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DESIGN AND IMPLEMENTATION OF ALLISON SCANNER AT THE KOMAC LEBT *

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Abstract

This study presents the design, specifications, and experimental result of the Allison scanner installed at the injector of the 100 MeV proton accelerator operated at Korea Multi-purpose Accelerator Complex (KOMAC). The Allison scanner was developed to enable precise characterization of the proton beam's phase space at the injector stage. Detailed design parameters and operational principles of the system are described. Experimental measurements were conducted under various operating conditions to assess the performance and reliability of the scanner. Furthermore, the daily measurement data collected by the Allison scanner were analyzed to evaluate the long-term stability of the ion source.

ALLISON SCANNER

Principle of Allison Scanner

The Allison scanner is a widely known method for measuring beam emittance and it consists of two slits, two deflecting electrodes, and a Faraday cup. At a given position, the scanner sweeps the voltage applied to the deflecting electrode while measuring the beam current collected by the Faraday cup. By repeating this process at multiple positions, a two-dimensional phase space distribution of the beam can be measured.

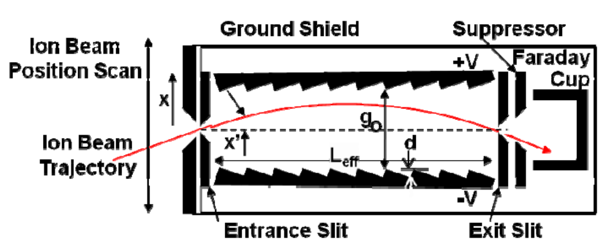

Figure 1: Schematic drawing of Allison scanner [1].

Figure 1 shows a schematic of the Allison scanner designed at the Spallation Neutron Source (SNS) in the United States. After the beam is collimated by the first entrance slit, it receives an angular kick due to the electric field applied to the deflecting plates. Only those particles whose initial angular components are exactly canceled by the electric field can pass through the second exit slit and are subsequently measured by the Faraday cup.

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Design of Allison Scanner at KOMAC LEBT

The Allison scanner installed at the KOMAC LEBT operates based on the same measurement principle as previously described. Its design is shown in Fig. 2. The KOMAC LEBT Allison scanner also consists of an entrance slit, deflecting plates, an exit slit, and a Faraday cup. In addition, a suppression plate is installed in front of the Faraday cup to suppress secondary electrons. Detailed design parameters such as the

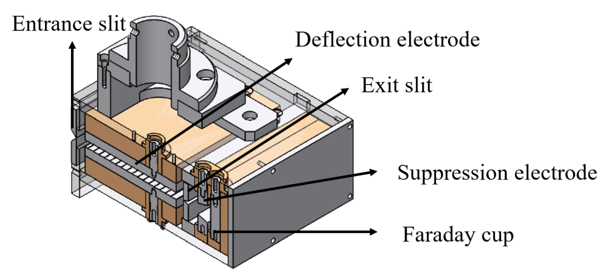

Figure 2: Drawing of Allison scanner at KOMAC LEBT.

size of the entrance slit, the length of the deflecting plates, and the gap between the plates were carefully determined to ensure accurate measurements. These specific values are summarized in Table 1.

Table 1: Design Parameter of Allison Scanner at KOMAC LEBT

Design Parameter	**Value**
Size of Entrance Slit	0.1 mm
Size of Exit Slit	0.1 mm
Maximum voltage for deflection electrode	1000 V
Maximum voltage for suppression electrode	1000 V
Length of deflection electrode	57 mm
Gap between deflection electrode	3.5 mm

System Configuration

Although the hardware of the Allison scanner was fabricated based on the specifications listed in Table 1, system integration with components such as the control box, control software, and power supply is essential for actual beam measurements. To enable this, a complete system was developed, and its configuration is shown in the following diagram.

Figure 3 illustrates the system configuration of the Allison scanner measurement system. The control box consists of an ADC, a DAC, and a motor controller. The motor controller drives the stepper motor mounted on the Allison scanner

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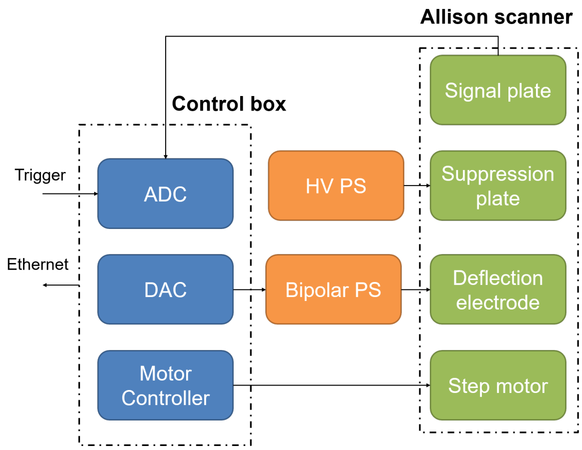

Figure 3: System configuration of KOMAC Allison scanner.

hardware, while the DAC provides analog control signals to a bipolar high-voltage power supply, which it applies voltage to the deflecting electrodes. An additional high-voltage power supply applies voltage to the suppression plate to prevent signal distortion caused by secondary electrons. Finally, the signal collected by the signal plate (i.e., the Faraday cup) is transmitted to the ADC in the control box and then communicated to the main control program via Ethernet.

To ensure seamless integration with the main control system, the EPICS (Experimental Physics and Industrial Control System) [2] framework was adopted for the control program. Although Control System Studio (CSS) can be used as a GUI tool for EPICS, a custom graphical user interface was developed using Python and PyQt5 to enhance flexibility and convenience in data handling.

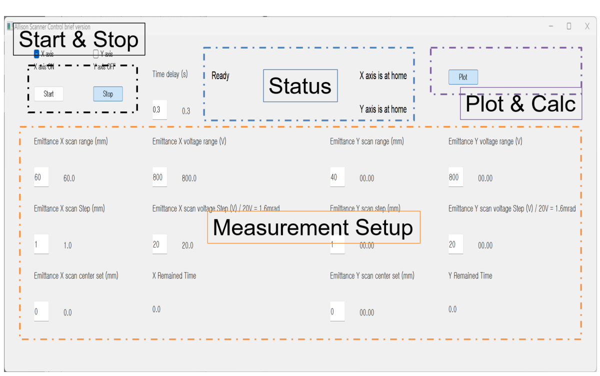

Figure 4: GUI of KOMAC Allison scanner.

Figure 4 shows the graphical user interface (GUI) of the Allison scanner, developed using Python and PyQt5. The GUI consists of several modules, including measurement parameter configuration, status monitoring, plotting, and data analysis. After the measurement is completed, the system processes the data in real time, allowing users to immediately view and analyze the results.

MEASUREMENT RESULT

After the complete assembly of the Allison scanner system, it was installed in the LEBT of KOMAC. The KOMAC LEBT consists of two solenoids and a beam diagnostics chamber, with the Allison scanner positioned in the diagnostics chamber located between the two solenoids. Following the installation, a measurement was conducted to characterize the phase space of a 50 keV, 25 mA proton beam extracted from the ion source.

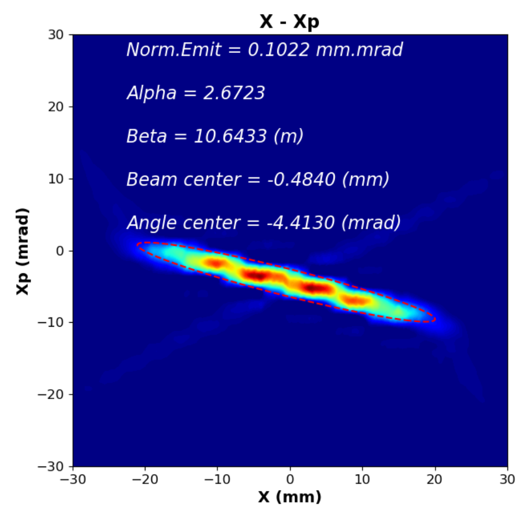

Figure 5: Measured Phase Space (X) at KOMAC LEBT.

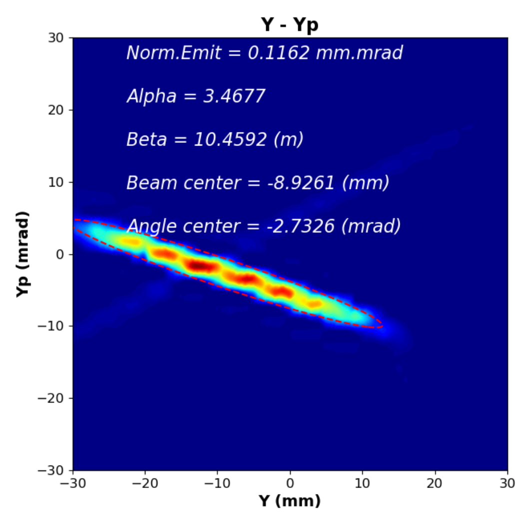

Figure 6: Measured Phase Space (Y) at KOMAC LEBT.

The figures above show the measured phase space distributions. Figure 5 presents the horizontal (x) phase space, while Figure 6 displays the vertical (y) phase space. The measured phase space shapes are generally consistent with

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expected beam profiles, and the corresponding emittance values were found to be in the typical range of 0.10 to 0.12 mm·mrad. The red ellipses shown in the figures represent four times the RMS emittance, providing a visual reference.

In addition to the proton beam, the presence of H_2^+ ions was also observed in the measured data, as commonly reported in similar experiments. Depending on the ion source conditions, H_3^+ beams were also detected. When applying Gaussian fitting to estimate the fraction of the proton beam, the proton component was found to be approximately 80 %, varying with the ion source settings. This result falls within the theoretically expected range.

Through multiple additional measurements and data verifications, it was confirmed that all data remained within reasonable and consistent ranges. Accordingly, in order to monitor the ion source conditions over time, daily measurements using the Allison scanner were conducted throughout the user beam service period in the first half of 2025. The results are summarized below.

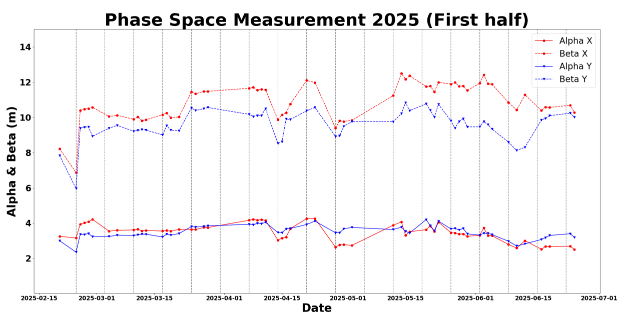

Figure 7: Twiss Parameter of Beam during First Half of 2025.

The figures show the daily measurement results obtained from the Allison scanner during the user service period in the first half of 2025. Since the ion source at this facility is operated weekly—starting every Monday and shutting down every Friday—the beam operation is maintained on a weekly cycle. Accordingly, the gray vertical lines in the figures indicate each Monday.

Figure 7 presents the Twiss parameters α and β. The red solid line represents the horizontal (x) α, the red dashed line indicates the horizontal (x) β, the blue solid line shows the vertical (y) α, and the blue dashed line corresponds to the vertical (y) β. The Twiss parameters remained relatively stable throughout the beam operation period in the first half of 2025.

Figure 8 shows the position and angular centers of the beam. The red solid line represents the center of horizontal position (x), the red dashed line indicates the center of horizontal angle (x'), and the blue solid line corresponds to the center of vertical position (y). Lastly, the blue dashed line represents the center of vertical angle (y'). The noticeable variation observed in the middle of the measurement period was confirmed to be the result of changes made following a brief one-week maintenance period.

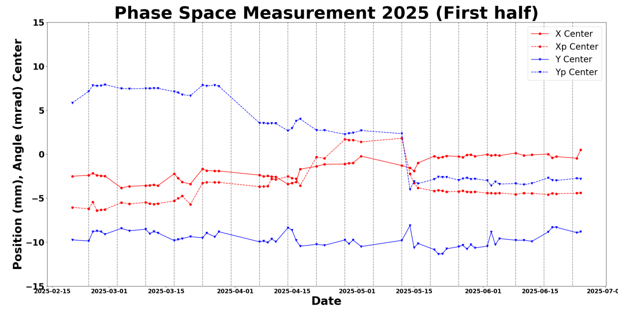

Figure 8: Position Center and Angle Center of Beam during First Half of 2025.

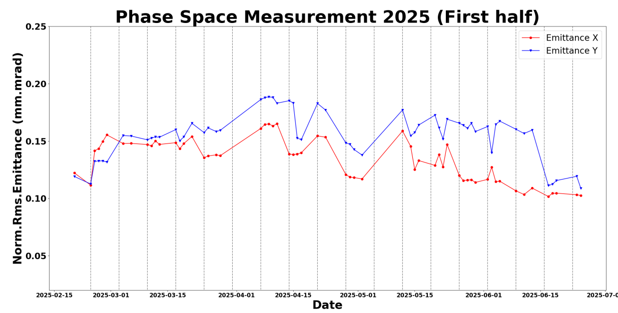

Figure 9: Normalized rms emittnace of Beam during First Half of 2025.

Figure 9 presents the measured normalized RMS emittance results. The red line corresponds to the horizontal (x) emittance, while the blue line represents the vertical (y) emittance. The emittance values gradually varied within the range of approximately 0.1 to 0.15. When viewed on a weekly basis, from Monday to Friday, the ion source conditions remained stable without significant fluctuations.

CONCLUSION

The design of the Allison scanner and the development of a phase space measurement and analysis system for the ion source have been successfully completed. The measured phase space distributions and other physical parameters obtained through this system were confirmed to be within reasonable and expected ranges. Based on these results, the system was employed to monitor the ion source during the user beam service period in the first half of 2025. It was observed that the ion source conditions remained stable during continuous weekly operation. The current system will continue to be used for ongoing monitoring of the ion source, with plans to utilize the collected data to improve overall system stability.

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[1] M. P. Stockli *et al.*, “Low-Energy Emittance Studies with the New SNS Allison Emittance Scanner”, in *Proc. PAC’09*, Vancouver, Canada, May 2009, paper TH6REP012, pp. 3974–3976.

[2] EPICS, `https://epics.anl.gov/`