# K500 operations and development

D.P. May, G.J. Kim, B.T. Roeder, H.L. Clark, G. Tabacaru, and F.P. Abegglen

## Introduction

During the 2020-2021 reporting period a total of 28 different beams, including 16 newly developed beams, were used for experiments, and there were a total of 36 beam tunings for these experiments. The SEE program and the radioactive-beam effort are treated separately in this progress report.

## Ion Sources

In August 2020 osmium was sputtered into the ECR1 ion source in order to develop a beam for an experiment. A single dowel of osmium was introduced radially with a linear feed-through. Using oxygen as a support gas proved to be problematic as more and more gas has to be introduced to support the plasma. After removing the osmium, the source had to be cleaned and flushed several times before the oxygen pressure could be maintained. Since osmium oxidizes so easily into the dioxide or tetroxide form, it may be advisable in the future to use nitrogen or neon as a support gas. Also, since osmium tetroxide, a heavy gas at room temperature is, highly toxic, special precautions need to be made in cleaning the source after running. Indeed, because of contamination and toxicity it is advisable that osmium not be run again.

In early November 2020 the ECR1 ion source catastrophically failed. The source developed a leak that was eventually traced to the interior of the aluminum plasma chamber. Glue was placed over several suspicious spots on the wall, and the source was able to pump down confirming that the chamber was now unrecoverable. The most likely spot is the one that has been under scrutiny for several years as the measured magnetic field strength at a position aligned with a joint between two NdFeB blocks has slowly decreased over several years. A new plasma chamber had already been assembled, so more permanent magnets were ordered for a new hexapole.

From early November to the end-of-the-calendar-year shutdown the 14.5 GHz ECR3 ion source was repurposed from charge-breeding to injection of noble gas beams into the K500 exclusively for the SEE program. Even with the lack of a biased disk ECR3 was able to supply the low intensities of $^{40}Ar^{11+}$, $^{84}Kr^{23+}$ and $^{129}Xe^{31+}$ sufficient for SEE. In early March of 2021 after the shutdown the new 6.4 GHz ECR4, described elsewhere in this progress report, became available for K500 injection.

## Cyclotron Beams

New beams of $^{21}$Ne at 28 and 40 AMeV, $^{94}$Zr at 13 AMeV, $^{129}$Xe at 6.3 AMeV, and $^{192}$Os at 6.3 AMeV were developed for experiments. The majority of experiments used the 2A line devoted to the recoil spectrometer MARS.

## Operations

For the period April 1, 2020 through March 31, 2021, the operational time is summarized in Table I, while Table II lists how the scheduled time was divided. Unscheduled maintenance time increased substantially partly due to restrictions on access to the lab during the pandemic. In addition later in the reporting period much time was spent on issues with the radio-frequency system, the major problem being that the lower frequencies became impossible to obtain. During the shutdown several repairs to seals and the replacement of a cracked insulator on the upper "B" resonator successfully resolved the issues. Beam development for this period mainly involved the repurposing of ECR3 and developing tunes for its injection line in November and then developing tunes for the new ECR4injection line in March. Scheduled time for outsider users, exclusively SEE customers remained about the same as in the last reporting period.

**Table I**. 2020-2021 Operational Time.

| **Time** | **Hrs** | **%Time** |
|---|---|---|
| Beam on Target | 4129 | 47.3 |
| Beam Development | 1391 | 15.9 |
| Scheduled Maintenance | 1672 | 19.1 |
| Unscheduled Maintenance | 1544 | 17.7 |
| Total | 8736 | 100 |

**Table II**. 2020-2021 Scheduled Beam Time.

| **Time** | **Hrs** | **%Time** |
|---|---|---|
| Nuclear Physics | 296 | 5.4 |
| Nuclear Chemistry | 680 | 12.3 |
| Outside Collaboration | 0 | 0 |
| Outside Users | 3153 | 57.1 |
| Beam Development | 1391 | 25.2 |
| Total | 5520 | 100 |