DEVELOPMENT OF PEPPER-POT EMITTANCE MONITOR FOR HIGH-INTENSITY ION BEAM ACCELERATED BY RIKEN AVF CYCLOTRON

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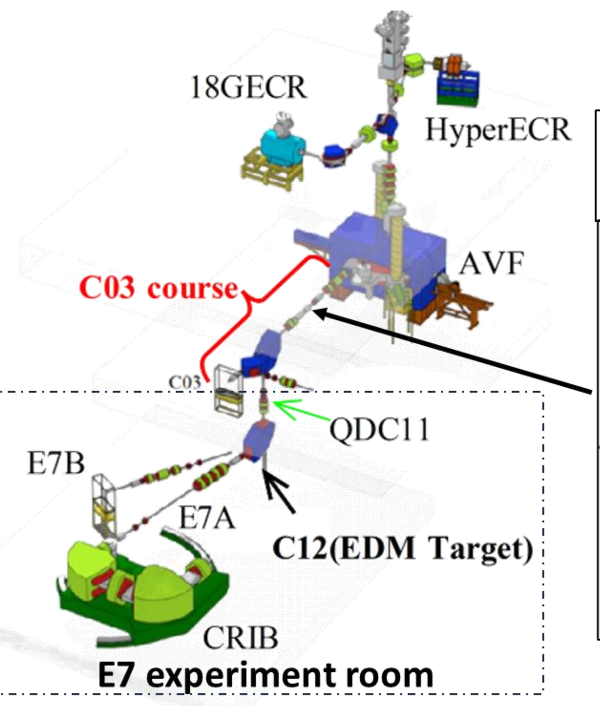
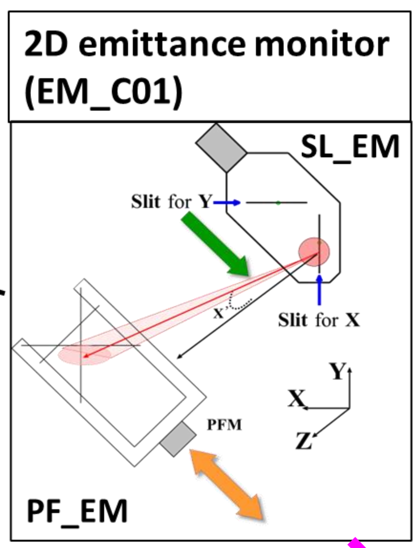
At the Center for Nuclear Study of the University of Tokyo (CNS), the measurement of Electric Dipole Moment (EDM) of Francium (Fr) is underway with the world highest precision. Fr is generated by nuclear fusion reaction by irradiating the gold (Au) target of EDM experiment device (EDM target) with oxygen ion beam 18O6+ of 7 MeV/u accelerated by RIKEN AVF Cyclotron.

Our goal is transporting beam of more than 18 eμA (400 W), without loss and converging beam to be 1 mm of SD of beam distribution on the EDM target.

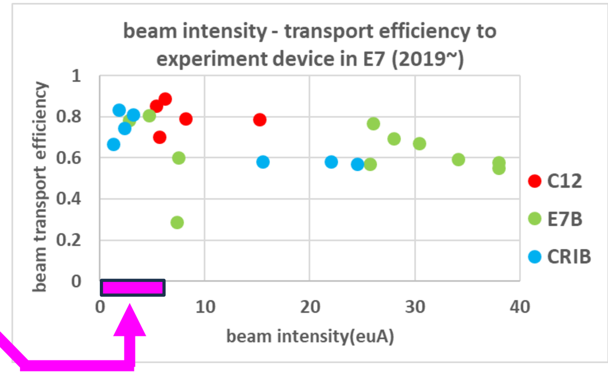
AVF Cyclotron and beam transport system to C12,CRIB, and E7B

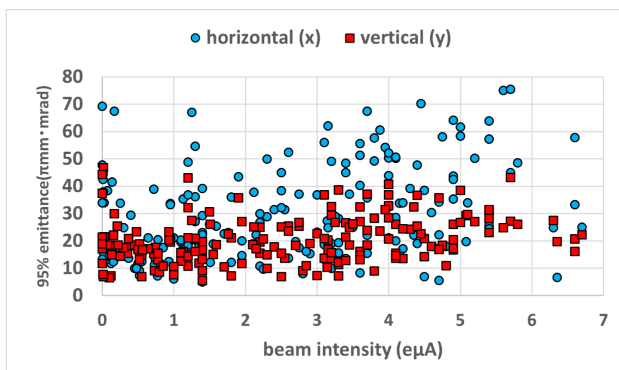




Our problem
Beam transport efficiency is average 66 %
When beam intensity > 10 eμA

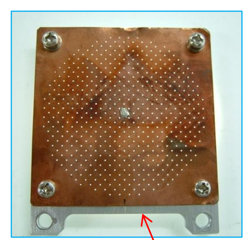
Beam emittance expands as intensity increase





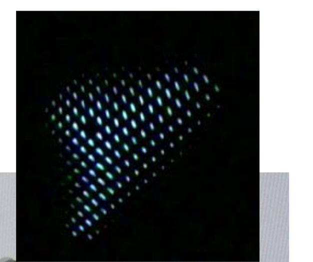
Pepper-pot emittance monitor

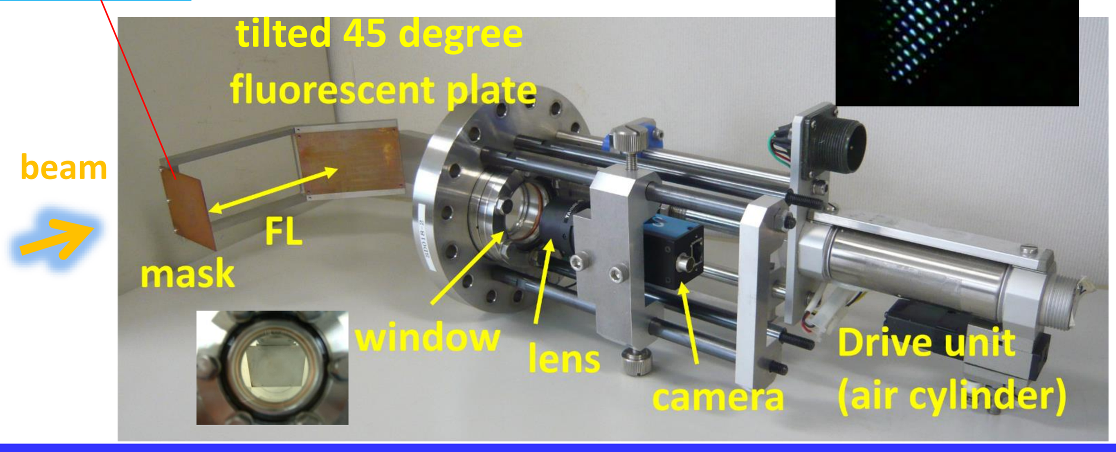
PEM mask



Cupper plate
Diameter of hall 0.3 mm
Distance between holls 2mm
Thickness 1 mm

Glowing at the positions where beams hit





Old emittance monitor (EM_C01) cannot measure High intensity beam because Cooling Ability < 130 W beam.
has unsolved measurement error.

Developing Pepper-pot emittance monitor for high intensity beam
We need more three additional development.

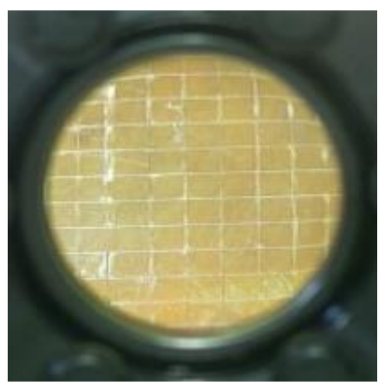
①reducing the radiation damage to a camera
②required angular accuracy for the accelerated beam
③beam shutter system to avoid heating PEM due to beam

① reducing the radiation damage to a camera - tele lens optics of camra

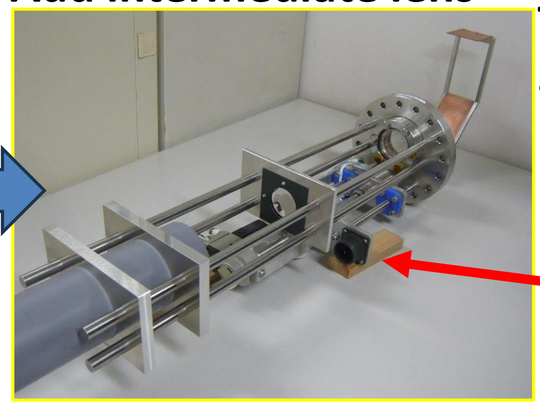
Achieving 2200 mm between Camera and PEM by now

periscope

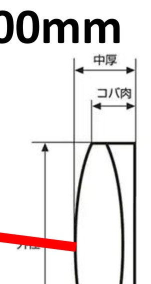
Tele lens only



Add intermediate lens

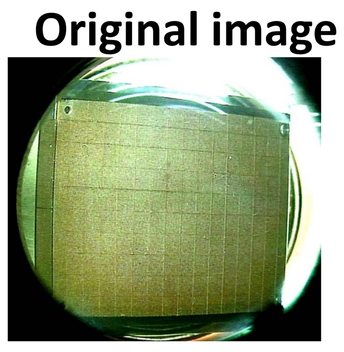


Achromatic lens focal length 200mm

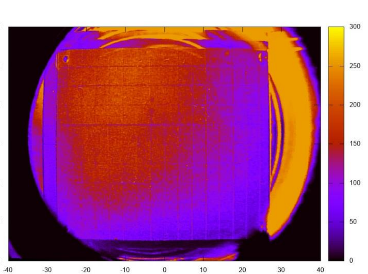


The view of fluorescent plate After using Achromatic lens

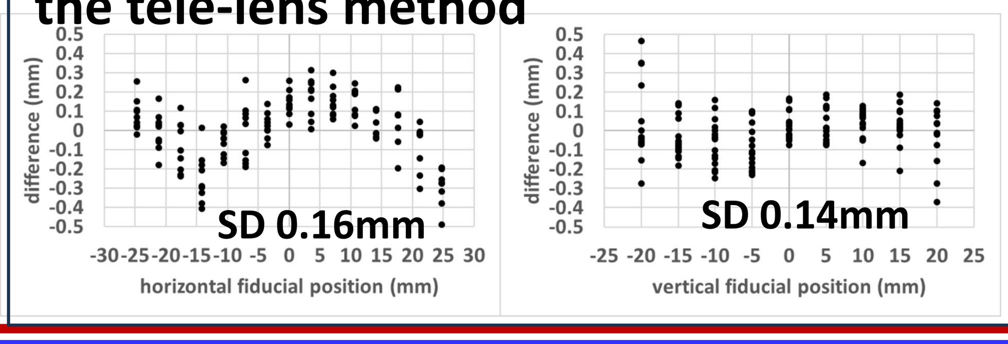
Original image



After processing



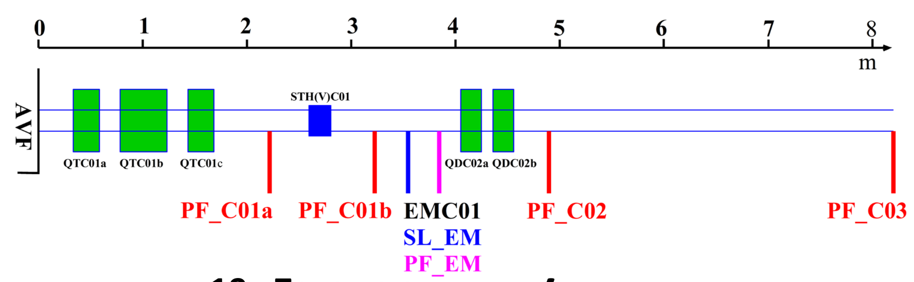
The relationship between position and the difference made by the distortion of the tele-lens method



②required angular accuracy for the accelerated beam

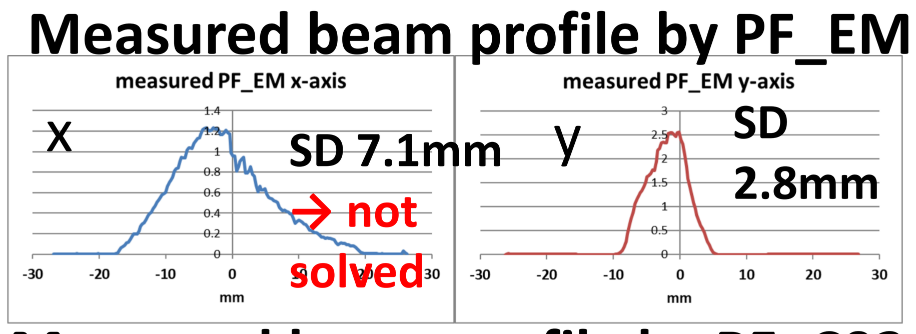
The way estimating σ matrix assumed to be true

Schematic view of C03 beam line

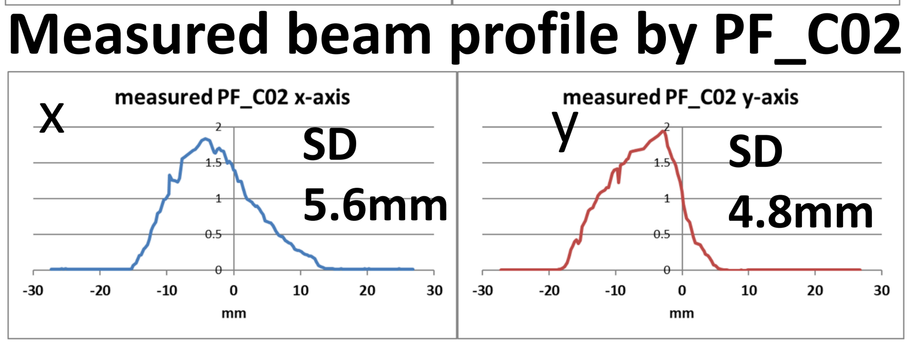


$^{19}F^{7+}$ 6.68MeV/u 5eμA

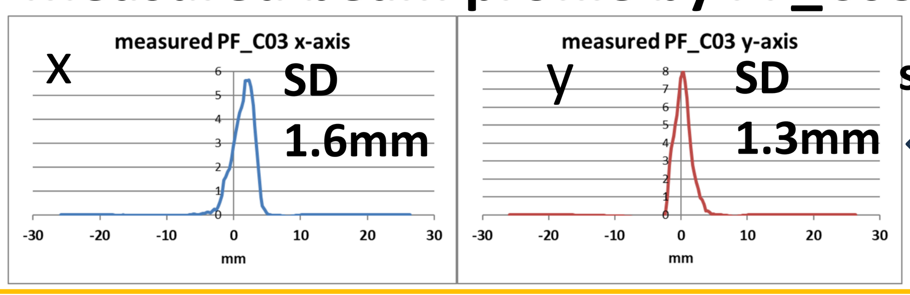
Measured beam profile by PF_EM



Measured beam profile by PF_C02



Measured beam profile by PF_C03



similar

Equation of σ matrix. σ11 known

$$\begin{pmatrix}\sigma_{11}(C02)\\ \sigma_{21}(C02)\\ \sigma_{22}(C02)\end{pmatrix} = \begin{pmatrix} m_{11} & m_{12} & m_{13}\\ m_{21} & m_{22} & m_{23}\\ m_{31} & m_{32} & m_{33}\end{pmatrix}\begin{pmatrix}\sigma_{11}(EM)\\ \sigma_{21}(EM)\\ \sigma_{22}(EM)\end{pmatrix}$$

$$\begin{pmatrix}\sigma_{11}(C03)\\ \sigma_{21}(C03)\\ \sigma_{22}(C03)\end{pmatrix} = \begin{pmatrix} 1 & 2L & L^2\\ 0 & 1 & L\\ 0 & 0 & 1\end{pmatrix}\begin{pmatrix}\sigma_{11}(C02)\\ \sigma_{21}(C02)\\ \sigma_{22}(C02)\end{pmatrix}$$

Solution of equation(SDx of PF_EM 8 mm)

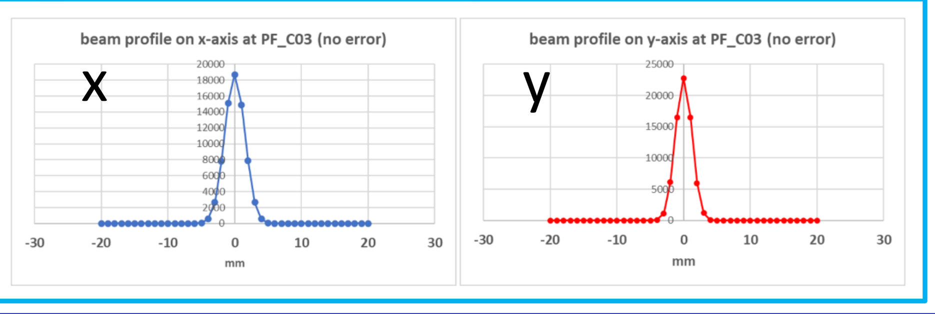
	σ_{11}	σ_{21}	σ_{22}	σ_{33}	σ_{43}	σ_{44}
PF_EM	64.0	67.46	71.20	7.84	1.47	0.56
PF_C02	31.36	-8.45	2.48	23.04	-5.87	1.59
PF_C03	2.56	-0.33	2.48	1.69	-0.65	1.59

σ matrix assumed to be true

$$\begin{pmatrix}\sigma_{11} & \sigma_{12} & \sigma_{13} & \sigma_{14}\\ \sigma_{21} & \sigma_{22} & \sigma_{23} & \sigma_{24}\\ \sigma_{31} & \sigma_{32} & \sigma_{33} & \sigma_{34}\\ \sigma_{41} & \sigma_{42} & \sigma_{43} & \sigma_{44}\end{pmatrix} = \begin{pmatrix} 28.1 & 44.6 & 0 & 0\\ 44.6 & 72.0 & 0 & 0\\ 0 & 0 & 7.0 & 1.3\\ 0 & 0 & 1.3 & 0.6\end{pmatrix}$$

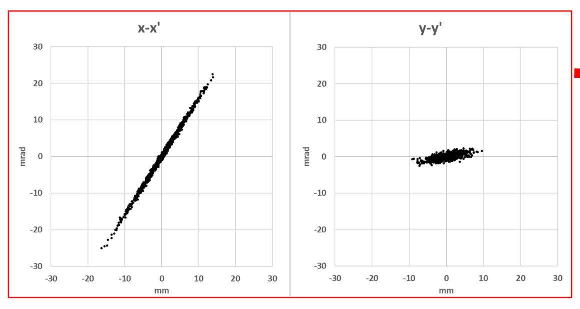
At EM_C01

PF_C03 calculated using above σ matrix

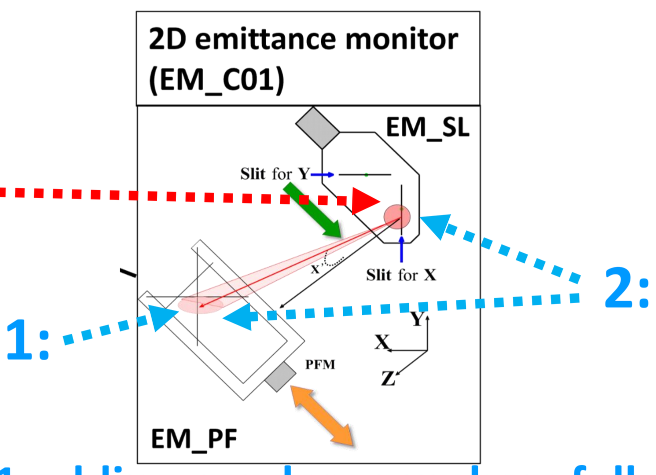


estimate the beam size including error at the EDM target due to the EM_C01 measurement error.

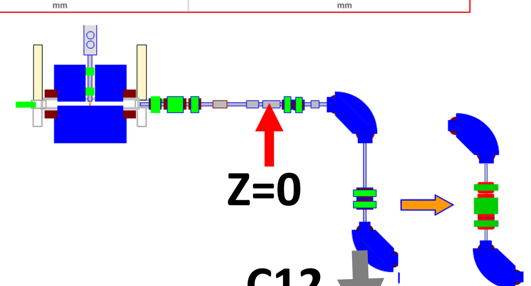
random numbers following 4-variables normal distribution
Calculated phase space at z=0



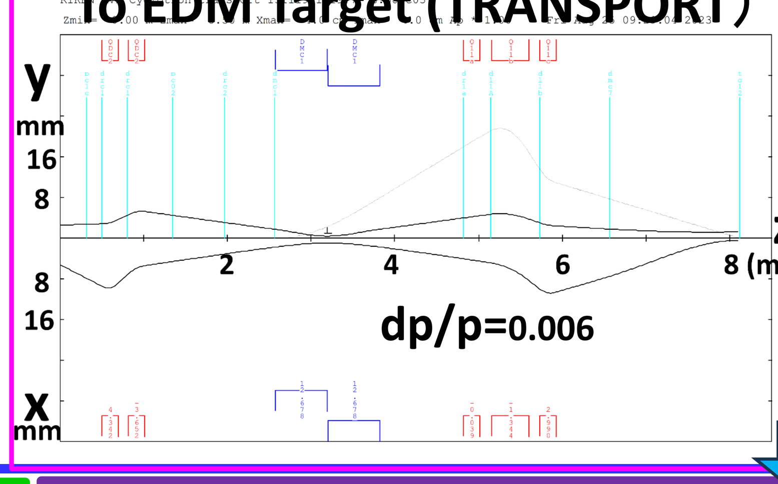
Error simulation



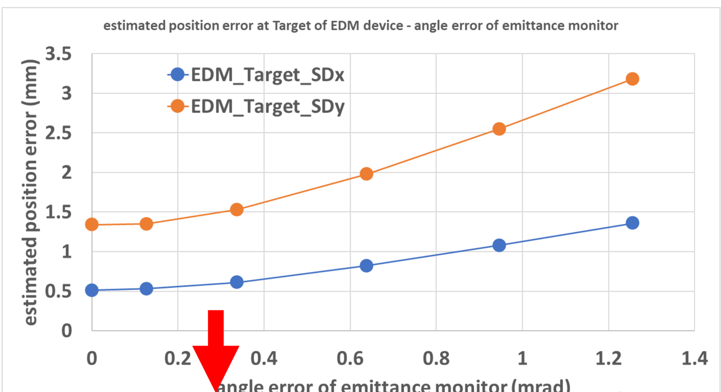
1:adding random numbers following normal distribution having SD as error
2: Recomputing angle



σ matrix assumed to be true
To EDM Target (TRANSPORT)



The relationship between angular error of EM_C01 and calculated beam size (SD) at EDM Target



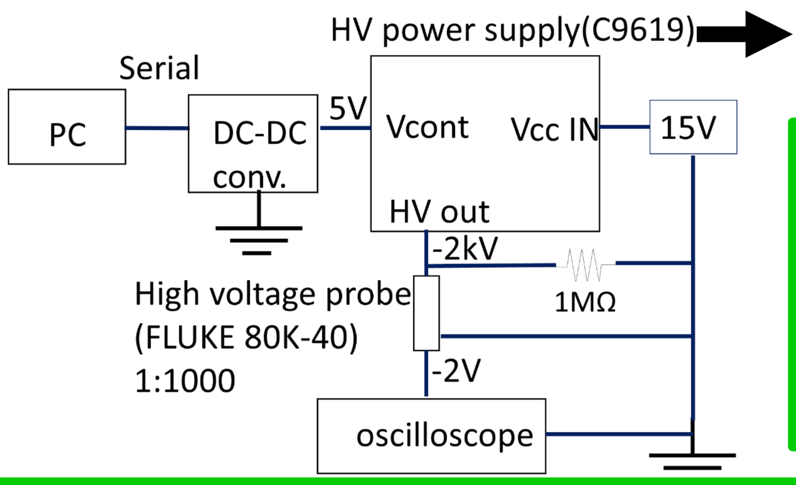
Required less than0.3mrad of angular accuracy of PEM

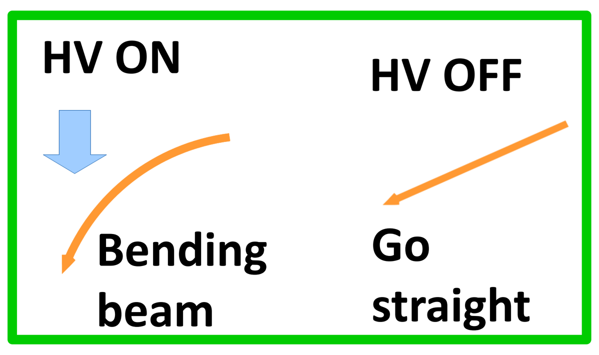
③Beam shutter system to avoid heating PEM from beam

No cooling — to shorten the measurement time

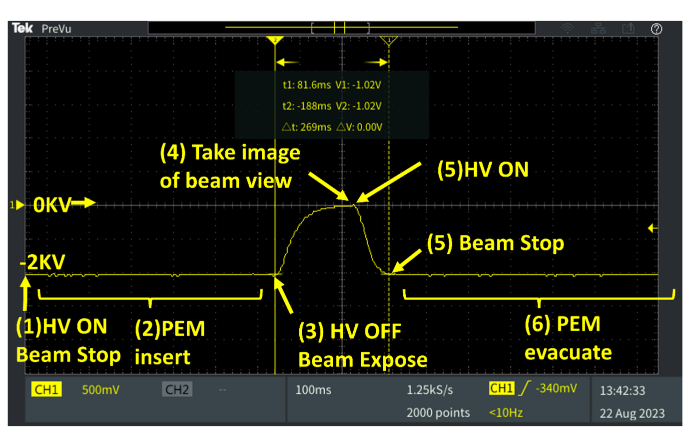
The beam stops by applying a high voltage to the electrode set in the beam line just behind an ion source and bending the beam sideways.

The diagram of the beam shutter control system





The measuring time reachs 0.27 seconds



Dividing the measurement errors of PEM from the emittance assumed to be true by error simulation.

Our requirement for facility of beam test
・low beam emittance,
・no correlation between x and y,
・three BPMs in a beam line,

Micro Analysis Laboratory, Tandem accelerator (MALT), The University of Tokyo. The PEM installation with tele lens camera optics was complete. This beamline has two BPMs at 735 mm upstream and 2070 mm downstream from the PEM. Moreover, since the PEM becomes BPM with the average position error of 0.15 mm, we have three BPMs.