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2024　14)International Technical Exchange Program List

4 件

＊所属・職名は2025年3月現在

＊Affiliation and Department displayed are current as of March 2025.

(Form14-2)

Project Title : Development of High Temporal Resolution TEC Database and Plasma Bubble Detection Method

Principal Investigator Name (Affiliation)
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Please write your research summary including purpose, methods, periods of stay in ISEE / International stay, achievements obtained from the program, and list of publications in maximum two pages.

In this project, we utilized GPS data from the Malaysian Real-Time Kinematic Network (MyRTKnet) and the Sumartran GPS Array (SuGAr) to study ionospheric irregularities, specifically focusing on phenomena such as equatorial plasma bubbles (EPBs). Data in RINEX format were processed using the methodology developed by Assoc. Prof. Dr. Yuichi Otsuka, the corresponding researcher from ISEE in this project. Data processing was conducted on 1 March 2022 and 15 January 2022 to verify and validate the method. 1 March 2022 is for a geomagnetic quiet day, and 15 January 2022, is for geomagnetic disturbance day which was also triggered by the Hunga Tonga volcanic eruption. From the processed data, TEC maps were generated using Spherical Cap Harmonic Analysis (SCHA) of order 4, degree 2, and a spherical cap radius of 10°. ROTI maps were created to analysis the EPB. Previous studies by Buhari et al. (2014, 2017) demonstrated the capability of MyRTKnet to detect EPB over Southeast Asia. In this work, EPBs were analyzed through TEC, ROTI, and detrended TEC plots. TEC was calculated at the effective height of 300 km with maximum zenith angle of 60°. ROTI maps were produced using a 0.25° x 0.25° latitude and longitude grid, applying a 5x5 boxcar averaging method. Methodologies outlined by Nishioka et al. (2008), Buhari et al. (2014), Shinbori et al. (2023), and Abadi et al. (2025) were employed to identify EPB occurrences. During a research stay at ISEE from 15 January to 28 March 2025, a discussion with Dr. Otsuka facilitated improvements in data processing methods and better characterization of EPB features. Outputs of this project include the developed programs for mapping TEC, ROTI, detrended TEC, and determining poleward expansion velocity, as illustrated in Figure 1 and Table 1. Currently, no publications have been finalized from this research; however, efforts are underway to publish these findings in peer-reviewed journals.

Table 1 : Latitudinal extension of EPB on 15 January 2022

EPB	Onset time (UT)	Maximum Time (UT)	Initial Lon	Final Lon	Initial Lat	Final Lat	Extension Lat	Velocity
A	10.40	11:10	118 °E	114 °E	8 N	-0.25 °N	8.25 °	330.54 m/s
B	12:10	12:40	99.25 °E	100 °E	10.75 N	1.25 °N	9.50 °	583.66 m/s
C	12:20	12.40	103 °E	98 °E	9.5 N	1 °N	8.5 °	783.31/s

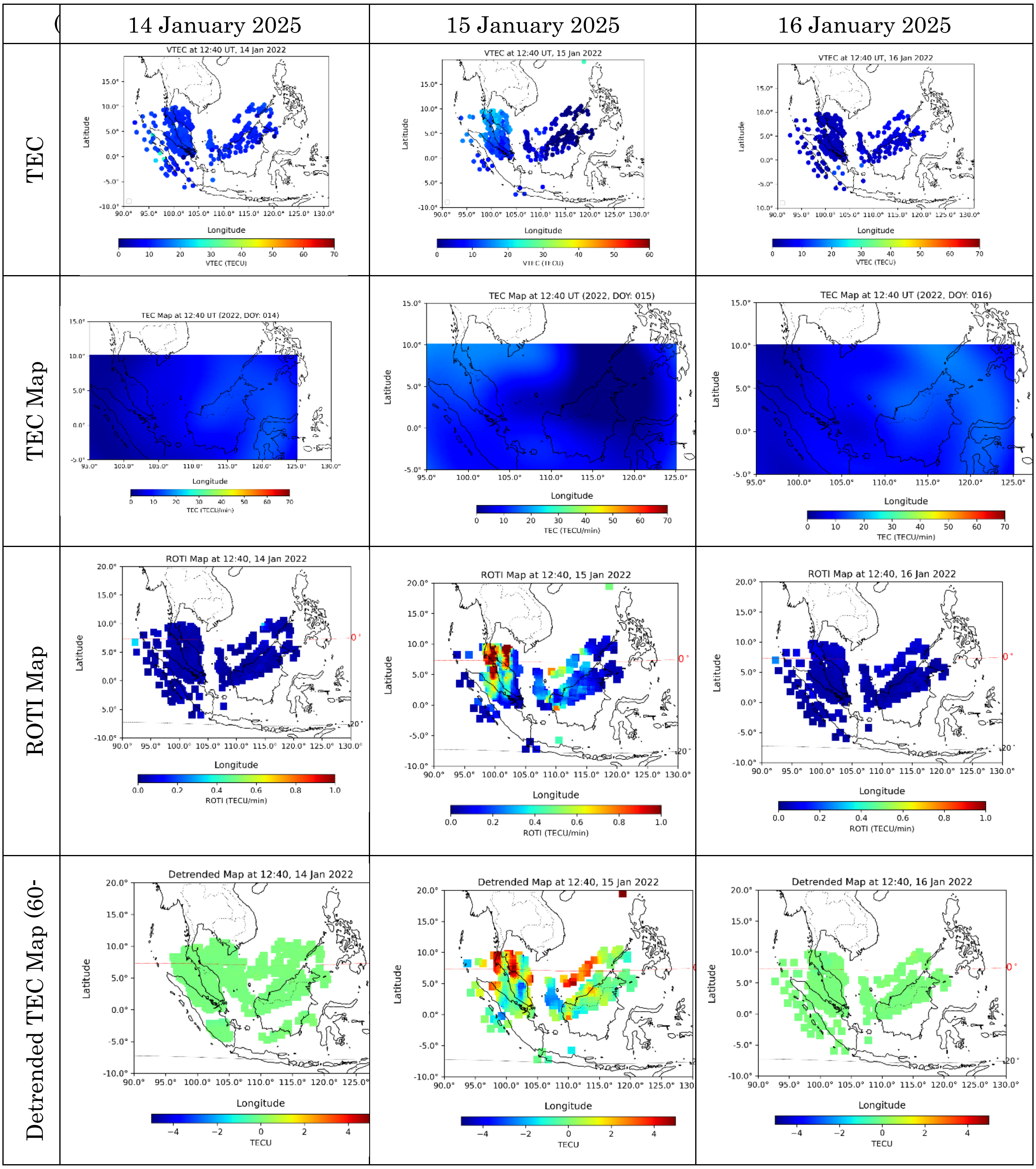

Figure 1 TEC, TEC map, ROTI map and Detrended TEC map (60-minutes windows) for 14 to 16 January 2022

(Form14-2)

Exchange program in technical-knowledge and expertise in the field of Digital Phase Array and Signal Processing

Shin'ichiro Asayama (SKA Observatory)

The corresponding ISEE researcher is constructing the next-generation digital phased array IPS observation system, which consists of 1,024 sub-arrays of 16 dipole antennas aligned in a straight line.

The PI visited ISEE from December 23-24, 2024. Fukui University of Technology (FUT) professor Yusuke Miyamoto and his students also visited and participated in an experiment to detect the Sun at 327 MHz using an antenna array consisting of 16 dipole antennas and an analogue signal receiver system. The PI prepared a Sun drift scan observation script with an SDR receiver, which was used in the experiment. It was confirmed that the antenna array formed a tied array beam as expected.

Array layouts for the next-generation digital phased array system were discussed after the experiment. Mutual coupling effects among the antennas and grating lobes are known to harm phased array systems. A trade-off between avoiding grating lobes and containing mutual coupling is a challenging task for planar-phased array layout design. The PI introduced the OSKAR simulator, which simulates digital beamforming for the aperture array of an SKA-sized phased array. The ISEE students shared the status of the impact of mutual coupling between antennas estimated by electromagnetic simulators. The participants also exchanged views on the requirements of the analogue RF signal system for the next-generation IPS observation system. As a result, it was found that the current baseline system does not meet some of the requirements, and design improvements need to be made. The PI and Prof. Iwai also discussed the construction strategy of the phased array instrument in the field.

The PI and the students continued their collaboration via emails and an online meeting. The PI visited ISEE again on January 29, 2025, and participated in the students' practice master's thesis presentations, providing feedback on them.

The outcomes were presented as poster presentations at the Japan Solar Physics Community Symposium on February 17-19, 2025.

(Form14-2)

粒子分析器開発のための低エネルギーイオン・中性ビームラインの技術開発と特性試験 -- 機械式粒子コリメータの特性試験 --

下山　学　（スウェーデン宇宙物理研究所）

目的

現在，将来の地球及び惑星超高層大気・プラズマ観測に向けた様々な粒子分析器の開発が進められている．これらの分析器の開発・較正にはビームラインが不可欠であるが，分析器の高性能化や測定パラメータレンジの拡大に伴い，ビームラインの開発や改良の必要が求められている．そこで本技術交流では，各研究機関が有するビームライン技術の交換を通して，今後必要となるビームライン技術や開発方針について議論する．特に ISEE 滞在期間中には，スウェーデン宇宙物理研究所（IRF）において開発中の機械式粒子コリメータの特性試験を ISEE 所有のイオンビームラインを用いて行う．機械式粒子コリメータは粒子の方向を機械的に制限し平行化する技術であり，粒子分析器をはじめビームラインの特性改良にも用いられることが計画されている．以下，特に機械式粒子コリメータの特性試験について報告する．

機械式粒子コリメータ

今回設計したコリメータは，粒子軌道と垂直に配置された複数（12 枚）の金属ブレード（厚さ 50 μm）からなる（図 1）．各ブレードは同一サイズ・形状（58 x 6 mm^2）で，複数の粒子入射口が設けられている．図 2 の断面図に示したように，ブレード間の距離を調整することで通過可能な粒子の方向を制御する．この設計では，コリメータ内部の粒子軌道（+z 方向）に平行なブレード断面（YZ 及び ZX 面）の面積を小さく保てることから，粒子のコリメータ内での前方散乱を最小限に抑えることが出来る．図 3 にレイトレーシングシミュレーションの一例を示した．上図がコリメータを通過した粒子軌道，下図がブレードによって遮断された粒子軌道である．+Z 軸に対して-50° < az < 50°の速度を持つ等方的な入射粒子を仮定した場合のコリメータの角度分布特性を図 4 に示す．az=0°を中心として FWHM~7°のメインピークに加え，az=±40°付近にサイドローブが存在している．このサイドローブは，コリメータのサイズ，ブレードの枚数，ブレード厚等の制限に対して，角度応答や粒子透過率を最適化した結果生じたもので

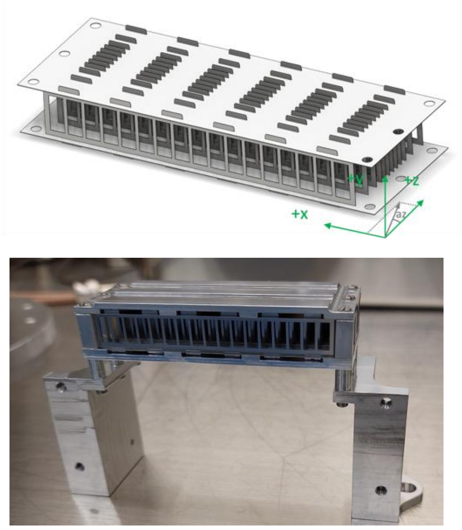

図 1．（上）機械式粒子コリメータの CAD モデルと（下）そのプロトタイプモデル

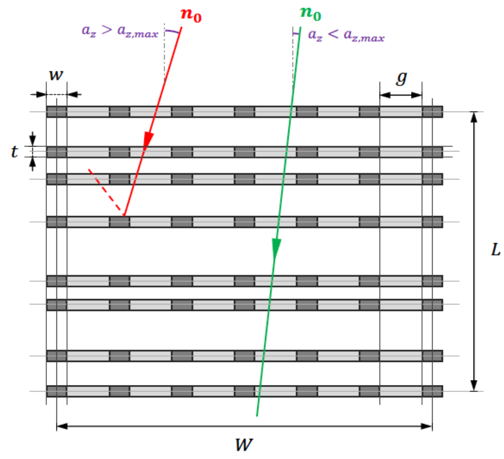

図 2. 機械式粒子コリメータの断面図．（緑線）通過粒子の軌道，（赤線）遮断される粒子の軌道（Maynadie, Master thesis, 2023).

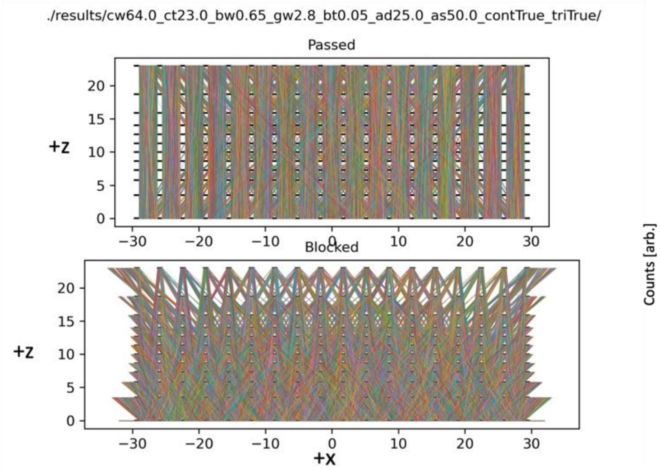

図 3．レイトレーシングシミュレーションの一例．（上）コリメータを通過した粒子の軌道，（下）コリメータブレードにより遮断された粒子の軌道．黒実線はコリメータブレードを表している．粒子は z=0 面から入射し+z 方向に進む．

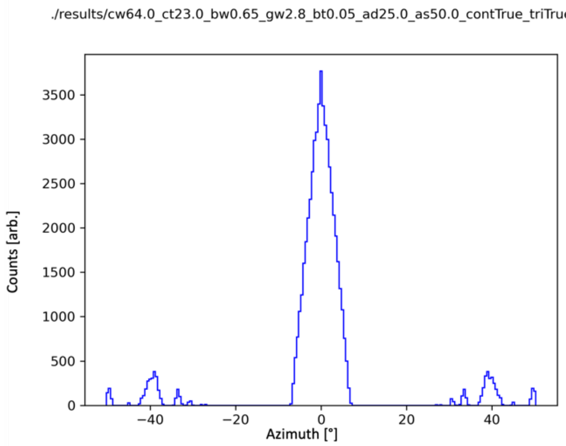

図 4．レイトレーシングシミュレーションで得られたコリメータの角度応答特性．

ある．またシミュレーションからは，ブレードのアライメントが角度分布特性に大きく影響することが分かっているため，ブレードの保持構造も適切に設計する必要があり，試作機を用いた粒子ビームに対する応答試験が不可欠であると考えられる．

特性試験

ISEE 出張期間：2024 年 11 月 15 日～2024 年 11 月 24 日（ISEE 滞在は 11 月 18 日～2024 年 11 月 22 日）
試験方法と成果：設計・製作したコリメータを ISEE 所有の低エネルギーイオンビームラインに設置し，イオンビームを照射してその角度応答特性を計測した（図 5）．粒子検出機には，ISEE 所有のシングルアノード MCP 及び位置検出アノード付き MCP を使用した．図 6 が計測された角度応答特性である．0°付近に FWHM~7°のメインピークが存在し，±40°付近にサイドローブがみられる．この特性は図 4 に示したシミュレーション結果とよく一致する．シミュレーション結果に見られるサイドローブの小さな構造（例えば±35°付近）は試験結果でははっきりと確認は出来ない．これは計測の角度ステップが十分に密でなかったことが主な原因であると考えられる．さらに計測結果には角度応答の非対称性が見られるが，真空槽内の構造体によるイオンビームの反射・散乱による可能性が高く，コリメータの特性ではないと推測される．以上の結果から，製作されたコリメータは設計通りの角度応答特性を示したと結論付けられる．コリメータブレードの設計手法やブレードの保持機構等，今回得られた知見は，粒子分析器やイオンビームラインの改良に即時に活用可能である．

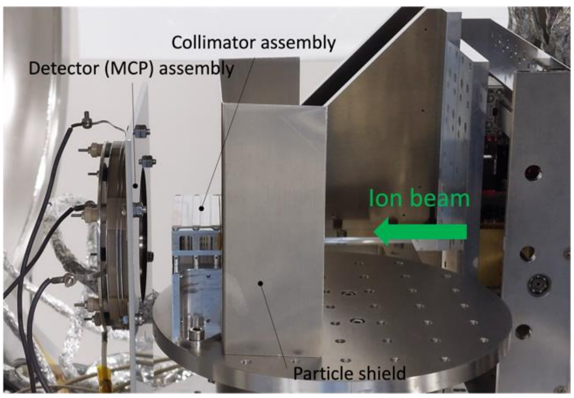

図 5．イオンビームライン真空槽中のターンテーブル上に設置された粒子コリメータ．ターンテーブルを回転させコリメータのイオンビームに対する角度を変化させる．

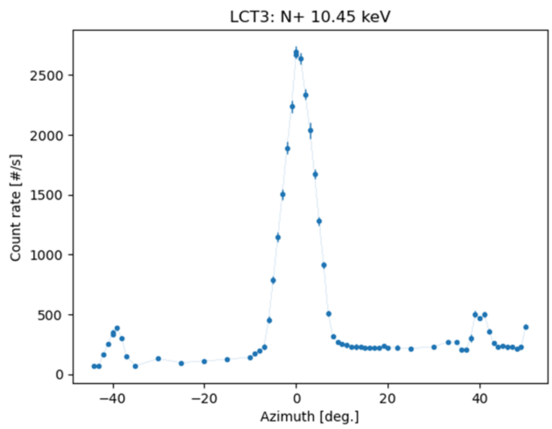

図 6．粒子コリメータの N^+イオンビームに対する角度応答特性．

(Form14-2)

International exchange on chemical pretreatment and measurement techniques for high-precision isotope analysis of rock and sediment samples

Yoshihiro Asahara (Graduate School of Environmental Studies, Nagoya University)

1. Purpose of this project

In this international technical exchange, researchers specializing in isotope geochemistry from Nagoya University and the Korea Institute of Geoscience and Mineral Resources (KIGAM) share chemical preparation techniques and measurement techniques using mass spectrometers. The objective of this exchange is twofold: first, to improve the accuracy of isotope analysis of geological samples such as rocks, sediments and ore minerals; and second, to improve the technical skills of researchers, including young researchers, through face-to-face exchanges. This project focuses on the analysis of isotopes of lithium (Li) and rare earth elements (REE) in a variety of geoscience samples, with an emphasis on the advancement and development of isotope analysis techniques.

2. Methods

The project members are Dr. Seung-Gu Lee, Korea Institute of Geoscience and Mineral Resources (KIGAM), Korea; Dr. Narges Daneshvar, Institute for Space–Earth Environmental Research (ISEE), Nagoya University; Mr. Kazuma Wakayama, Graduate School of Environmental Studies, Nagoya University; Masayo Minami, ISEE, Nagoya University; and myself.

In this project, the chemical pre-treatment of the samples was performed at the clean room chemistry laboratory of the Graduate School of Environmental Studies of Nagoya University and at the clean room chemistry laboratory of KIGAM. In addition, the following mass spectrometers were used in the project:
(a) Thermal ionization mass spectrometer (TIMS), GVI IsoProbe-T, with 9 Faraday cups (Nagoya University),
(b) Multi-collector inductively coupled plasma mass spectrometer (MC-ICP-MS), ThermoFisher Scientific Neptune Plus, with 9 Faraday cups (KIGAM), and
(c) Inductively coupled plasma mass spectrometers (ICP-MS), Perkin Elmer NexION350 (KIGAM) and Agilent 7700x (Nagoya University).

3. Periods of stay in ISEE / International stay

(i) Stay in KIGAM, Korea
From 16/3/2025 to 21/3/2025, Asahara, Y., Wakayama, K.
From 19/3/2025 to 21/3/2025, Minami, M.
(ii) Stay in ISEE, Nagoya University, Japan
From 24/3/2025 to 29/3/2025, Lee, S.-G.

4. Achievements obtained from the program

4-1 Isotope ratio measurement of trace amounts of Nd by TIMS (Jul. 2024~Mar. 2025)

The concentration and isotopic composition of REEs can provide reliable insights into the source material and chemical conditions of geological samples. Neodymium (Nd) in particular is a prominent REE, and its analysis is crucial for understanding the REE composition in various geologic contexts. The general Nd isotope ratio measurement ($^{143}Nd/^{144}Nd$) at TIMS requires about 100 ng of Nd separated and extracted from geological samples. However, only a few ng to 20 ng of Nd can be recovered from ultrabasic rocks originating in the Earth's mantle by the conventional chemical pretreatment. Daneshvar and Asahara enhanced the ionization efficiency of Nd in TIMS by fine-tuning the ion source of TIMS (e.g., adjusting the spacing of filaments used to apply the sample) for 10–20 ng of Nd sample extracted from the ultrabasic rocks, thereby attaining near-normal levels of analytical accuracy and precision in isotope ratio. Subsequent to the collection of these data, Lee, Daneshvar and Asahara engaged in a discussion on the fine-tuning of the ion source and the underlying mechanisms that enhanced ionization efficiency.

4-2 Isotope ratio measurement of Li by MC-ICP-MS (Dec. 2024~Mar. 2025)

Lee, Wakayama, Asahara, and Minami performed lithium (Li) isotope ratio ($^{7}Li/^{6}Li$) measurements on Li fractions chemically separated from volcanic rock samples at a laboratory in Nagoya University by MC-ICP-MS at KIGAM. The study revealed that the recovery of Li from the samples was nearly 100%, and the separation from homologous elements such as sodium (Na) and potassium (K) was almost perfect. However, it was observed that the Li fraction contained impurities, including group 4 elements, zirconium (Zr), and titanium (Ti). These impurities led to a degradation in the isotope ratio measurement due to their contamination. Addressing this challenge will require the development of methods to purify the Li fraction after chemical pretreatment by removing impurities such as Zr and Ti. Furthermore, Li isotope ratio measurements by MC-ICP-MS are typically performed in static mode (i.e., the collectors, that is Faraday cups, receiving the ^{6}Li and ^{7}Li ion beams are fixed), however, the MC-ICP-MS at KIGAM is equipped with more ion counting detectors than a conventional instrument, and the Faraday cups could not be positioned in the standard location to receive the ^{6}Li and ^{7}Li ion beams simultaneously. Consequently, an attempt was made to execute the measurement in dynamic mode (one detector receives ^{6}Li and ^{7}Li ion beams alternately), which has been found to be sufficiently accurate. In the future, we plan to establish a Li isotope ratio measurement method in dynamic mode for MC-ICP-MS at KIGAM.

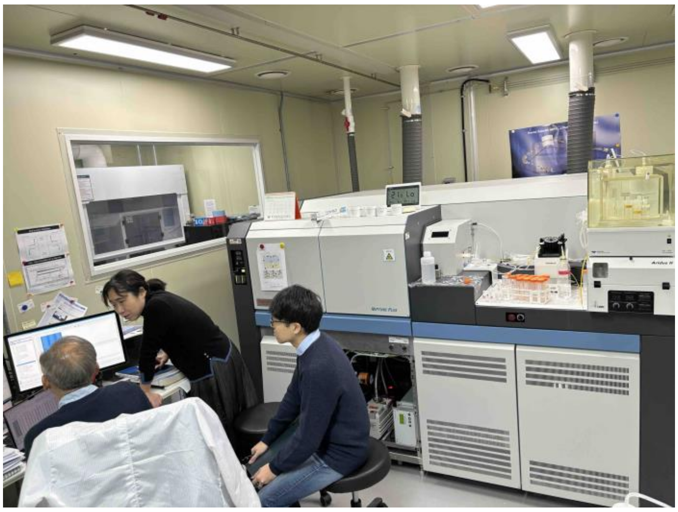

Fig. 1 Li isotope analysis by MC-ICP-MS at KIGAM.

4-3 Confirmation of the accuracy of quantitative Eu analysis by two ICP-MS instruments (Dec. 2024~Mar. 2025)

The concentration and isotopic composition of europium (Eu), which can exhibit a different valence (+2, +3) than that of other REEs (+3), can provide significant constraints on the process of magma differentiation and the recovery of the redox state. Magma differentiation and redox state affect the degree of europium (Eu) abundance, and in the case of samples with extremely low Eu concentration, isobaric interference effects may appear in the Eu concentration, significantly reducing the accuracy of the quantitative values. Therefore, Lee, Daneshvar, Wakayama, Minami and Asahara performed quantitative analysis using KIGAM and Nagoya University ICP-MS, which have different basic performance such as molecular ion generation rates, and contrasted the two measurement results. The results showed no difference in Eu concentrations between the two measurements, confirming that the correction for molecular ions during the measurement was accurate.

5. List of publications

(1) Azizi, H., Nouri, F., Asahara, Y., Minami, M., Tsuboi, M., Takahashi, H.A., Whattam, S.A. (2024) Ultrapotassic rocks in the Saray Peninsula, Northwest Iran: An example of carbonate peridotite melts in a post-collision system in the late Miocene. *Lithos* **488-489**, 107788.

(2) Azizi, H., Yara, I., Ali, S.A., Mohammad, Y.O., Asahara, Y., Minami, M., Shin, K.C., Anma, R., Whattam, S.A. (2025) The Penjween gabbro, northeastern Iraq, revealing a forearc hyperextension regime with a slow spreading ridge center in the Late Cretaceous. *Geochemistry* **85**, 126241.

(3) Lee, S.-G. (2024) Optimization of separation and MC-ICP-MS methods for determining Eu isotopic ratios in Si- and Ba-rich fractionated igneous rocks and other natural materials. *Spectrochimica Acta Part B: Atomic Spectroscopy* **218,** 106991