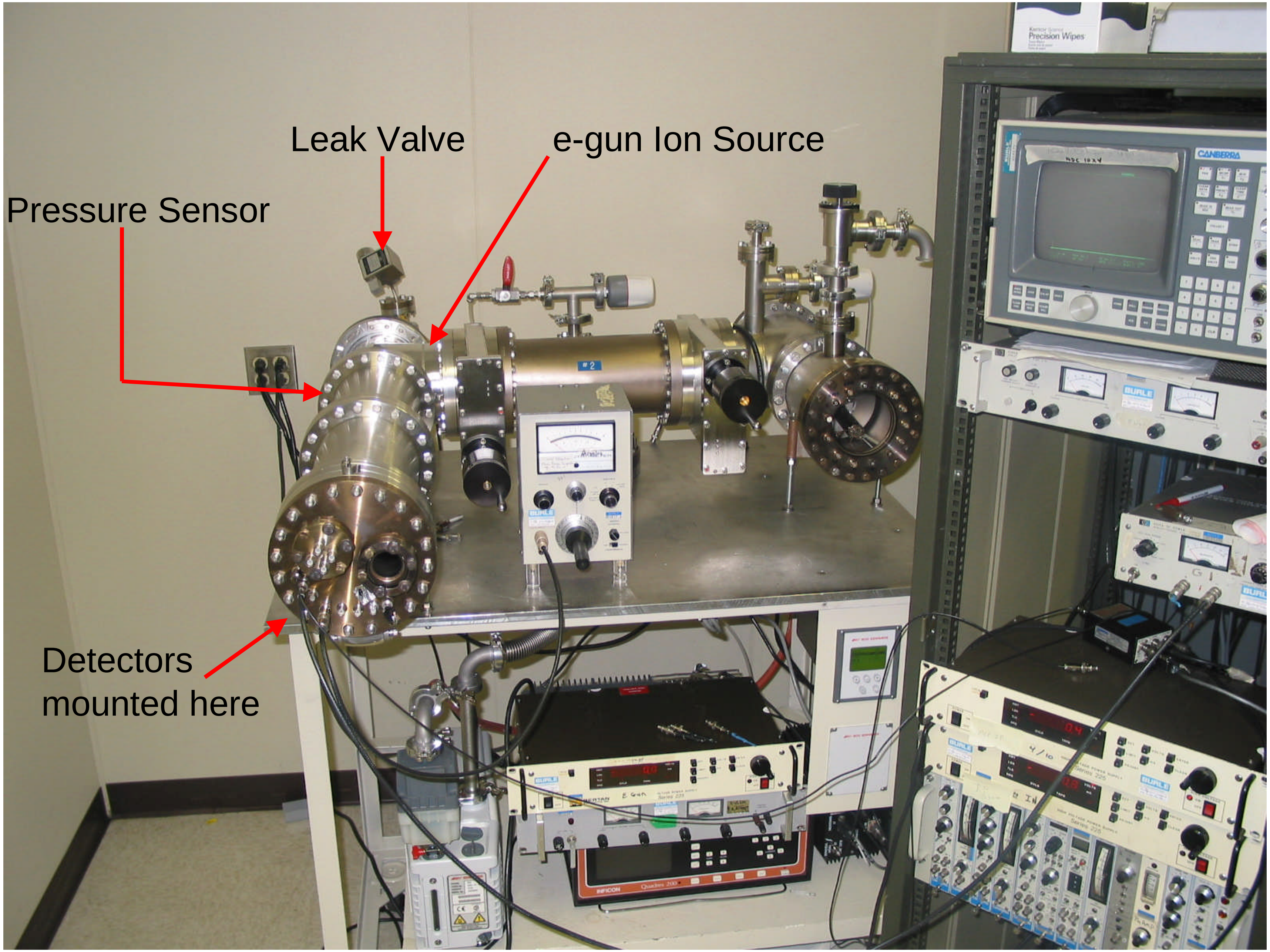
Microchannel Plate Detectors

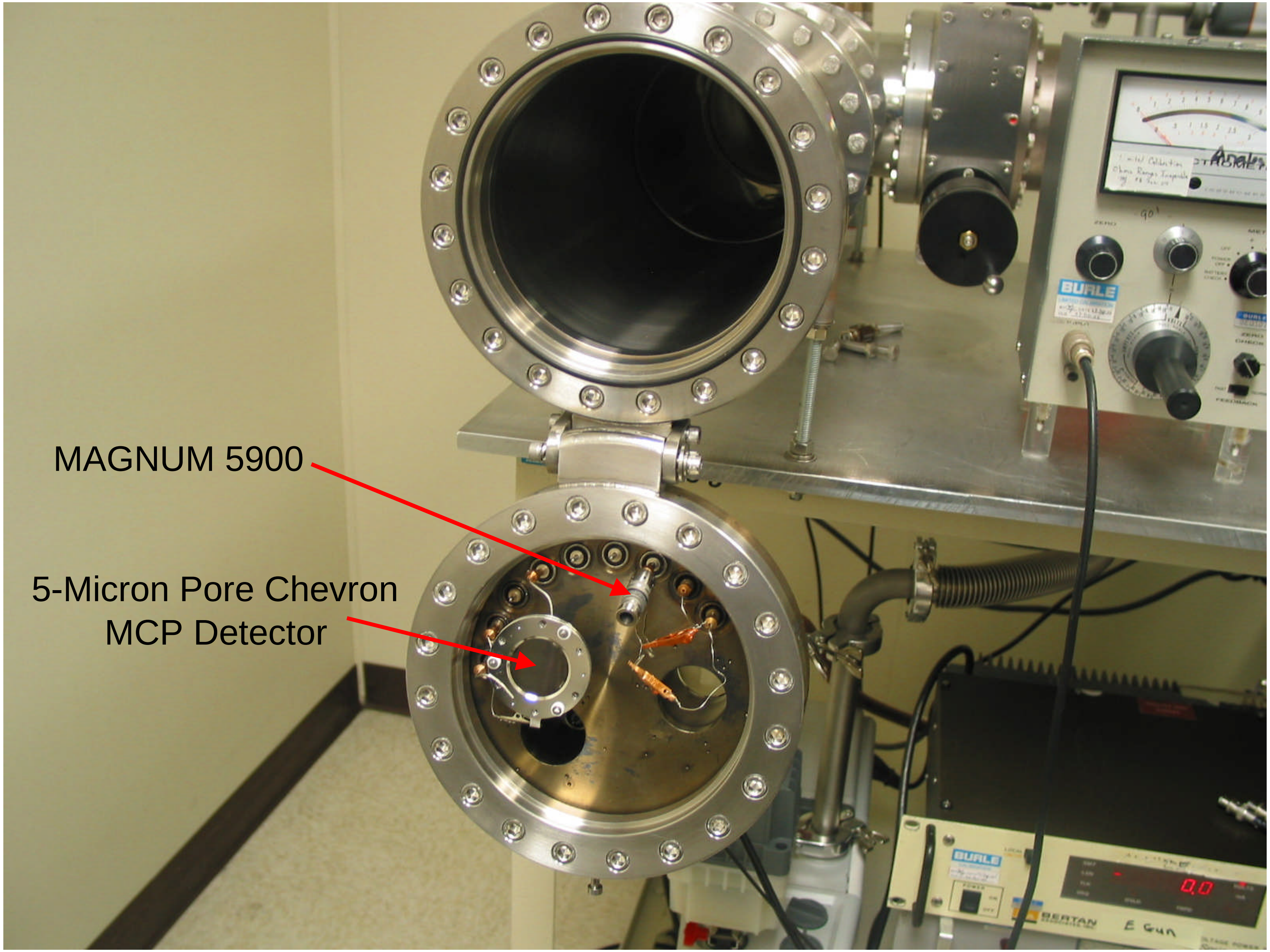
Vacuum Requirements

- Typical MALDI Time-of-Flight Mass Spectrometers require an ion flight path length of 1 to 2 meters.
- Modern quadrupole based instruments typically operate at vacuum pressures in the high 10^{-6} Torr range because ions need to travel 25 cm. or more before they reach the detector without colliding with residual gas molecules.
- If it were possible to shrink the flight path length requirement to less than 5 cm (approx... 2”) then it should be possible to operate a system in the milli-Torr range.
- Milli-Torr vacuum levels can be achieved with simple low cost vacuum pumps.
- Multiplier performance outside of the normal 10^{-6} Torr operating range has not been well characterized.

Experimental Apparatus

- BOC Edwards turbo pumped vacuum chamber
- BOC Edwards Turbo pressure monitoring system was used as Chamber Pressure Monitor.
- Chamber pressure was modulated using a Granville Philips precision leak valve. Chamber was backfilled with lab air.
- Dark current measurements made with Keithley Instruments, Model 600B electrometer.


Leak Valve
e-gun Ion Source
Pressure Sensor
Detectors
mounted here

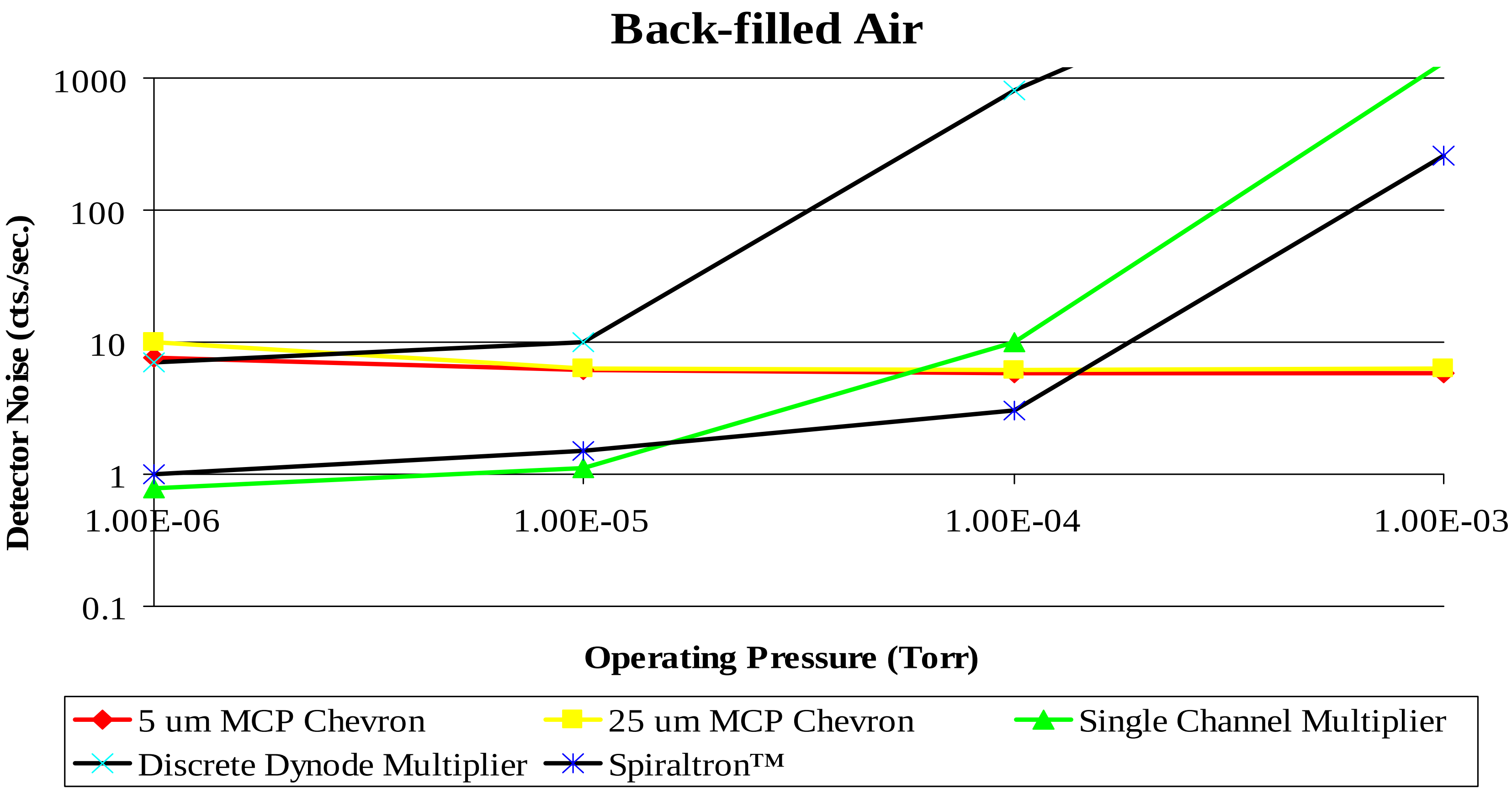

MAGNUM 5900
5-Micron Pore Chevron
MCP Detector
E Gun

The Effects of Poor Operating Pressure on Multiplier Performance and Lifetime

Historical Data

ELECTRO-OPTICS

Noise vs. Operating Pressure For Various Electron Multipliers



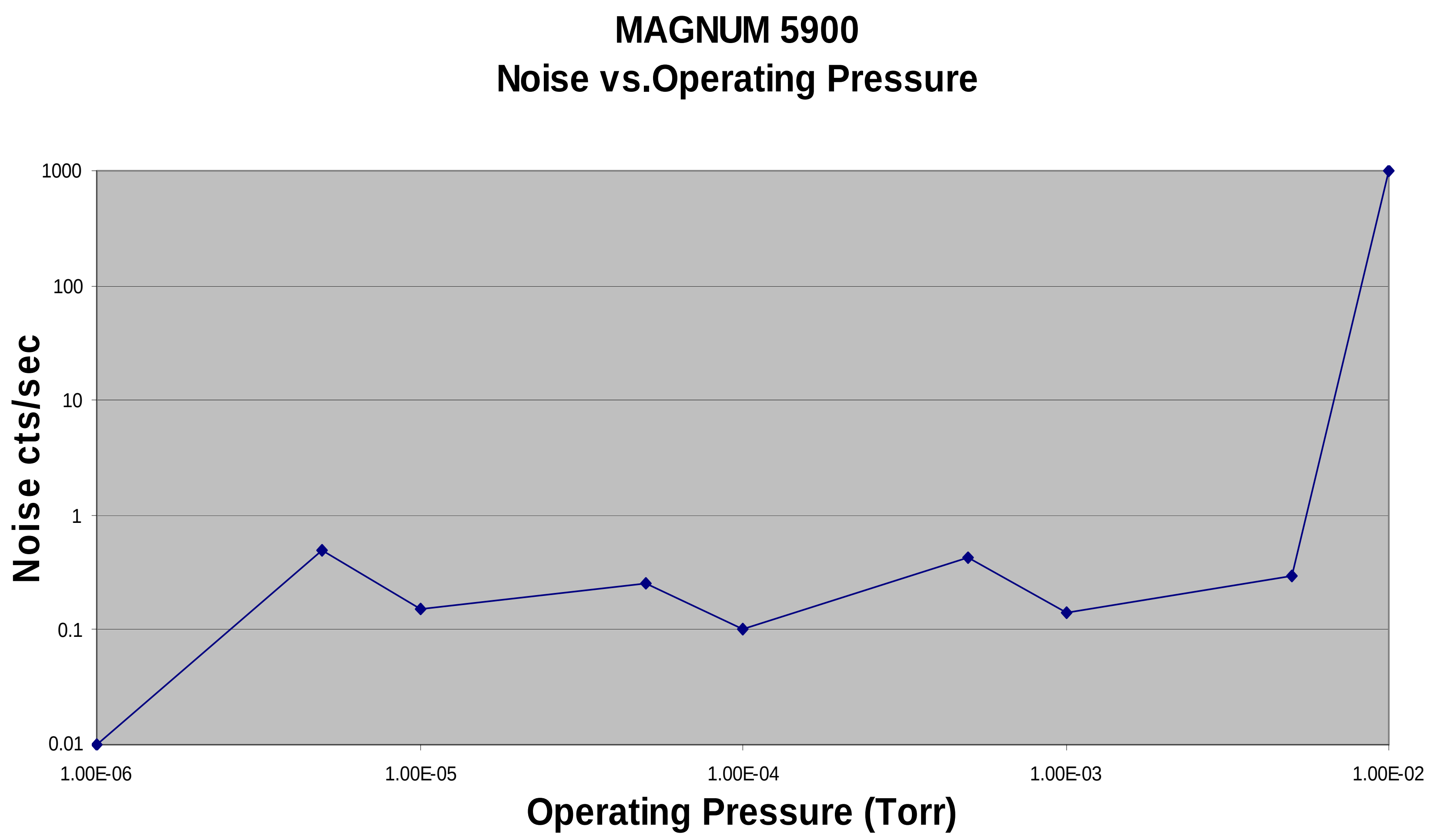
Ref. Characterization of Common Electron Multipliers in Harsh Environments; Pittcon 2005; Bruce Laprade & Ray Cochran

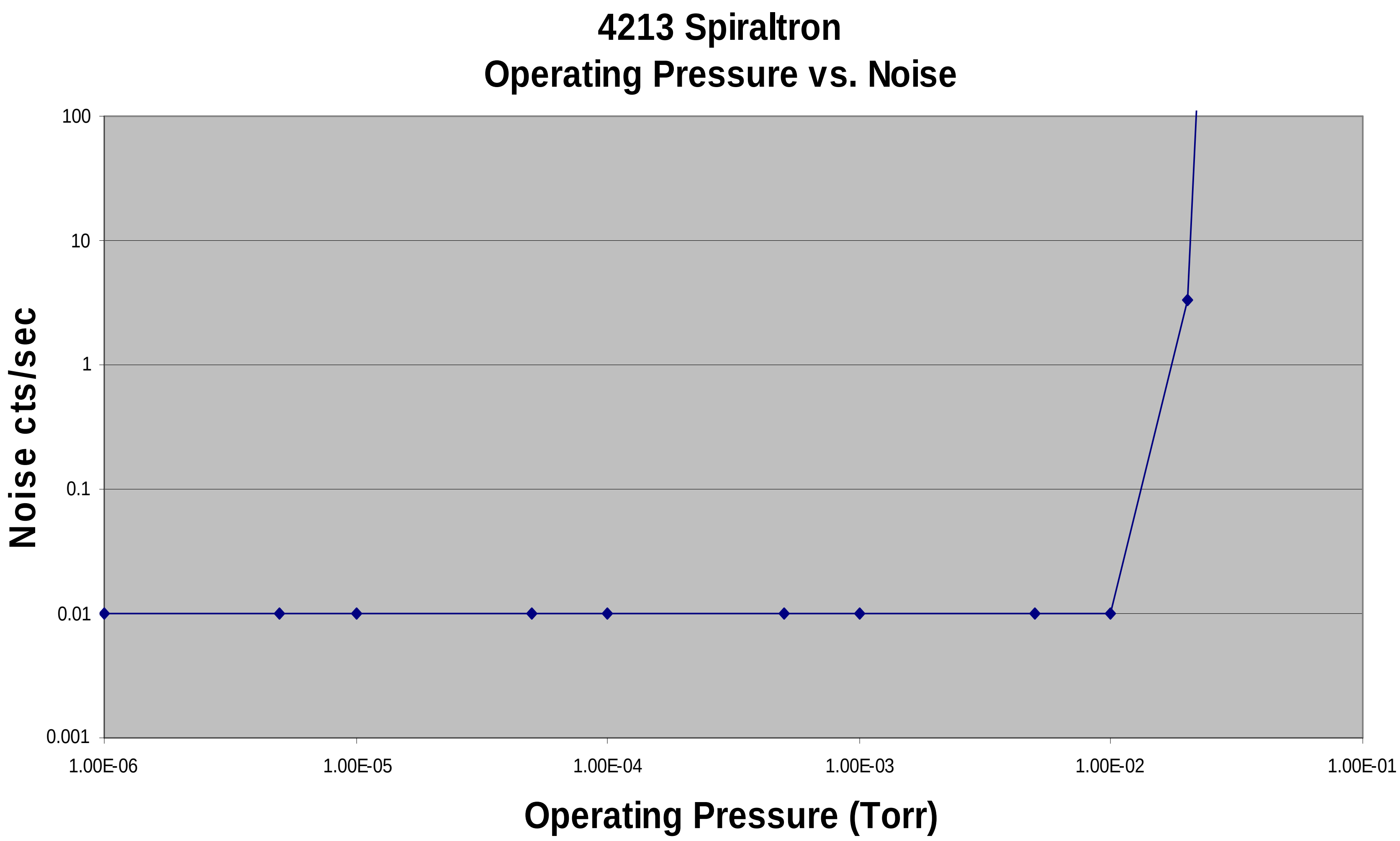
Test Procedure

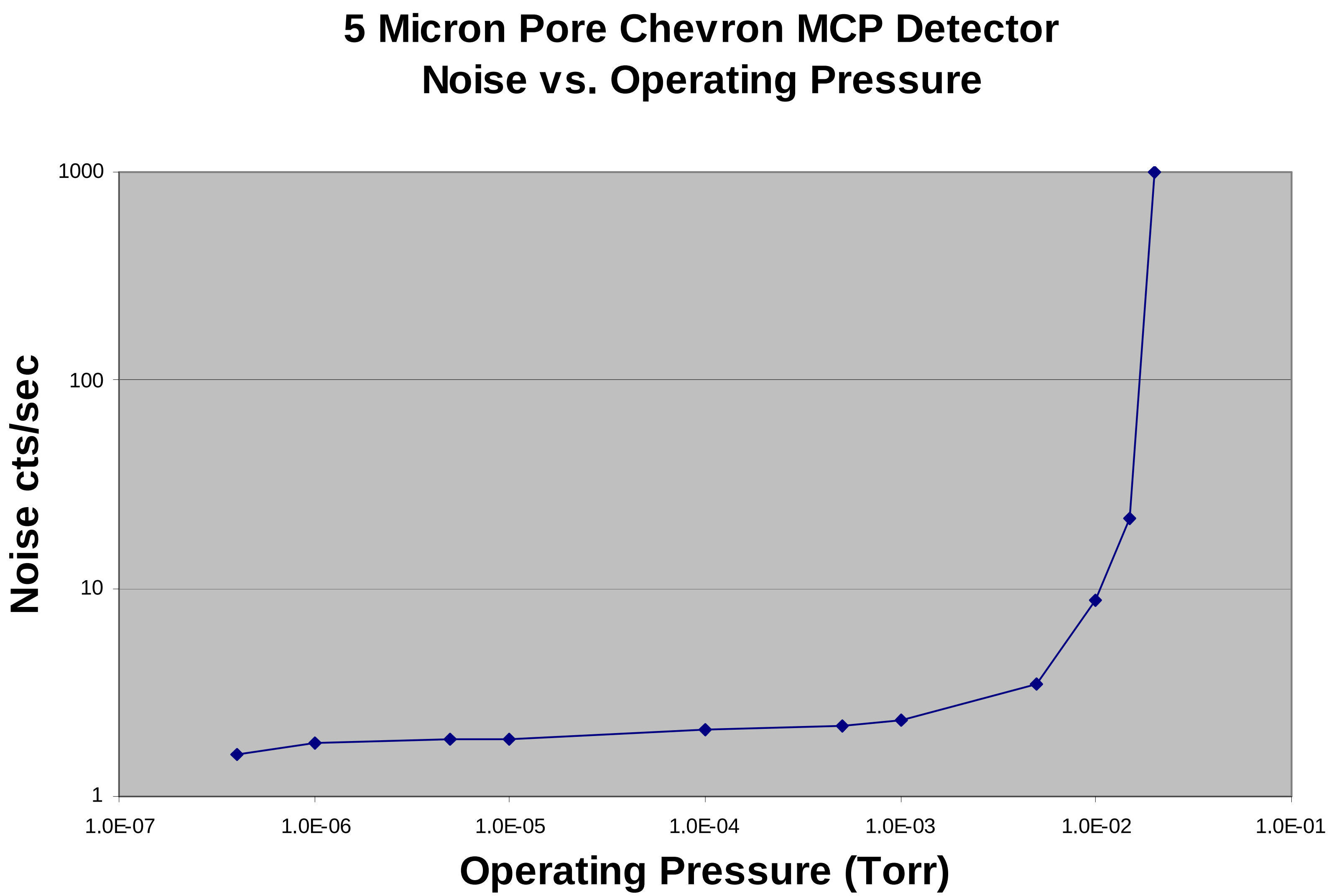
BURLE ELECTRO-OPTICS

Operating limits for selected detectors were explored in greater depth under the following conditions

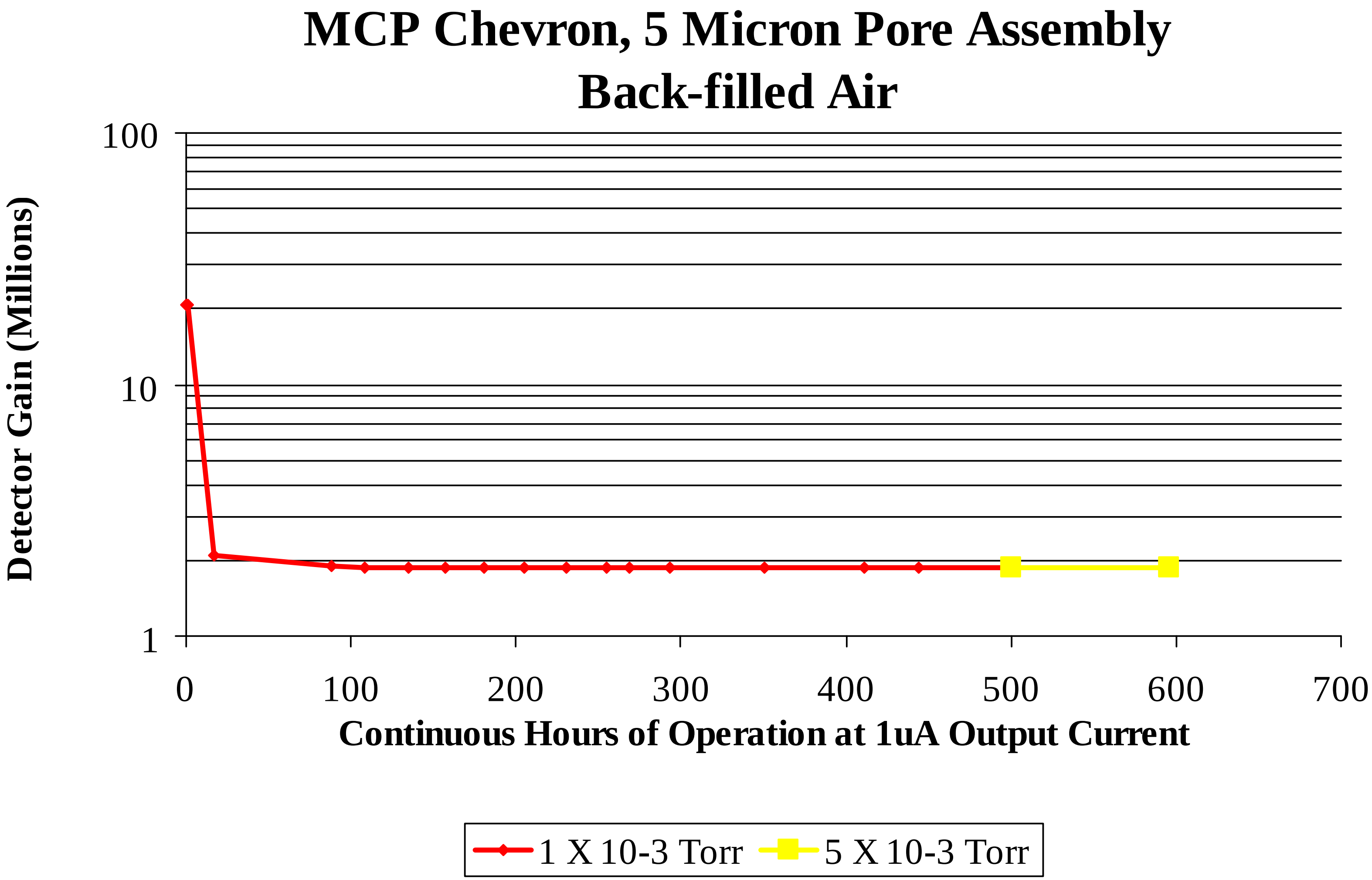
1. Gain adjusted to $1x10^6$
2. Chamber pressure adjusted with backfilled lab air
3. Detector operated at approximately 15,000 cts/sec for 5 minutes between readings
4. Readings repeated over two week interval
5. Chamber vented to air overnights and over weekends


MAGNUM 5900
Noise vs.Operating Pressure
1000
100
10
1
0.1
0.01
Noise cts/sec
1.00E-06
1.00E-05
1.00E-04
1.00E-03
1.00E-02
Operating Pressure (Torr)

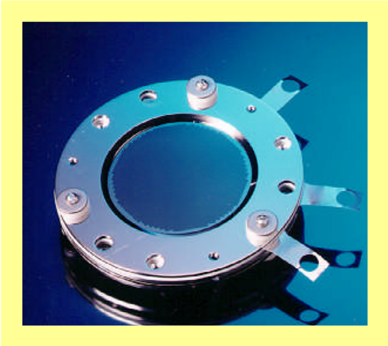

4213 Spiraltron
Operating Pressure vs. Noise
100
10
1
0.1
0.01
0.001
Noise cts/sec
1.00E-06
1.00E-05
1.00E-04
1.00E-03
1.00E-02
1.00E-01
Operating Pressure (Torr)


5 Micron Pore Chevron MCP Detector
Noise vs. Operating Pressure
Noise cts/sec
1000
100
10
1
1.0E-07
1.0E-06
1.0E-05
1.0E-04
1.0E-03
1.0E-02
1.0E-01
Operating Pressure (Torr)

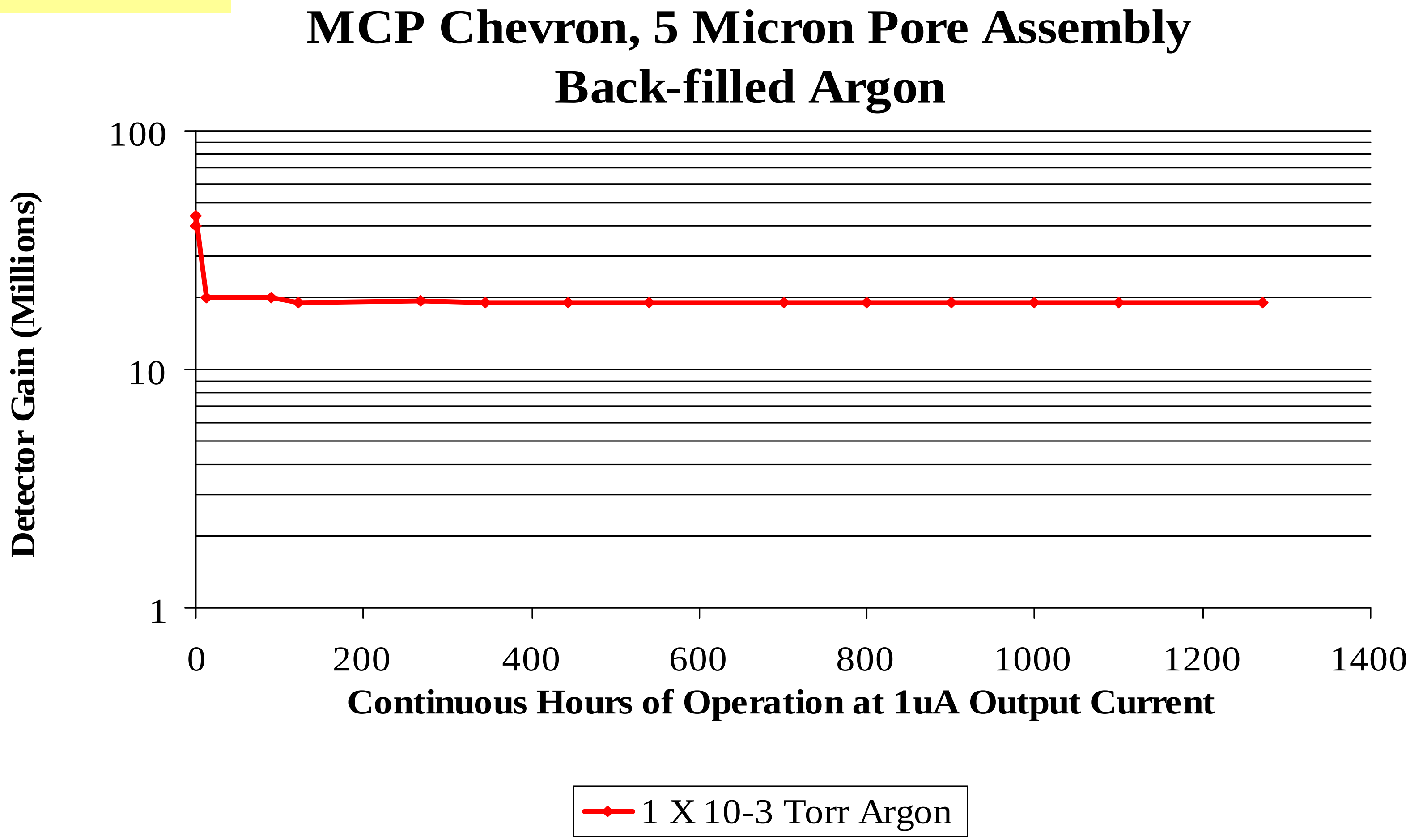
Lifetime at High Pressure:



Ref. Characterization of Common Electron Multipliers in Harsh Environments; Pittcon 2005; Bruce Laprade & Ray Cochran



Lifetime at High Pressure



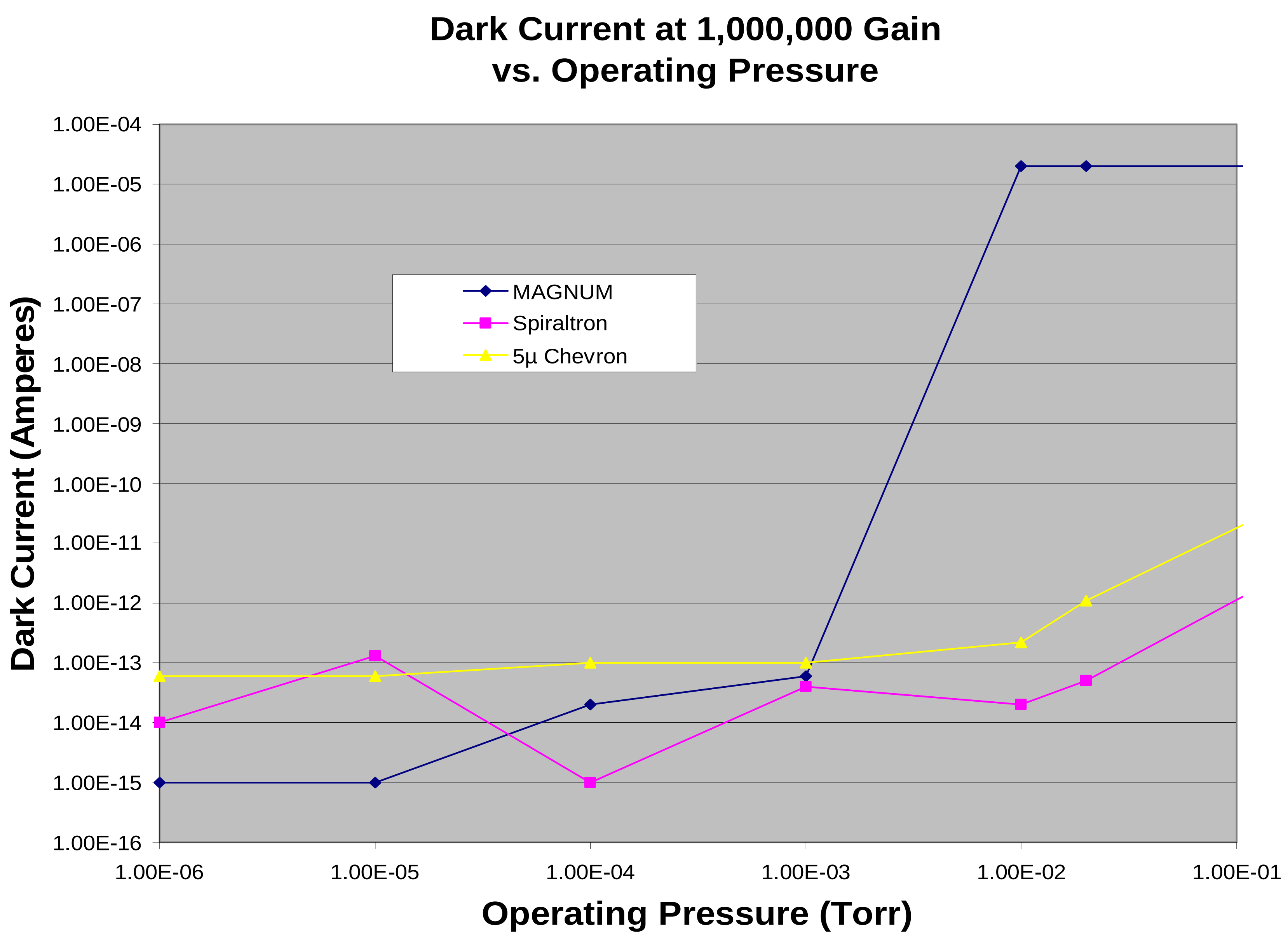
Ref. Characterization of Common Electron Multipliers in Harsh Environments; Pittcon 2005; Bruce Laprade & Ray Cochran

Noise Sensitivity

BURLE ELECTRO-OPTICS

- Minimum detectable noise count in new characterization data had a gain of 50,000

- Dark current measurements were made under the same conditions to detect noise that may be present below the 50,000 gain threshold


Dark Current at 1,000,000 Gain
vs. Operating Pressure
Dark Current (Amperes)
1.00E-04
1.00E-05
1.00E-06
1.00E-07
1.00E-08
1.00E-09
1.00E-10
1.00E-11
1.00E-12
1.00E-13
1.00E-14
1.00E-15
1.00E-16
MAGNUM
Spiraltron
5µ Chevron
1.00E-06
1.00E-05
1.00E-04
1.00E-03
1.00E-02
1.00E-01
Operating Pressure (Torr)

Observations

BURLE
ELECTRO-OPTICS

1. MAGNUM, Spiraltron™ and MCP Chevron detectors operated well at higher pressures than previously reported

2. MCP detector with Mounting Pad (MP) MCPs tolerated regular venting to atmosphere without apparent damage

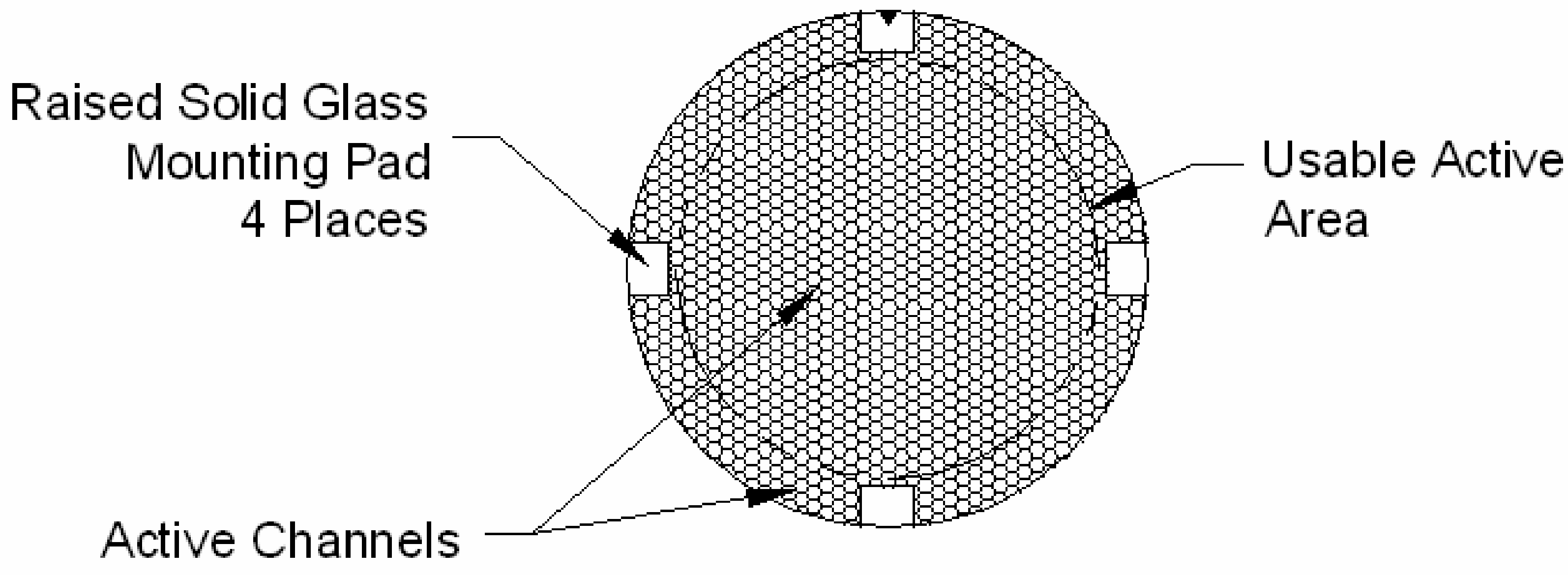
3. MP MCPs did not experience bowing as a consequence of atmospheric exposure

BURLE Electro-Optics' new, patent-pending MountingPad™ Technology Microchannel Plates virtually eliminate warping and cracking problems of MCPs.

It is to resolve these issues that BURLE Electro-Optics developed and introduced the MCP MountingPad™ technology. This construction prevents the MCPs from warping and cracking due to hydration. The design is compatible with Chevron™ and Z-Stack configurations, and is available in cartridge and detector assemblies. Simplified storage requirements allow these MCPs to be stocked for increased efficiency, shorter cycle times, and improved field service performance. These products are identical in form, fit and function to traditional MCPs, which results in a seamless upgrade.

MountingPad™ MCPs are being implemented as standard in BURLE Advanced Performance and BiPolar Time-of-Flight detector products ranges. This technology has already been successfully implemented with major manufacturers

Standard MountingPad™ Configuration



Summary of Results

BURLE ELECTRO-OPTICS

Discrete dynode multipliers develop ion feedback at pressures above 10^{-5} Torr

Single Channel Electron Multipliers Operate well at pressures into the mid 10^{-5} Torr Range

Spiraltron™ Electron Multipliers operate well into the 10^{-2} Torr Range

MAGNUM Electron Multipliers® operate well into the 10^{-3} Torr Range

Chevron® style, 5µ pore MCP detector with mounting pad MCPs operate well into the 10^{-2} Torr Range

Mounting Pad MCPs tolerate long term atmospheric exposure

Conclusions

BURLE
ELECTRO-OPTICS

1. At $1x10^6$ gain, the Spiraltron™ operated at the maximum high pressure, $2x10^{-2}$ Torr. It is recommended for use as a point detector in high pressure applications.

2. The Chevron™ detector operated at $1.5x10^{-2}$ Torr pressure. 5µ Pore MCP detectors are recommended for applications requiring fast timing, two dimensional or large area detection, or a low profile detector design.

3. Low noise, high gain and high pressure operation of a detector is dependent upon proper hardware design.