TIME DEPENDENCE OF ION BEAM TRANSVERSE PHASE-SPACE PORTRAIT ORIENTATION DURING LINAC PROTON INJECTOR PULSE

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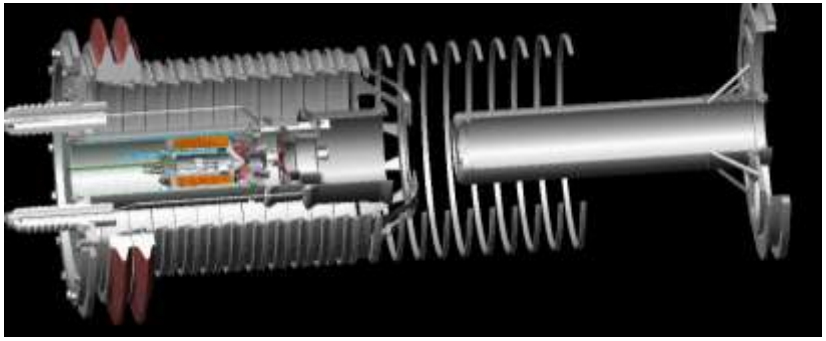
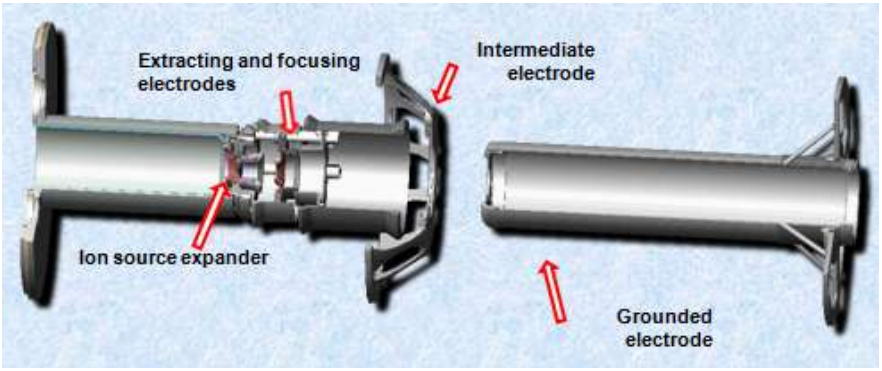
INR RAS Linac proton injector

- Peak current – up to 100 mA
- Ion energy – 400 keV
- Energy instability - ± 0.1 %
- Pulse duration - 10-200 us
- PRR – up to 100 Hz
- Normalized emittance for 90% of beam - 0.15 π cm mrad
- Ion source – type of duoplasmatron
- Beam current instability along 200 us pulse and pulse-to-pulse instability ~ ± 1%
- Arc modulator discharge current – up to 50 A
- Cathode life time – ~ 8 000 hours of ion source operation

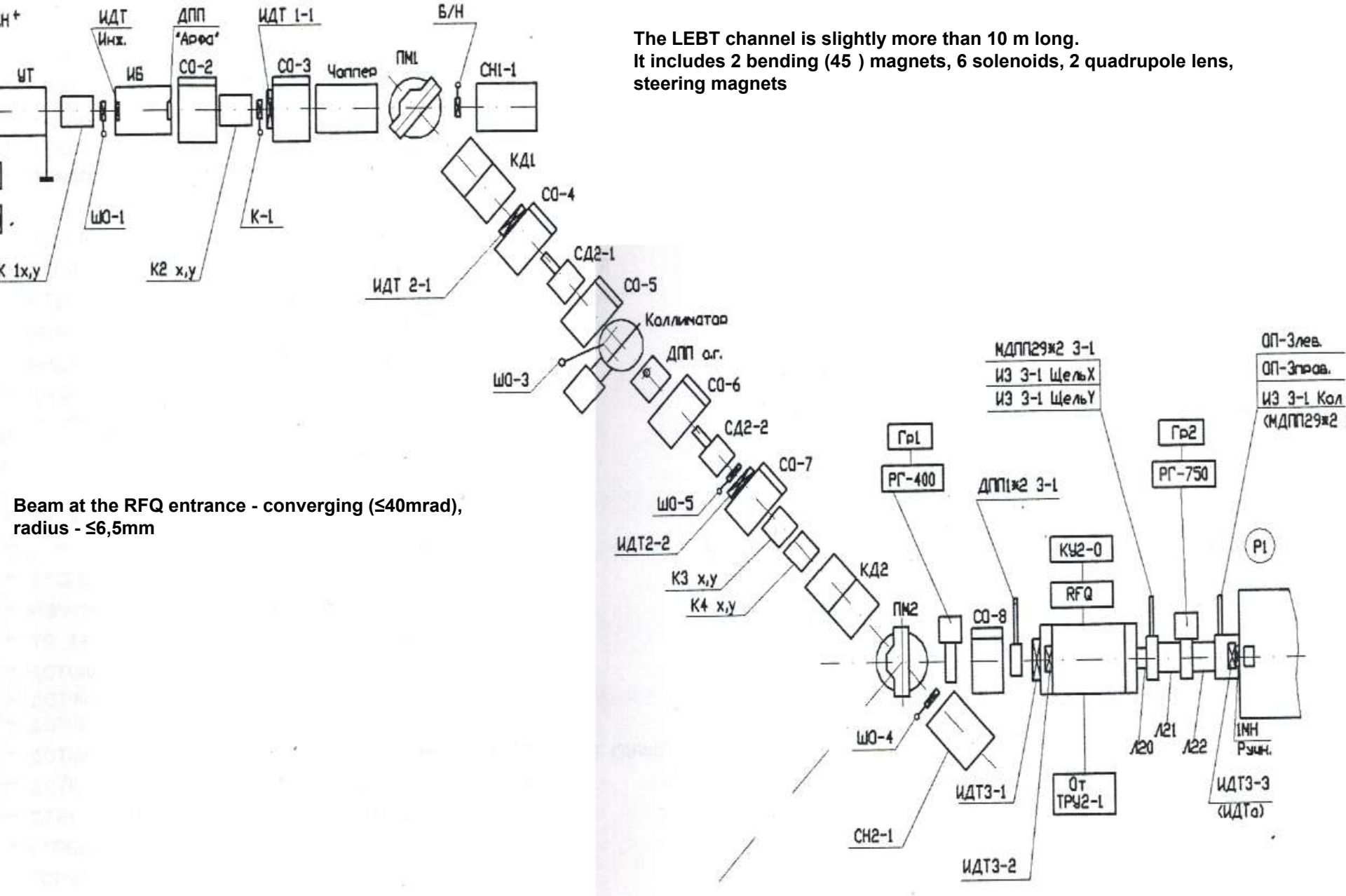
Total resistence of the water divider ≈1.5МОм
The divider current ≈ 0.3A



Ion sourse supply rack
at 400 kV potential



The tube is about 1600 mm long.
Summary length of two inner accelerating gaps – 100+120=220 mm.
Acceleration: first gap – 95 keV; second gap - 400 keV



The LEBT channel is slightly more than 10 m long.
It includes 2 bending (45) magnets, 6 solenoids, 2 quadrupole lens, steering magnets

Beam at the RFQ entrance - converging (≤40mrad), radius - ≤6,5mm

It has found that the causes of observed position/shape phase-space portrait changes during high voltage injector pulse can be as follows:

- instability of high voltage pulse;
- dynamic of ion beam space charge compensation process;
- change of the injector ion beam current;
- the IE potential changes.

The injector accelerating voltage instability is now not worse than 0.085%.
Pulse-to-pulse voltage instability does not exceed 0.04%.
So the summary instability equals value of 0.125% or less.

The observation has been performed:

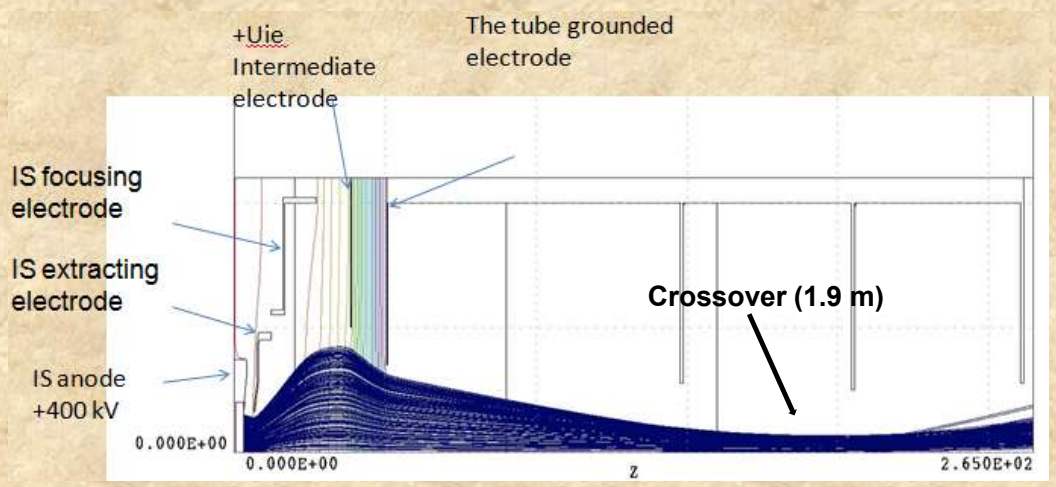
- the injector vacuum pumps have been switched off when the injector being operated at nominal mode; significant decreasing of beam current value due to residual gas molecules ionization has been fixed only when pressure in the tube being increased from 5 microtorr to 0.2 millitorr.

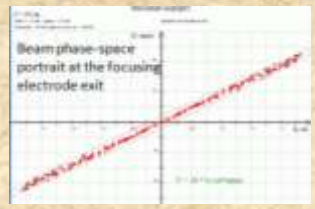
In our injector space charge compensation of the ion beam is prevented by electric fields of the accelerating tube beam forming system (extraction and focusing). These fields eliminate accumulation of electrons arising due to both ionization of residual gas molecules and when a beam hits apertures and walls of the ion pipe.

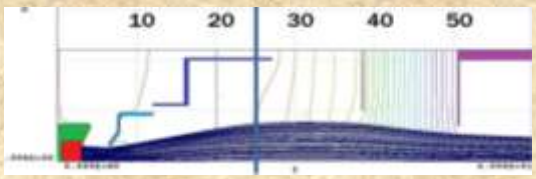
Conclusion:

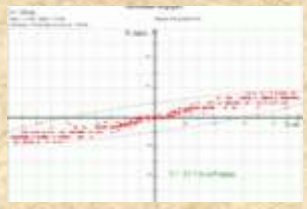
- space charge compensation at the injector and the initial part of LEBT channel is not observed.

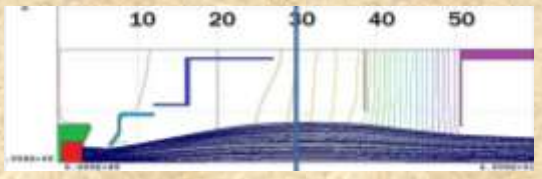
Calculation results (TRAK, Space Charge codes)
The proton injector beam focusing and acceleration

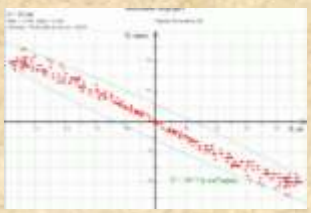


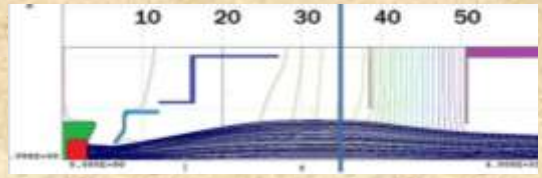


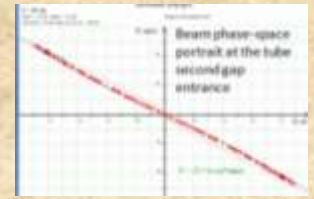


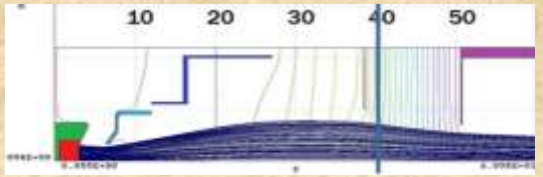


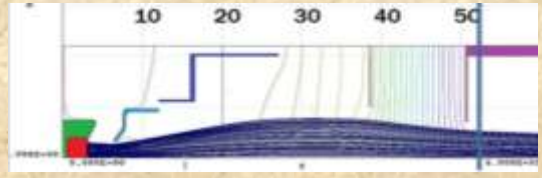


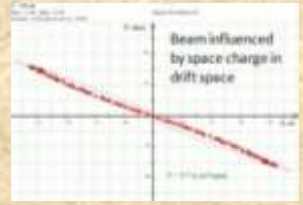


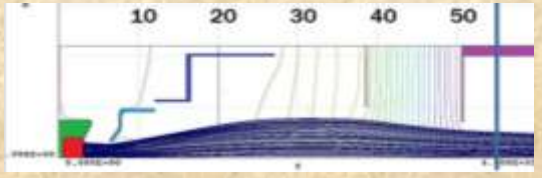




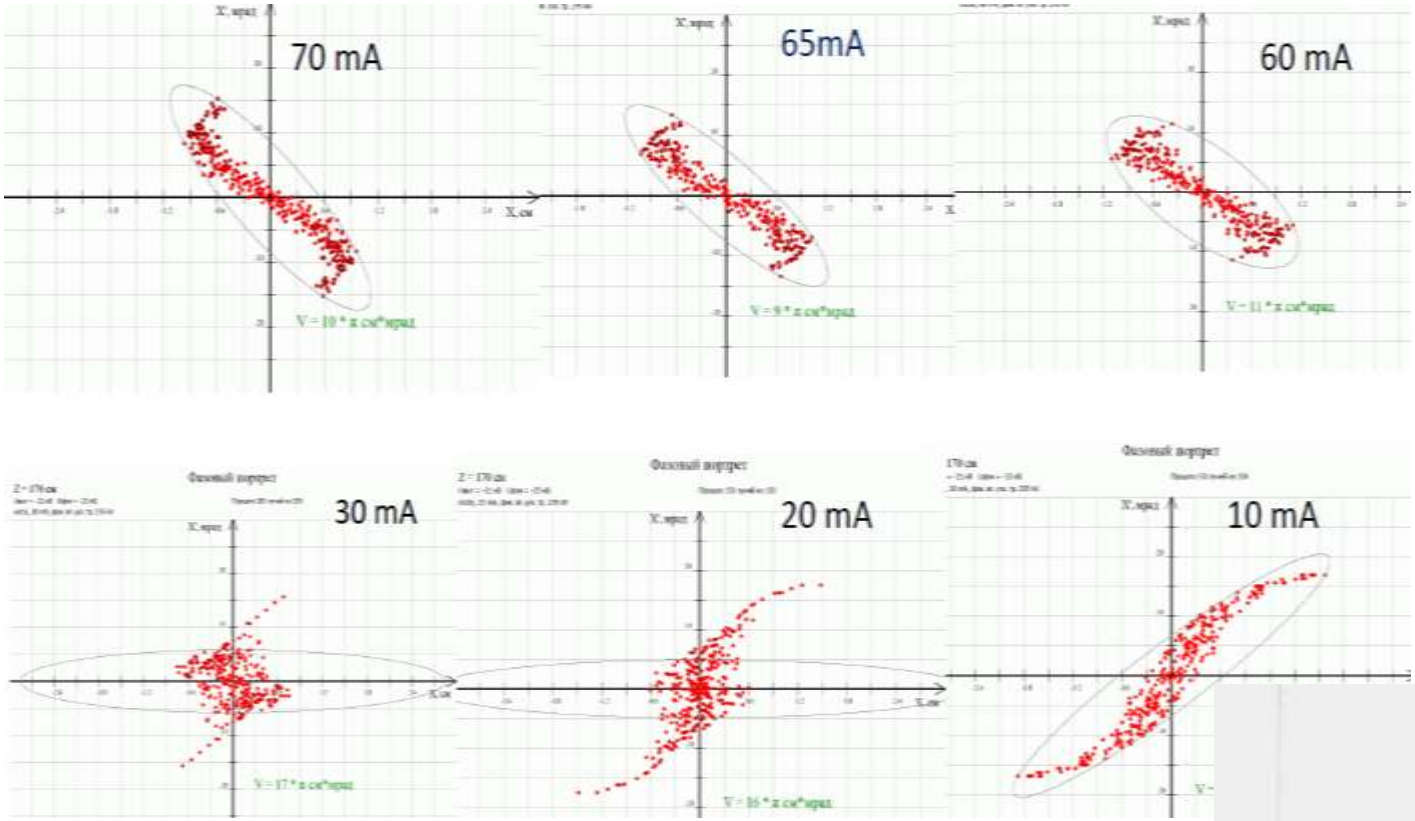








Influence of beam amplitude on position/shape of the injector output beam phase-space portrait

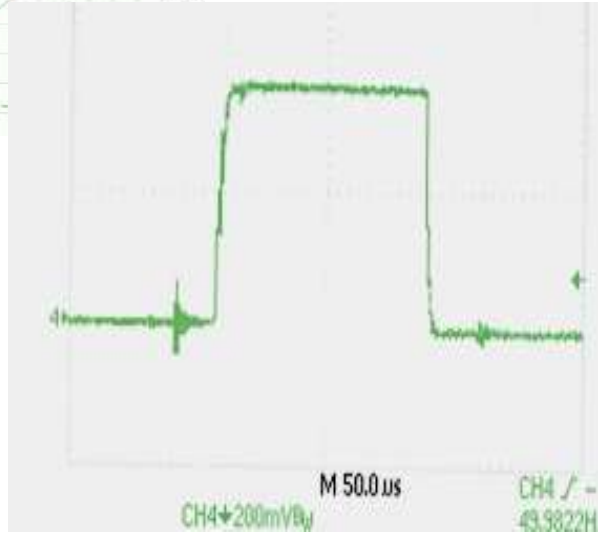


Influence of ion beam current change on phase-space portrait orientation is especially important in case of IS “noisy” operation mode, when an ion beam current fast variations can reach tens percent of maximal value.

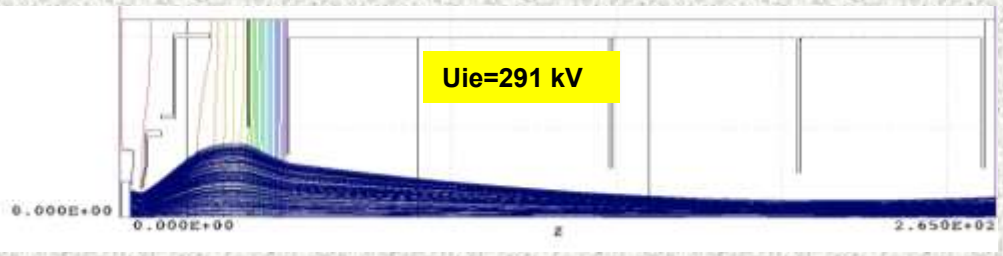
However, at the present time duoplasmatron has “noiseless” operation mode. As we can see, beam current transients up to 8% result in notable change of phase-space portrait orientation when current is about 65 mA.

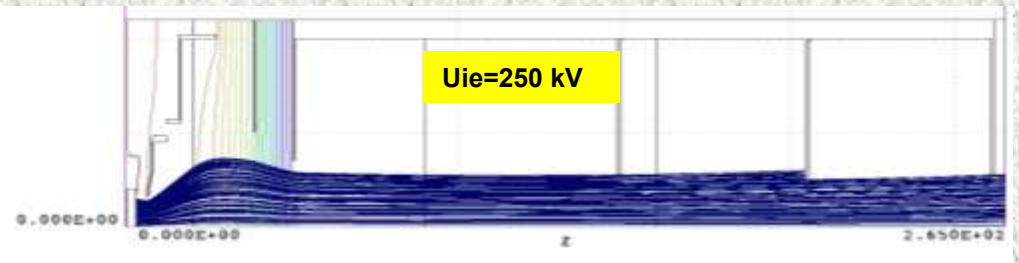
Additionally, to improve stability of beam current during a pulse and pulse-to-pulse stability the transistor stabilized arc modulator (instead of the thyristor unit based on artificial line) with no more than 0.5% discharge current instability along a pulse has been developed and placed in operation.

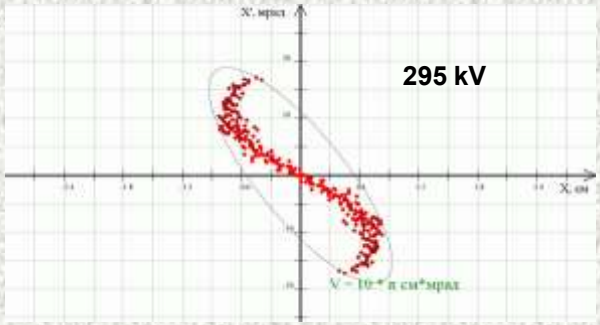
Now a total beam current amplitude instability ≈ 1.0%.

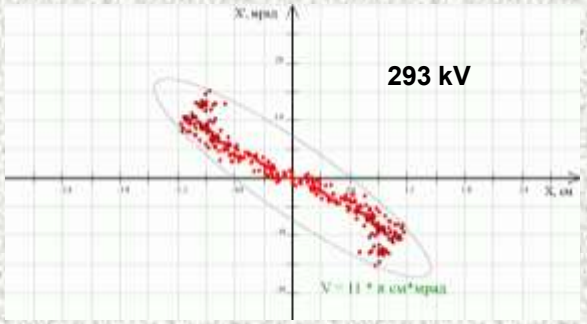


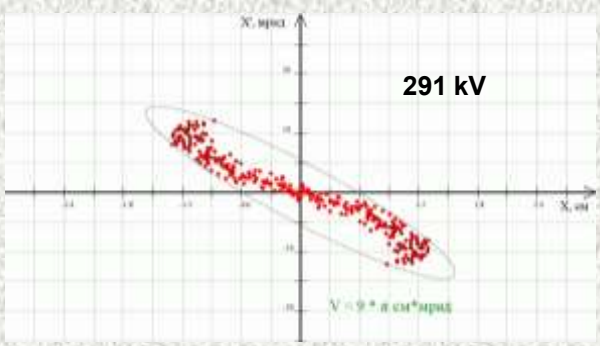
Influence of the IE potential value on position/shape of the injector output beam phase-space portrait

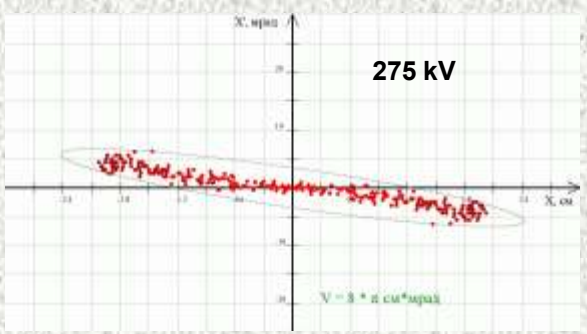


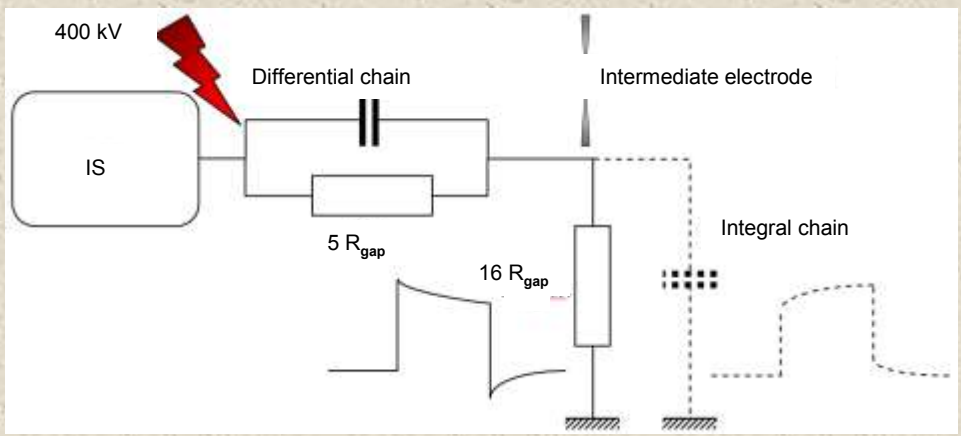


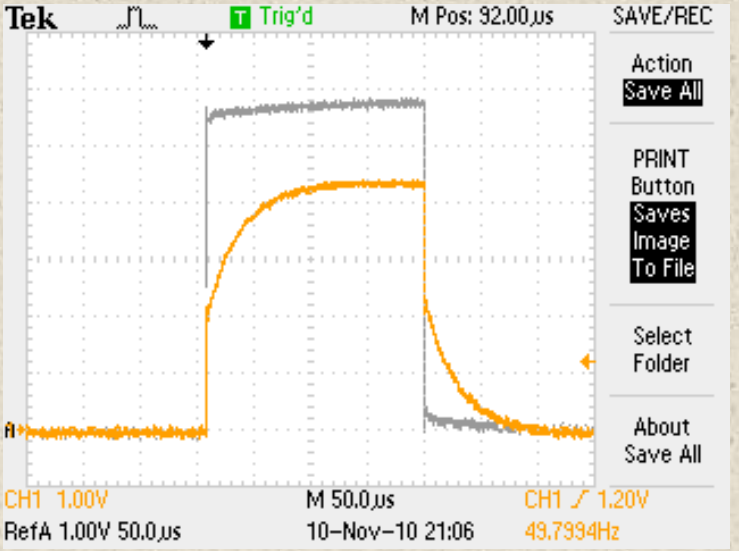









400 kV
Differential chain
Intermediate electrode
IS
5 R_{gap}
16 R_{gap}
Integral chain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Trig'd
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SAVE/REC
Action
Save All
PRINT
Button
Saves
Image
To File
Select
Folder
About
Save All
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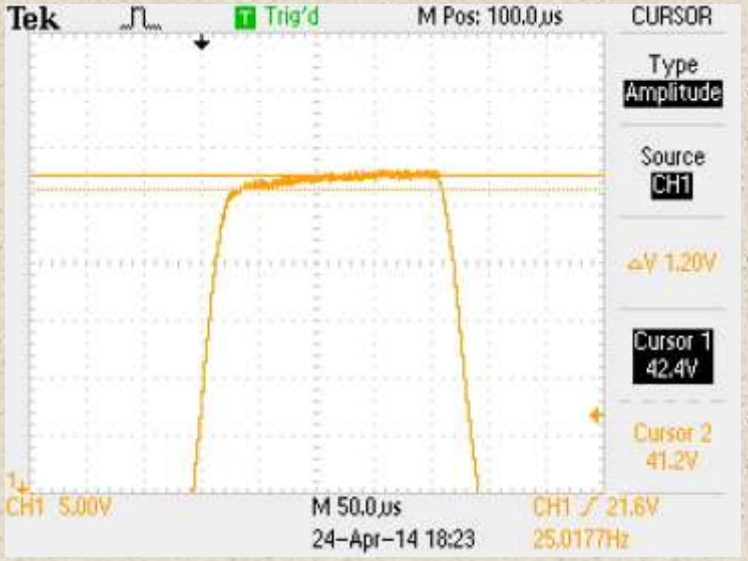
M 50.0µs
CH1 ∕ 1.20V
RefA 1.00V 50.0µs
10-Nov-10 21:06
49.7994Hz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CH1 ∕ 21.6V
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25.0177Hz


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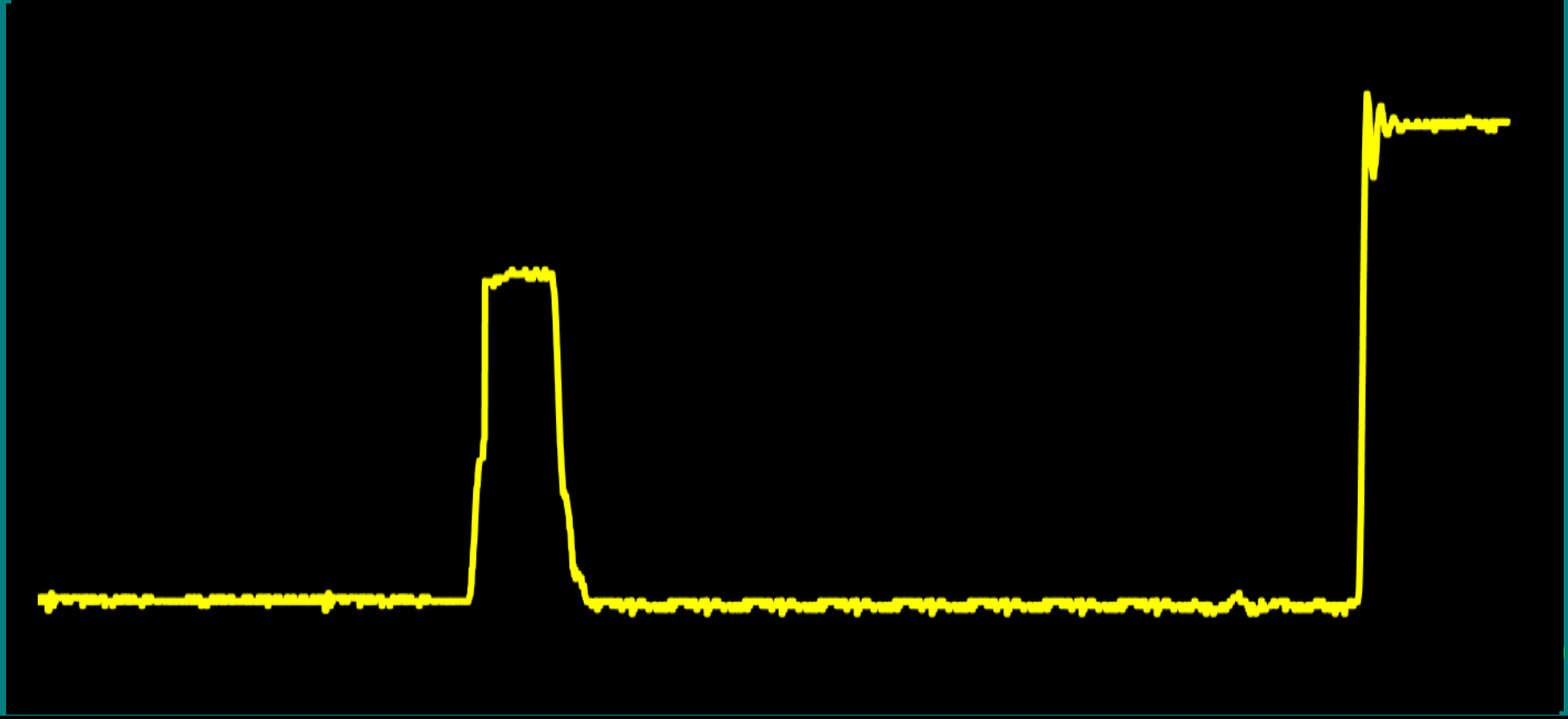

Conclusion

Analysis of the processes leading to change of phase-space portrait orientation during HV pulse at the output of the proton injector results in conclusion that the main processes are change of the ion beam current and turn-on transients of the 400 kV accelerating tube intermediate electrode potential.

Due to:

- installation of the accelerating tube compensated divider,
- stabilizing of duoplasmatron discharge current,
- improvements conducted to increase accelerating voltage stability,

a change of phase-space portrait orientation during beam pulse does not observed within accuracy of measurements.

A satisfactory agreement of beam parameter measurements and numerical simulation has been achieved.

Acknowledgments

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Thank you for attention!