Improvement of the FEBIAD ion source at SPIRAL1

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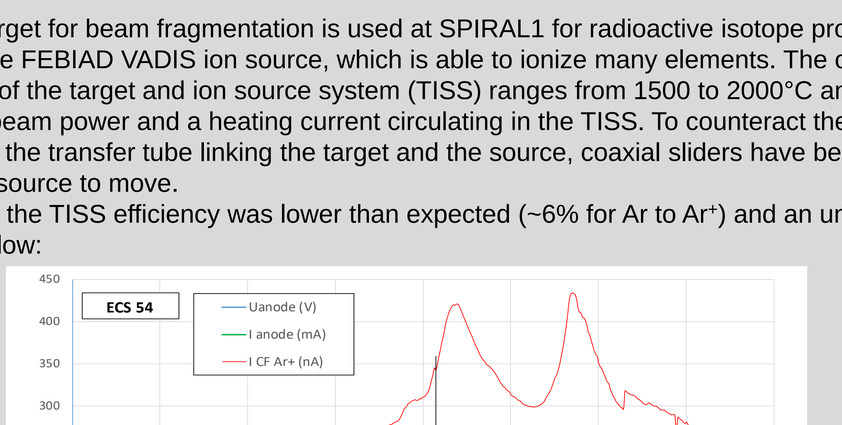
ABSTRACT

The behaviour of the Forced Electron Beam Induced Arc Discharge (FEBIAD) ion source used at GANIL within the Target Ion Source System (TISS) of the "Système de Production d'Ions Radioactifs Accélérés en Ligne" (SPIRAL1) has been recently investigated to improve its performances and render them reproducible. Off line systematic studies of the evolution of working parameters (cathode shape, cathode heating, anode current) with time and temperature configuration have clearly shown the origin of issues was mainly related to an excessive temperature of the anode insulators. Modifications of the TISS have allowed the reduction of the anode current drift and an ionisation efficiency of ^{40}Ar of 15%, stable over more than eight days. The system is still under improvement to stabilize its Ar ionization efficiency to 25%, which is the maximum observed during testing.

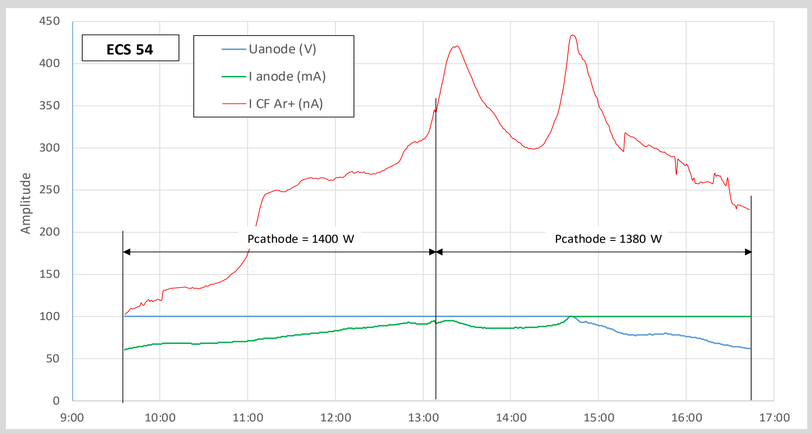
FEBIAD TARGET AND ION SOURCE SYSTEM AT SPIRAL1



FEBIAD adapted for SPIRAL1 before this work

A graphite target for beam fragmentation is used at SPIRAL1 for radioactive isotope production. It is coupled to the FEBIAD VADIS ion source, which is able to ionize many elements. The operating temperature of the target and ion source system (TISS) ranges from 1500 to 2000°C and is provided by the primary beam power and a heating current circulating in the TISS. To counteract the thermal expansion of the transfer tube linking the target and the source, coaxial sliders have been installed allowing the source to move.

Before 2020, the TISS efficiency was lower than expected (~6% for Ar to Ar^+) and an unstable behavior as shown below:



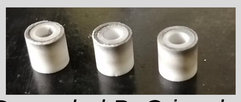
Example of initial performance of the ion source. The Ar^+ current changed by a factor of 4 over a few hours. The current exchanged between the cathode and the anode drifted until saturation of the polarizing power supply.

The goal of the present study is to obtain a stable behavior during a week and an Ar^+ efficiency higher than 10%.

TESTS AND MODIFICATIONS

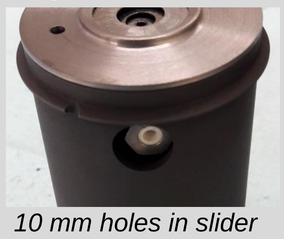
Off-line test are performed at the SPIRAL1 test bench. Performances of the TISSs are evaluated by measuring intensity of the beam through a dipole, allowing charge/mass spectroscopy of the beam. Several configurations were tested :

Initial configuration (A): cathode-anode current drift over time.
The beam contained Be, revealing BeO insulator deterioration.



Degraded BeO insulators

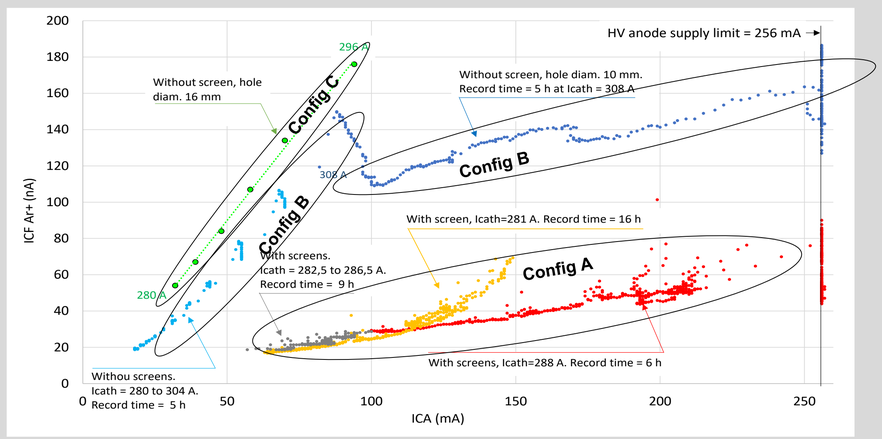
Without Ta thermal screen (B): as the graphite sliders act as thermal screen, the Ta reflector gave too much insulation and was removed. This modification led to an important performance improvement.



10 mm holes in slider

Without Ta screen and with larger aperture around BeO Insulator (C):
To further decrease the temperature of the insulators, the holes in the graphite sliders were enlarged to help the power dissipation.
Very little Be^+ in the beam (~nA) => the BeO are not damaged.

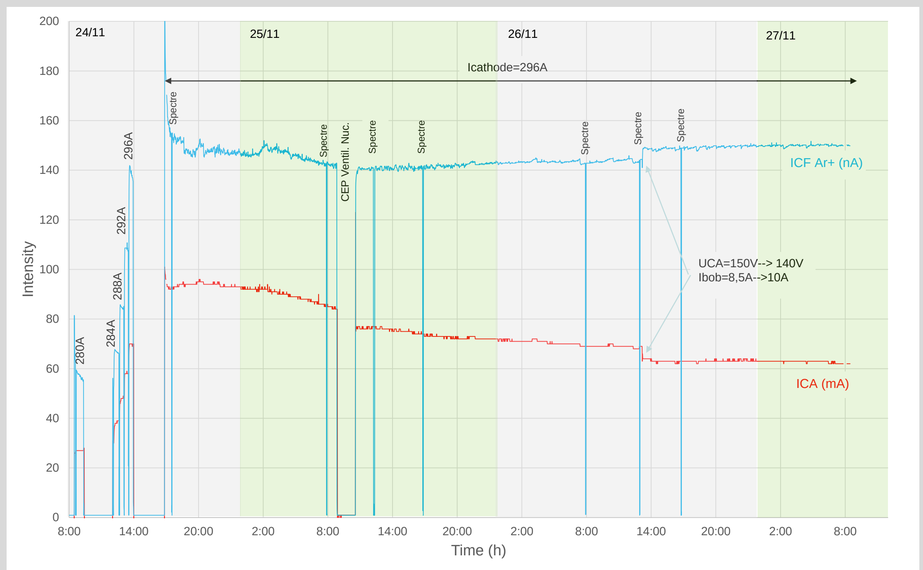
16 mm holes in slider



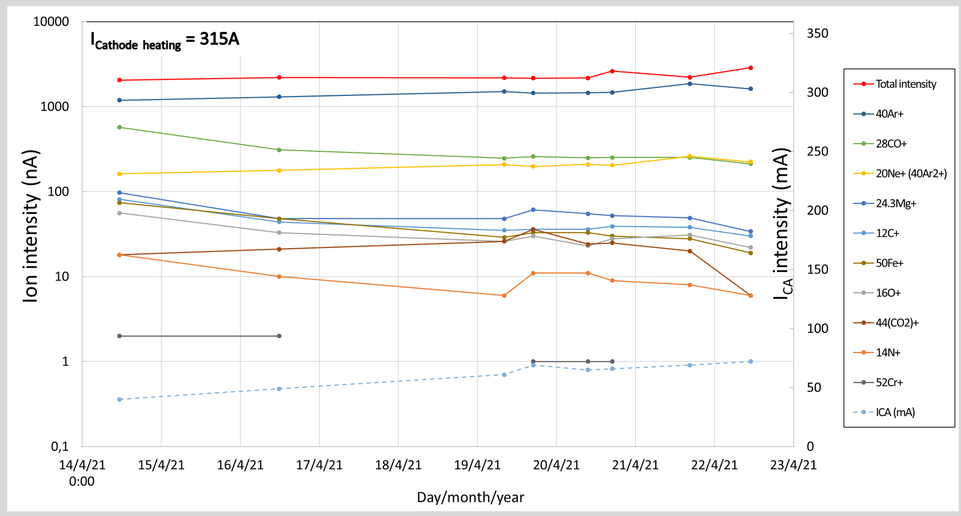
Ar^+ current as a function of the current I_{CA} exchanged between the cathode and the anode. This graph indicates that part of I_{CA} is not participating to the ionization.

RESULTS

The FEBIAD ion source at SPIRAL1 is now capable of providing 13% of Ar^+ efficiency over a period of 8 days, with stable performances.

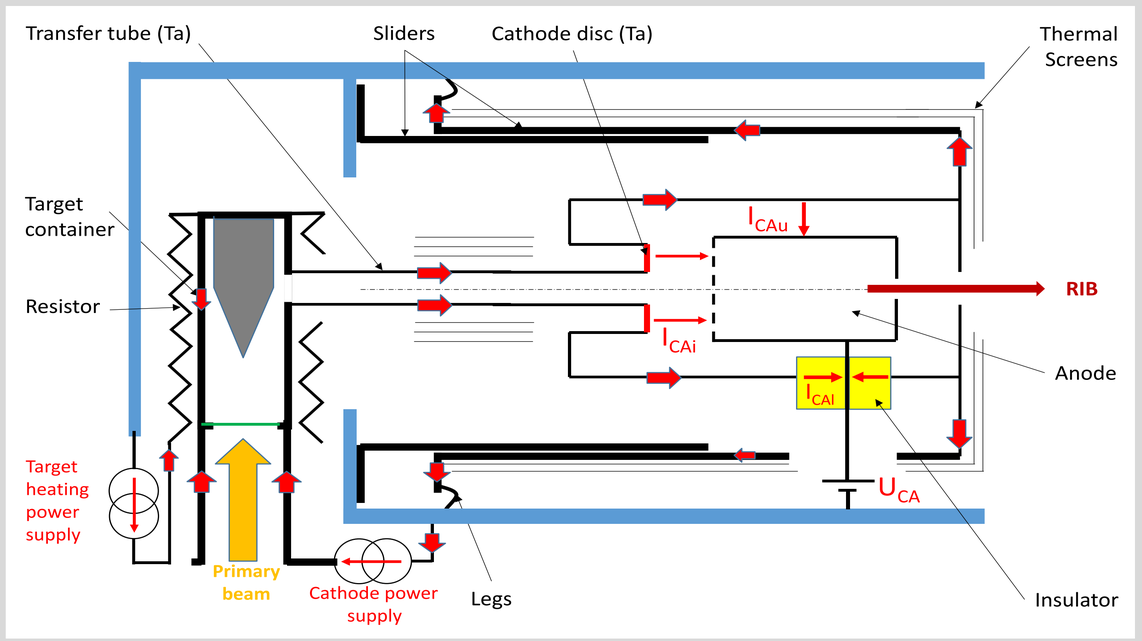


Performance of the last version before on-line test. The blue line shows the Ar^+ current over 3 days. The blue line is the current I_{CA} exchanged between the anode and the cathode.



Beam of the last version. A mix of noble gases is injected into the target with a capillary. Iron sample placed in the target confirm the FEBIAD's ability to ionize this element.

UNDERSTANDING OF THE FEBIAD



Schematic of the current circulation routes in the FEBIAD TISS

Current exchanged between cathode and anode :

- $-I_{CAi}$: current emitted from the cathode disc, which is responsible for the ionization
- $-I_{CAu}$: current emitted from the cathode cylinder to the anode cylinder
- $-I_{CAl}$: leak current passing through the BeO insulator

There is a direct link between the BeO insulator degradation and the Be and Mg currents in the beam of the FEBIAD. This allows us to evaluate the conditions of the insulators during testing.

Temperature of the BeO insulators is the main source of the I_{CA} current drift. Reducing the insulator's temperature while keeping hot the cathode and the anode is a key to obtain high efficiency and long operation time.

PERSPECTIVES

The next goal and challenge of the version currently undergoing tests is to maximize the anode temperature while maintaining an Ar+ ionization efficiency of 25% for ten days. This efficiency has already been achieved but only for a period of 3h.

References :

[1] *L. Penescu, R. Catherall, J. Lettry, and T. Stora, Rev. Scient. Instrum. 81, 02A906 (2010)*
[2] *B.E. Schultz, J. Sandor, P. Kunz, A. Mjos, O. Kester, F. Ames, 9th Int. Part. Accel. Conference*
[3] *Y. Otokawa, A. Osa, T.K. Sato, M. Matsuda, S. Ichikawa, and S.C. Jeong, Rev. Scient. Instrum. 81, 02A902 (2010)*
[4] *B. Tang et al., Nuc. Inst. Meth. Phys. Res. B 463 (2020) 154-157*
[5] *R. Kirchner and E. Roeckl, Nuc. Inst. Meth. Phys. Res.133 (1976)187-204*
[6] *G. Reboul, Phénomènes thermo-électriques et électro-capillaires dans les gaz. J. Phys. Theor. Appl., 1908, 7(1), pp. 840-856. https://hal.archives-ouvertes.fr/jpa-00241415.*
[7] *A.W. Pryor, « The electrical conductivity of beryllium oxide », Journal of Nuclear Materials 14 (1964) 258-264*