# IMPROVEMENT OF THE 20-MEV PROTON ACCELERATOR AT KAERI*

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*Abstract*

The 20-MeV proton accelerator has been operating since 2007 when it got an operational license at Korea Atomic Energy Research Institute (KAERI) by Proton Engineering Frontier Project (PEFP). A microwave ion source was newly developed to satisfy the requirement of minimum 100 hour operation time without maintenance. After the long-time operation test at test bench, it was installed to drive the 20-MeV proton accelerator. The beam radius and emittance were measured to check the characteristics of the accelerator both at the LEBT and at the end of the 20-MeV DTL. In this paper, the microwave ion source is presented and the measurement results of the beam property are discussed.

## INTRODUCTION

The PEFP 20-MeV linac is a front part of the 100-MeV proton accelerator developed by PEFP, which will be installed in Gyeong-Ju city in 2011. The 20-MeV linac has been temporarily installed and operating at KAERI to check its operational characteristics from 2007 [1]. Since then, several parts were upgraded to satisfy the requirement of the 100-MeV machine.

One of the important parts is the ion source. At the beginning of the operation, a duoplasmatron type ion source was used. It satisfied all the requirements in the viewpoint of the proton beam itself such as a peak beam current and beam emittance. But the operation scenario of the 100-MeV machine requests a minimum 100 hour operation time without maintenance which is difficult for such a kind of ion source to withstand because of the filament life time. Therefore, microwave ion source was developed to satisfy the operation time requirement. After the test at the test bench, the microwave ion source was installed at the proton injector of the 20-MeV linac to drive the machine. The electric sweep scanner was installed at the LEBT to measure the emittance. In addition, a wire scanner was installed at the beam line which was located at the end of the 20-MeV linac to measure the beam radius and emittance of the proton beam driven by the microwave ion source.

## MICROWAVE ION SOURCE

A microwave ion source was developed. The requirements of the ion source are described in Table 1. The characteristic of the ion source is its compactness by using single solenoid magnet [2][3].

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### *DC Beam Operation at Test Bench*

The most importance check point was its minimum operation time without maintenance. Therefore, a long time operation test was performed at the test bench.

Table 1: Ion Source Requirements

| Parameters | Values |
|---|---|
| Particle | Proton |
| Energy | 50keV |
| Current | 1~20mA |
| Operation Mode | Pulse |
| Pulse Length | 50μs~2ms |
| Repetition Rate | 0.1~120Hz |
| Emittance (Normalized rms) | 0.2 π mm mrad |
| Life Time | > 100 hrs |

It was operating in DC beam mode during test and its beam current was monitored. The result of 100 hour operation test is shown in Fig. 1.

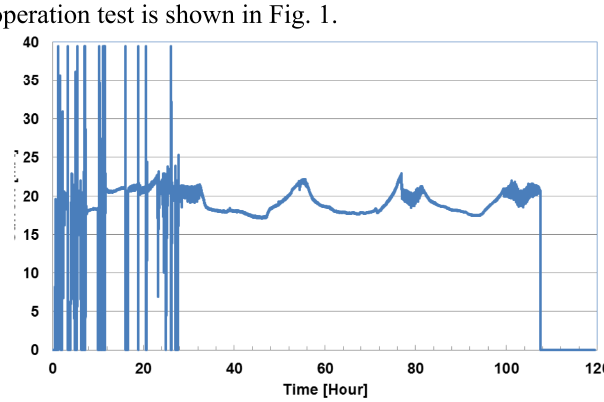


Figure 1: 100 hour operation test result.

Figure 2: Microwave window after 100 hour operation test (left: Aluminum nitride, right: Boron nitride).

The sparks for initial 28 hours was due to the parameter setting and conditioning in DC beam extraction. After the initial sparks, the ion source could be operating more than 80 hours without any sparks. In Fig. 1, the beam current was fluctuating about 10% with a 24 hour period. This fluctuation reflected the change of the environmental conditions such as ambient temperature and cooling water temperature. After the 100 hour operation test, the boron nitride and alumina, which were used as a microwave window, were checked and found to be no serious damage as shown in Fig. 2.

### *Pulse Beam Operation at 20-MeV Linac*

The microwave ion source was installed at the proton injector of the 20-MeV linac as shown in Fig. 3 in 2011. The solenoid magnet power supply and microwave system were installed in high voltage deck. The control system for such power supplies were implemented in EPICS control system of the 20-MeV linac. During the pulse operation, the microwave system was operating in CW mode and the pulse beam was extracted by using the semiconductor switches located in the high voltage power supply output line. The ACCT (AC Current Transformer) was used as a beam current monitor which was located in front of the RFQ. Because the LEBT (Low Energy Beam Transport) was located between the ion source and RFQ, the measured beam current was influenced not only from the ion source operating parameters but also the LEBT operation parameters such as solenoid magnet current. The typical pulse beam current profile is shown in Fig. 4, which corresponds to 20mA peak, 2ms pulse width.

Figure 3: Microwave ion source.

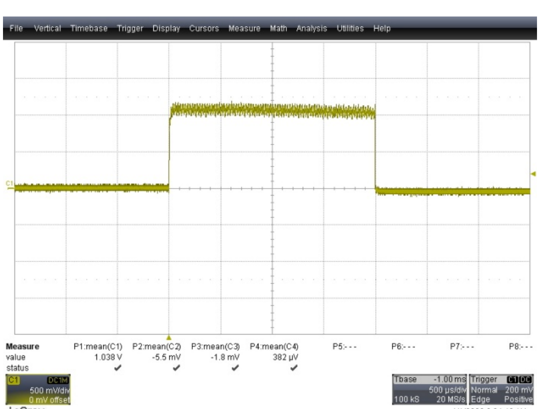


Figure 4: Pulse beam current (20mA, 2ms).

The beam emittance was measured by using the electric sweep scanner. The scanner was located in the centre position of the two LEBT solenoid magnets. The operation conditions of the ion source were such that the gas flow was 3.0 sccm, the microwave power was 500W and the solenoid current of the ion source was 80.6A which corresponded to the 10% higher than the ECR condition at the microwave window position. The measured beam distribution in phase space is shown in Fig. 5. The emittance was 0.35 π mm mrad in normalized rms value which is higher than the designed one. The proton fraction was also deduced from the beam distribution in phase space, and the proton faction was 77% [4]. In the operation conditions, the gas flow rate was higher and the microwave power was lower than the typically used values in other laboratory. We try to measure the beam parameters depending on the various operation conditions to optimize the operating conditions of the microwave ion source.

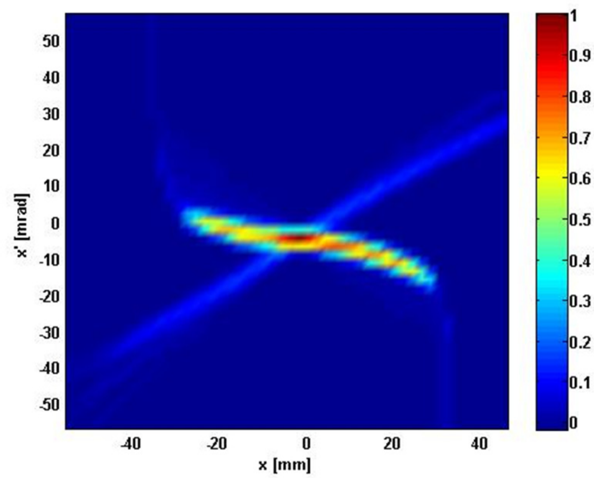


Figure 5: Beam distribution in phase space.

## 20-MEV BEAM RADIUS AND EMITTANCE MEASUREMENTS

A wire scanner was installed in the 20-MeV beam line to measure the beam radius and emittance of the 20-MeV proton beam driven by the microwave ion source. The specification of the wire scanner is shown in Table 2. The beam line was located at the end of the 20-MeV DTL. It consists of several beam diagnostic devices, quadrupole triplets, beam window for external beam and target station. The concrete blocks and lead blocks were used to shield the radiation as shown in Fig. 6.

The beam profile was measured for the various operating conditions of the quadrupole magnets located in the upstream of the wire scanner. The measured beam profile was fitted by using the Gaussian and the rms beam radius was compared with the PARMILA results as shown in Fig. 7. The comparison showed good agreement between measurement and simulation.

A quad scan method was used to calculate the emittance from the measurement data. During the calculation, we used the thin lens approximation [5]. The fitting result is shown in Fig. 8 and the measured normalized rms emittances were such that 0.22 π mm mrad in horizontal (x) direction and 0.25 π mm mrad in vertical (y) direction. Compared with the PARMILA simulation results, which was 0.21π mm mrad in horizontal, 0.27 π mm mrad in vertical, the measurement results showed good agreements.

Table 2: Wire Scanner Specifications

| Parameters | Values |
|---|---|
| Beam Energy | 20MeV |
| Peak Beam Current | 1mA |
| Beam Pulse Width | 50μs |
| Beam Repetition Rate | 1Hz |
| Wire Material | Tungsten |
| Wire Diameter | 120μm |
| Fork Aperture | 50mm |
| Stroke | 40mm |
| Number of Wire | 2ea. |

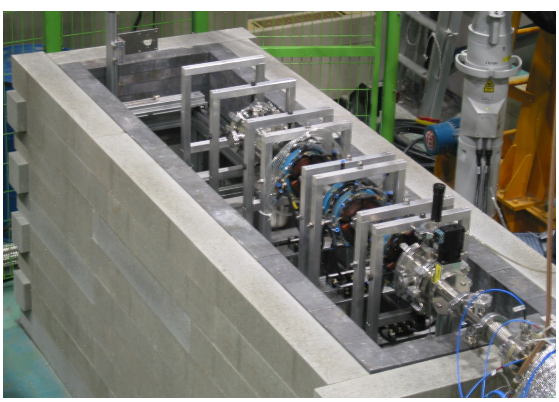

Figure 6: 20-MeV beam line.

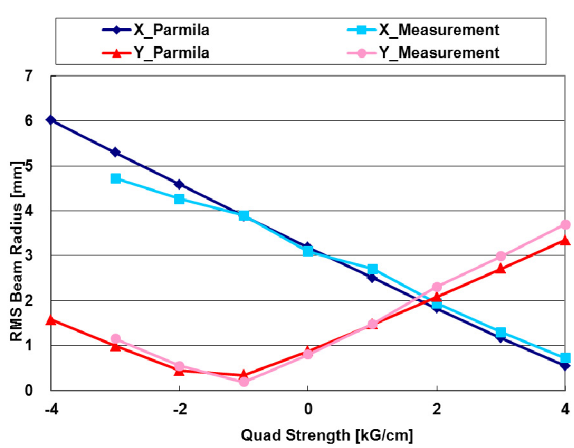


Figure 7: Comparison between beam radius measurement and simulation

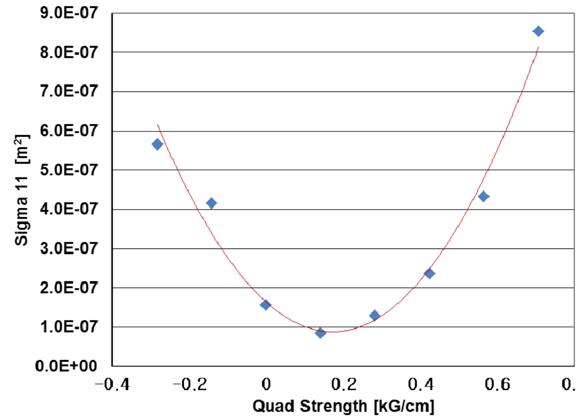


Figure 8: Fitting with thin lens approximation formula.

## CONCLUSION

A microwave ion source was installed and operating since 2011 for the PEFP proton injector. The 100 hour operation test at the test bench showed that it could satisfy the important requirement for the PEFP ion source. The initial measurement of the pulse beam emittance and proton fraction showed that it needed still optimization in operation parameters.

The beam radius and emittance of the 20-MeV proton were measured by using the wire scanner and quad scan method. Both results showed that there were good agreements between measurements and simulations.

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