NGX: A new noble gas multi-collector mass spectrometer from Isotopx

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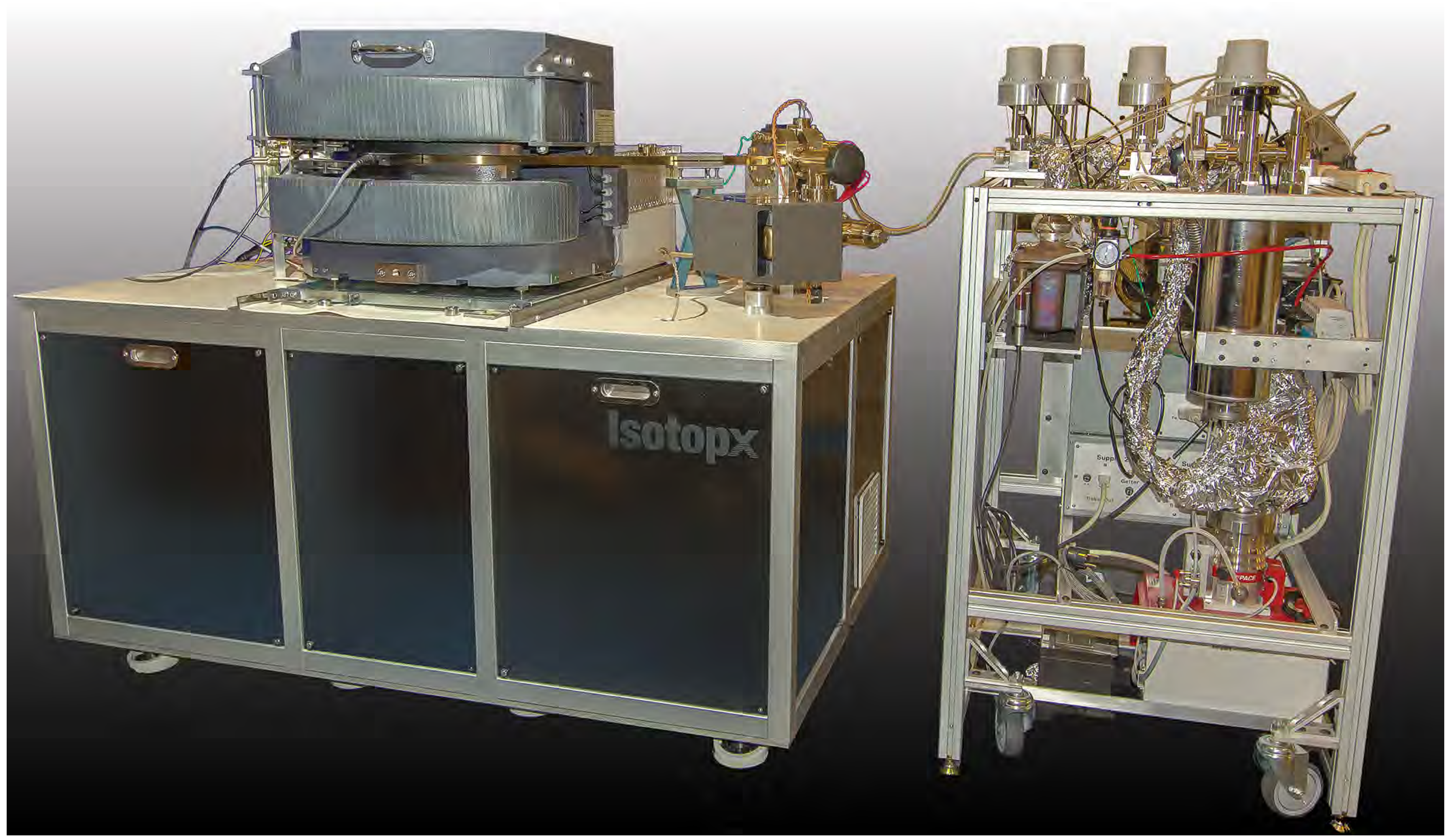
Isotopx

Excellence in mass spectrometry



Introduction

Accurate and precise isotope ratio analysis of rare gases requires a static vacuum, sector field mass spectrometer with a low internal volume and ideally a multi-collector. Here we describe the performance of NGX, a new multi-collector noble gas mass spectrometer with low volume and a versatile multi-collector arrangement offering a high degree of flexibility on collector position and configuration.

Design Philosophy

The aim was to design a multi-collector noble gas mass spectrometer capable of achieving very high precision isotope ratio performance whilst maintaining the straightforward operation of previous generation instruments such as VG5400 and MAP 215. This dual requirement resulted in a decision to use a fixed multi-collector (mix of Faradays and multipliers) that can be configured during manufacture for the multi-collection of one noble gas species whilst permitting all other noble gases, including He, to be analyzed in peak jumping mode.

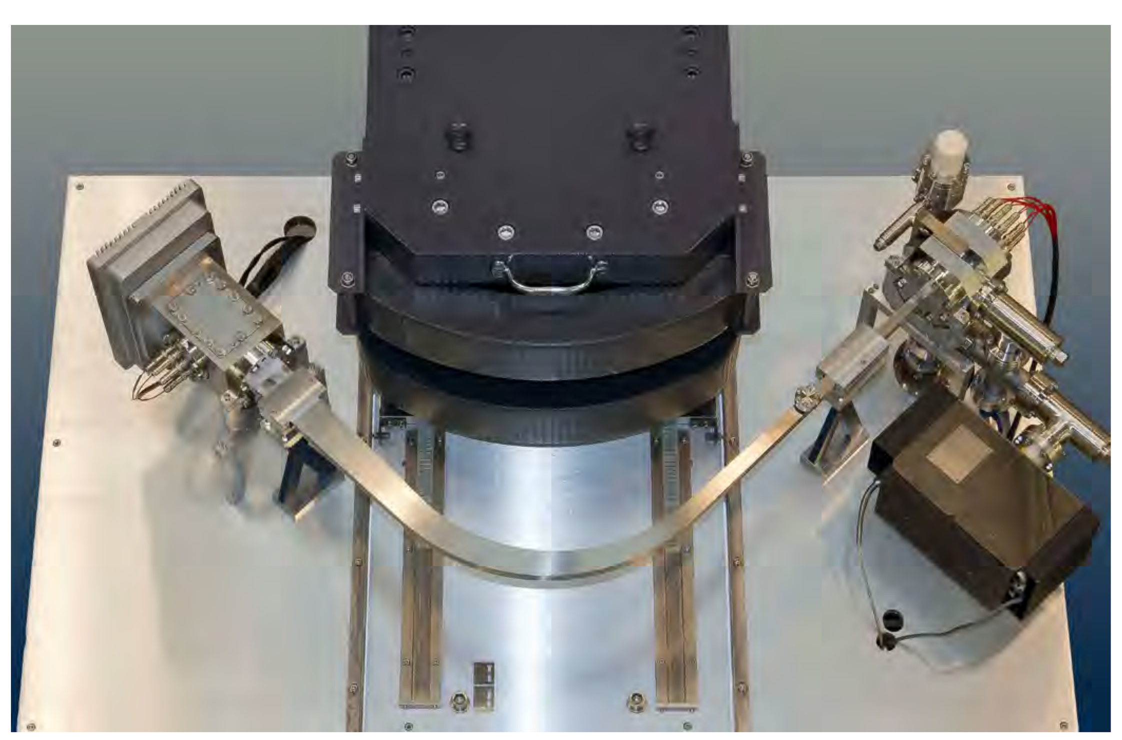


Figure 1. NGX from above showing geometry.

Low Volume / High Sensitivity

In a static vacuum mass analyzer there is an inverse relationship between instrument volume and sensitivity hence it is important to minimize overall volume wherever possible. In order to accommodate a multi-collector whilst maintaining very low volume, NGX uses an asymmetrical ion optical geometry where the magnet shortens the image length of the ion beam. This allows use of a significantly shorter flight tube which keeps the internal volume as low as possible (Fig. 1).

NGX's magnet features an exit lens or 'pole piece' which rotates the focal plane at the collector so it becomes perpendicular to the direction of travel of individual ions. This permits use of a smaller volume collector block (Fig's. 1 and 2).

54cm Effective Radius Magnet

NGX uses a large, 27cm radius air-cooled electromagnet. The magnet has an effective radius of 54cm (the same as the VG 5400) and is based on the Phoenix TIMS system which routinely operates at up to m/z 270.

The use of the exit lens 'pole piece' (Fig. 2) means that the angle between individual ion beams and the focal plane remains essentially constant across the array minimizing efficiency variations across the collector.

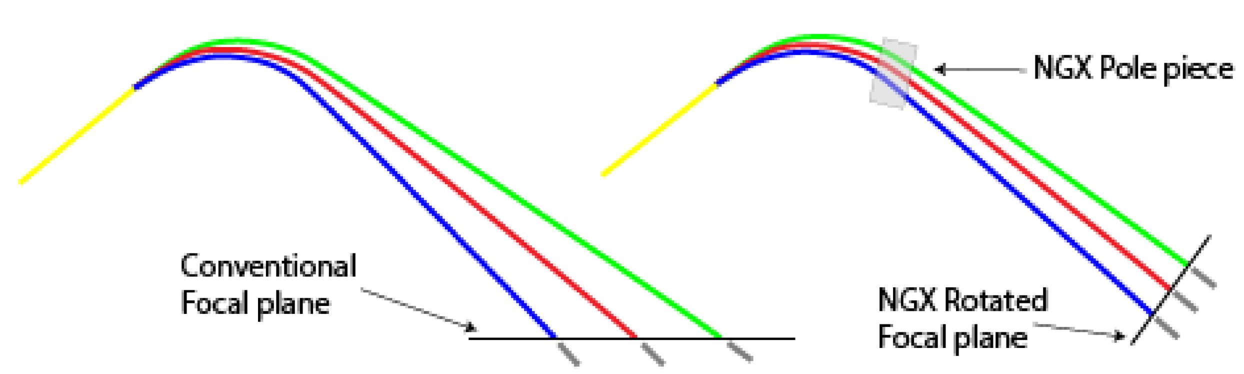


Figure 2. NGX pole piece rotates the image focal plane improving collector efficiency and lowering the collector volume.

NGX Multi-collector

Although the geometry is fixed during manufacture, the NGX collector can be configured in many different ways.

A typical argon configuration consists of five Faraday buckets with an ion counting multiplier on the low mass side of the array to count ^{36}Ar on small samples (Fig 3.). This would produce an instrument optimized for multi-collector argon isotope analysis but which could be used in peak jumping mode for any of the other noble gases including He.

Equally the collector could be configured with nine Faradays optimized for Xe isotope analysis (Fig. 5) or a very low volume system could be constructed using a single Faraday and a single multiplier allowing collection of any of the noble gases in peak jumping mode at very high sensitivity.

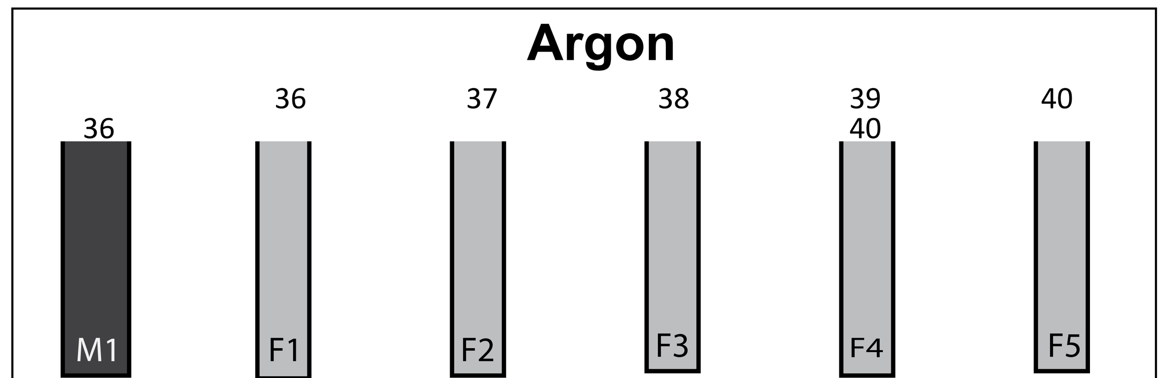


Figure 3. Example configuration for multi-collector Ar isotope analysis with one multiplier (M1)and five Faradays (F1 to F5)

Any (or all) of the Faradays can be exchanged for multipliers during manufacture if required.

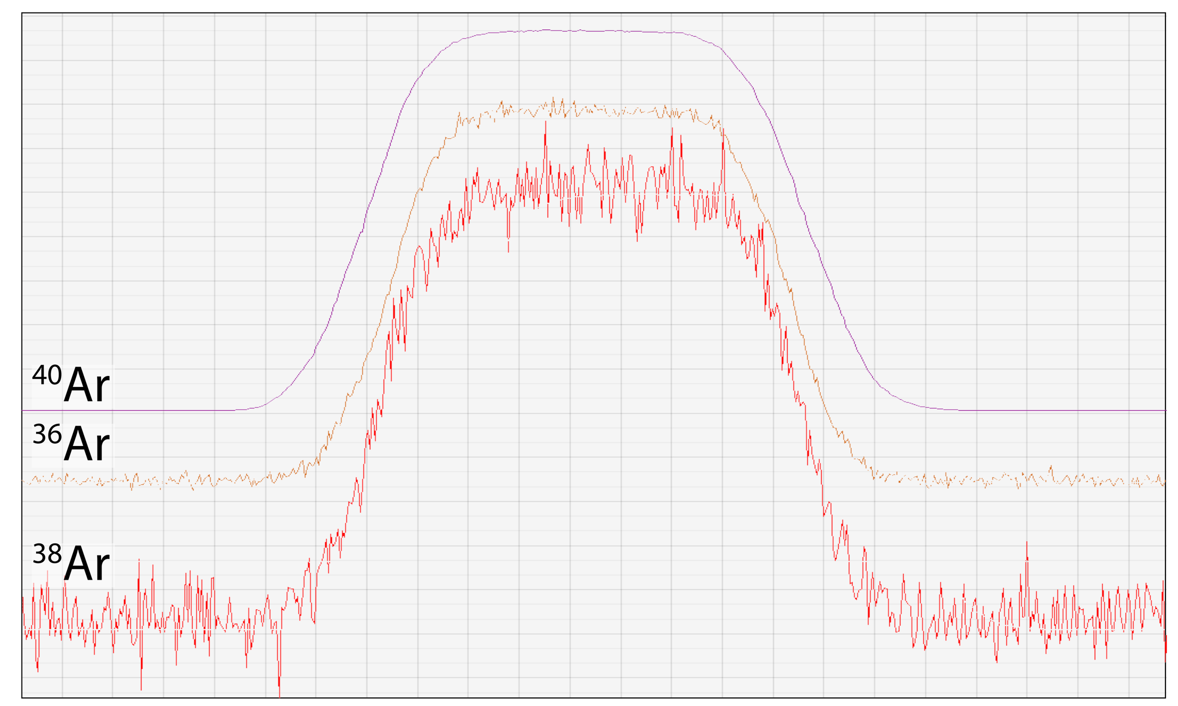


Figure 4. Coincidence of ^{36}Ar, ^{38}Ar and ^{40}Ar. Each trace is automatically scaled.

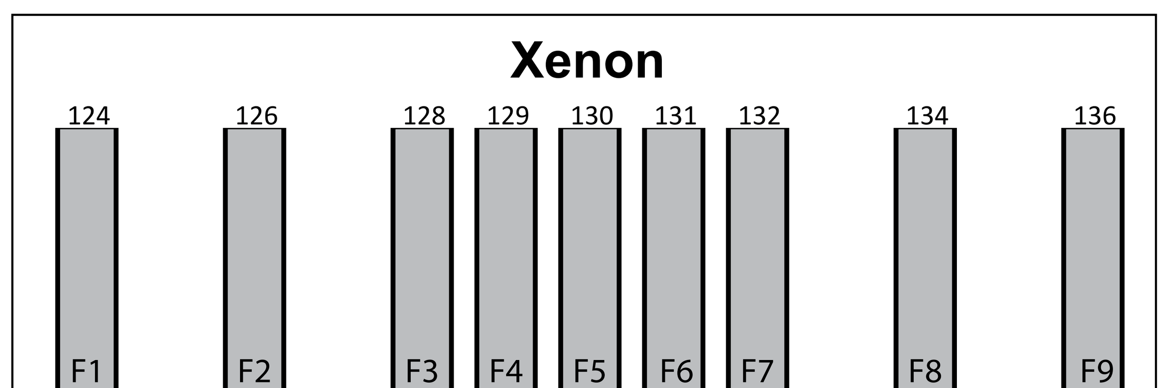


Figure 5. Example configuration for multi-collector isotope analysis of Xe. This set-up shows 9 Faradays but multipliers could be used if required.

1e^{11}Ω and 1e^{12}Ω Faraday Amplifiers

In order to measure a range of signal intensities it is important that the Faraday amplifiers maximize dynamic range whilst remaining linear. NGX's Faradays can be fitted with Isotopx ***X***act Faraday amplifiers containing either 1e^{11}Ω or 1e^{12}Ω gain resistors. The 1e^{12}Ω amplifiers have lower noise characteristics and extend performance to very low beam intensities.

Table 1 compares the noise levels of 1e^{11}Ω and 1e^{12}Ω resistors in the same amplifier housing over integration periods ranging from one second to 300 seconds. The 1e^{12}Ω resistors show lower noise by a factor of ~1.5 over this range of integration periods.

Table 1 shows that for an integration period of 10 seconds the noise level on 1e^{12}Ω resistors is 6.5e^{-17} A. To achieve this same noise level the 1e^{11}Ω boards require an integration period of at least 40 seconds. This improved noise performance makes the 1e^{12}Ω amplifier is ideally suited for use with small noble gas samples where the ion beam intensity is changing relatively quickly.

	Noise (Amps)		
Integration time (secs)	1e^{12} Ω n=5	1e^{11} Ω n=4	1e^{11}/1e^{12}
1	2.3E-16	3.8E-16	1.7
5	1.0E-16	1.7E-16	1.6
10	6.5E-17	1.2E-16	1.8
20	5.1E-17	7.3E-17	1.4
40	3.6E-17	6.3E-17	1.7
60	3.6E-17	5.1E-17	1.4
300	3.5E-17	4.9E-17	1.4

Table 1. *Noise comparison between 1e^{12}Ω and 1e^{11} Ω resistors.*

Slow signal response has historically limited the performance of 1e^{12}Ω amplifiers but both 1e^{11}Ω and 1e^{12}Ω versions of the latest amplifiers have significantly faster signal decay.

Figure 6 shows the response of the ***X***act 1e^{12}Ω amplifiers used in NGX in the first 10 seconds after an ion beam of 5 volt/5e^{-12}A was switched off the Faraday. The signal from the amplifier drops to <5ppm of the initial intensity within 4 seconds, opening up the use of 1e^{12}Ω Faraday amplifiers for dynamic style acquisitions for the first time.

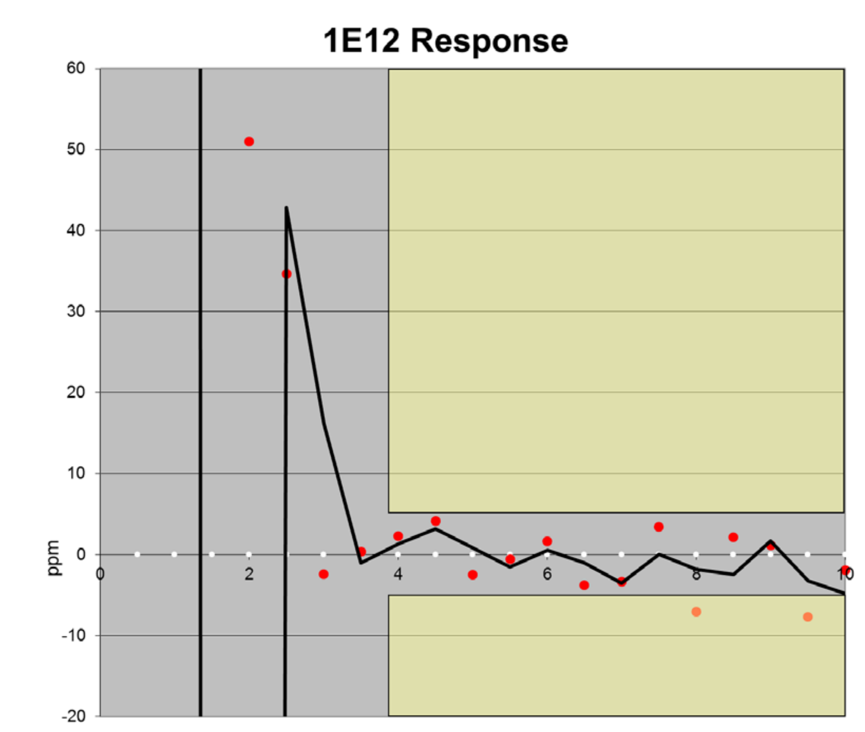


Figure 6. Response of NGX 1e^{12}Ω Faraday amplifiers in the 10 seconds after a 5 volt/5e^{-12}A ion beam was switched off the Faraday.

NGX Provisional Specifications

Mass range: 1 – 200 Daltons at 8kV accelerating voltage

Background: 5 x 10^{-14} cc STP at m/z 36

Sensitivity
Argon : > 1×10^{-3} amps/Torr at 200μA trap current
Helium : > 2 x 10^{-4} amps/Torr at 800μA trap current

Abundance Sensitivity: 1ppm at 10^{-7} Torr (defined as the relative contribution of ^{40}Ar at m/z 39)

Static Volume: ~800cc (6 Faradays/Multipliers configured for Ar)

Rate of rise: < 1 x 10^{-12} cc STP/min for ^{40}Ar

Resolution: Faraday : >600, Multiplier : >600

Peak side stability: <25ppm in mass over 30 min

Amplifier response
1×10^{11}Ω - Signal decay of <5ppm of 8 volts in 2 seconds
1×10^{12}Ω - Signal decay of <5ppm of 5 volts in 4 seconds