CONSTRUCTION AND STATUS OF NEWGAIN RFQ

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Abstract

A new injector called NEWGAIN will be added to the SPIRAL2 Linear Accelerator in parallel with the existing one. It will be mainly composed of an ion source and a Radio Frequency Quadrupole (RFQ) connected to the superconductive LINAC. The RFQ is a standard four-vane bulk copper cavity, composed of 7 segments of about 1m. The new RFQ will accelerate at 88.05 MHz particles with charge-over-mass ratio (Q/A) between 1/3 and 1/7, from 10 keV/u up to 590 keV/u. This paper will present the status of the RFQ section fabrication and its necessary support systems. The fabrication and delivery of these components will lead to its installation, which is a major milestone for the project.

INTRODUCTION

The purpose of the NEWGAIN project [1] is to develop a new injector, consisting of a superconducting electron cyclotron resonance (ECR) ion source and a Radio Frequency Quadrupole (RFQ) (A/q = 7), for the SPIRAL2 LINAC. It will enable GANIL to provide ion beams of worldwide highest intensities (from proton to uranium), thus opening up unprecedented opportunities for nuclear structure and reaction studies at the extremes of the chart of nuclides from N=Z nuclei at the proton dripline to super-heavy species, including the discovery of new elements, and the production of radioisotopes. It also makes it possible to extend the use of SPIRAL2 beams to interdisciplinary research as well as applications.

The NEWGAIN RFQ cavity RF is very close to the SPIRAL2 RFQ cavity, currently operating in GANIL as they both operate at the same frequency. The choice was made to mechanically assemble the cavity with metallic vacuum gasket between copper parts as tube and vanes. The RF design and thermomechanical study of this new RFQ follow the procedure developed at CEA and presented in Refs. [2, 3].

RFQ DESCRIPTION

The RFQ cavity is made of seven sections, each one meter long, directly coupled. Each of these sections results from the assembly of four vanes into a copper tube. The vanes are bolted to the tube with Helicoflex seals. These seven sections are also mechanically joined via metal seals at the copper tubes.

The RFQ cavity in Fig. 1 is also equipped with:

- 56 tuners,
- 4 RF power couplers
- 24 pumping ports (equipped with 12 turbomolecular pumps)
- 18 pick-ups for voltage law control and LLRF
- 580 cooling connectors (on cavity, end flanges, tuners and power couplers).

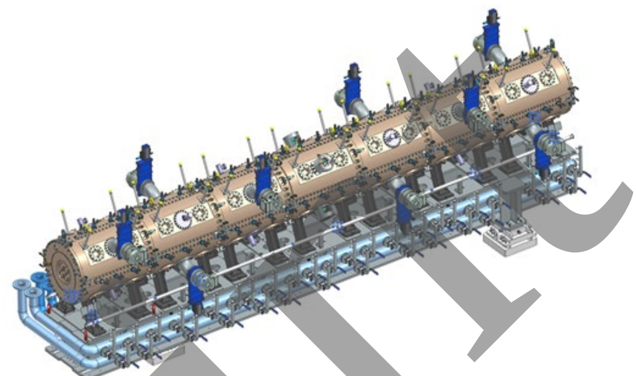

Figure 1: General layout of the NEWGAIN RFQ.

RFQ FABRICATION

Qualification Phase

Since January 24, the RFQ contract was assigned by an international tender to CINEL company. The first part of the contract validated the manufacturing process of an initial vane, realized with a machining tolerance of ±20 µm for the modulations and the vane ends (Fig. 2)

Figure 2: First vane of NEWGAIN RFQ.

This vane was then installed on a copper test piece (Fig. 3) to qualify the assembly process using a large racetrack-shaped Helicoflex® seal (Seals manufactured by Technetics Group). A leak test was then performed.

Figure 3: Assembly test for Helicoflex® seal.

The successful completion of this first stage enabled the start of fabrication for the first section, with the launch of production for the three remaining vanes and the tube.

Section Fabrication

The tube was subsequently manufactured in several steps, specifically involving precision machining of the electrode mounting surfaces. The cooling channels were completed, and the ends were sealed using electron-beam welding.

Each vane was machined with an extra thickness at its mounting surface within the tube. After an initial blank assembly, the positions of the four vanes were measured with a first CMM. The base of each vane was then re-machined to guarantee precise alignment with the beam axis.

The vanes were then reinstalled in the tube. Their positions were verified by a second CMM measurement, followed by pinning to ensure repeatable positioning during future reassemblies. Next, the vanes were cleaned and assembled one by one, incorporating both a Helicoflex® seal and an RF seal. A leak test was performed before proceeding to the installation of the next vane.

This installation process must meet two critical requirements: vacuum tightness (Accepted leak lower than 1×10^{-9} mbar l/s) and precise positioning, which is only achieved through proper metal-to-metal contact with the tube. This requirement necessitates high tightening torque for each screw, fastened into the tube via Helicoil inserts.

Figure 4: Section assembly.

Figure 4 shows the tooling used to insert the vane into the tube. The vane is consistently installed in the top position, requiring a second tool to rotate the tube itself. During this assembly phase, significant attention is paid to the preparation of the Helicoflex® sealing surfaces and their protection while positioning the tools and the vane within the tube.

The pumping ports (elbows and flanges with port for vacuum equipment) are then assembled with Helicoflex® seals. An overall leak test is then performed on the section. The hydraulic plungers and connectors are installed and pressure-tested up to 10 bar. The section is then ready for shipment in a vertical position, using dedicated transport tooling as shown in Fig. 5.

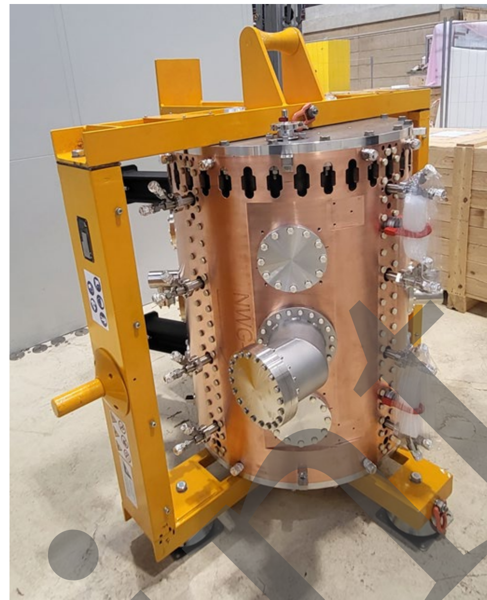

Figure 5: RFQ section ready for delivery.

Fabrication Status

Currently, all vanes and tubes are under fabrication. The main challenge at this moment is maintaining the positioning tolerances of the vanes within the tube during the assembly with the Helicoflex® seals. The high tightening torque required to achieve metal-to-metal contact between the vane and the tube induce positioning errors exceeding the technical specifications (±50 µm), despite the presence of positioning pins.

This issue is currently under analysis and several improvements are being implemented (including the addition of bronze inserts in the vanes, a new pin design, and an optimized seal tightening process to ensure more uniform seating of the vane).

To date, sections 6 and 7 have been delivered to CEA Saclay where their SAT (leak tests and pressure tests of hydraulic systems) was performed.

Section 5 currently shows vane positioning at the exit that is out of specification. Its status is being evaluated before potentially proceeding with a new assembly of the vanes.

The assembly of section 4 is scheduled for May 2026, incorporating the various improvement proposals provided by CINEL and Technetics Group.

From now on, all remaining sections will be delivered to GANIL over the coming months, with the arrival of the final section (Section 1) scheduled for early December 2026.

RFQ INSTALLATION

Assembly Test Bench at CEA Saclay

A 7-meter-long RFQ support was manufactured for this project to facilitate its assembly and alignment relative to the accelerator's beam axis, as well as to allow for thermal expansion due to the deposited power (in the range of 100 kW). Due to the access constraints of the accelerator building at GANIL, it was divided into four parts. An assembly tool was also developed to allow for the joining of two successive sections with an accuracy better than ±30 µm. This tooling is based on the same principle as the one previously implemented at GANIL for the assembly of the first RFQ, but also includes a lifting capability for the sections, due to the lack of an overhead crane in this room, unlike the RFQ1 room.

To qualify the RFQ assembly process, this equipment, along with the first two delivered sections (6 and 7), was initially delivered to CEA Saclay. An assembly test (Fig. 6) is currently underway to qualify these tools and to check the correct fit of the large circular Helicoflex® seal between 2 sections.

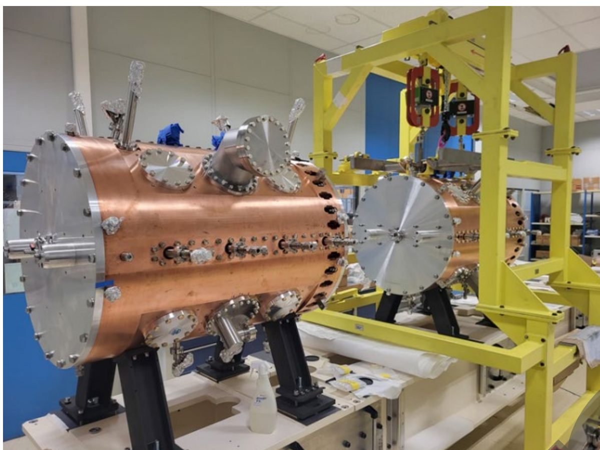

Figure 6: Two assembled sections.

RFQ Installation at GANIL

The RFQ integration procedure is currently being drafted. It incorporates the SAT (Site Acceptance Tests) at GANIL for the RFQ sections (leak tests, pressure tests, fiducialization by surveyors, sealing surface preparation, etc.) before their transfer into the tunnel, as well as the requirements for installing the support and tooling in the accelerator room.

This procedure [4] will outline the sequential installation of the sections, the various tests and adjustments at each stage (such as leak testing each inter-section seal), the RF tuning used to recover frequency and accelerating voltage law, the installation of other components as the tuners (as well as the preparation of the 56 sealing surfaces), and the final alignment of the RFQ on the beam axis. The goal of this procedure is to ensure the RFQ is fully prepared for the power conditioning stage.

RFQ assembly at GANIL is expected to begin in October 2026, depending on the progress of the civil engineering works of an extra emergency exit in the existing building. Three months will be required to assemble the seven sections on their support before moving to the RF tuning phase using bead-pull measurements. The final copper plungers will then be manufactured and installed on the RFQ using Helicoflex® seals during spring 2027. In parallel, the RFQ cooling system will be installed at GANIL near the RFQ1 system.

Hydraulic connections, vacuum system assembly, RF power source connections, and cabling are scheduled to start in mid-2027 to begin cavity conditioning by the end of 2027 following the process used with the first RFQ [5].

CONCLUSION

All major contracts for the RFQ are underway, primarily for the RFQ sections and end plates (manufactured by CINEL as part of the RFQ contract), the cooling system of the cavity, the RF pick-ups, the final copper plungers, and various RF tuning accessories.

The RF couplers have already been delivered some months ago and are identical to those implemented on the first RFQ of SPIRAL2.

A major milestone for the RFQ will be reached by the end of this spring with the assembly of two sections at Saclay, which will validate the positioning tolerances of the sections and their vacuum tightness. All the equipment will then be shipped to GANIL over the course of this summer.

One of the last major points remaining to be fully addressed is the control of the final vane assembly to maintain the positioning tolerances of the vanes within the tubes. Thanks to a joint effort with CINEL and Technetics Group, the upcoming sections are expected to meet these positioning requirements.

ACKNOWLEDGEMENTS

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