# II. 5. Two-dimensional Beam Profile Monitor for Alpha Emitter

*Tanaka S. K.[1], Dammalapati U.[1], Harada K.[1], Itoh M.[1], Ito S.[1], Inoue T.[1], Kawamura H.[1], Sakamoto K.[1], Uchiyama A.[1], Yoshioka R.[1], and Sakemi Y.[1]*

[1]*Cyclotron and Radioisotope Center, Tohoku University*
[2]*RIKEN Nishina Center*
[3]*Center for Nuclear Study, the University of Tokyo*

Search of the permanent electric dipole moment (EDM) using various kinds of atom and molecules has been carried out in recent years. The infinite value of electron EDM would imply of a new physics beyond the standard model of particle physics. We are preparing the precise measurement of the electron electric dipole moment (EDM) using a francium in CYRIC. Francium is one of a suitable atom to search the electron EDM. It is the heaviest alkaline metal so that it has a large enhancement factor of EDM and can be applied laser cooling technique.

Francium is produced by nuclear fusion reaction between an oxygen beam ($^{18}\mathrm{O}$) provided from CYRIC and gold target. The intensity of the Fr production is limited such as $10^6$ /s by the the intensity of the oxygen beam[1)]. Fr is ionized by surface ionization on the gold target, and transport 12 m length to the measurement area which is free from background noise of the cyclotron acceralator. Then the Fr ions are neutralized and load to the trapping area by heating the foil. The size of the yttrium foil is only $10\ \mathrm{mm} \times 10\ \mathrm{mm}$, so that the control and focus of the $\mathrm{Fr}^+$ beam to this small area is important to the efficiency of the number of the Fr loaded to the trapping area. Also, we need to care about the other ions along with the Fr ions which cause atomic collisions in the trapping area. Typically, the intensity of francium beam is $10^6$ /s and that of other ions ($\mathrm{K}^+, \mathrm{Ca}^+$, $\mathrm{Au}^+$ ...) is $10^{10}$ /s. We removed light ions from $\mathrm{Fr}^+$ with Wien Filter[2)]. Two-dimensional beam profiles of both Fr beam and other ions beam are valuable information to optimize the purity of the Fr beam. However, $\mathrm{Au}^+$ is not removeable with the specification of mass filter, and we couldn't observe the Fr beam profile hidden from the dominant other ion beam profiles. Therefore, we developed new two-dimensional beam profile monitor for alpha emitter ion beam separated from the other ion beam by using a micro channel plate (MCP) and phosphor screen.

Two beam profile monitors (BPM1 and BPM2) are installed on the Fr beamline (Figs. 1 and 2). BPM1 is loaded on the downstream end of the beamline. Beamline downstream of the neutralizer is free from electromagnetic field so that beam profile on the neutralizer can be reconstructed geometrically from BPM1. The BPM2 is used to make a diagnosis of the production distribution of Fr ions and other dominant number of ions on the target, since production distribution of these ions are different from that of Fr ions.

Two BPMs are consisted of a chevron micro channel plate (MCP) which has a diameter of 40 mm, and a phosphor screen. The MCP is a chevron MCP (two plates mounted) which has a diameter of 40 mm, and the phosphor screen is RHEED screen (SG63-2). The impacts of the ion beams on the MCP produce cascade of electrons that propagate through the one of the small channels by applying a strong electric field across the MCP. The electron clouds are converted to the visible light by the phosphor screen and observe it by CCD camera (Basler acA2500-14um for BPM1 and acA1300-60gm for BPM2).

Since intensity of the Fr beam is relatively small compared to the other ion beams, we could not observe the Fr beam by using this method. Fr beam profile is observable from produce cascade of electrons by decay alpha of $^{210}\mathrm{Fr}$ instead. So, the measurement sequence is as follows:

- Inject the ion beam to the BPM. Dominant part of the ion beam is observable.
- Keep injection for 10 minutes which is enough to accumulate the Fr atoms on the surface of the MCP
- Stop injection to the BPM. Just after that, we can observe the Fr beam profile.

In case of BPM2, SSD detector is installed nearby the MCP to observe the decay alpha particles from $^{210}\mathrm{Fr}$ to measure the absolute Fr beam intensity.

We test these two BPMs by produced Fr ion beams. Figure 3 shows a typical result of this test measurement. The total brightness on the monitor is increased by the number of the Fr atoms on the MCP. After the stop beam injection, we can observe only the decay alpha particle from Fr atoms. Therefore, we can obtain both beam profile of Fr and the others simultaneously.

As described above, we developed the two-dimensional beam profile monitor for alpha emitter especially francium. Also, we used it for the improvement of the Fr beam by using the Wien Filter and achieve the purity of 1 instead $10^{-6}$ without the filter.

**References**

1) H. Kawamura, et al., *JPS Conf. Proc.* **6** (2015) 030068.
2) Arikawa H, "The development of the high purity francium beam toward the search for the violation of the fundamental symmetry (in Japanese)", Master thesis, Tohoku University (2015).


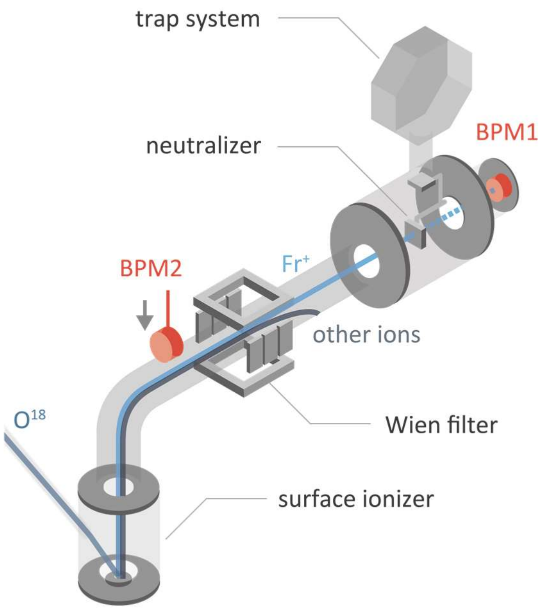


Figure 1. Fr beamline

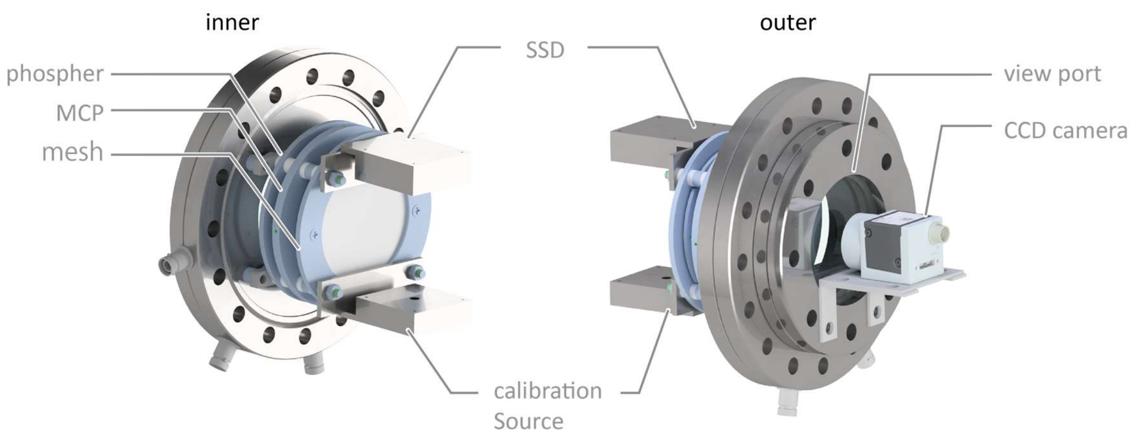


Figure 2. The schematic view of the BPM1

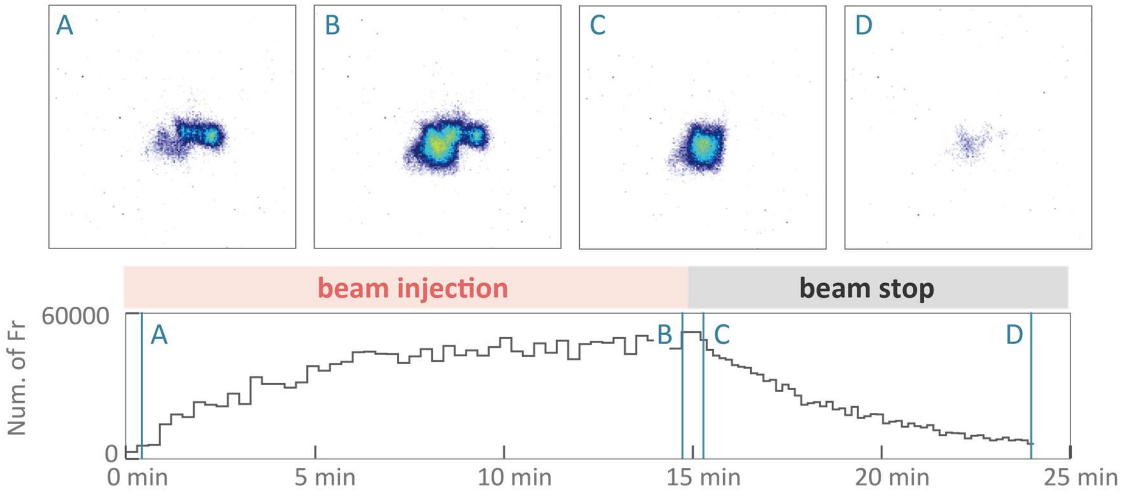


Figure 3. Typical measurement sequence of beam profile monitor