The US-J Workshop 2004 on Heavy Ion Inertial Fusion

High-flux ion extraction from a drifting plasma source

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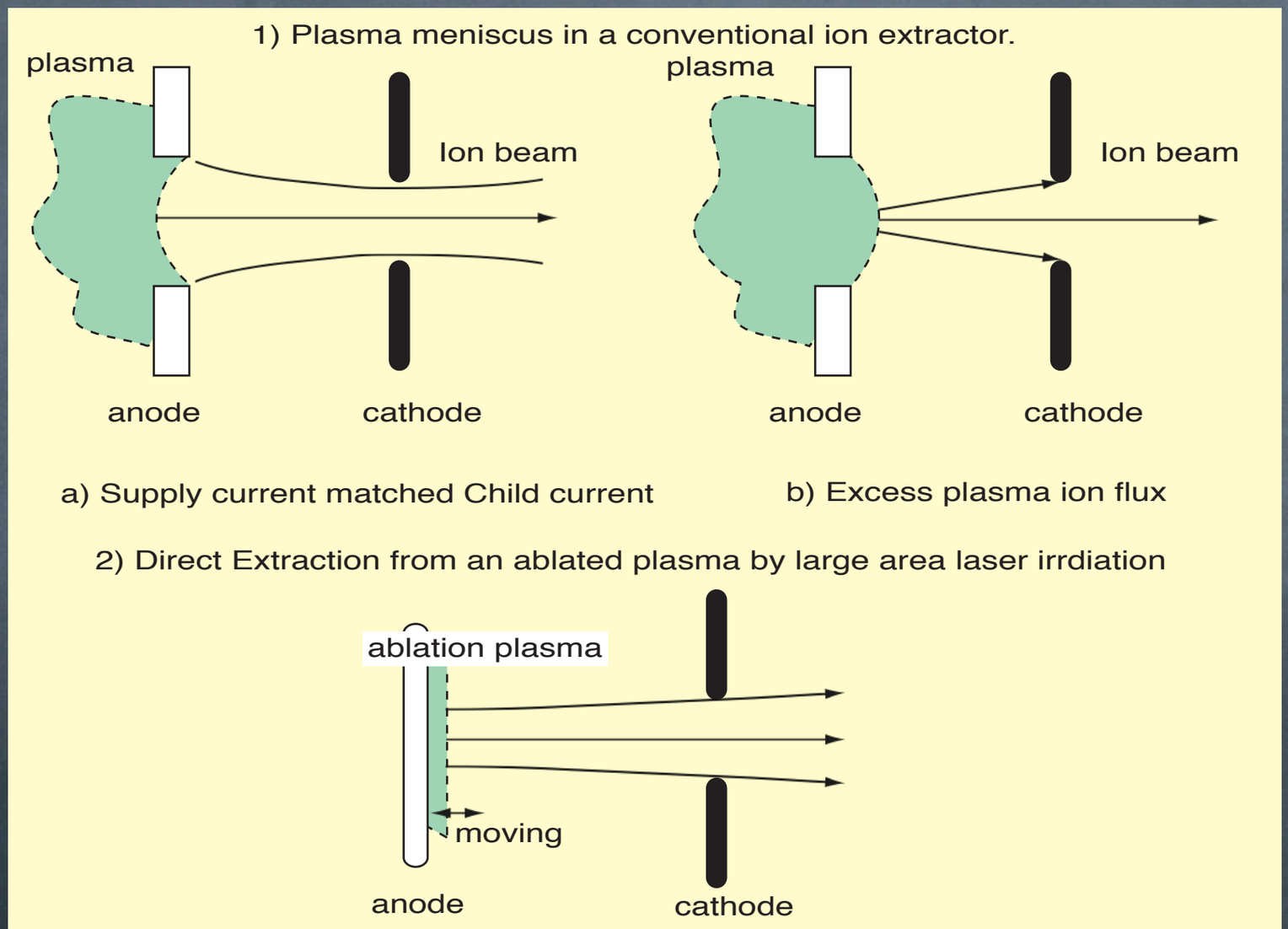
"Can we make a laser ion source like a surface ionization type?"

H.I.F. Requires

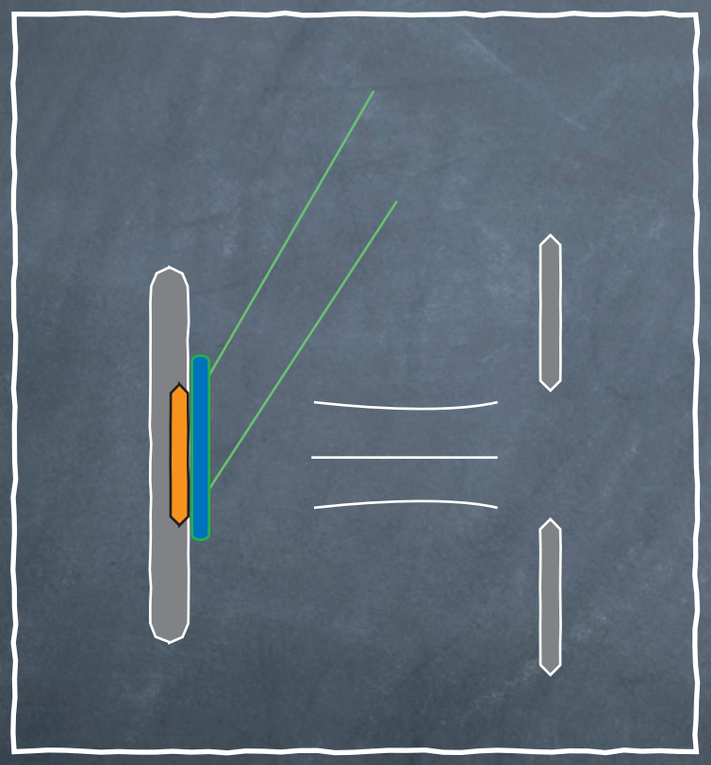
Number of Ions	~ 10^{14} ions
Ion Current	~ A
Duration	~ 10μsec
Emittance	< 1 π mm·mrad
Charge State	1-3
Pulse Shape	Fast Rising & Flat-top

- High Brightness and High Current
- High dense and low temperature plasma

Pulsed ion sources usually meet changes of the plasma.



Why direct extraction?



- Low temperature plasma
  - ↳ beam quality
    +1 ions
- No plasma fill
  - ↳ fast rising
    breakdown
- One dimensional extraction
  - ↳ no fluctuation of
    emitting surface shape

but moving!

How does the emitting surface move?
How much does it influence on the beam optics?

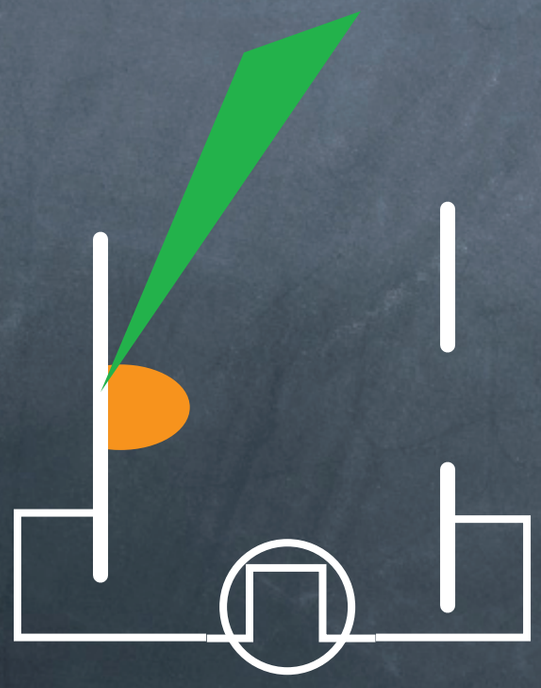
Is it possible to develop the laser ion source
like a surface ionization type?

We investigated

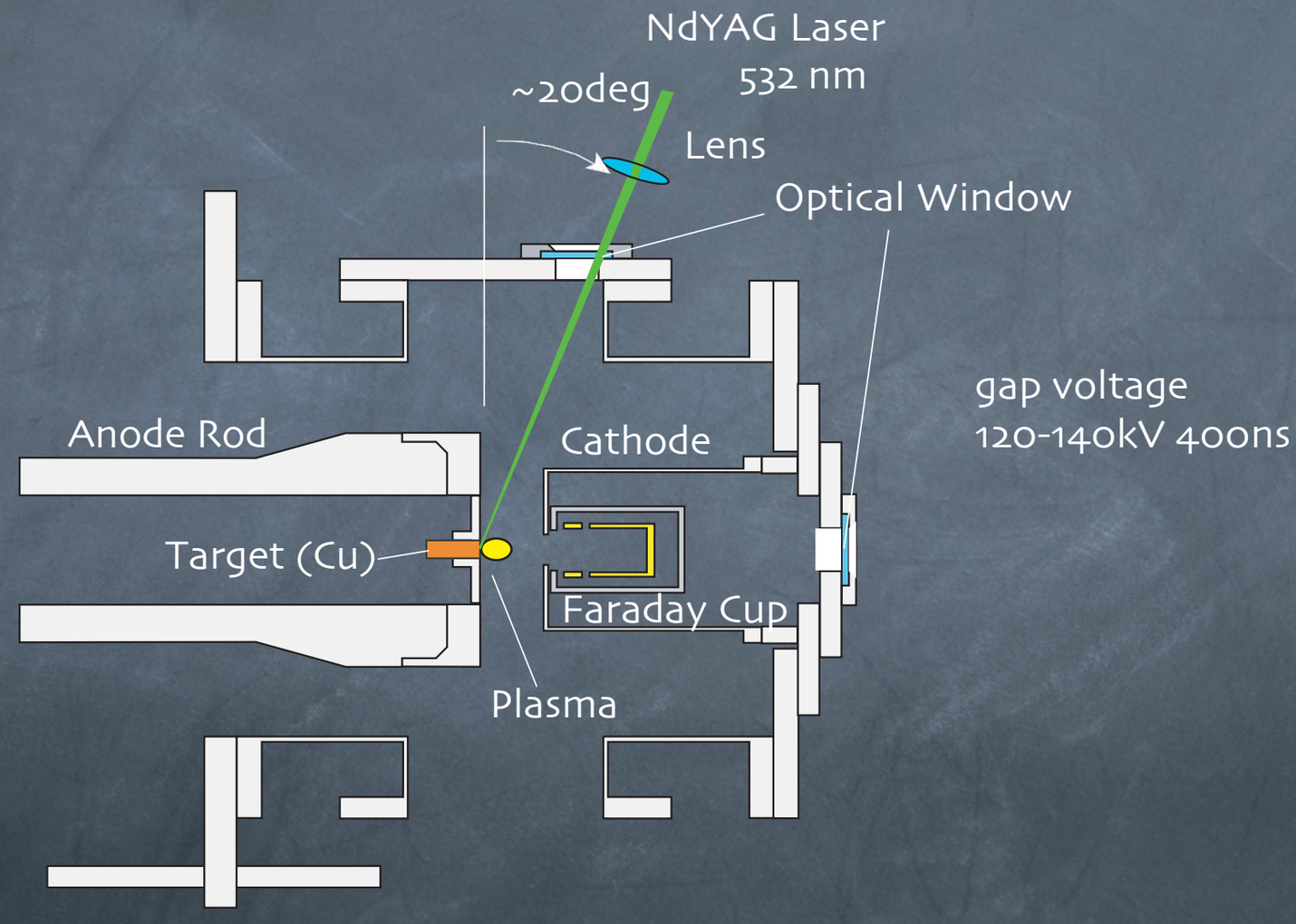
the dynamics of the emitting surface

for small spot laser irradiation

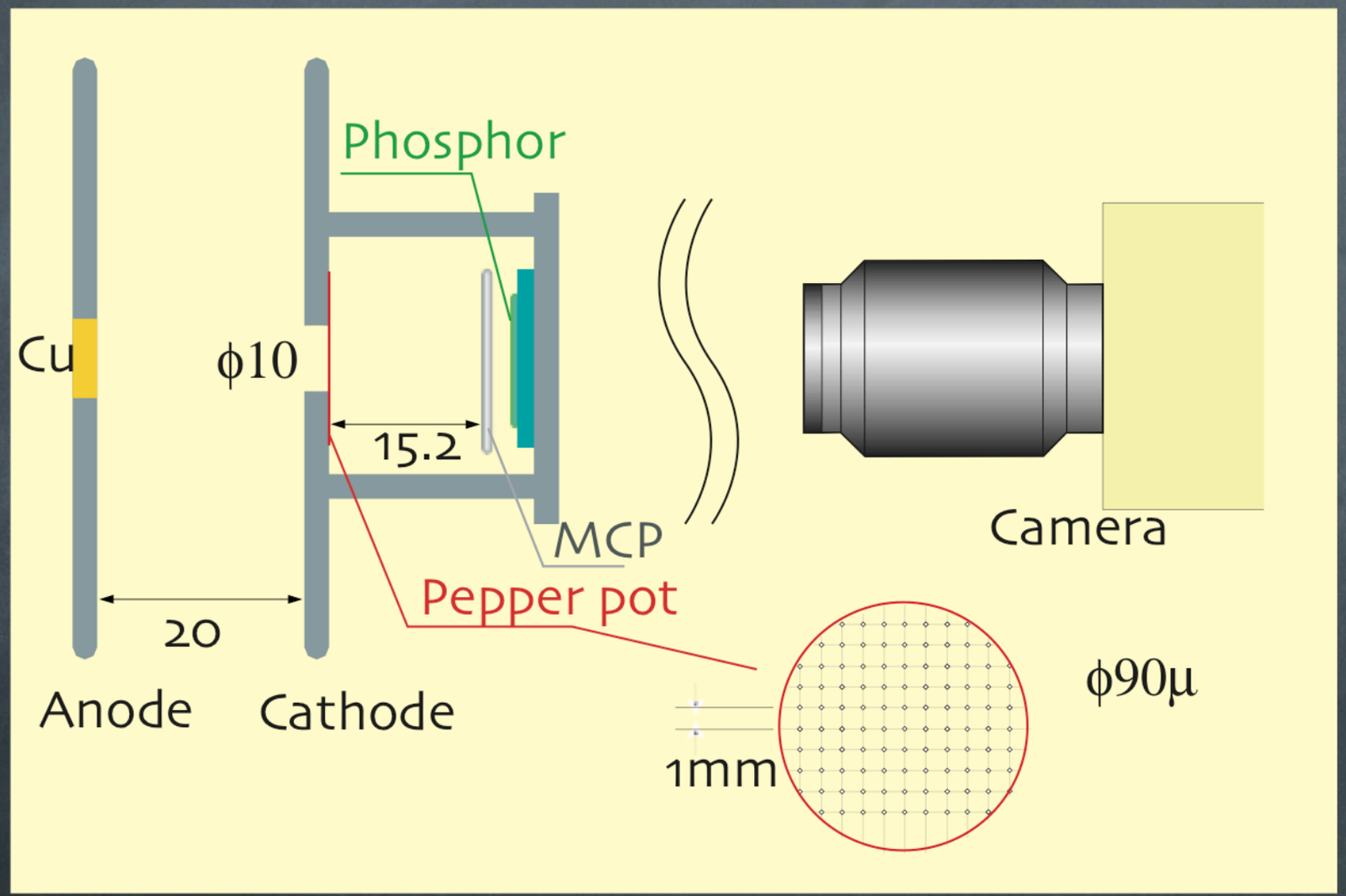
measuring ion current waveforms and pepper pot images



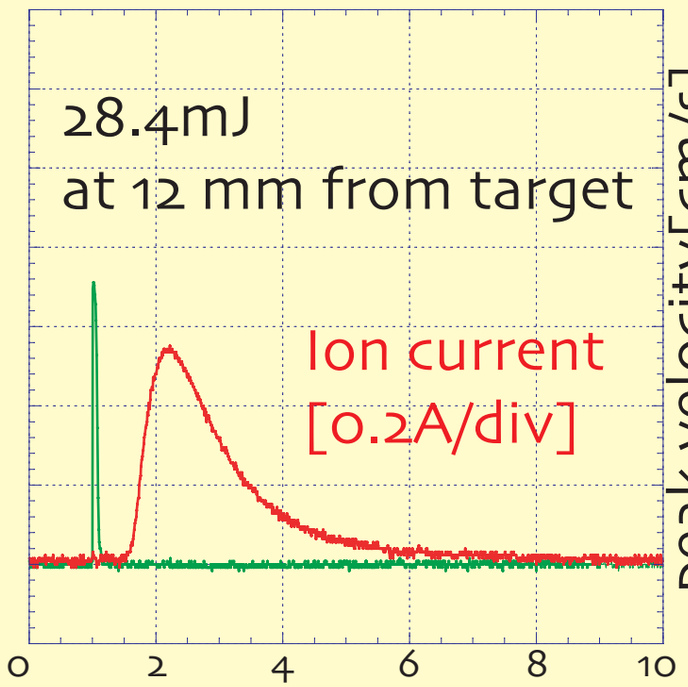
Schematic View of Laser Ion Source

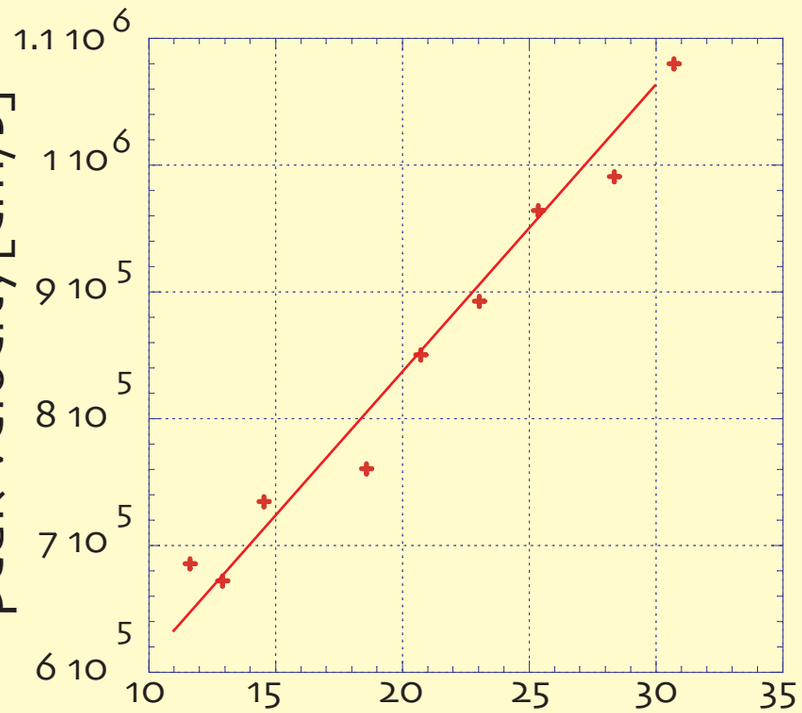


★ Pepper-pot Emiitance Measurement



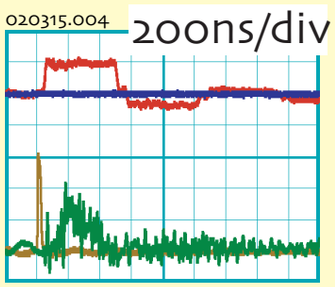
★ Ion current waveform and peak velocity



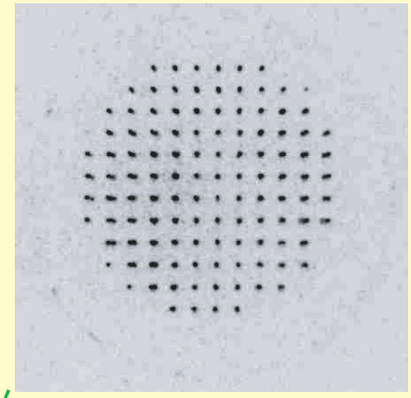


★ Insufficient supply of ions [16.6mJ]

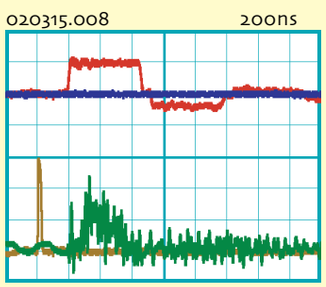
100nsec



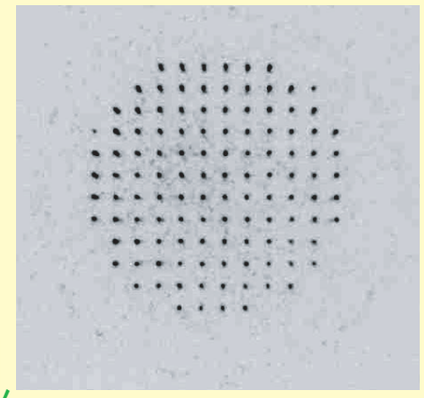
accel. 120kV/div
current 20mA/div



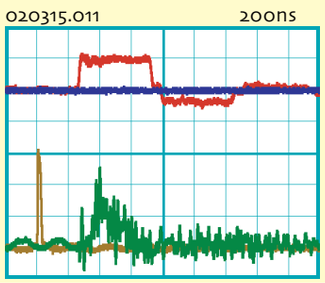
200nsec



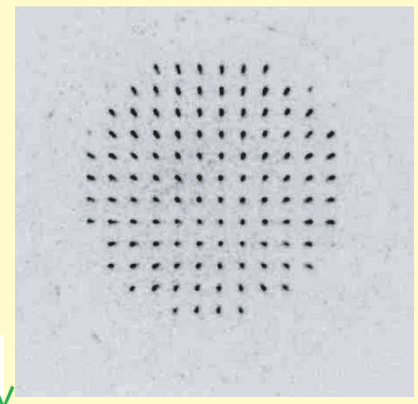
accel. 120kV/div
current 20mA/div



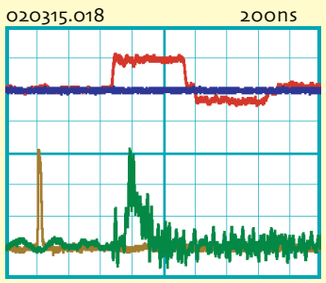
300nsec



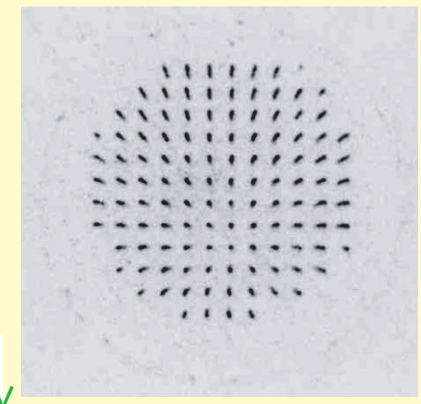
accel. 120kV/div
current 20mA/div



500nsec

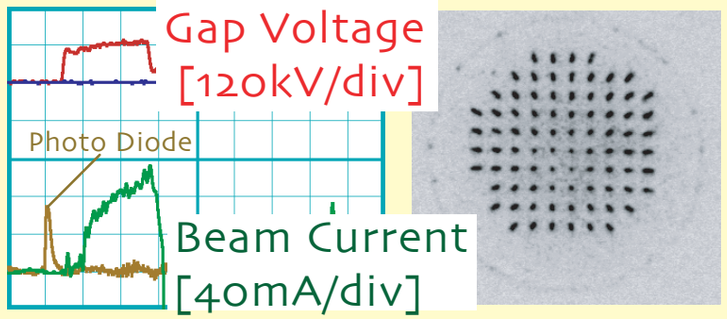


accel. 120kV/div
current 20mA/div

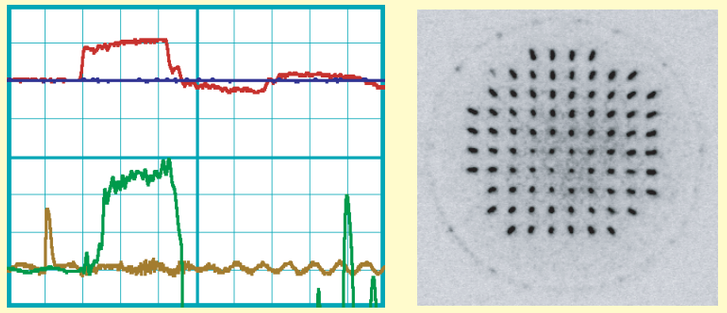


Typical Current Waveforms and Beam Images [33.3 mJ]

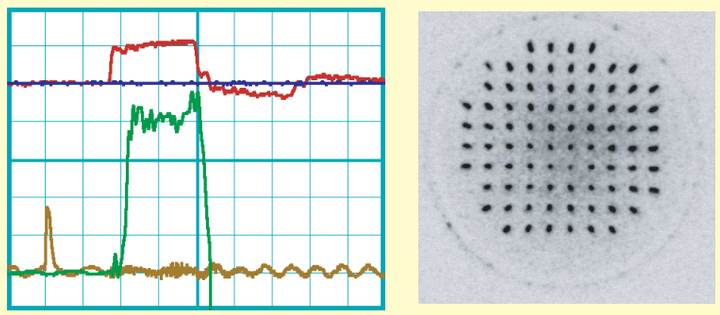
td = 100ns 200ns/div



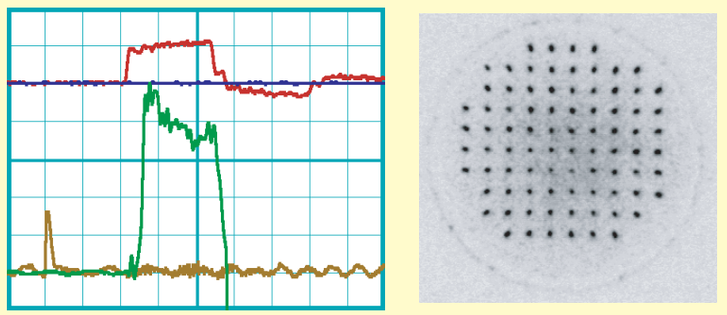
td = 200ns



td = 300ns

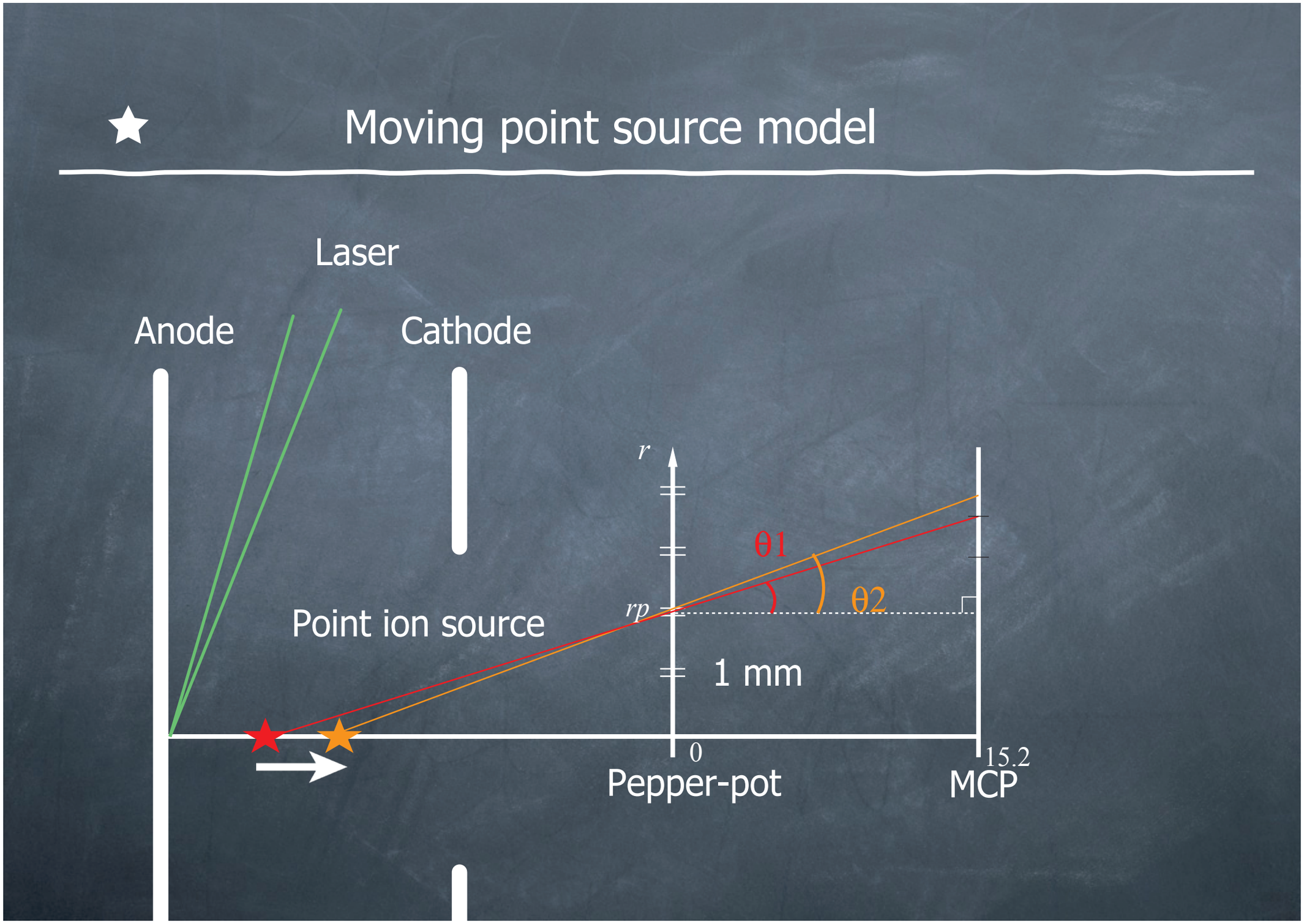


td = 400ns

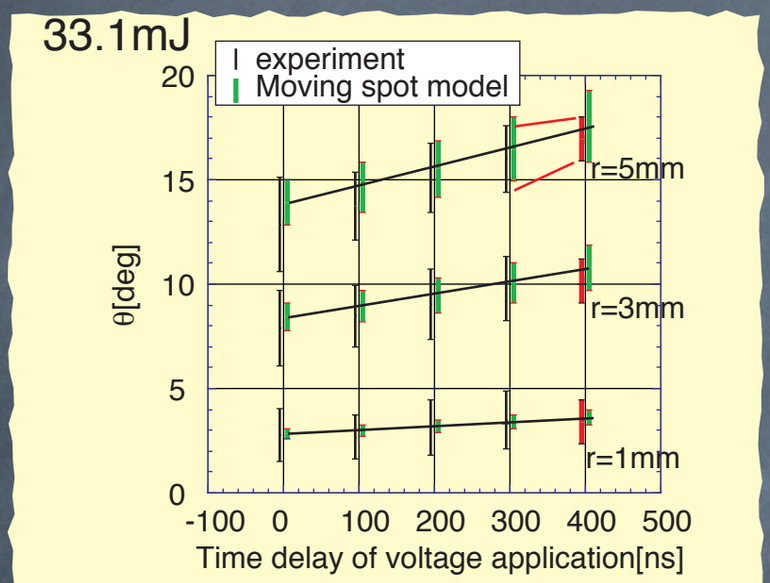


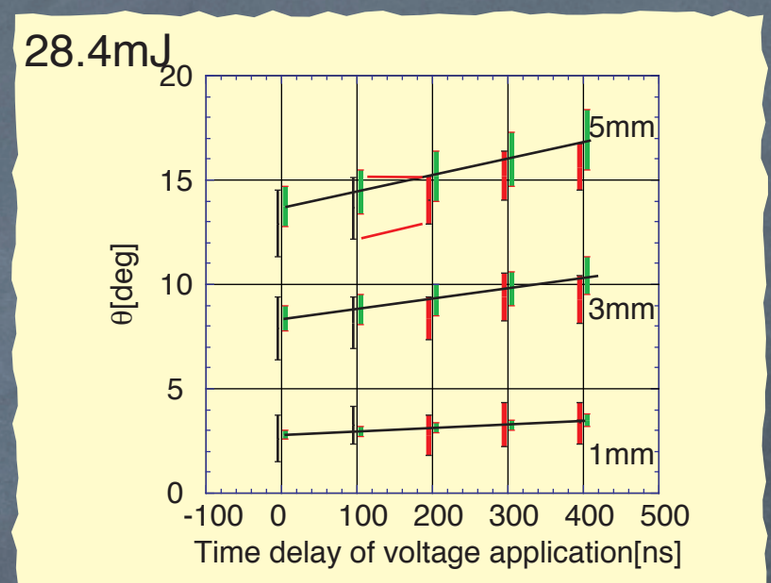
td :Time Delay of Voltage Application

Moving point source model



Emitting surface slows down?

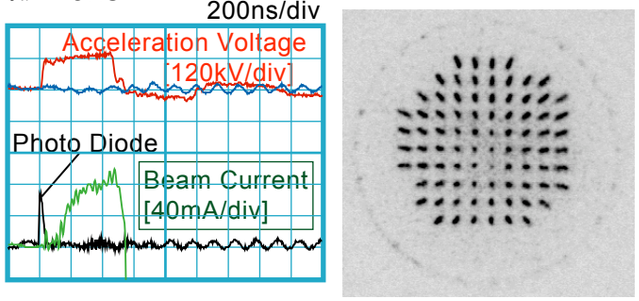




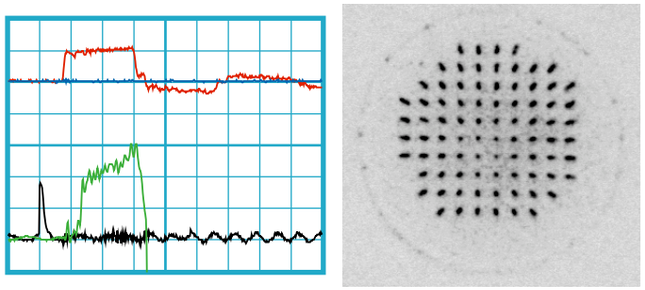
- Beam image changes from the radial pattern to a dot-like one.
- Current waveform also becomes a rectangle while changing to a dot-like pattern.
- $\Delta\theta$ is the same at any points, the influence of movement of the emitting surface is not seen.

a) 33 mJ

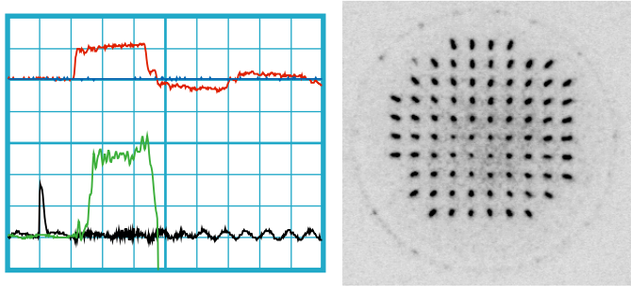
t_d = 0ns



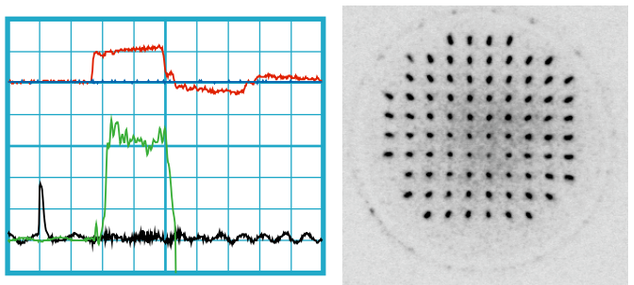
t_d = 100ns



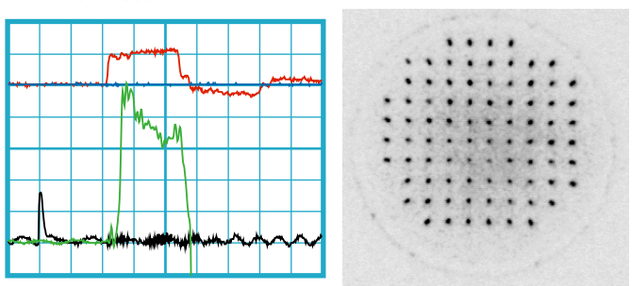
t_d = 200ns



t_d = 300ns

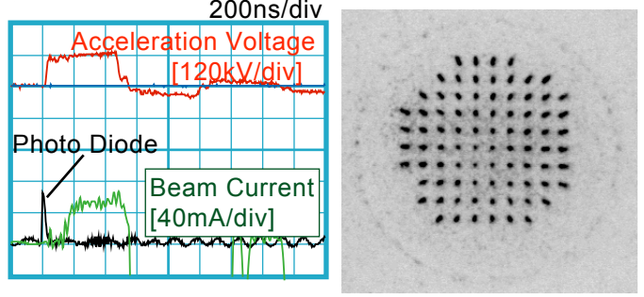


t_d = 400ns

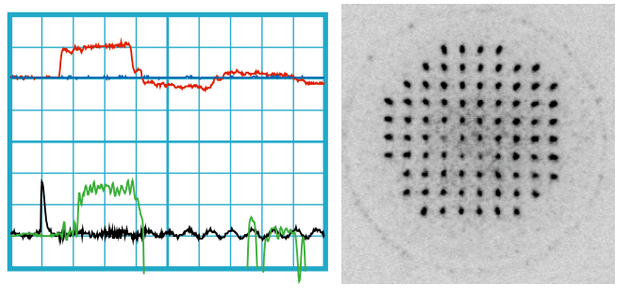


b) 28 mJ

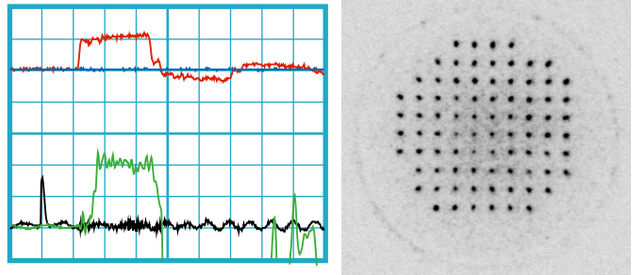
t_d = 0ns



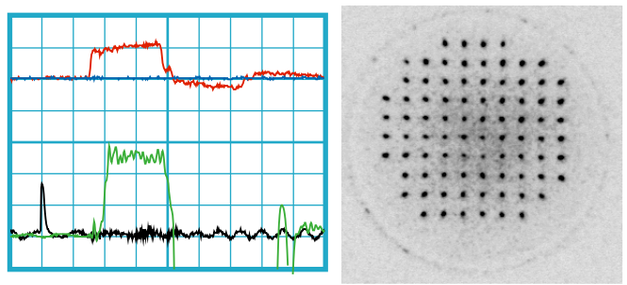
t_d = 100ns



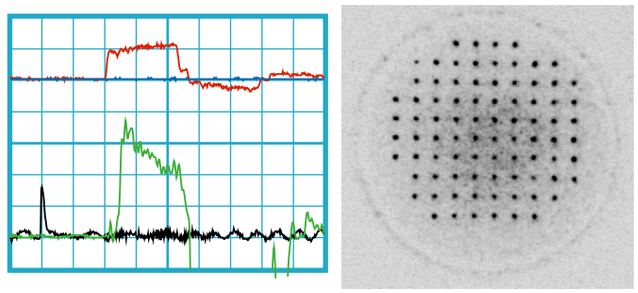
t_d = 200ns



t_d = 300ns



t_d = 400ns



Beam Emittance can be improved.

- The emittance was 0.35 [π mm･mrad] and
  this equivalent temperature (30eV) was comparable to the drift energy.

- In order to suppress the distortion of electric field,
  a SUS mesh was placed at 4mm from the target.
  The emittance was improved to 0.25 [π mm･mrad] .

- The configuration of extractor is not optimized
  for the extraction from one point source,
  The emittance may be improved much.

- Large area irradiation makes it possible to extract one dimensionally.

- Large area irradiation reduce the drift velocity.

Summary

- Fast rising(40ns) & Flat-top Waveform
- 160mA Cu ion with 0.35 [π mm·mrad]
- Studying about the behavior of
  the emitting surface expanding from small spot
- There is a "Matching condition" where
  emitting surface doesn't move so much
  and current is flat.
- Large area direct extraction laser ion source
  is a good candidate.

★ Discussions 2

- "Is that certainly the case with 1D extractor though experiments were done with 2D?"
  - I can't answer this question. It was not a bad result in experiments at least. However, a certain compromise may be necessity between 1D and 2D. So this is just next step.

- "How about purity of charge state?"
  - We didn't measure charge states, but we don't worry about this. Because 1D extractor requests low intensity irradiation so temperature will be low. We expect pure 1+ ions.

- "How about longitudinal energy dispersion?"
  - We didn't measure , because our extraction voltage is not constant. It depends on moving of the emitting surface. If the emitting surface does't move so much , It will be fine.