Interim repair of ECR2 plasma chamber defect

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Following scheduled maintenance earlier this year, the 14.5 GHz electron-cyclotron-resonance (ECR) ion source, ECR2, was brought back online and resumed normal operation. During the initial operational phase, ECR2 demonstrated stable and expected performance across a range of ion beam productions, including $^{16}O^{6+}$, $^{20}Ne^{9+}$, $^{63}Cu^{22+}$, and $^{78}Kr^{25+}$.

In the first week of this resumed operational period, a significant and abrupt vacuum pressure degradation occurred within the plasma chamber during an attempt to produce a $^{90}Zr^{26+}$ beam. This rapid increase in pressure triggered the ECR2 interlock system, a safety mechanism designed to immediately terminate the microwave power and/or extraction high voltage in the event of poor vacuum conditions. The shutdown protected both the microwave transmitter and the ion source from damage caused by high reflected power or electrical arcing. As a result, the ion production was halted.

To identify the source of the pressure anomaly, a leak detection test was performed using a calibrated helium leak detector. All external seals, joints, and high-stress regions of ECR2 were systematically probed. Elevated readings were localized to a specific area, prompting a targeted visual inspection that identified a narrow, jagged surface defect on the inner wall of the plasma chamber (see Figure 1). The irregular geometry of the defect suggests it may have resulted from repeated venting cycles

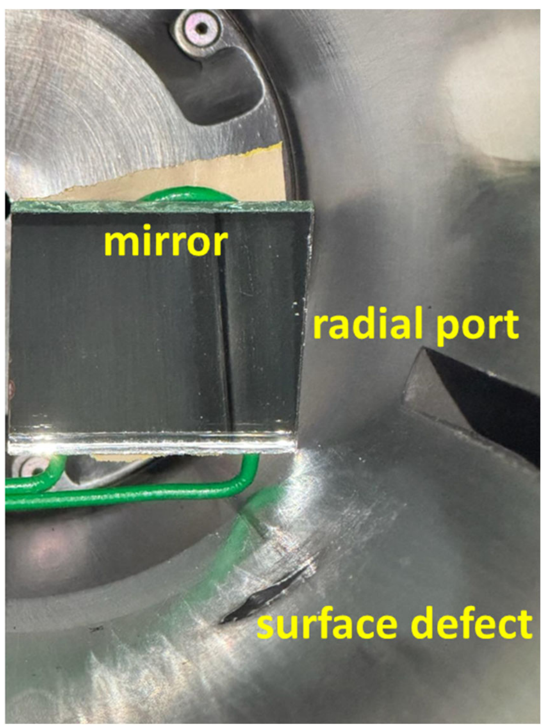

Fig. 1 . Localized surface defect on the inner wall of the aluminum plasma chamber, with a mirror mounted in a green support fixture to aid the precise application of PERMABOND 919, a high-temperature-resistant cyanoacrylate adhesive to the affected area.

or from recurring thermal or plasma-related strain, potentially intensified by the ECR2 operating conditions used for $^{90}Zr^{26+}$ production. Damage from the high-energy electron fracturing of the plasma can probably be ruled out since the NdFeB permanent magnet in this area showed no sign of damage. A more thorough analysis will be necessary to determine the precise nature and origin of the defect, enabling the development of effective remediation and preventative strategies.

Given the urgency of maintaining ECR2 operations and the long lead time associated with manufacturing a replacement aluminum plasma chamber, an interim repair was performed to minimize downtime. The affected area was first cleaned using a light abrasive pad to remove surface contaminants and ensure proper adhesion. A thin layer of PERMABOND 919, a high-temperature-resistant cyanoacrylate adhesive compatible with ultra-high vacuum environments, was then carefully applied. Special care was taken to fully fill the defect without excess material, thereby minimizing the risk of outgassing. It was then cured at room temperature for 24 hours to achieve full bond strength and vacuum integrity. Immediately after the curing period and subsequent pump-down, the final helium leak test confirmed the successful restoration of the vacuum seal, with no detectable leakage.

Further action was taken to reinforce the repaired area and mitigate the risk of future degradation. A precision-fit copper liner, routinely used for lithium beam production and thoroughly cleaned prior to installation, was inserted into the plasma chamber. The liner provides mechanical protection and shields the defect area from direct plasma exposure.

Post-repair performance tests using helium, nitrogen, argon, and copper confirmed that ECR2 is operating within expected parameters. Background vacuum pressure returned to its nominal level of 10^{-7} Torr, and stable beam outputs were observed. In parallel, a new aluminum plasma chamber is being designed with upgraded permanent hexapole magnets and enhanced cooling capabilities [1]. This new chamber will serve as a long-term solution to improve the performance and operational longevity of the ECR2 ion source.

[1] D.P. May *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2021-2022), p. IV-8.