TRANSFORMATION of BEAMS in PLASMA LENS and INVESTIGATION of Z-PINCH DYNAMICS

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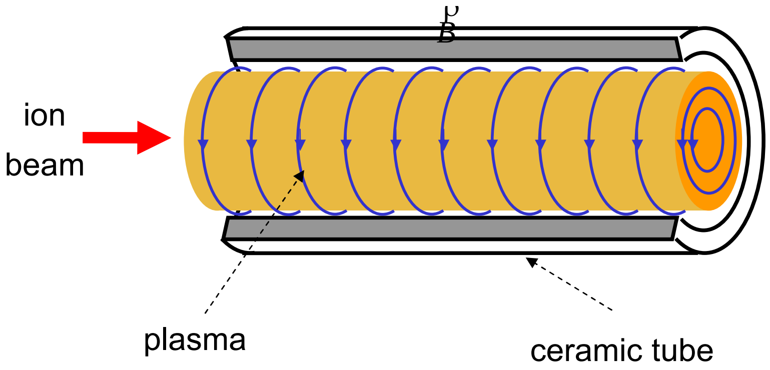
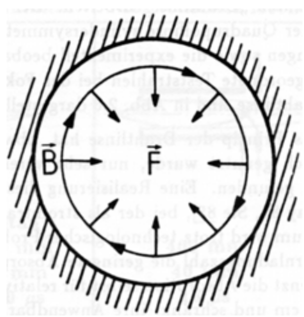
Abstract. ***The plasma lens can carry out not only sharp focusing of ions beam. Plasma lens provides formation of hollow beams of ions. Application of the several plasma lenses allow to get a conic and a cylindrical beams. The plasma lens can be used for obtaining a beams with homogeneous spatial distribution.***

By measuring the distribution of ions in the beam at the input and output lenses can determine the current distribution in the pinch through the numerical calculation.

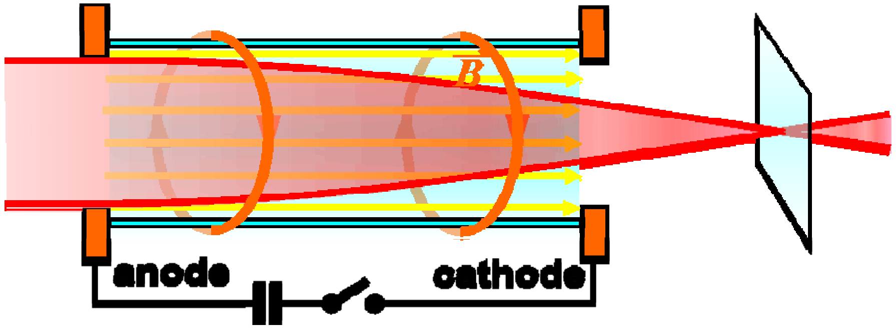
Ion focusing in a plasma lens



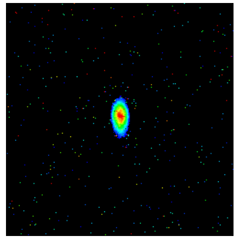


$$F = Zev_z B_\phi(r)$$

$$B = \frac{\mu_0}{2} jr$$

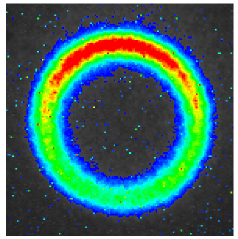


linear B-field



$d_{min} \sim \varepsilon I^{-1/2}$.

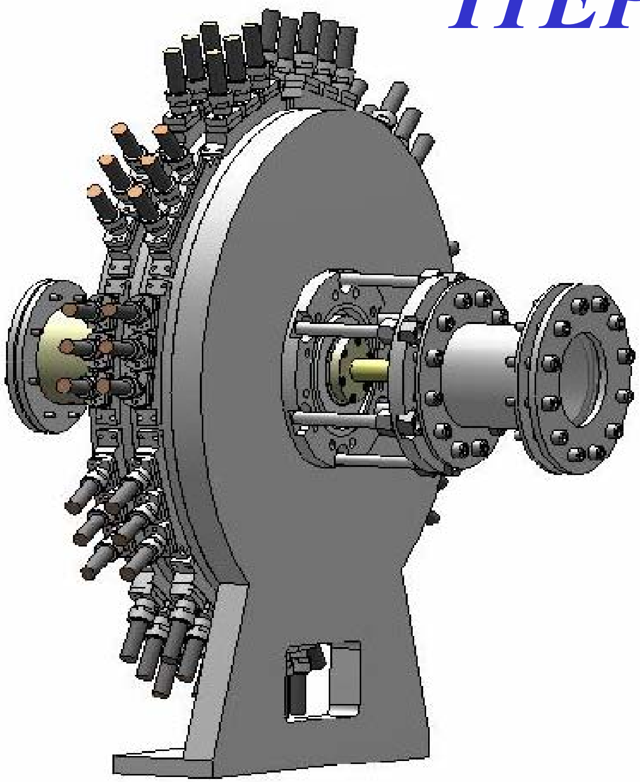
nonlinear B-field

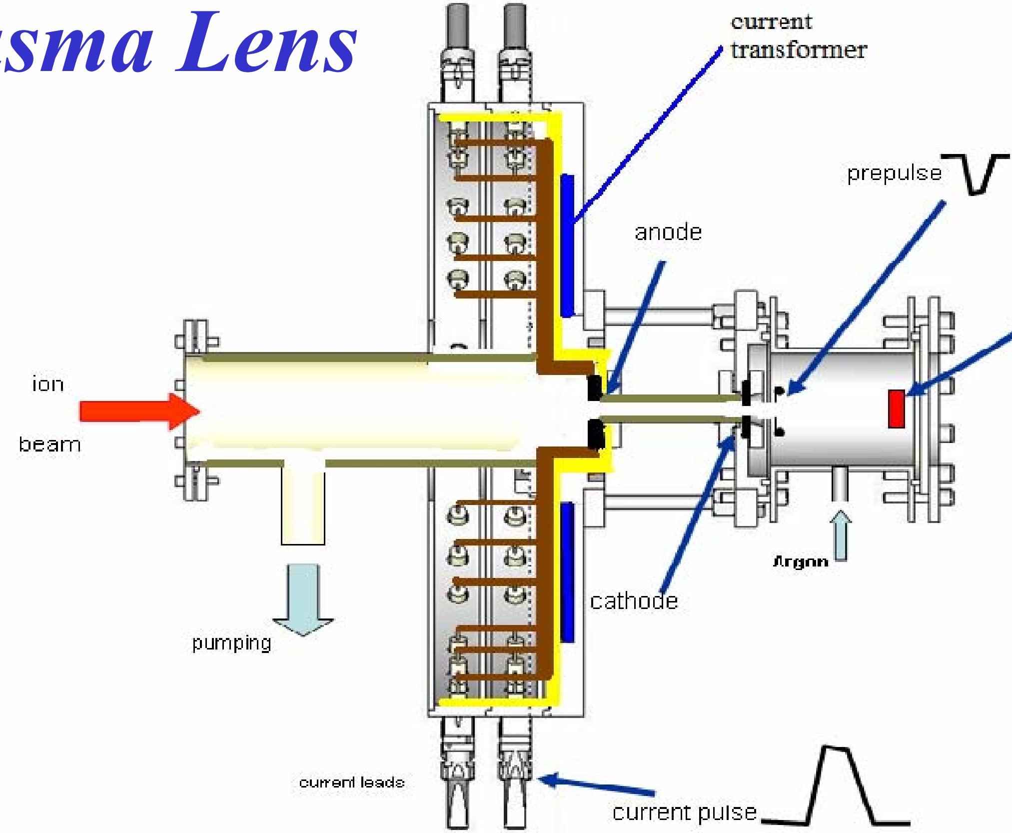


Advantages of plasma lens :

- **focusing power is proportional to the magnetic field strength;**
- **there is no limit for the magnetic field magnitude connected with saturation;**
- **charge neutralization of ion beam into the plasma lens ;**

ITEP Plasma Lens





Features of discharge	current generator
Switch (Short pulse T = 5 μs) Discharge current pulse duration Max discharge current	Thyratron TDI1-150/25 T = 5 μs at C = 25 μF I = 200 kA
Switch (Long pulse T = 20 μs) Discharge current pulse duration Max. discharge current	ThyratronTDI1-200k/25H T = 20 μs at C = 160 μF I = 400 kA

The plasma discharge current 120 кА

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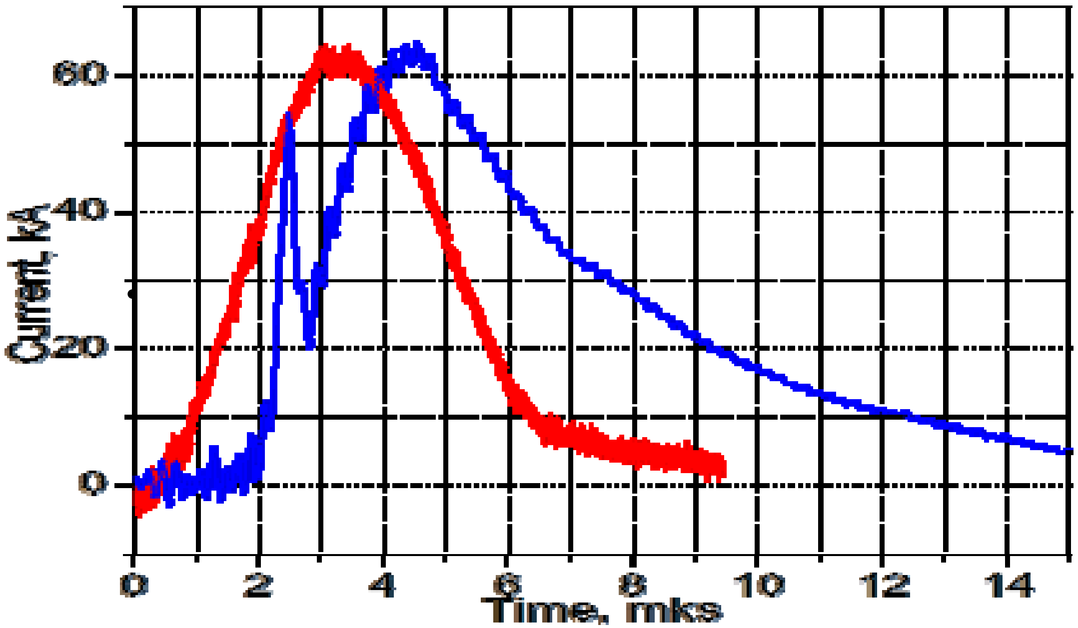
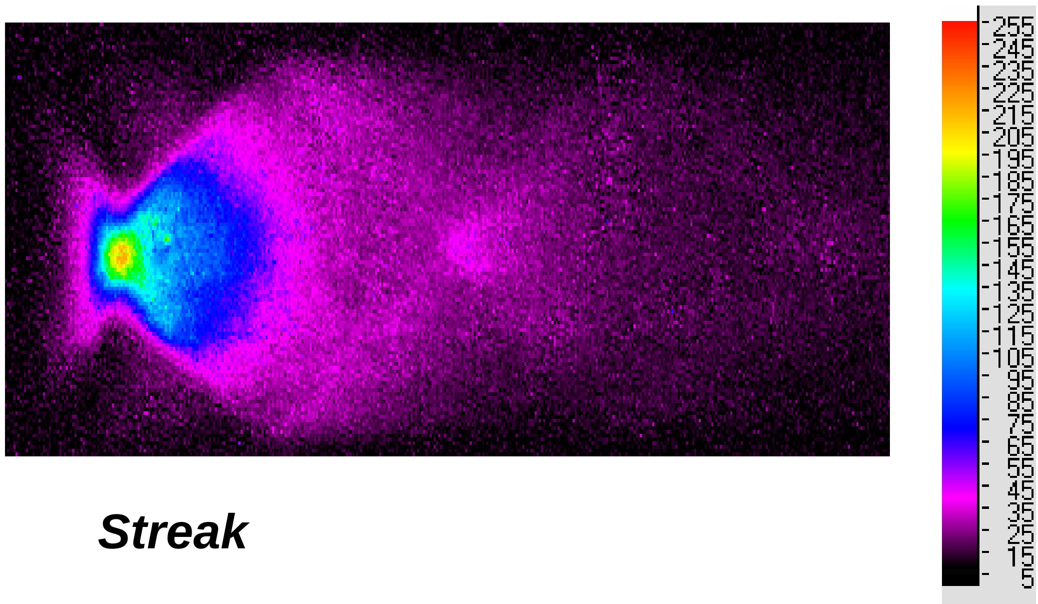
Discharge





Streak

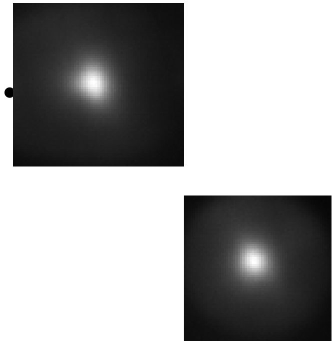
T ~ 17 eV (200 000 °K)

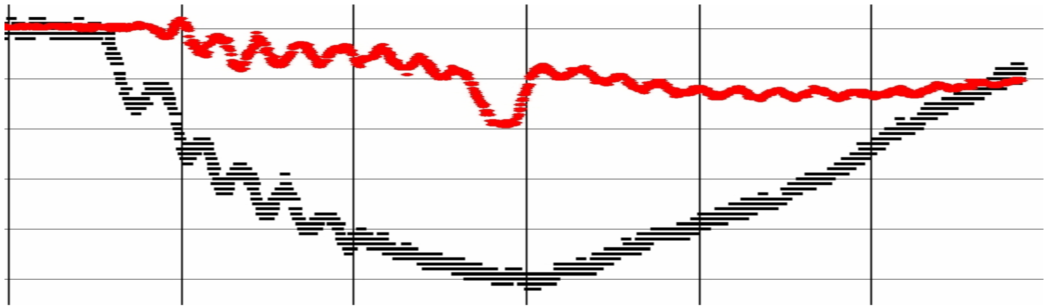
P ~ 400 bar

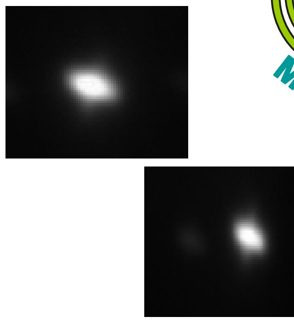
n_e ~ 1-2•10^{19} 1/cm3

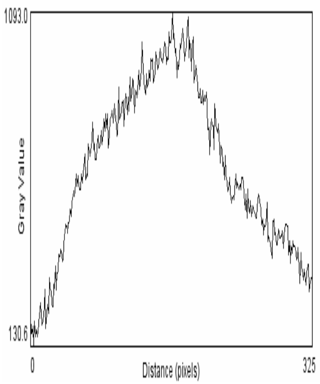
Z_i^{max} ~ 7

Light output from scintillator and the density distribution of ion Fe^{+26} at T μs after beginning of discharge

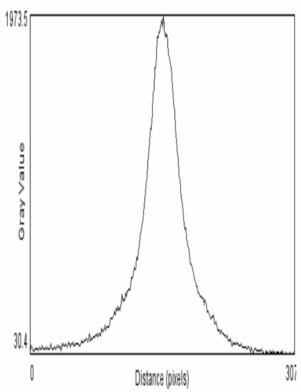




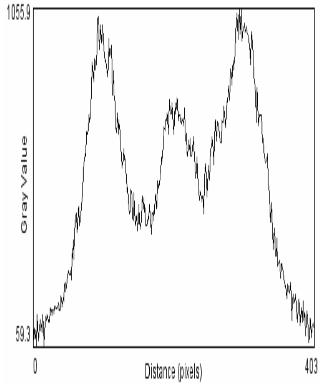




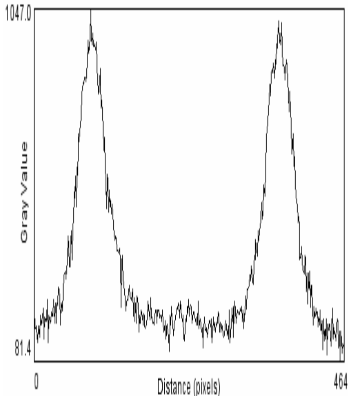
T = 0 μs



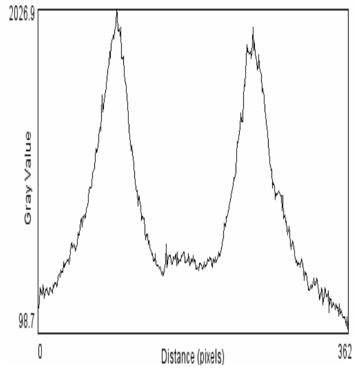
T = 0.5 μs



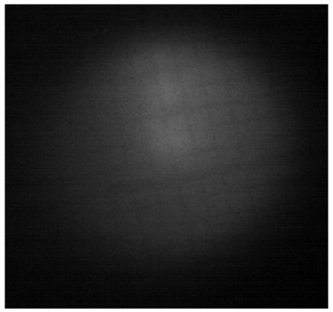
T = 1.5 μs

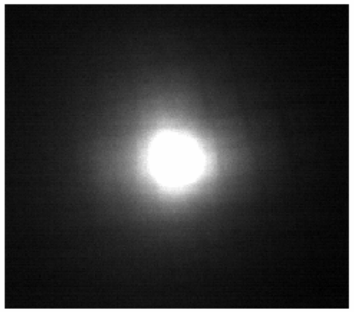


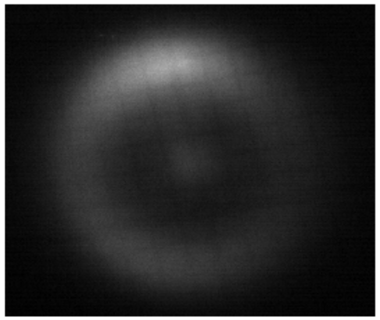
T = 1.7 μs

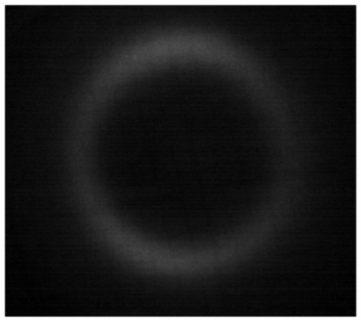


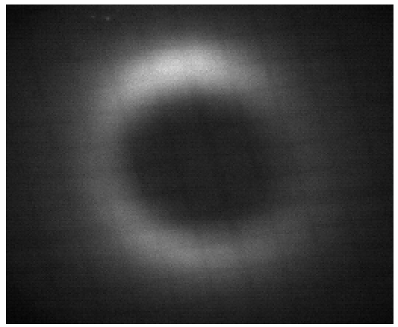
T = 2.3 μs



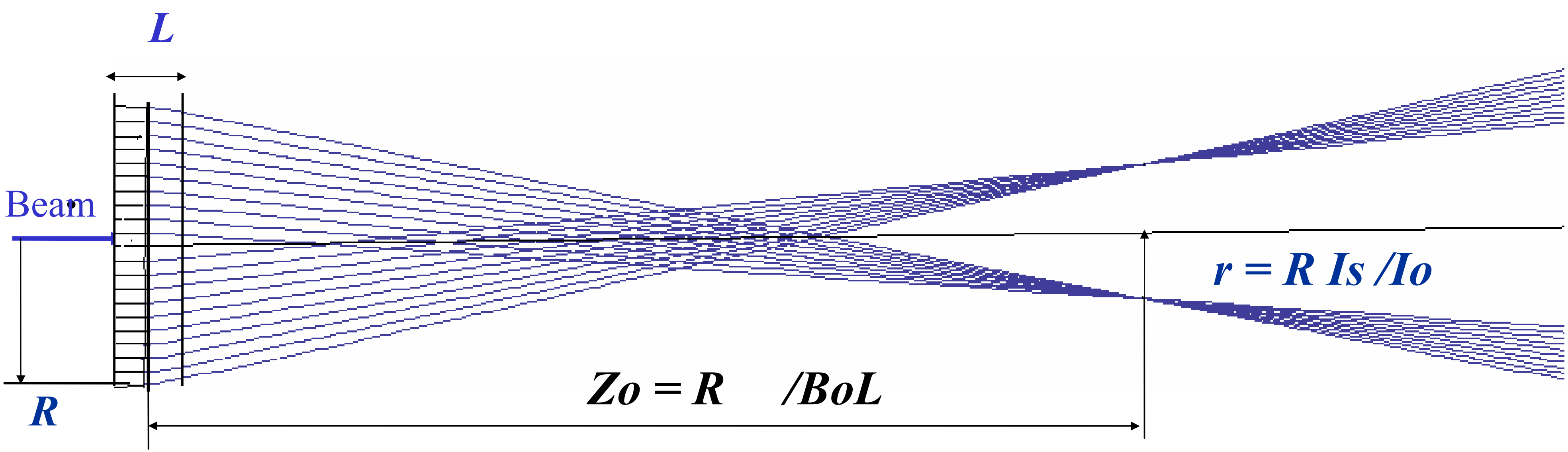






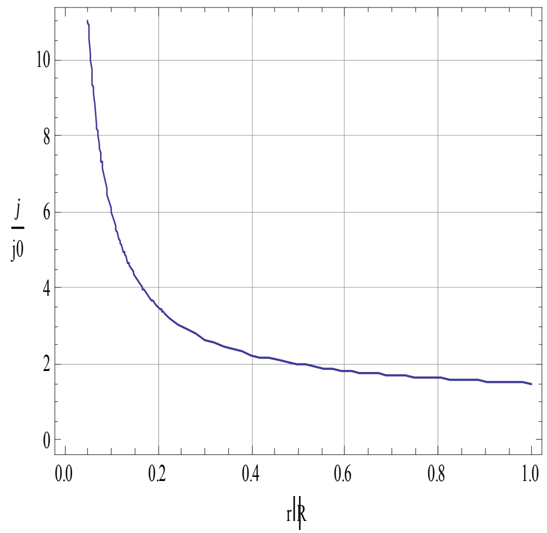


Forming ideal hollow beams (thin lens)

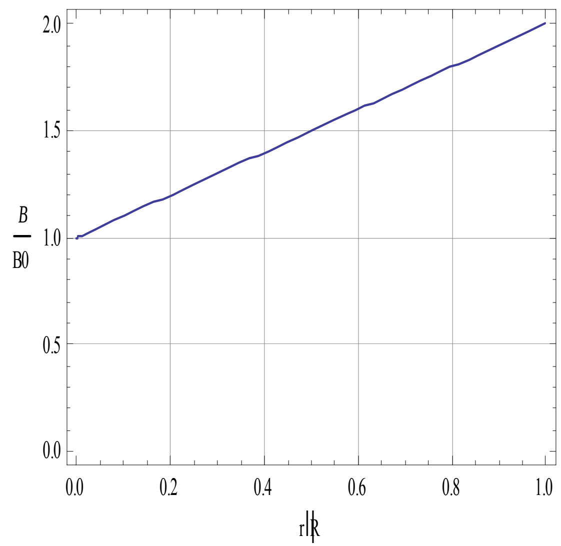


–the beam rigidity, ***Bo*** –field strength due to uniform discharge current Io of radius ***R***.

The paraxial beam is converted to a ring, if the distribution of the discharge current density is a superposition of the homogeneous and the singular distribution

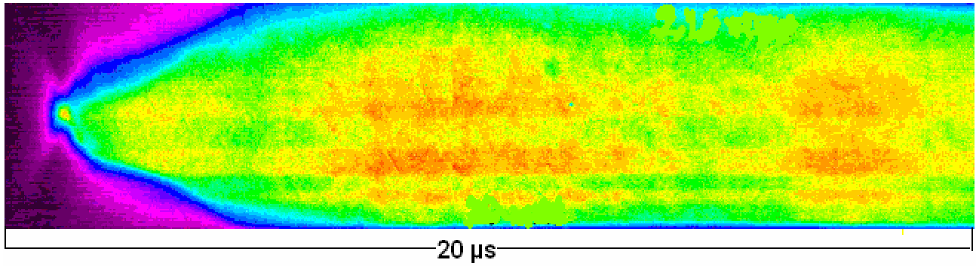


j = Io/πR2 + Is /2πRr

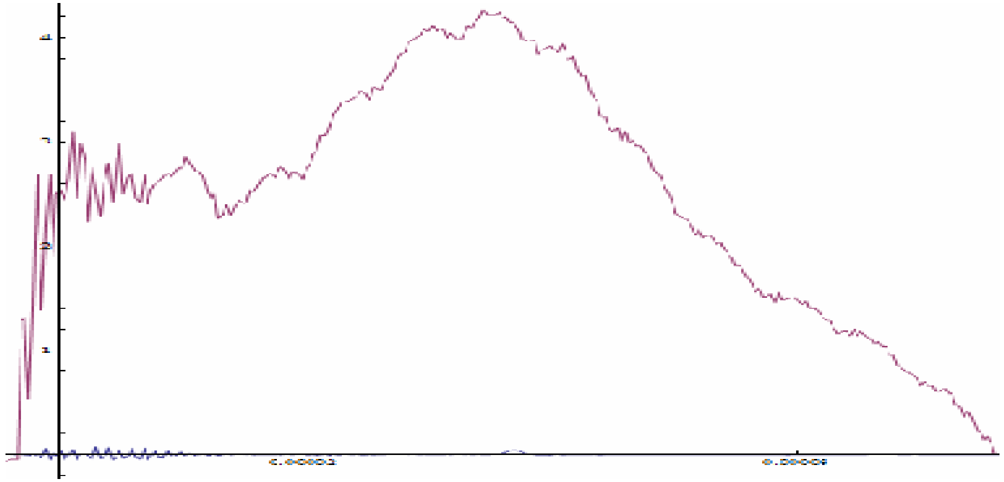


B = Bo (r/R + Is /Io).

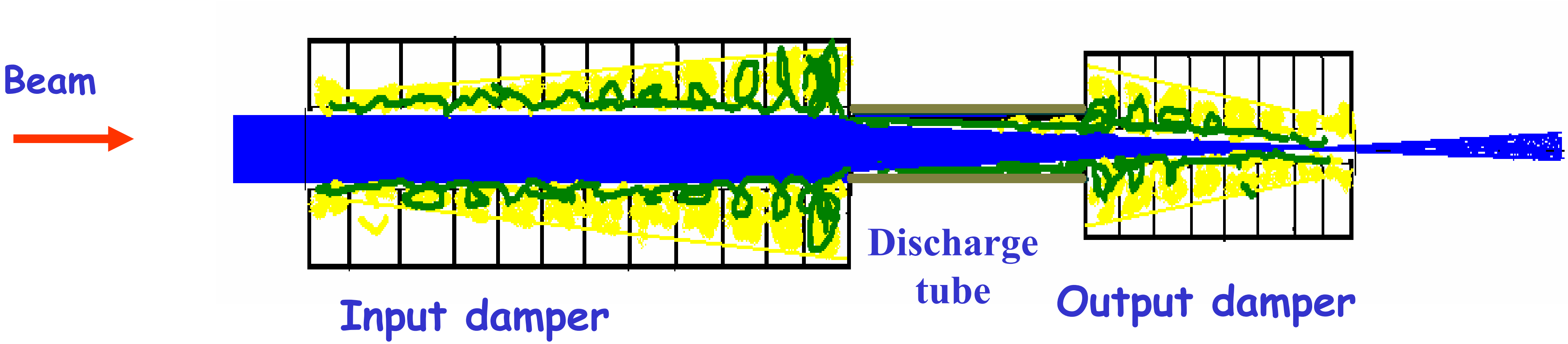
Features of the long discharge



The luminosity of the plasma



The discharge current



FORMATION OF THE HOMOGENEOUS BEAM - <u>*Theoretical*</u>

Equilibrium quasiBennett distribution of the discharge current

$$j = I(1 + \tilde{A}) / \pi R^2 (1 + \tilde{A} (r/R)^2)^2$$

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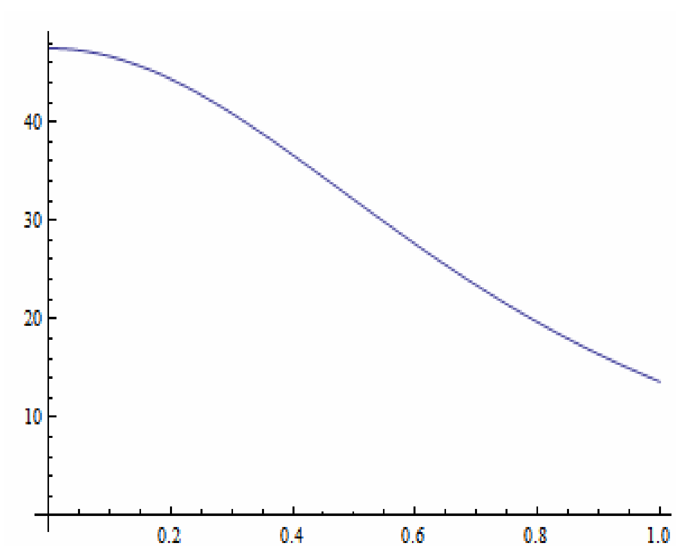
<u>*For lens current I = 80 kA $\tilde{A}$ = 0.85*</u>

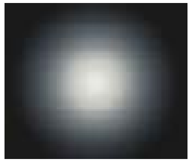
Distributions of ions of C^{+6} (300 MeV/n)

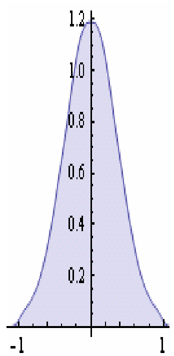
The distribution of the discharge current

j, kA/cm ^{2}

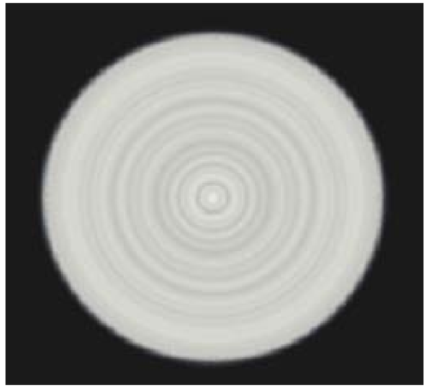


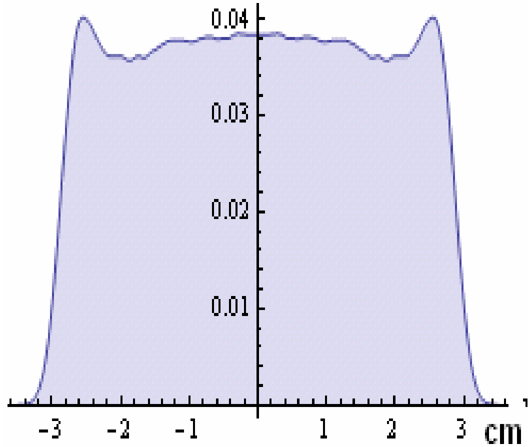
R, cm





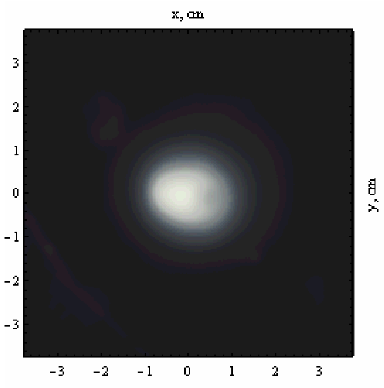
The initial Gaussian distribution.





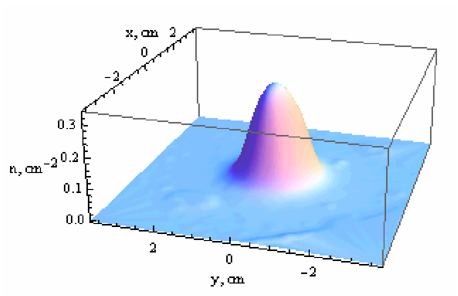
Transformed distributions at position of 150 cm behind the lens

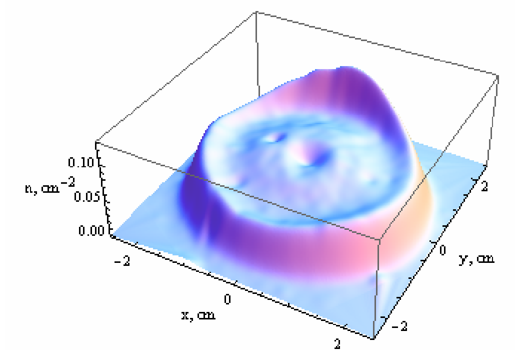
FORMATION OF THE HOMOGENEOUS BEAMof C^{+6} (300 MeV/n) –*Experimental*

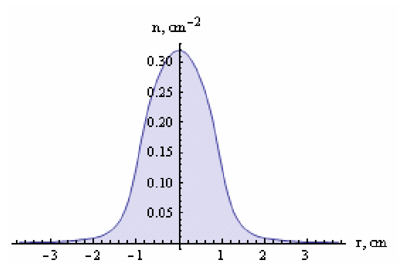


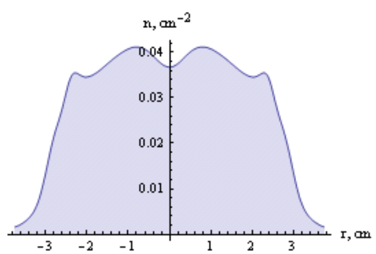
The initial distribution.

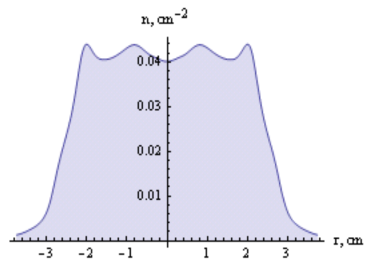
Transformed distributions at position of 110 cm behind the lens for different initial pressure of argon

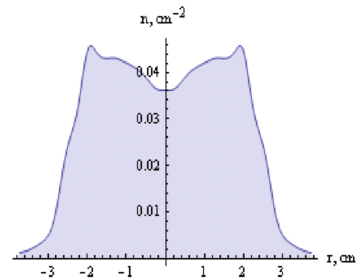










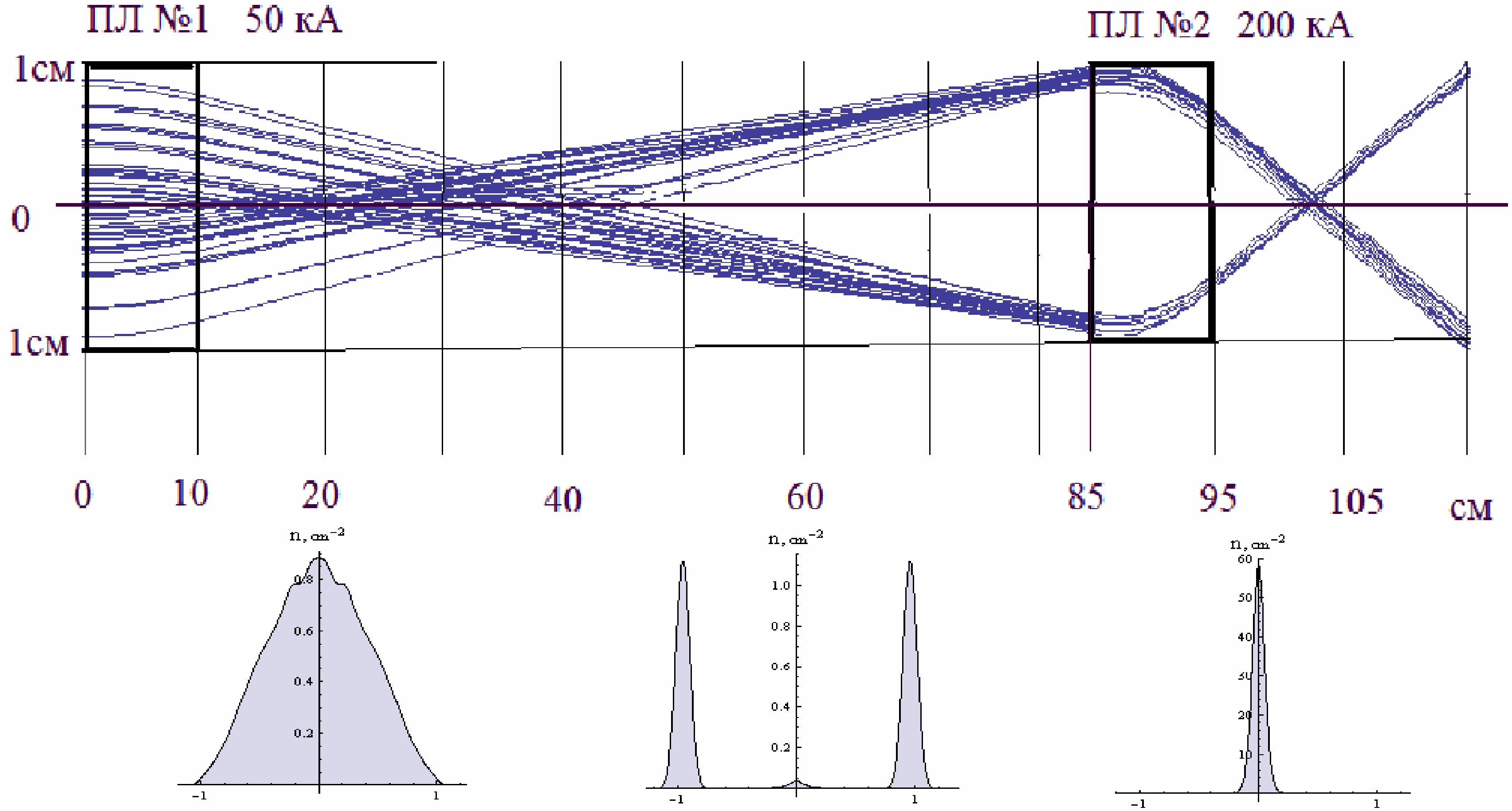


2 Torr

4 Torr

7 Torr

TWO-DIMENSIONAL TRANSFORMATION OF THE BEAM



Пучок на входе в ПЛ №1 Пучок на входе в ПЛ № 2 Пучок в фокусе

Light output from scintillator and the density distribution of ion Fe^{+26} at the time T after discharge switch

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T = 0.5 μs | *T = 1.7 μs* | *T = 8.5 μs*

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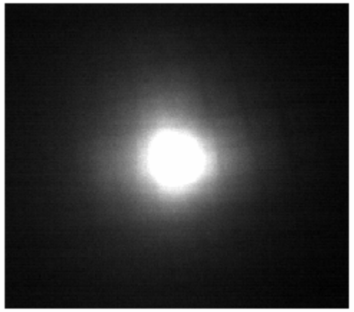
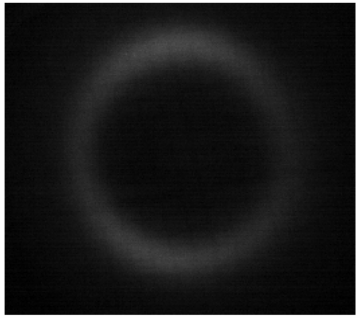
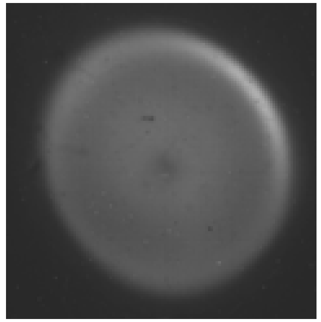
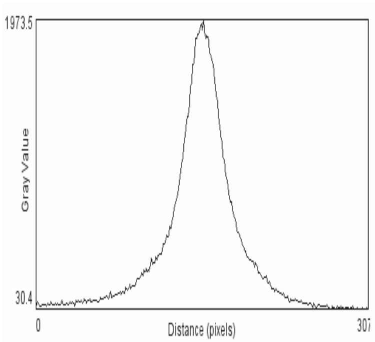
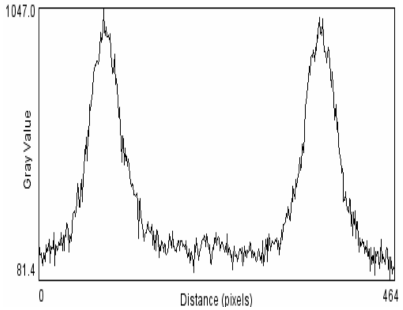
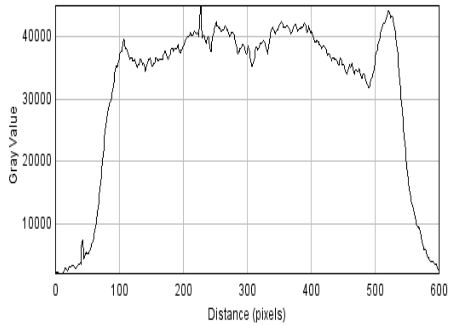


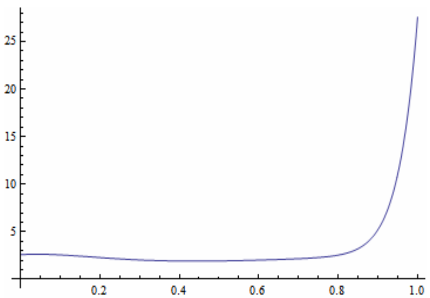


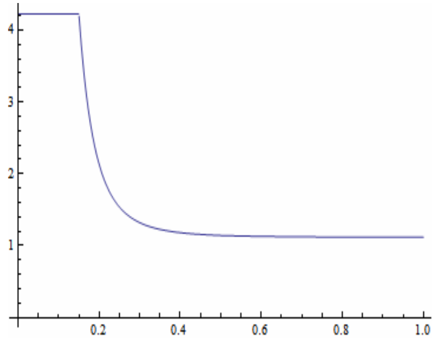


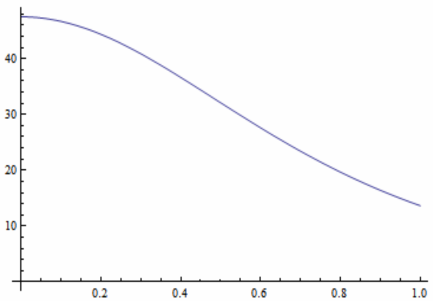








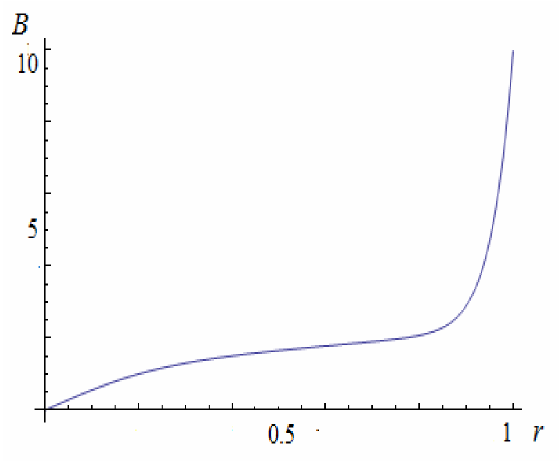


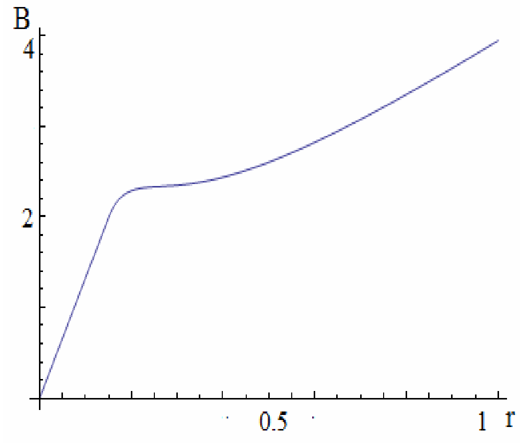


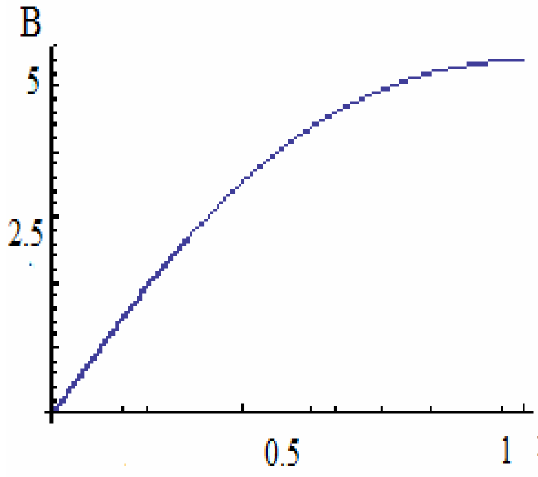
Experimental distributions current density in z-pinch of the plasma lens

Z – pinch dynamic

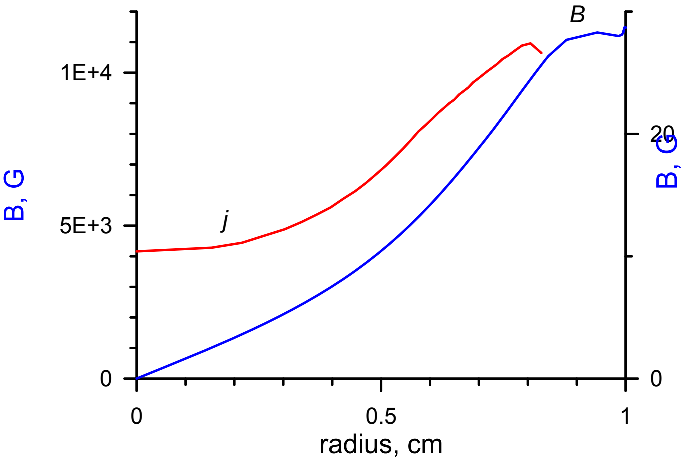
Experimental distributions self magnetic field in lens z-pinch



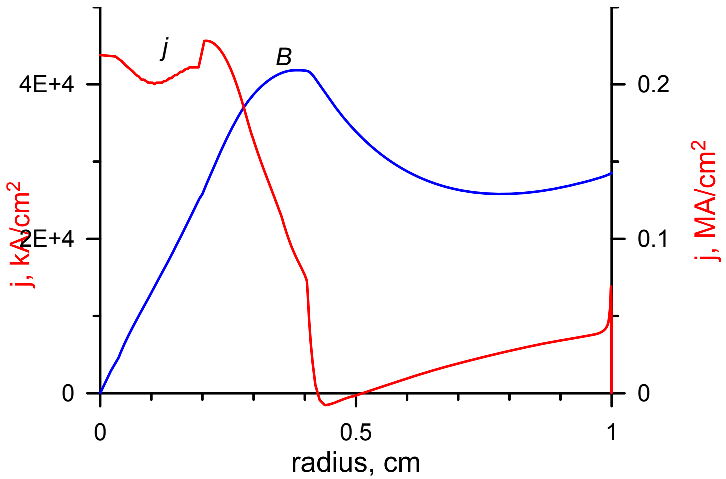




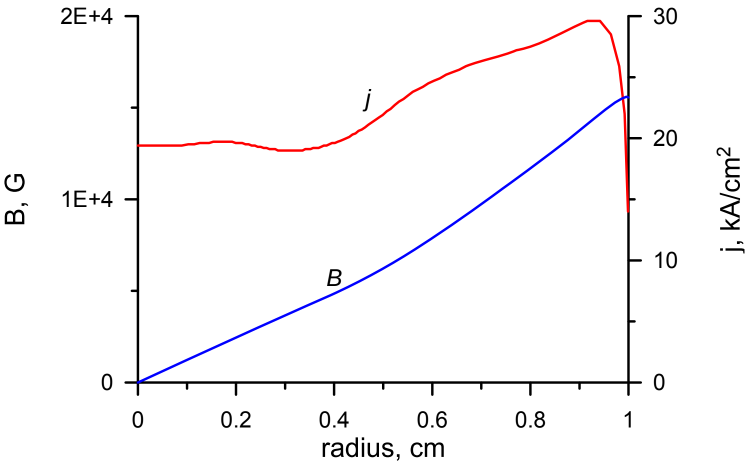
Magnetohydrodynamics simulation



T = 0.5 μs



T = 1.6 μs



T = 8.5μs

CONCLUSION

The plasma lens can carry out not only sharp focusing of ions beam with considerable reduction of their sizes. At those stages of the plasma discharge at which the magnetic field is nonlinear, formation of other interesting configurations of beams is possible.

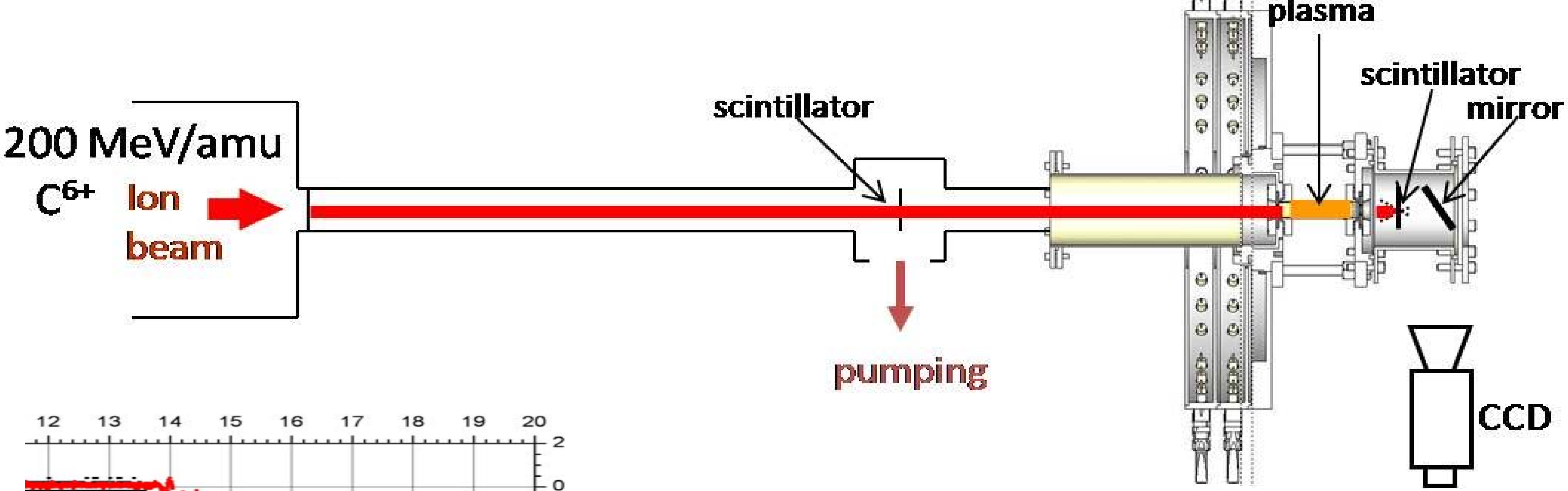
The plasma lens provides formation of hollow beams of ions in a wide range of parameters that allows to consider it as a possible variant of a terminal lens for realization of inertial thermonuclear synthesis.

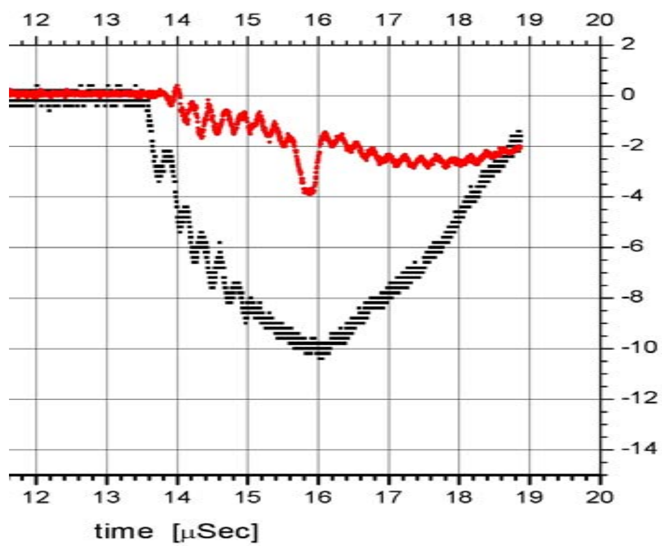
The plasma lens can be used for transformation of beams with Gaussian distribution of particles density in a beams with homogeneous spatial distribution.

Application of the several plasma lenses which are in different stages of the plasma discharge, presumes to create some nontrivial spatial configurations of ions beams.

The plasma lens represents the universal tool for investigation of plasma discharges.

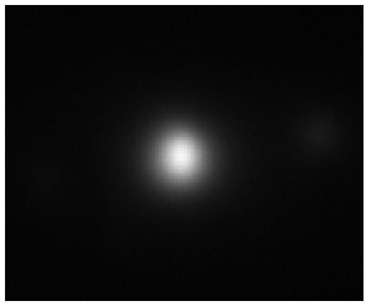
The experemental set-up

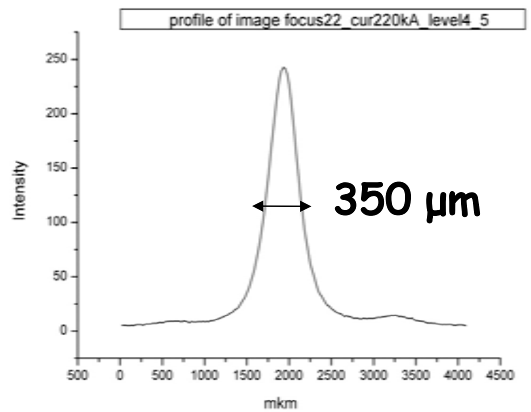




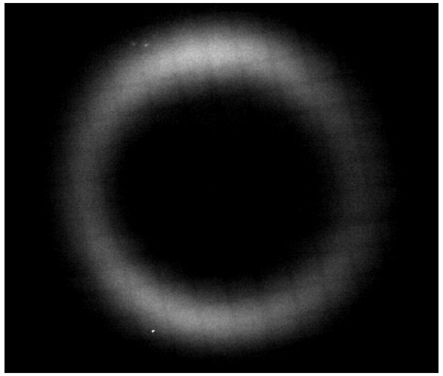
Time scanning of a discharge luminescence and a discharge and beam currents for short pulse mode.

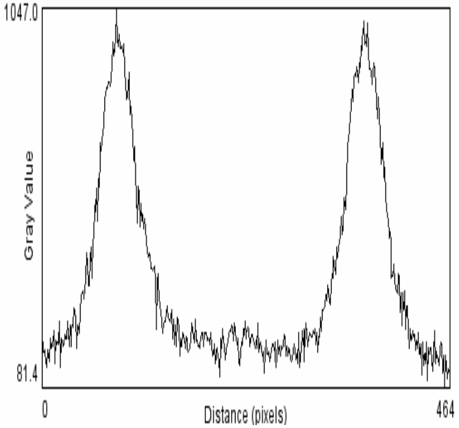
Results of focusing C^{+6} ions



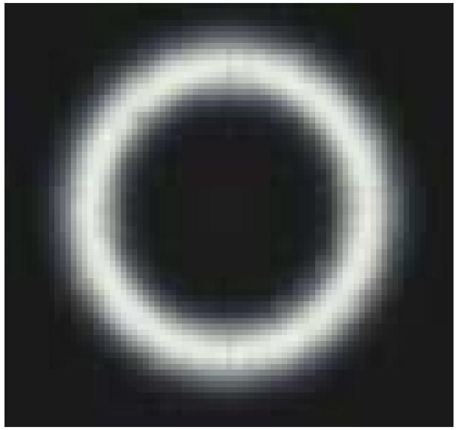


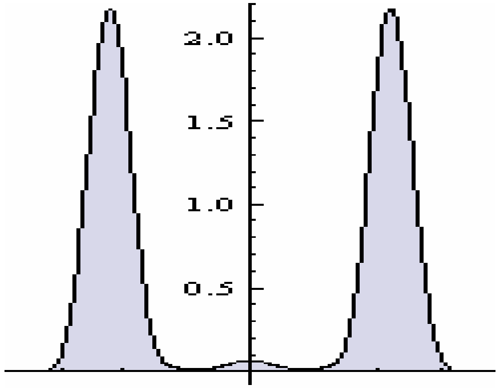
The light output from a scintillator





The distribution of ion Fe^{+26} in time 1.7 μs behind discharge switch for distances 30 см and discharge current 150 кА. The ring diameter - 9 мм .





The light output from a scintillator and the distribution of ion Fe+26 density calculated in the model approximation for the experimental condition.