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Multidynamic measurement of small Neodymium (Nd⁺) ion signals on Faradays using *X*act amplifiers with 1e¹¹ Ω and 1e¹² Ω (1T) resistors

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Introduction

Thermal Ionization Mass Spectrometry is an extremely sensitive detection technique. For Neodymium, measured as Nd⁺, ion yields of 1 ion per 50 atoms loaded are typical for triple filament geometries on a *Phoenix TIMS*. This efficiency is of huge importance for applications where there is very little sample material e.g. garnet growth rims in metamorphic studies, or low element concentration e.g, mantle minerals such as clinopyroxene.

The sensitivity has to be coupled with sensitive detectors. Ion counters are one possible route, but their dynamic range prevents enough ions to be measured to produce sensible precision and accuracy.

The promise of using Faradays with $1e^{12}$ Ω (1T) resistors as an alternative to conventional $1e^{11}$ Ω resistors holds out promise. The theoretical noise improvement should be a factor of 3. However, this analytical benefit would be negated if for example the gain between resistors was not stable, or the baselines were unstable with time.

This work compares the isotope ratio performance of neodymium on Faraday collectors coupled with Isotopx *X*act $1e^{11}$ Ω and *X*act1T ($1e^{12}$ Ω) amplifiers on a *Phoenix TIMS* system. Measurements of neodymium were made at different ion intensities focussing on ion signals in the 5 to 50mv range.

Method

We have analysed a single large load of Nd (400ng) on a triple rhenium filament assembly. The ion beam was kept very stable during an analysis, and then reduced between analyses.

The analysis method chosen was the multidynamic method. This method eliminates any gain or efficiency variables,

and so the only variable should be the signal/noise ratio. Measurements were taken in a 3 cycle dynamic routine which has been described elsewhere. Integration times for each mass position were 15 seconds with a 3 second delay between each mass position to allow the resistor to return to baseline before starting the next integration. A total of 200, 3 cycle, ratios were taken in 10 blocks of 20 seconds. At the start of each block baselines were measured at +/-0.5amu for each of the 3 cycles. The baselines were applied to the subsequent block of data. Since the baselines were taken either side of the peak, they also correct for any peak tailing which may occur from the peaks. This tailing would be virtually nil considering the abundance sensitivity (<1ppm) and the small size of the ion beams considered here.

Resistor response

The speed of response of the resistor (Tau) is crucial for high precision dynamic measurements. The signal must return to baseline before the next integration is taken otherwise a bias will appear which will be proportional to the size of the ion beam. The *Phoenix* uses new *X*act electronics which have extremely fast response times compared to older generation amplifiers. For example, *X*act $1e^{11}$ Ω resistors baseline from an $8e^{-11}$ A ion signal is within 2ppm of this intensity ($<2e^{-16}$ A) within 2 seconds.

Historically, 1T ($1e^{12}$ Ω) resistors have exhibited long response times, Richter et. al (2011) report having to wait 15 seconds for the ion current to decay. Figure 1 shows the Tau response of an Isotopx *X*act1T ($1e^{12}$ Ω) amplifier board. The ion signal was $5e^{-11}$ Amps before switching to baseline. The signal decay is extremely rapid and overshoots the zero point before rebounding back and decaying to <5ppm of the original signal within 3 seconds and returning to baseline.
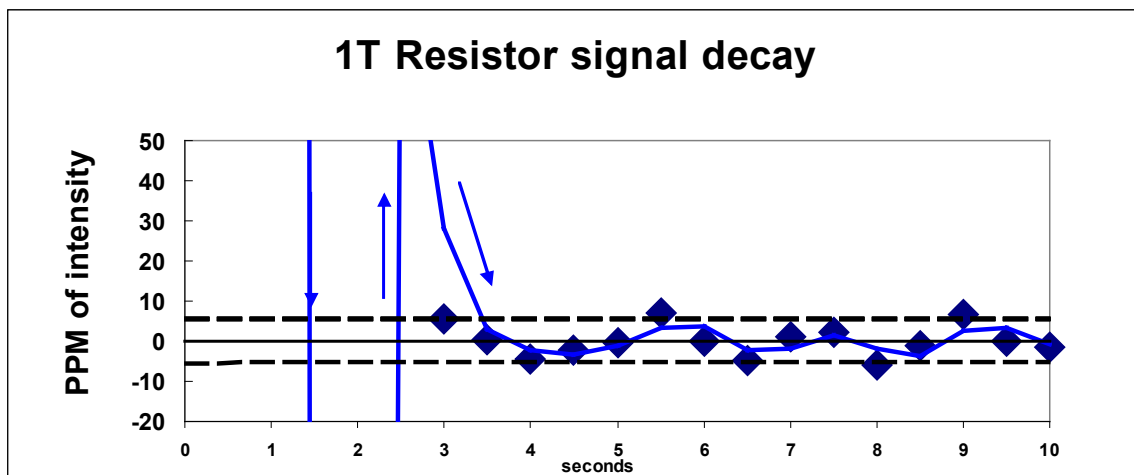

Figure 1. *Tau response of the Xact1T resistors*

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Neodymium isotope ratios at different intensities.

Xact 1e[11] Ω resistors - Table 1 and Figures 1, 2 and 3 shows the data for isotope ratios measured using 1e[11] Ω resistor between 700mv (7e[-12] A) and 4 mv.

For the $^{143}Nd/^{144}Nd$ the data remain consistent until 50mv. At this point the precision on the $^{143}Nd/^{144}Nd$ is <30ppm 1se (+/-0.00003 2SE). The $^{145}Nd/^{144}Nd$ and the $^{142}Nd/^{144}Nd$ are also within error of ratios obtained at higher intensities. For lower intensities the data becomes scattered, and so a cut off at 30ppm 1rse is marked in red on Table 1 at 50mv ^{142}Nd corresponding to 20mv ^{143}Nd and 13mv ^{145}Nd.

Xact1T resistors - Table 1 and Figures 1,2 and 3 shows a series of measurements using the 1T resistor. At the higher intensities the ratios are identical within error to the 1e[11] Ω resistors. This indicates that the tau response is adequate. As the intensity decreases the ratio remains constant until 13mv below which the errors expand and the ratio is neither precise nor accurate. The limit is marked in red on Table 1 and is just over 3 times lower in intensity than the 1e[11] Ω data. Interestingly the precision and accuracy at ~ 50mv ^{142}Nd is **the same for both** 1e[11] and 1e[12] Ω resistors with precision of <30ppm 1RSD for the $^{143}Nd/^{144}Nd$ obtained.

Conclusions

Using Isotopx **Xact** Faraday amplifiers multidynamic measurements are possible at low intensities and accurate and precise data can be obtained for both 1e[11] Ω and 1T (1e[12] Ω) resistors.

At intensities down to 50mv ^{142}Nd the data are essentially the same irrespective of the resistor value with precision at 50mv ^{142}Nd of <30ppm 1RSD.

With **X**act1T resistors the isotope ratio remains precise (<100ppm 2se) and accurate down to 10mv ^{144}Nd and 5mv ^{143}Nd, below this the errors expand and the data is not useable.

	^{142}Nd (amps)	^{142}Nd (mv)	$^{143}Nd/^{144}Nd$	%1se	$^{145}Nd/^{144}Nd$	%1se	$^{142}Nd/^{144}Nd$	%1se
	7.1E-12	706	0.512095	0.0003	0.348402	0.0003	1.141827	0.0005
	4.9E-12	485	0.512096	0.0004	0.348395	0.0004	1.141819	0.0006
	3.0E-12	296	0.512082	0.0008	0.348399	0.0008	1.141837	0.0012
1E+11	1.1E-12	105	0.512113	0.0016	0.348371	0.0020	1.141793	0.0019
	4.9E-13	49	0.512057	0.0028	0.348383	0.0030	1.141822	0.0042
	1.1E-13	11	0.512261	0.0106	0.348341	0.0135	1.143178	0.0139
	4.9E-14	5	0.511754	0.0191	0.348499	0.0340	1.142667	0.0265
	3.6E-14	4	0.512215	0.0257	0.348698	0.0274	1.142779	0.0221
	^{142}Nd (amps)	^{142}Nd (mv)	$^{143}Nd/^{144}Nd$	%1se	$^{145}Nd/^{144}Nd$	%1se	$^{142}Nd/^{144}Nd$	%1se
	6.88E-12	688	0.512121	0.0003	0.348419	0.0003	1.141855	0.0005
	4.98E-12	498	0.512127	0.0003	0.348421	0.0003	1.141861	0.0005
	2.94E-12	294	0.512117	0.0006	0.348415	0.0006	1.141837	0.0007
1T	9.67E-13	97	0.512169	0.0010	0.348432	0.0017	1.141870	0.0013
	5.16E-13	52	0.512116	0.0023	0.348425	0.0022	1.141833	0.0018
	1.26E-13	13	0.512106	0.0042	0.348400	0.0050	1.141863	0.0045
	4.83E-14	5	0.512418	0.0083	0.348734	0.0123	1.141554	0.0105

*Table 1. Neodymium isotope ratios of JNd-i Nd standard at different ion intensities using **X**act 1e[11] Ω and **X**act1T amplifiers. Reference ratios are $^{143}Nd/^{144}Nd$ 0.512104, $^{145}Nd/^{144}Nd$ 0.348404, $^{142}Nd/^{144}Nd$ 1.141840*

References

Richter, S., Kuhn, H., Aregbe, Y., Hedberg., Horta-Domenech., Mayer K., Zuleger E., Burger S., Boulyga S., Kopf A., Poths J., Mathew K. 2011 Improvements in routine uranium isotope ratio measurements using the modified total evaporation method for multi-collector thermal ionization mass spectrometry. J.Anal At. Spectrom, 2011, 26, 550-564.
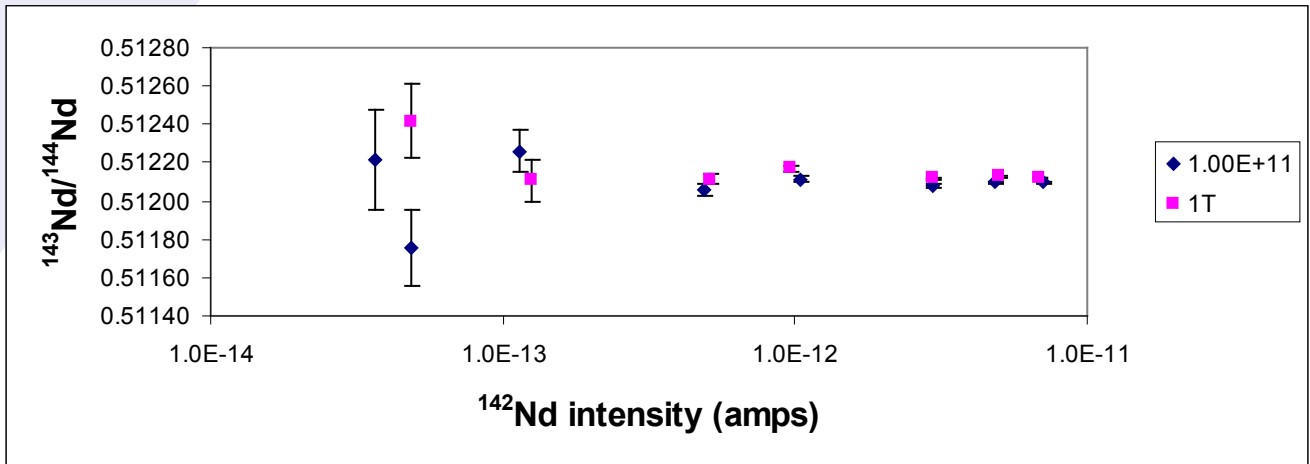
Figure 1. Variation in $^{143}Nd/^{144}Nd$ with decreasing ion current

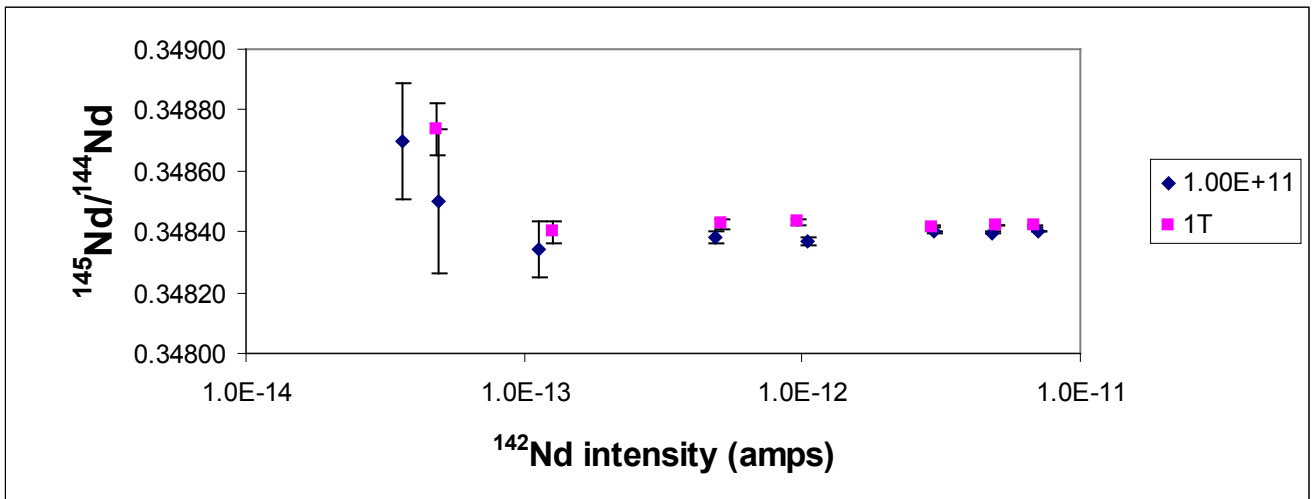*Figure 2.* Variation in $^{145}Nd/^{144}Nd$ with decreasing ion current

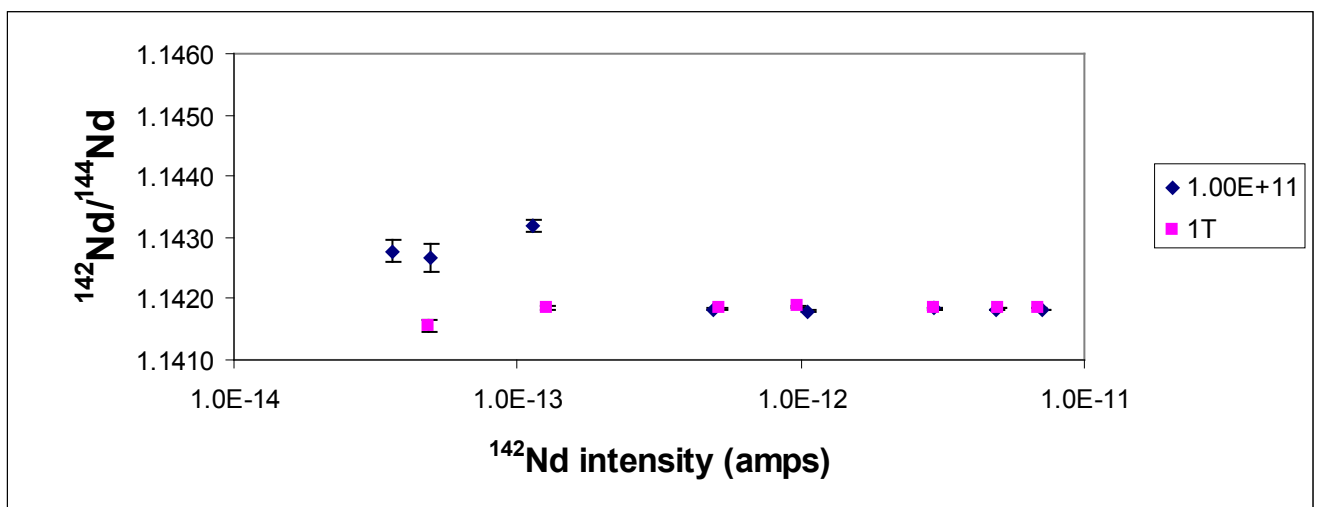*Figure 3.* Variation in $^{142}Nd/^{144}Nd$ with decreasing ion current

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