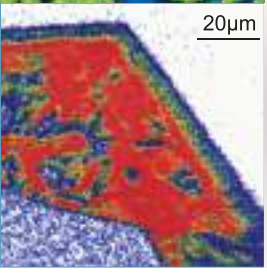
IMS 7f-GEO

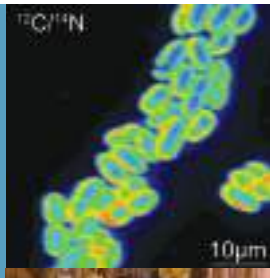
Compact, High Throughput SIMS for Geoscience Laboratories



GEOCHEMISTRY

TRACE ELEMENT ANALYSES

ENVIRONMENTAL STUDIES



CAMECA® SCIENCE & METROLOGY SOLUTIONS / AMETEK®

CAMECA IMS 7f-GEO: A specialist instrument for applications in geosciences.

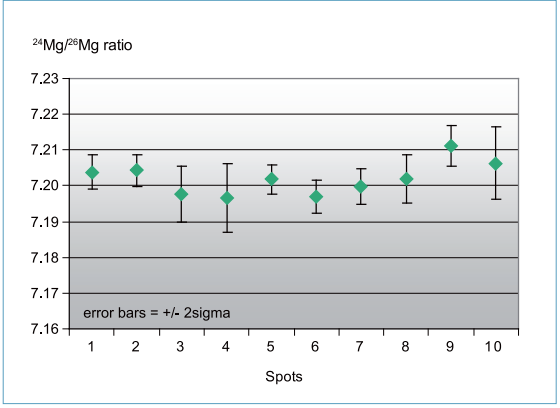
SIMS & geosciences

The success of Secondary Ion Mass Spectrometry in the geoscience field relies on its performance in terms of:

- high sensitivity which is mandatory for high precision measurements or to achieve low detection limits;
- elemental as well as isotopic information ranging from low mass (H) to high mass (Pu) species;
- in-situ analysis of any solid flat polished surface;
- high spatial resolution from tens of microns down to sub-micron scale.

The CAMECA IMS 7f-GEO has been developed to meet these requirements.

The IMS 7f-GEO covers a wide range of applications: high precision stable isotope ratio measurements, Rare Earth Element (REE) analysis, trace element mapping down to micron scale resolution...



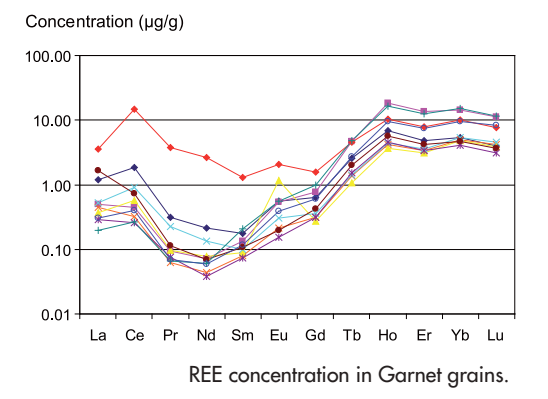
Stable isotopes: $^{24}Mg/^{26}Mg$ ratio measured in San Carlos olivine.

A new SIMS instrument for geosciences from the pioneer and world leader in SIMS.

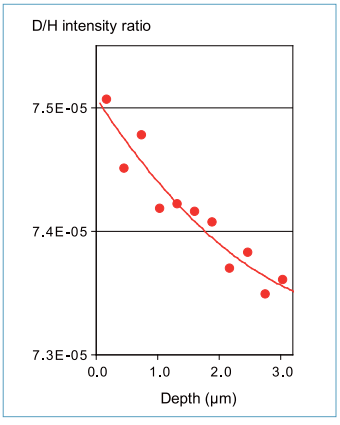
In order to achieve both high precision and high throughput, the choice of the appropriate detectors is the first issue. It is well known that Faraday cups (FCs) are preferred to Electron Multipliers (EMs) provided the secondary ion intensities are high enough.

Secondly, in the absence of parallel detection, it is crucial to perform the switching between the different species as fast as possible, and to monitor all relevant parameters that may compromise the achievable precision.

CAMECA's mono-collection compact SIMS model, the IMS 7f-GEO, fully meets these instrumental requirements and is perfectly suited for high precision stable isotope and trace element analysis.



REE concentration in Garnet grains.

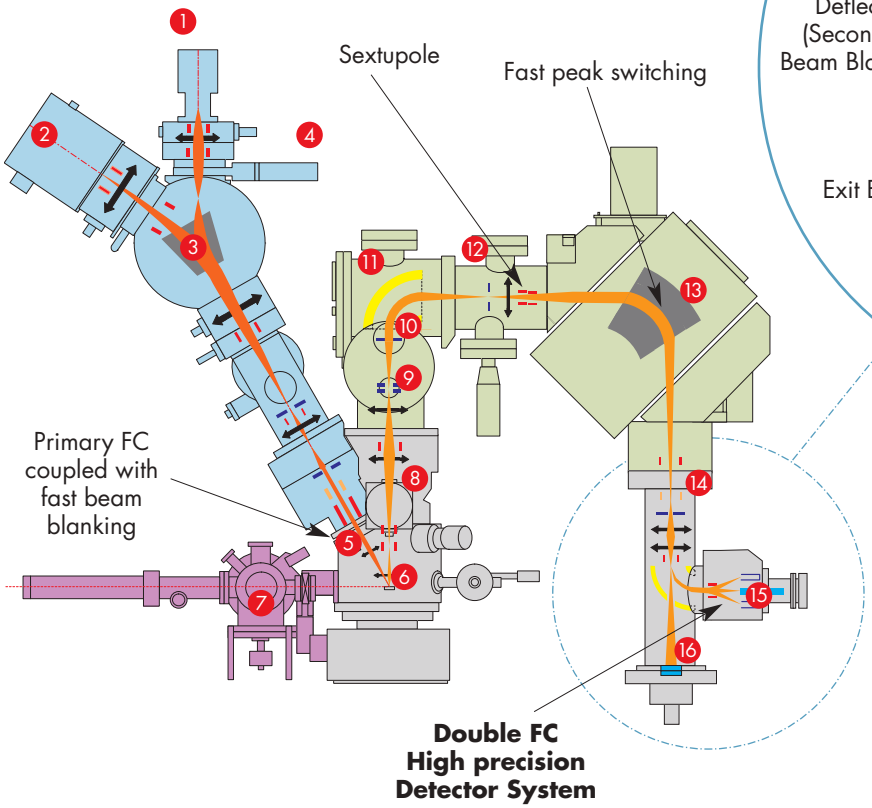


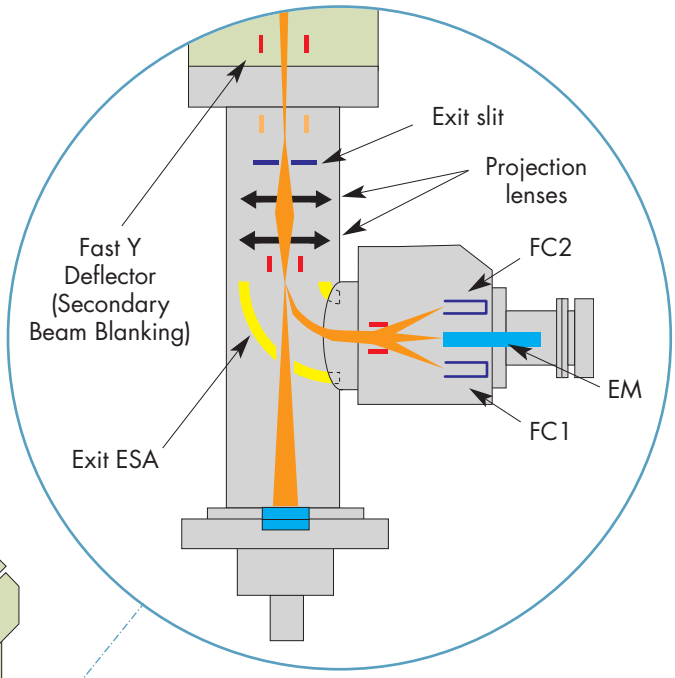
In-depth variation of the D/H ratio from the surface of a Goethite crystal.

The IMS 7f-GEO is equipped with a state-of-the-art Ultra High Vacuum system designed for light element analysis like Hydrogen, Deuterium, Oxygen...

IMS 7f-GEO
Main Technical Features

Derived from our proven IMS 7f and IMS 1280 instruments, the IMS 7f-GEO is equipped with a high precision detection system combining one double Faraday cup detector system and one Electron Multiplier.





1 *Microbeam Cesium ion source*
2 *Duoplasmatron ion source*
3 *Primary Beam Mass Filter (PBMF)*
4 *Cesium source isolation option*
5 *Primary Faraday cup*
Motor driven primary column aperture
6 *Sample (-10kV to +10kV)*
(Z axis in option)
7 *UHV airlock system,*
(Sample storage chamber in option)
8 *Normal incidence Electron Gun (NEG)*
9 *Motor driven contrast aperture & entrance slit*
10 *Motor driven field aperture*
11 *Electrostatic Analyzer (ESA)*
12 *Motor driven energy slit*
13 *Fast laminated magnet*
14 *Motor driven exit slit*
15 *Electron Multiplier & double FC detectors*
16 *Ion image detector*

Full computer automation, user-friendly interface

The **IMS 7f-GEO** is fully computer controlled, including the ion sources, lenses, diaphragms, slits and the sample stage.

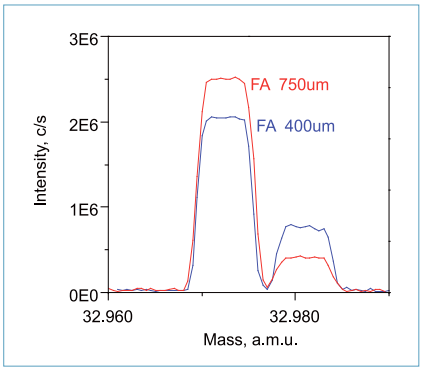
The software package covers instrument tuning and control, data acquisition and processing; it also includes a powerful chain analysis program allowing **overnight unattended operation**.

Using a PC computer running under MS Windows®, the **IMS 7f-GEO** guarantees both ease of use and high analysis throughput.

QUASI-CONTINUOUS PRIMARY BEAM INTENSITY MONITORING

- Combination of a fast beam blanking and a Faraday cup equipped with repeller and running in charge mode
- For every elementary acquisition (80ms), a given percentage (software controlled) is dedicated to the primary intensity (Ip) measurement
- One Ip value returned per data point

This allows a more reliable primary beam drift correction, therefore minimizing short term instrumental stability effects.



^{33}S mass spectra, MRP(10%) = 4400. The larger FA gives a higher transmission, while keeping a flat top peak.

SEXTUPOLE AT THE ENTRANCE OF THE MAGNET

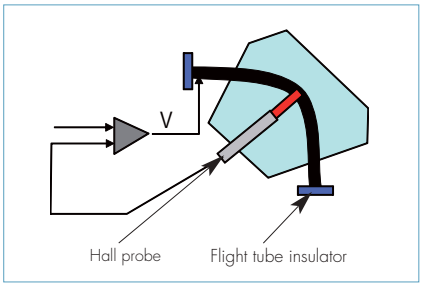
- 2nd order aberration cancellation allowing the use of a larger Field Aperture (FA) at constant MRP

This provides higher instrument transmission at high mass resolving power (MRP).

FAST MASS PEAK SWITCHING SYSTEM

- Combination of magnetic and electrostatic beam deflection
- During a mass jump the Hall probe measures the B field. The Hall probe signal is used to apply an electrostatic voltage feedback on the magnet flight tube. This voltage rapidly deflects the secondary beam and therefore allows to speed up the peak positioning in the exit slit plane.
- As fast as 0.3 sec at high MRP
- Applicable over the full mass range (compatible with REE analysis)

This brings benefits in terms of precision and analysis throughput.

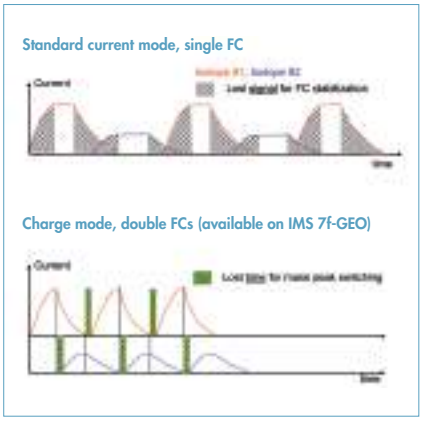


Fast mass peak switching system

DOUBLE FARADAY CUP SYSTEM

- 2 Faraday cups coupled with 2 acquisition channels are implemented
- High precision FC electrometers minimize the short term detection noise and guarantee a long term stable baseline
- A secondary beam blanking system allows to control exactly the time the secondary beam is addressed into a given FC channel
- 2 different resistor types are available for each FC (e.g. $10^{10}\Omega$ for ^{16}O and $10^{11}\Omega$ for ^{18}O)
- FCs running in charge mode: no need for FC settling time between two isotopes, thus shortening the acquisition time.

This configuration allows to run analyses in a pseudo bicollection mode well suited for stable isotope high precision analysis.



MAJOR ANALYSIS THROUGHPUT IMPROVEMENT

The **IMS 7f-GEO** achieves a **major improvement in analysis throughput** thanks to the implementation of the new double FC detector system working in charge mode.

Example: $^{18}O/^{16}O$ analysis:

- Primary beam control precision: 1‰
- Analysis required precision: 0.4‰
- ^{18}O signal intensity: ~2E6c/s

Mode	Requested measurement time
EM/EM	3016 sec.
FC/FC (charge mode)	**56 sec.**

An advanced tool for mineral analysis allowing sub-permil precision in stable isotope ratio measurements.

High mass resolution and flat top peak shape combined with the new double Faraday cup system allow the **IMS 7f-GEO** to measure stable isotope ratios in minerals at high spatial resolution, with high precision and high throughput.

Oxygen isotope analysis

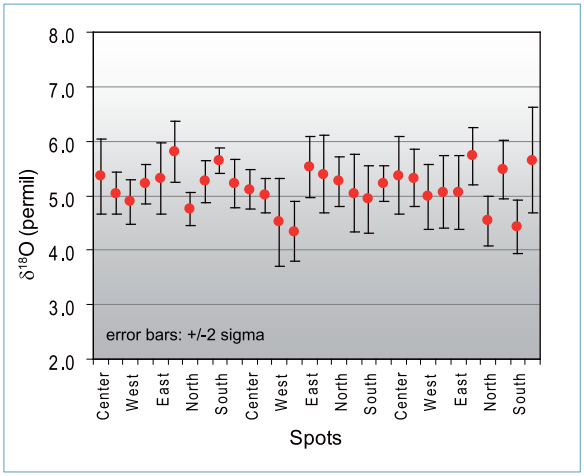
Measurements are performed using a highly focused Cs^+ primary beam, and the charge compensation is achieved using the Normal incidence Electron Gun (NEG) system working in "self-neutralization" mode.

Experimental conditions:

- *Cs^+, negative secondary ions, NEG, MRP: 2500*
- *Analysis area size: ~10x10µm²*
- *Detection: ^{16}O on FC1 ($R=10^{10}\Omega$), $I(^{16}O)$~1E9 c/s*
  ^{18}O on FC2 ($R=10^{11}\Omega$), $I(^{18}O)$~2E6 c/s
- *Total integration time: 56s*

Spot to spot reproducibility (1σ): 0.37 ‰
Mean internal error (1σ): 0.27 ‰

$\delta^{18}O$ measured on a synthetic quartz sample.



Each data point corresponds to a different spot of the sample. The runs are distributed over an area of 15mm in diameter across the sample.

Sulfur isotope analysis on microbial mats

Thanks to its new double FC detection system, the **IMS 7f-GEO** delivers high precision sulfur isotopic compositions of sedimentary sulfates and sulfides. These are useful for understanding the activity of modern microbial ecosystems. Sulfur data obtained on microbial mats (fine laminated layers of diverse microbial communities) are shown here.

Experimental conditions:

- *Cs^+, negative secondary ions*
- *Analysis area size: ~25x25µm²*
- *Detection: ^{32}S on FC1, $I(^{32}S)$ ~ 2E8 c/s,*
  ^{34}S on FC2, $I(^{34}S)$ ~ 1E7 c/s,
- *Total integration time: 120s*

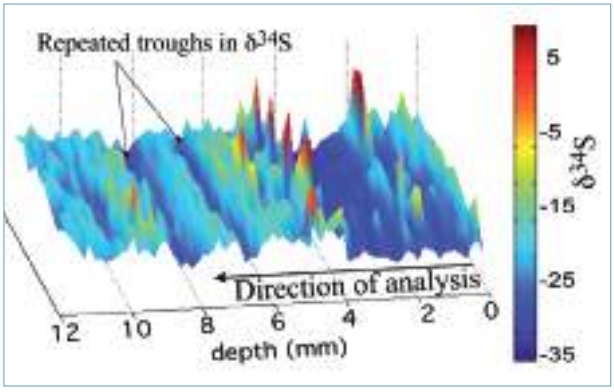
Both external error (std. variation of multiple adjacent points on standards) and internal error were ~1‰. This value is substantially smaller than the up to 20‰ variation observed within the sample.

Using the IMS 7f-GEO, it was possible to capture small-scale (~100µm-1cm), 2-dimensional, $\delta^{34}S$ variability in sulfides with excellent precision.

Data from: D.A. Fike et al., GCA 73, p. 6187 (2009).

$\delta^{34}S$ obtained on a sulfide sample (Rio Guerrero, Mexico).

Incubations analyzed in 2D grids perpendicular to the surface (~150µm between consecutive analysis).



Construction of 2D isotopic datasets revealing both in-depth isotope gradients as well as lateral heterogenieity. Reproducibility is shown by the two minima at 6 and 8mm.

From stable isotope ratio measurements to trace element analysis, CAMECA's IMS 7f-GEO covers a wide range of applications in geochemistry.

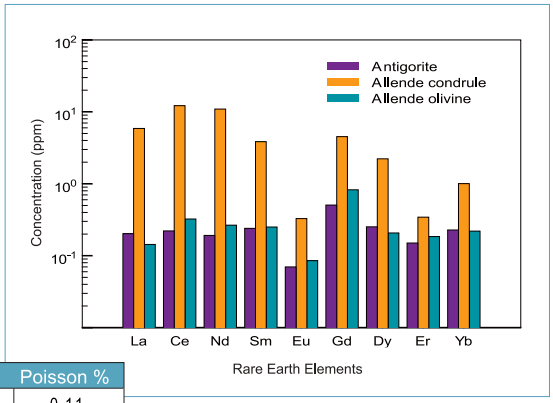
Rare Earth Element analyses at ppm concentration level

For mineral studies, the combination of high density O^- primary beam and high transmission mass spectrometer of the **IMS 7f-GEO** results in precise analysis of trace elements (REE, e.g.) at the ppm concentration level.

Experimental conditions:

- *O^-, positive secondary ions*
- *Analysis area size: <25µm in diameter*
- *Energy filtering technique*
- *Detection: ^{28}Si on FC2 ($R=10^{11}\Omega$) all other species on EM*
- *Total integration time: 27min*

Average standard error over REE/Si ratios < 0.2%



Rare Earth Element analysis on Allende meteorite and terrestrial Antigorite.

Ratio	Mean	Std. err %	Poisson %
139La/Si	7.15E-04	0.14	0.11
140Ce/Si	6.18E-04	0.12	0.12
141Pr/Si	7.45E-04	0.13	0.11
143Nd/Si	9.12E-05	0.12	0.22
149Sm/Si	1.14E-04	0.15	0.20
151Eu/Si	3.97E-04	0.12	0.15
156/Si	2.82E-04	0.22	0.18
157Gd/Si	2.42E-04	0.24	0.14
159Tb/Si	6.96E-04	0.07	0.12
161Dy/Si	1.35E-04	0.21	0.18
165Ho/Si	6.68E-04	0.14	0.12
167Er/Si	1.65E-04	0.11	0.17
169Tm/Si	6.31E-04	0.15	0.12
172Yb/Si	1.49E-04	0.22	0.18
175Lu/Si	5.54E-04	0.13	0.13

REE ratio measurements on NBS 610: the experimental errors are in the sub-percent level and are determined by statistics.

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