PROGRESS OF PIP-II ACTIVITIES at IJCLab

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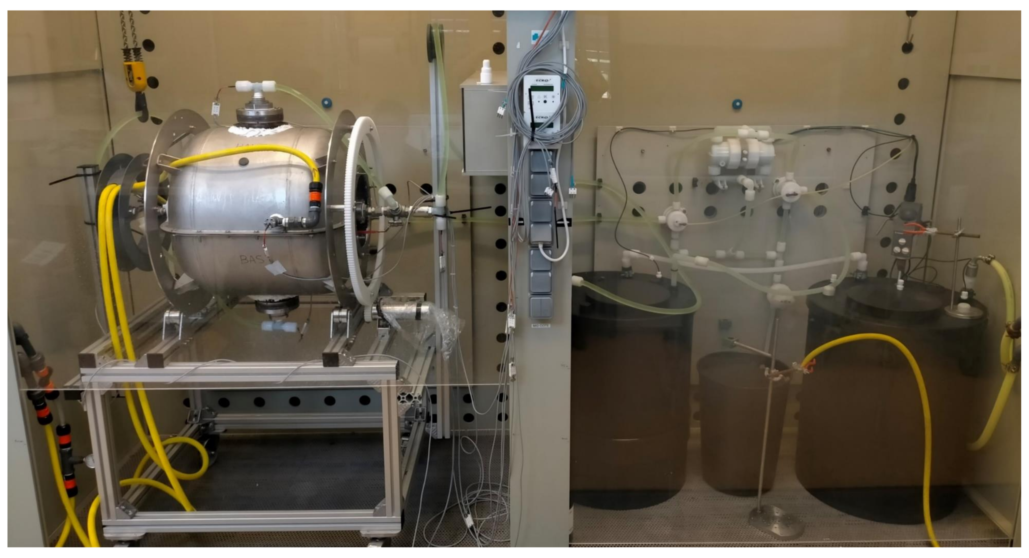
Since 2018, IJCLab is involved in PIP-II project on the design and development of accelerator components for the SSR2 (Single Spoke Resonator type 2) section of the superconducting linac. First pre-production components have been procured by Fermilab, fabricated, surface processing and cavity qualification in vertical cryostat are on-going. IJCLab has upgraded its facilities by developing a new set-up to perform rotational BCP. The progress of all processing and testing activities for PIP-II project will be reported and, in particular, a dedicated study to qualify removal uniformity compared to static BCP will be presented.*

INTRODUCTION

IJCLab, unique actor for CNRS/IN2P3 contribution to PIP-II, is strongly involved in the pre-production and production phases of PIP-II project and more specifically on the design and development of accelerator components for a section of the superconducting linac named SSR2. The manufacturing and the surface processing of the first prototype SSR2 cavities are on going. The first step of surface preparation consists in a bulk BCP (Buffered chemical polishing) performed on the bare cavity, followed by a light BCP and heat treatment after the helium tank integration. The required average material removal will be in the range of 150-200µm to eliminate the damaged layer created during the manufacturing. In this context, IJCLab has upgraded its facilities by developing a new rotational setup BCP starting from the existing one used to perform static BCP of Spoke resonators dressed with their helium vessel. It was experimented on a SSR2 prototype bare cavity equipped with a removable dummy tank. Static and rotational treatments were performed in order to estimate the surface quality and homogeneity of the niobium removal.

Rotational BCP setup at IJCLab



EXPERIMENTAL SETUP

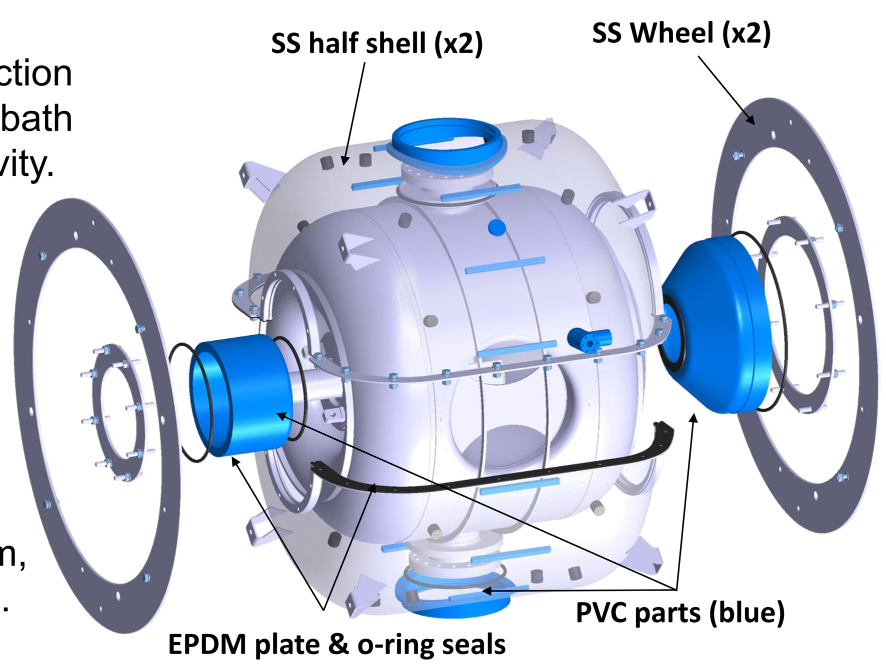
Dummy tank

The heat generated during the chemical reaction is dissipated through both the chilled acid bath (8°C) and a water flow (10°C) around the cavity.

To achieve this, a removable dummy tank was designed for the SSR2 bare cavity. Once the two wheels are attached to the dummy tank, it is installed on the rollers of the chemistry cart.

By means of a motorized gear mechanism, the cavity can be rotated along its beam axis.

Dummy tank:

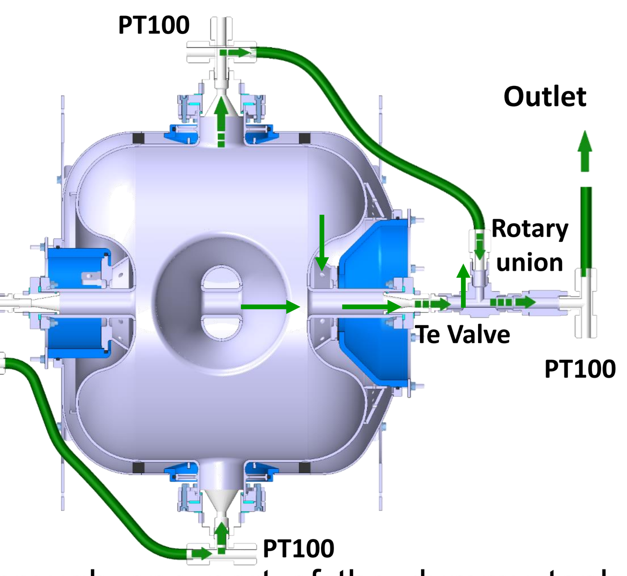


Acid and Water circuits

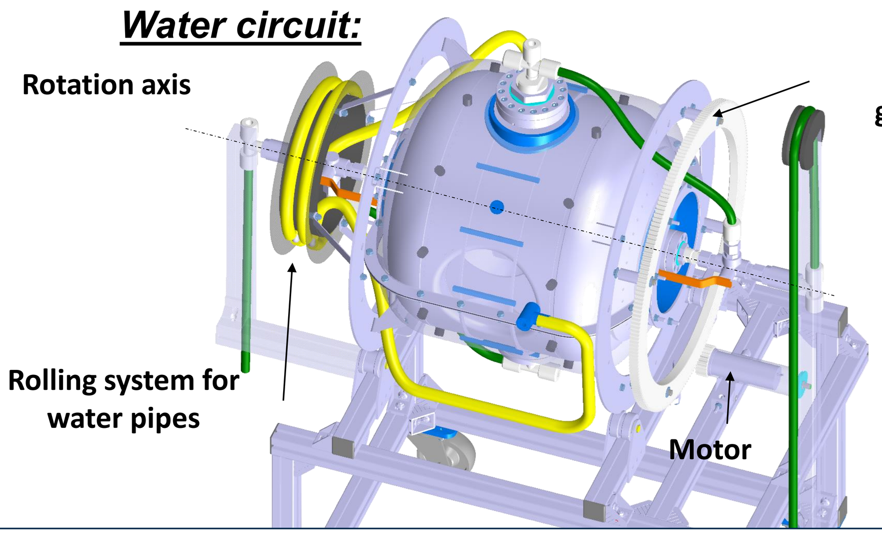
The acid (a standard mixture with 1:1:2.4 volume proportions: hydrofluoric HF, nitric HNO3 and ortho-phosphoric H3PO4) enters through two ports and exits through the other two ports. The 3-way ball valves ensure complete filling and draining by forcing the acid flow only toward side ports.

The cavity is completely filled with acid before rotation motion. Two rotary unions at each extremity allowing full rotation of the acid circuit.

Acid circuit:



Water circuit:



The water enters through one port of the dummy tank and exits through another port. A rolling system of the water pipes restricts the rotation to a back and forth motion of ± 350°.

EXPERIMENTAL RESULTS

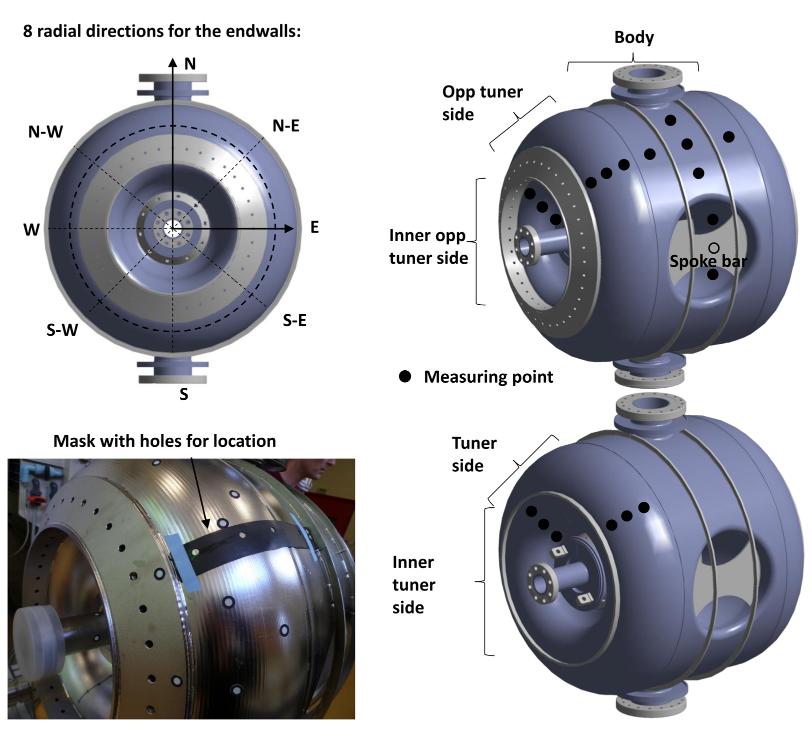
Experimental protocol

- 3 BCP: 1 static (BCP1) and 2 rotational (BCP2 & BCP3)
- Targeted material removal 50µm by BCP (Total removal around 150 µm)
- Identical parameters except rotation speed and niobium concentration in the acid at the start of the operation
- Thickness measurement with ultrasonic sensor after BCP (a hundred points)

Main parameters of BCP

Parameter	Unity	BCP1	BCP2	BCP3
Duration	min	75+75	150	150
Rotation speed	rpm	-	0.5	0.5
Niobium concentration	g/l	11.5	2.37	6.48
Acid flow rate	l/min	14.4	14.4	14.4
Cavity filling	%	100	100	100
T° acid set point	°C	12	12	8
T° water set point	°C	9	9	9

Campaign of thickness measurement:



Main results

Parameter	Unity	BCP1	BCP2	BCP3
Max acid T° at outlet	°C	22	14	15
Weight difference	kg	0.6	0.78	0.815
Average removal	µm	48.4	62.9	65.7
Etching rate	µm/min	0.32	0.42	0.43
Frequency shift	kHz	-1.75	-17.1	-13.5
Etching sensitivity	kHz/µm	-0.04	-0.275	-0.208

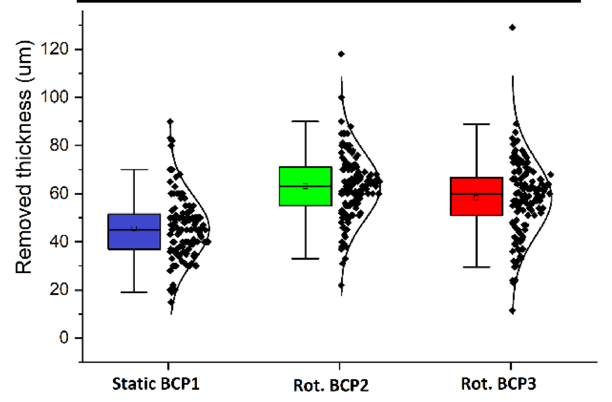
- ➢ Etching rate higher for rotational BCP than for static BCP: it's difficult to conclude as the etching rate is significantly impacted by both Niobium concentration and temperature.
- ➢ Final acid T° maintained below 15°C for rotational BCP whereas it raised above 20°C for static BCP: Rotation improves clearly acid mixing and thus avoids acid overheating.
- ➢ Frequency shift induced by static BCP is negligible and one order of magnitude lower than for rotational BCP. By simulating a uniform removal with COMSOL, the etching sensitivity is estimated at -0.52 kHz/µm. We can effectively conclude qualitatively that a rotational BCP leads to a more uniform material removal.

Thickness measurements

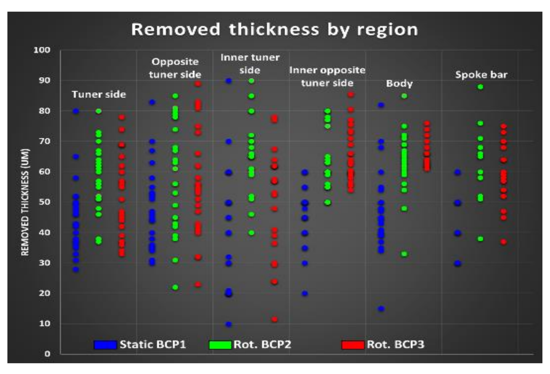
Parameter	Unity	BCP1	BCP2	BCP3
Average removal evaluated by weight	µm	48.4	62.9	65.7
Average removal estimated by thickness	µm	45.5	63	58.3
Standard deviation	µm	13.5	14	15.5

- ➢ No obvious improvement of the homogeneity of thickness removal
- ➢ Similar standard deviation for all BCP partially explained by the low reproducibility of thickness measurements with ultrasonic probe on non-flat surfaces: A tiny positioning error of the probe leads to an error of several tens of µm because of the curvature
- ➢ Only in region with low radius of curvature as the cavity body, it appears that the reproducibility of the measurement is good enough to unveil a better homogeneity during rotational BCP.

Distributions of data points:



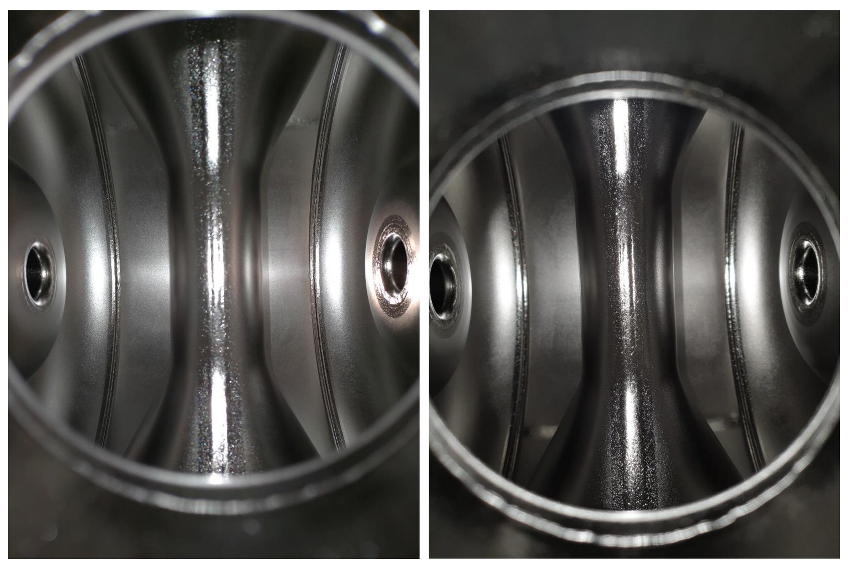
Removed thickness by region:



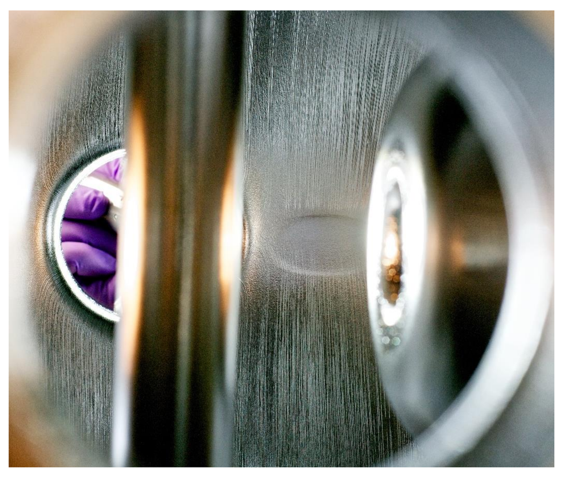
Visual inspection

- ➢ No difference in term of surface quality between static and rotational BCP
- ➢ No obvious trace of groove or bubble mark on the walls after static BCP as it was observed on previous experience on SSR1 cavities at Fermilab

Surface finishing of SSR2 cavity after static BCP (Left), after rotational BCP (Right):



Surface finishing of SSR1 cavity after static BCP:



CONCLUSION

The new rotational BCP setup at IJCLab is now operational. Compared to the previous static BCP, the treatment is more convenient for the operators, more efficient and less risky (no intervention is required at half the time). Project-wise, the implementation of rotational BCP is a real improvement in term of cost, human resources, time and risk. However, even though some indicators like the frequency shift tend to confirm a better homogeneity with rotational BCP, we were unable to prove by direct measurement of material thickness a more uniform removal. The limited accessibility and low reproducibility of the measurement on curved surfaces lead to non-negligible errors. Finally, quality-wise, rotational BCP allows a better mixing of the acid significantly limiting the acid temperature increase over time, thus guaranteeing optimal SRF performances.

* Work supported, in part, by U.S. Department of Energy, Office of Science, Office of High Energy Physics, under U.S. DOE Contract No. DE-AC02-07CH11359

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