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PERMANENT MAGNETS UNDER IRRADIATION AND RADIOACTIVE ALKALI ION BEAM DEVELOPMENT FOR SPIRAL I

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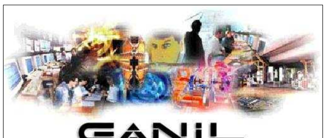

GANIL
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Abstract

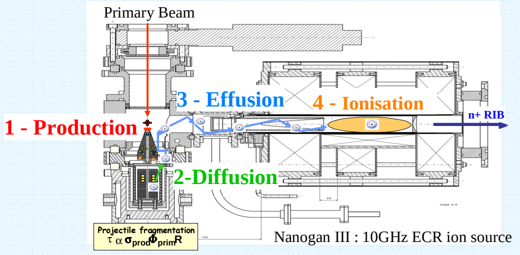
Up to now, eighteen Target & Ion-Source Systems (TISSs) have been built and used for the production of radioactive ion beams on SPIRAL 1 facility, based on the Isotope Separator On Line (ISOL) method. The TISSs are composed of a carbon target and the fully permanent-magnet ECRIS Nanogan III. After irradiation and a period of two years for radioactive decay, each irradiated TISS is dismounted and, if its magnetic field is still suitable, the ECRIS is associated to a new target. In this way, thirty-two runs have been performed using new or renewed TISSs. Sometimes, however, the measurement of the magnetic field after irradiation shows a degradation of the permanent magnets. Our experience with these TISSs is reported here.

In a second part, we present the progress with the NanoNaKE setup, which aims to extend the radioactive ion beams used in SPIRAL I to the alkali elements, by coupling a surface-ionization source to the Nanogan III ECRIS via a compact 1+ ion beam line. The main issues and difficulties are discussed and the preliminary solutions are described.

SPIRAL 1 at GANIL:

Radioactive Ion Beam (RIB) facility

The primary beam is stopped in a thick carbon target. The projectile fragmentation (1) produces the exotic elements in the first part of the target and they are stopped in the second part. The gaseous elements diffuse (2) out of the target and effuse through the cold transfer tube (3) in the N+ ECR ion source. This ion source produces a multicharged radioactive ion beam (4) which is accelerated by the CIME cyclotron and conveyed to a physics area.



Nanogan III : 10GHz ECR ion source

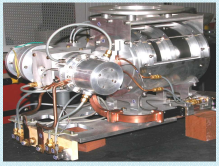
Technology Used

Carbon targets

Ar, Ne, Kr, O, N production (1,4kW)

He production (3,3kW)

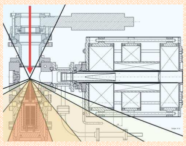
Nanogan III



All permanent-magnet ion source

Magnets Material **FeNdB**	Remanence		Coercivity	
	Br typical (Tesla)	Br min. (Tesla)	HcB typical (kA/m)	HcB min. (kA/m)
VACODYM 655 HR	1,28	1,22	990	925

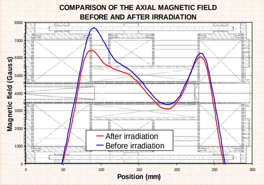
Permanent magnets under irradiation



Neutrons produced by nuclear reaction between a primary beam and the target can have high energies (> 10MeV). Because of the high cross section between the high-energy neutrons and the boron atoms of the permanent magnets, those are degraded.
These reactions produce neutrons but also charged particles, like protons or alpha-particles, for example, which damage the magnets further. [1]

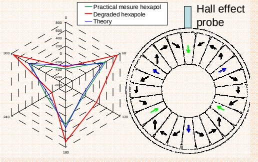
Effect on the magnetism structure

Axial magnetic field



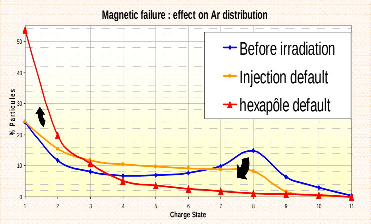
The magnetic field at injection is lower than before irradiation. Magnets in the injection crown have been damaged.

Hexapole mesurement



Magnets have changed their magnetism. Coercivity of the magnets decreases with neutrons and the magnet properties are modified.

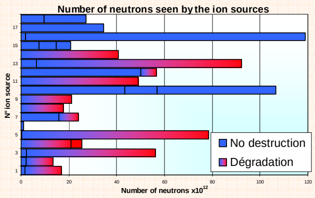
Effect on the performance



Each TIS is tested (intensity and efficiency) with a stable argon beam, using a calibrated leak (6 µAp).

In the SPIRAL I facility, 18 TISSs were used for 32 irradiation periods.
If we look at their efficiencies as a function of the number of neutrons seen by the ion sources, we can see there is no reliable way of forecasting the lifetime of the ion source.

The destruction of the magnets depends of neutrons flux, but also depend on the primary beam (energy, intensity, position on the target) and the kind of target which was used.



Conclusion

18 Nanogan III ions sources were constructed since the start of SPIRAL 1. Only five of them are still in use at the present time. The effect of neutrons is clearly demonstrated but it isn't possible to know exactly when the ion sources will be break down. We can only check the performance at the end of the run using a stable beam of argon and then judge whether the ion source will still be useful for producing radioactive ion beams.

Nanonake: Issues and Difficulties

Introduction

In the framework of the production of multi-charged radioactive alkali ion beams in SPIRAL I at GANIL, a surface ionization source to produce singly-charged ions of Na and K associated with the multi-charged ECR NANOGAN III was developed [2]. The system, called NanoNakE, has shown the possibility to obtain the 1^+ capture and the $1^+/N^+$ transformation in the ECRIS for the radioactive $^{47}K^{5+}$ but with an efficiency which is lower than expected [3].

To understand this problem, several hypothetical problem areas were investigated:
- ✓ Interaction of the 1^+ ion beam, along the 1^+ beam line with the residual gas (energy and angular spreads), due to the low conductance of the pumping path. Residual gas is composed of outgassing of the hot parts (oven, ionizer) and gas flow coming from the N^+ source.
- ✓ Possible interaction of the 1^+ beam with the backward N^+ ion beam extracted from the ECR ion source.

In order to make a correct diagnostic, complete and stringent tests are being made with very careful procedures. To this end :
- ✓ A small alkali ion system, built in order to generate a constant 1^+ flux of alkali stable beam, was calibrated.
- ✓ This system was coupled with the 1^+ beam line and the ECR ion source. Transmission measurements were performed with different parameters.
- ✓ Finally, the plasma capture was tested.
- ✓ Simulations were also performed with the CPO (Charged Particle Optics) [4] and SIMION [5] codes.

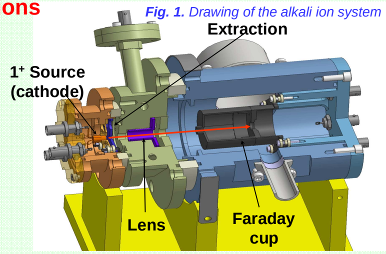
1st step: Source of stable $^{39}K^{1+}$ alkali ions

Results: High 1^+ ion current extracted = 15 µAe
- Experimental Transport Efficiency ~90%
- Simulation Transport Efficiency ~100%

Parameters	Potential (V)
Source	1100
Extraction	685
Lens	975
Faraday Cup	0

Restriction:
- The system was tested only at high voltage for the source potential

Fig. 1. Drawing of the alkali ion system



2nd step: Alkali ion source + 1^+ beam line + ECR off (Platform voltage at 0V)

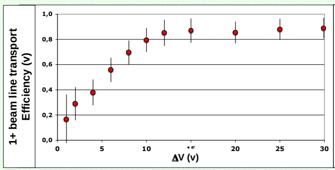


Fig. 2. $^{39}K^{1+}$ beam line transport efficiency

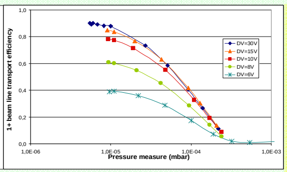


Fig. 3. $^{39}K^{1+}$ beam line transport efficiency versus gas pressure measured in the 1^+ beam line.

Gas pressure effect on the transport :
- ➢ Gas pressure effect has been verified
- ➢ For pressure > 10^{-4} mbar in 1^+ beam line the efficiency transport decreases.

Experiment:
- ⇨ Impossible to apply more than 700 V on the drift tube (Penning effect?),
- ⇨ ΔV>12 V better for a good transport (see fig. 2a), but may be too high for the ion capture by the ECR plasma?

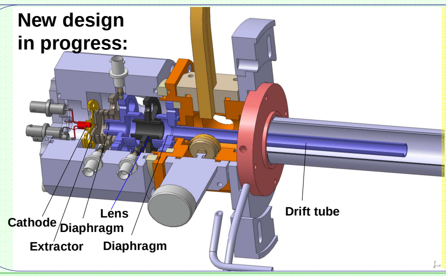
Problems:
- ⇨ At low voltage, the 1+ extraction is not well understood: difficult tuning and electrode-dependence
- ⇨ 1^+ cathode current depends on the voltage applied on the cathode
- ⇨ Too low acurrent emitted by the cathode at low 1^+ extraction potential to observe the beam at the exit of the ECRIS

3rd step: Alkali ion source + 1^+ beam line + ECR on

Problems:

-Difficult to observe the capture effect by the plasma at low current of 39K1+ (some nA compared to the background of the ECRIS)

New design in progress:



Characteristics:
- ➢ Better vacuum (~10^{-6}mbar, 1^+ beam line)
- ➢ Will be possible to extract the beam at higher energy (ΔV up to 1KV)
- ➢ Independent electrodes

Conclusion

Diagnosis of the 1+ beam line has been achieved. Several problems have been revealed.
- A gas pressure effect, coupling of the electrodes, limited value of extraction potential, Penning discharge.
- Difficulty to simulate ion transport at low energy (~<10 V)
- A new 1+ beam line is under construction, taking into account all these problems

References

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[2] C. Eléon et al., Proceedings of EMIS 2007, to be published by Nuclear Instruments and Methods in Physics Research, Section B (NIMB).
[3] C. Eléon et al., Proceedings of ICIS07, to be published in Rev. Sci. Instrum.
[4] CPO Programs, available on the web site http:// electronoptics.com
[5] SIMION Program.