High Compression and High Current Guns

The high current electron beam can be reached by means of:

- **low perveance electron guns with high voltage.**

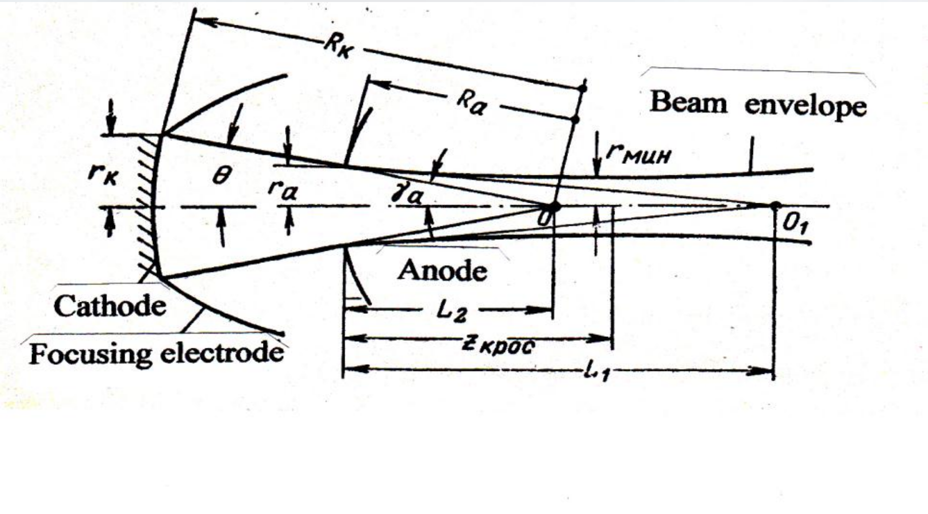
- **high perveance electron guns with relatively low voltage and with the possibility of following acceleration up to the final energy,**

The high compression of the electron gun to the final diameter can be achieved by means of:

- **electrostatic focussing, which is occuring, basically, inside the gun,**
- **magnetic compression of the electron beam, which takes place inside and outside from the anode of the electron gun.**

The right choice and right combination of these methods could lead to successful design of the SuperEBIS.

Pierse Electron Guns with Low Perveance and Compression

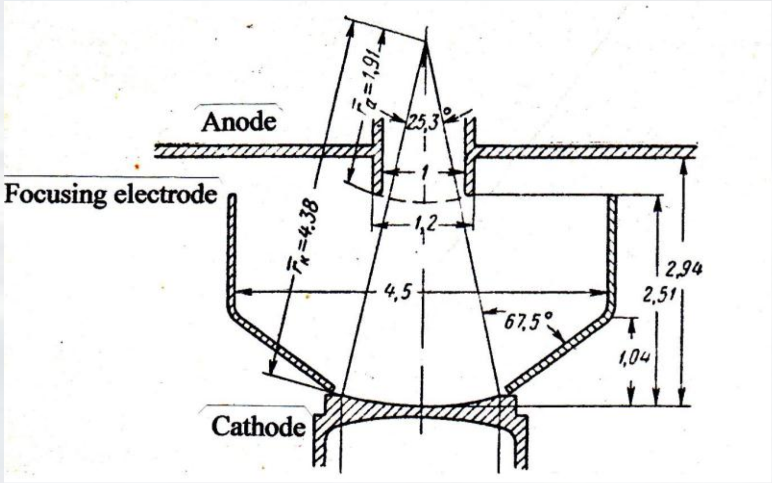


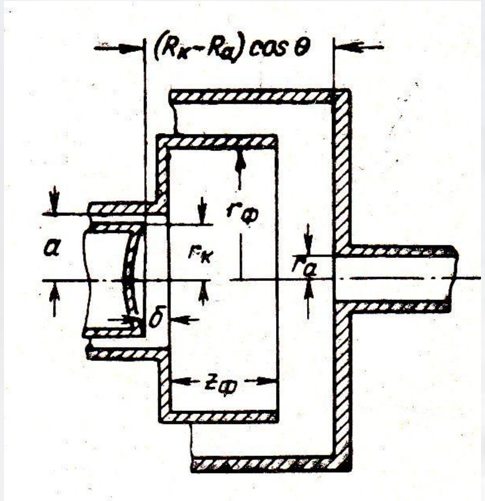
Microperveance P_m :

$$Pm = 14.68(1 - \cos\Theta)\frac{1}{(-\alpha)^2}$$

r_c - cathode radius,
Rc – cathode spherical radius,
r_a – anode radius, Ra – anode spherical radius,
2Θ - convergence angle,
$(-\alpha)^2$ - the Langmuir function taking into account the curvature of the anode and the cathode surfaces.

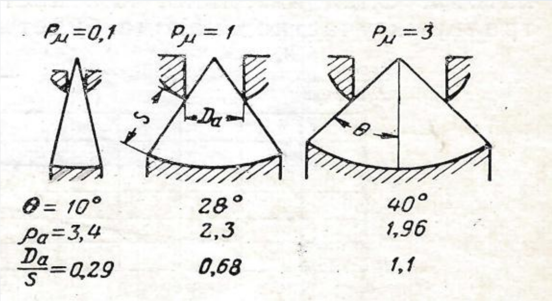
Pierse Electron Guns with Low Perveance and Compression



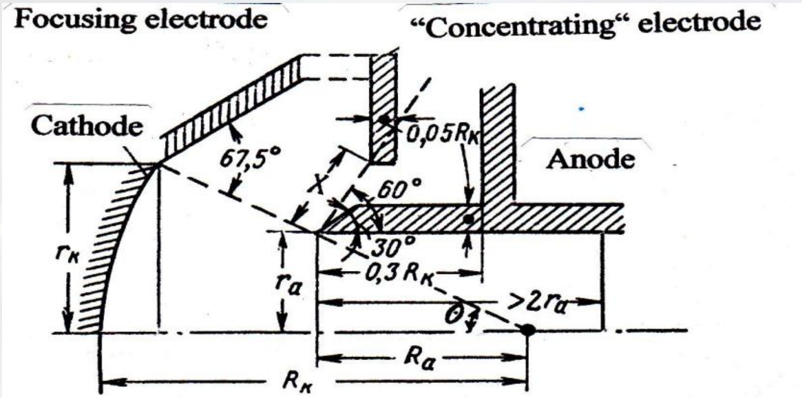


Advantages of this type electron gun are:
- **relatively simple form of electrodes,**
- **low aberration of the anode lenses.**

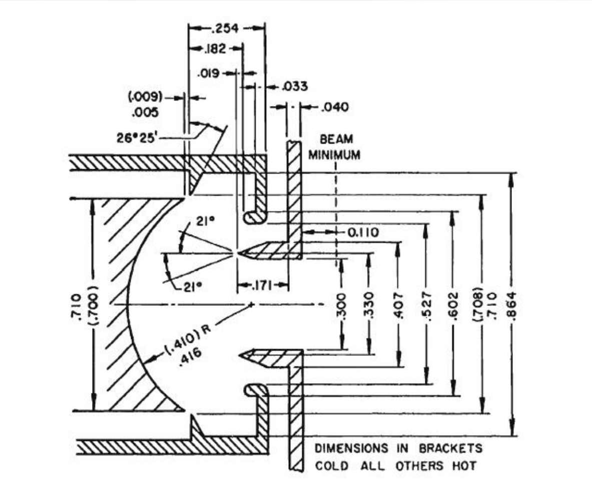
High Perveance and High Compression Electron Guns



The non-thermal paraxial – ray theory is inadequate for such high electrostatic convergent electron guns.



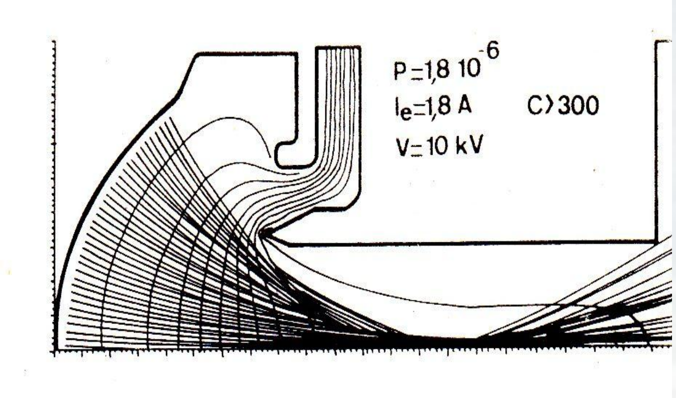
M. Müller, "New points of view in the design of electron guns for cylindrical beam of high space charge" J. Britt. IRE, vol.16, pp.83-94,1956 .

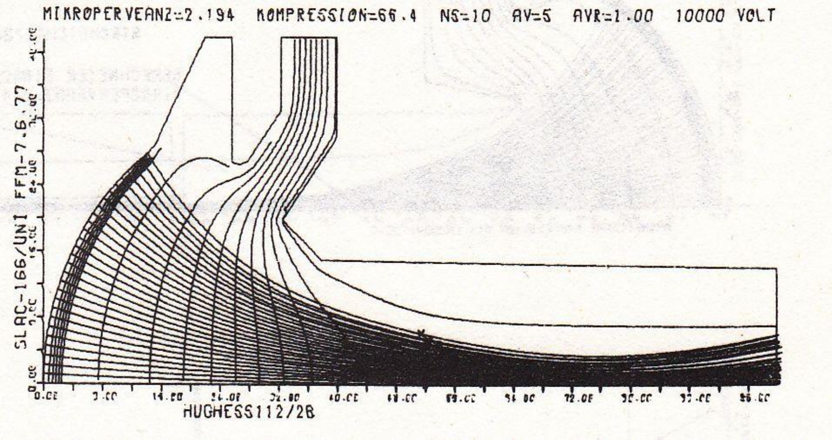


This is the famous electron gun type F5B with the perveance of 2.2×10^{-6} A/V$^{3/2}$ and area compression of 300

P. D. Frost, O. T. Purl and H. R. Johnson,"Electron guns for forming solid beam of high pervrance and high convergence ", Proc. IRE. Vol. 50, pp1800-1807;August, 1962

High Perveance and High Compression Electron Guns





Strong aberrations

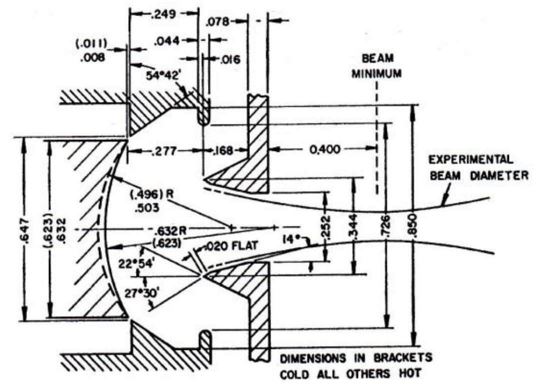
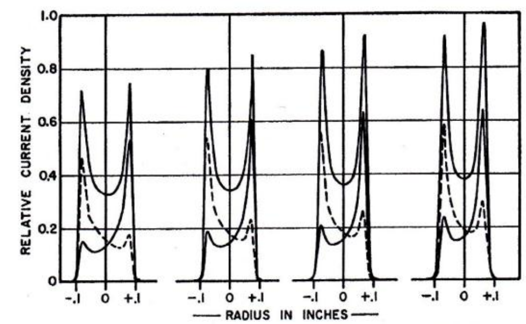
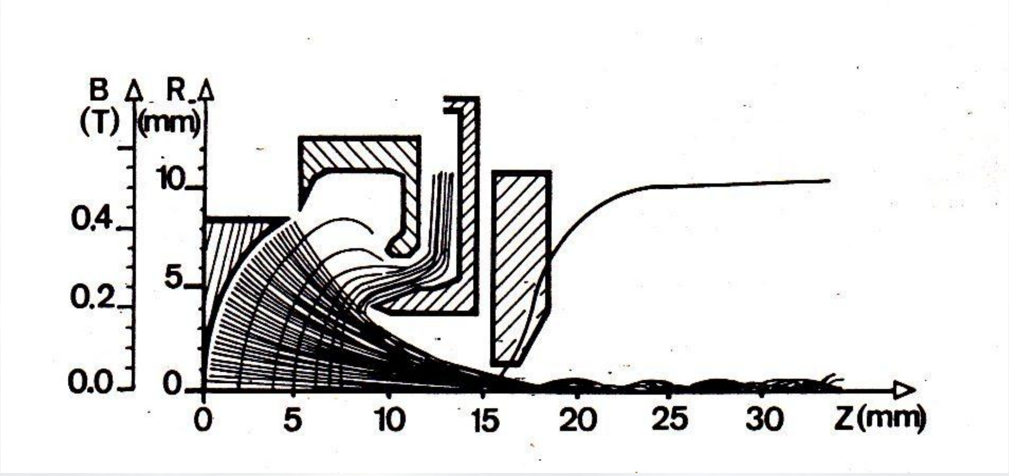


Fig. 9—Perveance 1.9×10⁻⁶ gun designed using the method of Brewer and Müller to compensate partially for the anode aperture. Shown as a dashed line is the reshaped cathode used to obtain complete anode hole compensation (type 4A) and an area convergence of 27:1 at 1 kv.



Non-homogeneous electron density

High Perveance and High Compression Electron Guns



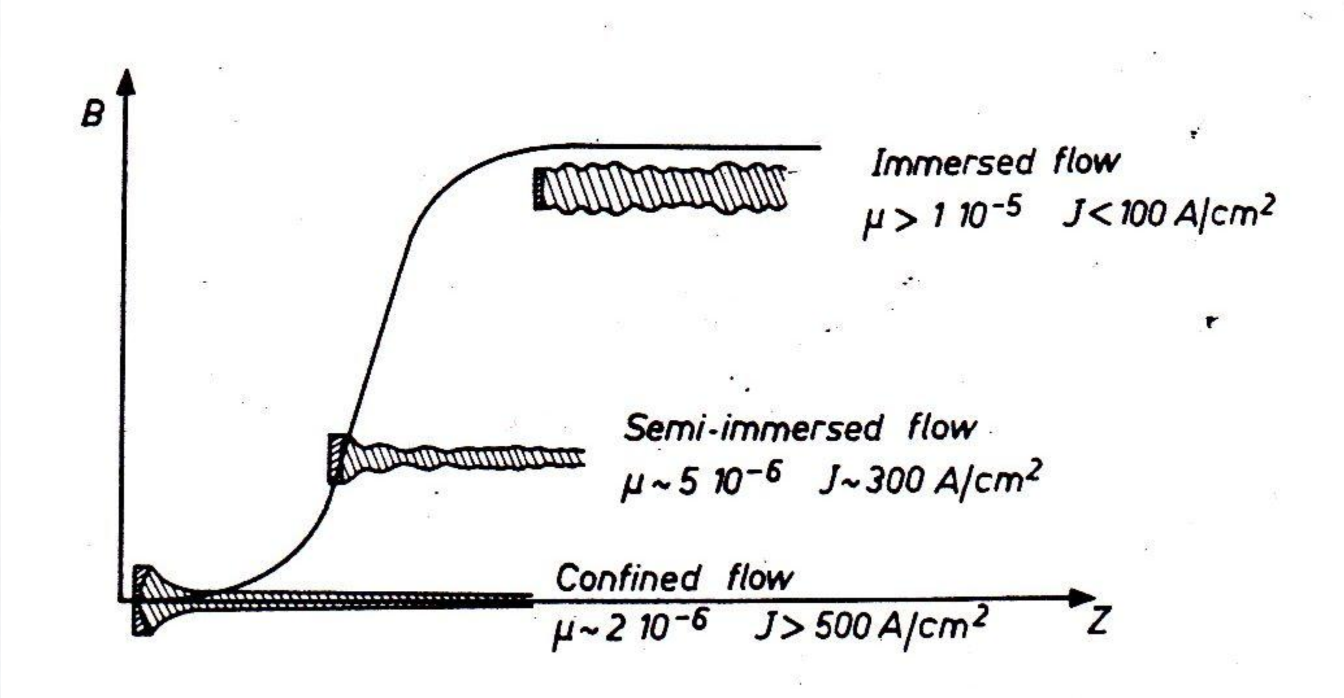
With its well-known advantages, the electron gun of this type has serious shortcomings:

- **Strong aberrations of the anode lenses,**
- **Non-homogeneous emission density across the radius**
- **Short distance between electrodes.**

All this makes it difficult to obtain a laminar flow of electrons. And also, it's a problem to operate with high voltage.

Magnetic Focussing Compression Systems

J .Arianer and c. Goldstein, „The ORSAY electron Beam ion Source“, IEEE Tran. On Nuclear Science,Vol. NS-32, No. 2, April 1976



The draw in vicinity of Z-axes is the case of magnetic compression into Brillouin flow

Magnetic Compression Electron Guns

Magnetic compression into Brillouin flow from high perveance and high convergent electron gun.

L. Kikushima, C. C. Johnson, " A High-Current Density Brillouin Focused Electron Beam", Proc. IEEE, vol.52, No.1, p.87-882, 1964

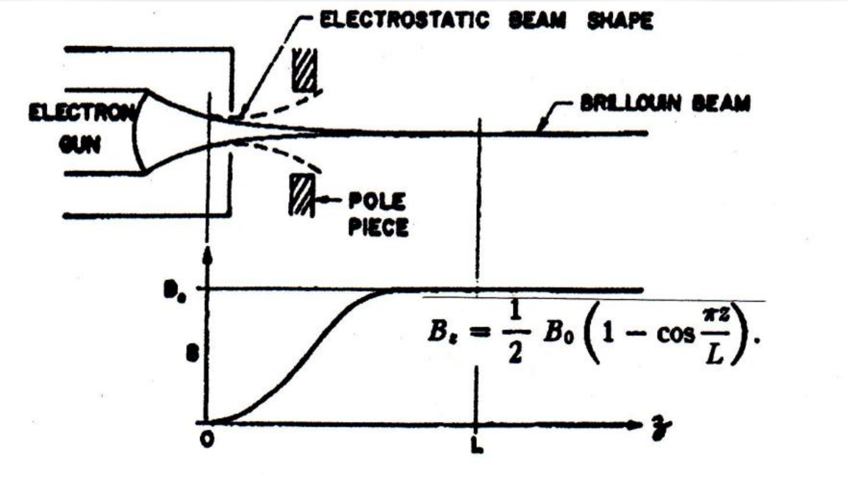


TABLE I
BRILLOUIN-FOCUSED ELECTRON BEAM

Current	2.4 amps
Voltage	10 kv
Perveance	2.4×10^{-6}
Area Compression	1350:1
Current Density	2500 A/cm²
Beam Diameter	0.013 in
Magnetic Field	7500 gauss
Power Density	25 Mw/cm²
Transition Length	0.40 in

Scaled F5B electron gun

The current density is quite the same as the Brillouin theory predicts (j_b =2600 A/cm^2).

Magnetic compression into Brillouin flow from high perveance and high convergent electron gun.

WARNING!

“It was also found that the ripple was quit sensitive to the entrance conditions and a 10 per sent error in slope or radius produced a 25 per sent ripple. For electrons guns of this type it would be useful to design electrostatic compression system specifically for that purpose, paying particular attention for the convergence near the cathode…”

Conclusion:

“For electron guns this type it would be useful to design electrostatic compression system specifically for this purpose, paying particular attention to convergence near cathode and beam slope. ”

L. Kikushima, C. C. Johnson ; January1964

Magnetic compression into Brillouin flow from low perveance and high convergent electron gun.

K. Amboss, "Studies of a Magnetically Compressed Electron Beam", IEEE Trans. On Electron Devices, vol. ED-16, No. 11, November 1969

TABLE I

Design Parameters of the Electron Gun

Perveance P	0.54×10^{-6} A/V$^{3/2}$
thode radius r_c	0.600 inch
urvature of cathode sphere $\bar{r}_c$	1.525 inch
Curvature of anode sphere $\bar{r}_a$	0.534 inch
$\bar{r}_a/\bar{r}_c$	0.35
Semiangle of convergence	23°

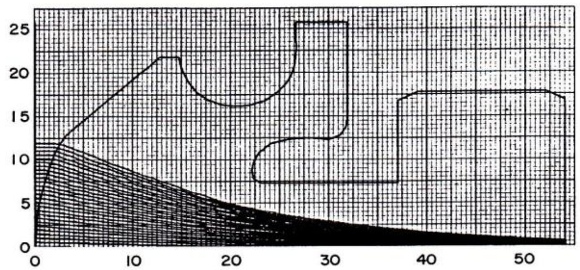


Fig. 2. Theoretical electron trajectories in the magnetic compression gun. Obtained by means of the nonthermal matrix iterative program (see [11]).

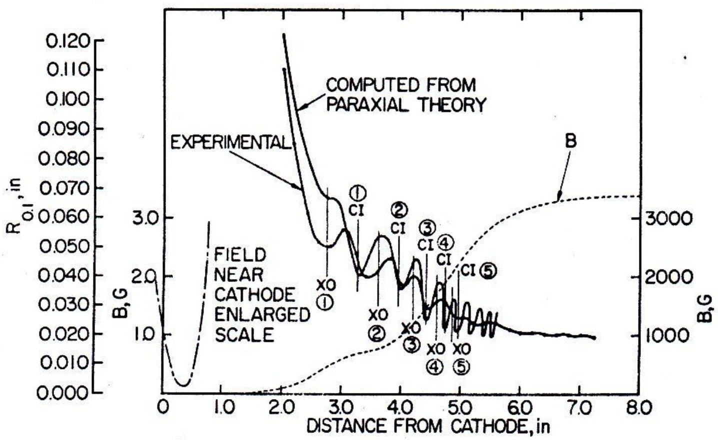


Fig. 6. Magnetic compression field and beam radius $R_{0.1}$ and location of cathode images and crossovers for area compression 1070.

Magnetic compression into Brillouin flow from low perveance and high convergent electron gun.

K. Amboss, "Studies of a Magnetically Compressed Electron Beam", IEEE Trans. On Electron Devices, vol. ED-16, No. 11, November 1969

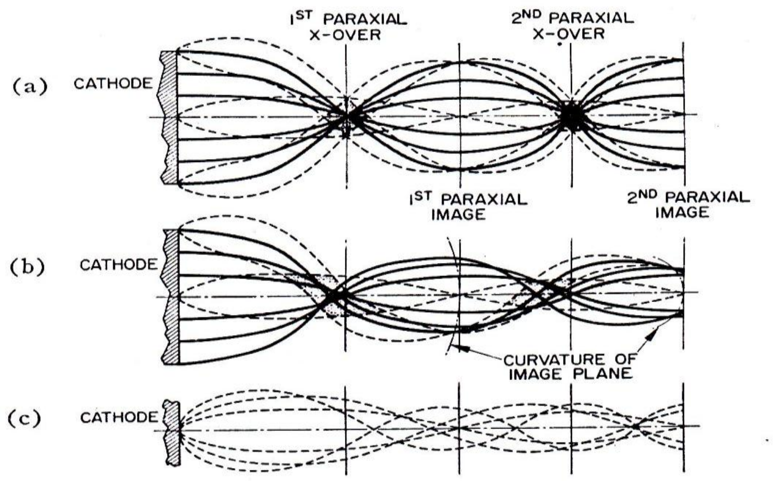


Fig. 16. Illustration of the mechanism responsible for the degradation in structure. (a) Paraxial beam. (b) Beam with distortion and curvature of field. (c) Spherical aberration of axial bundle.

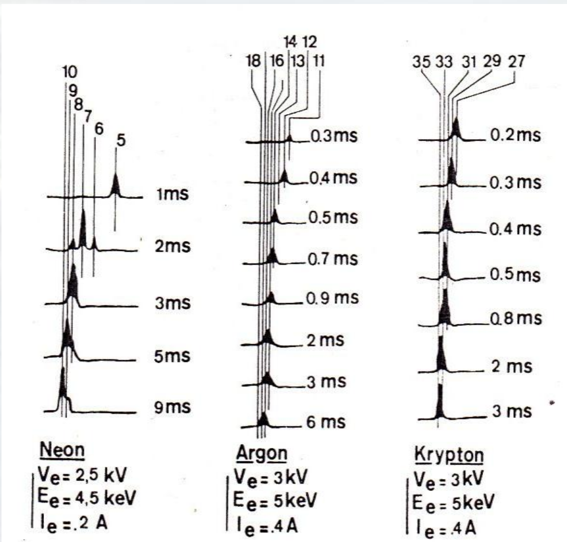
"It has generally been assumed that carefully shaped magnetic fields were necessary to obtain a nonrippling beam; our beam-probing experiments show that that is not in the case since the ripple and the thermal structure of the beam die out within a moderately short distance, even through the entrance condition are such that an initially undulating beam is produced."

Nevertheless, in general, this method of focussing is absolutely inapplicable in EBIS devices.

High Compression and High Perveance Electron Guns in EBIS Devises

CRYESIS - The First EBIS - Progect in the West

J .Arianer et. all.“CRyEBIS, An Advansed Multcharged Ion Source“, NIM, 193 (1982) 401-413, NIM, 198 (1982) 175-187



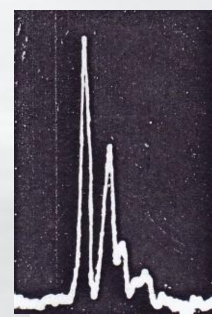
During first sequence of experiment (june –november 1978) phenomenon of SUPERCOMPRESSION has been observed.

„First of all, the source adjustment appeared extrimely critical during these preliminary tests, with a special mention for the electron gun position, the Backing field, the gas injection and the magnetic shims position.“

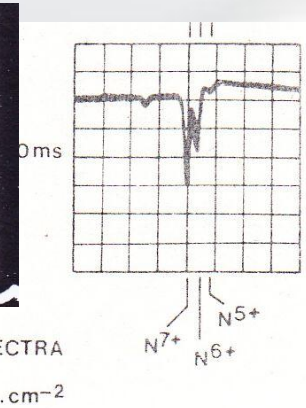
J. Arianer

Simplification of design led to the loss of electron density

Krion-2



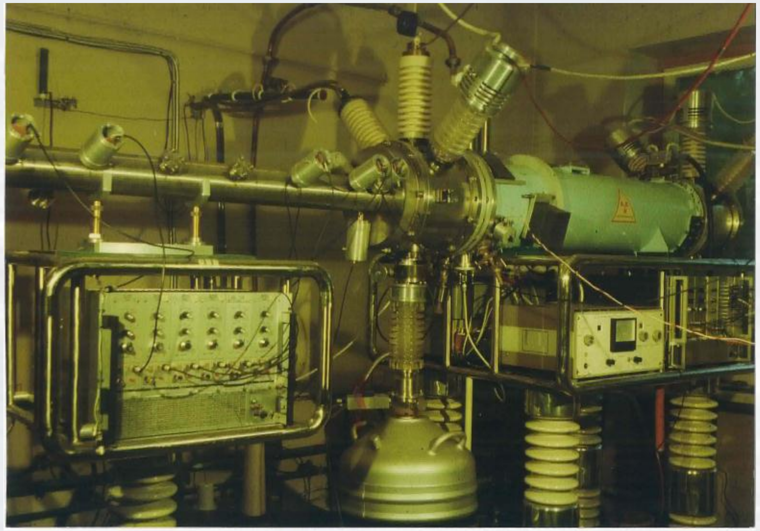
CRYSIS



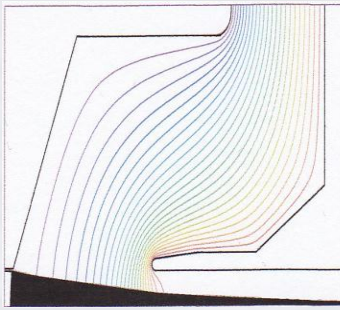
In general, the most part of EBISes in the West – CRYEBIS, CRYSIS, Frankfurt EBIS, Cornell EBIS ... , have run with electon density of a few hundred A/cm².

Choice and Experience

Low Perveance and High Voltage Pierce Gun.



(1985-1999) Krion-C 80 keV – 200 mA

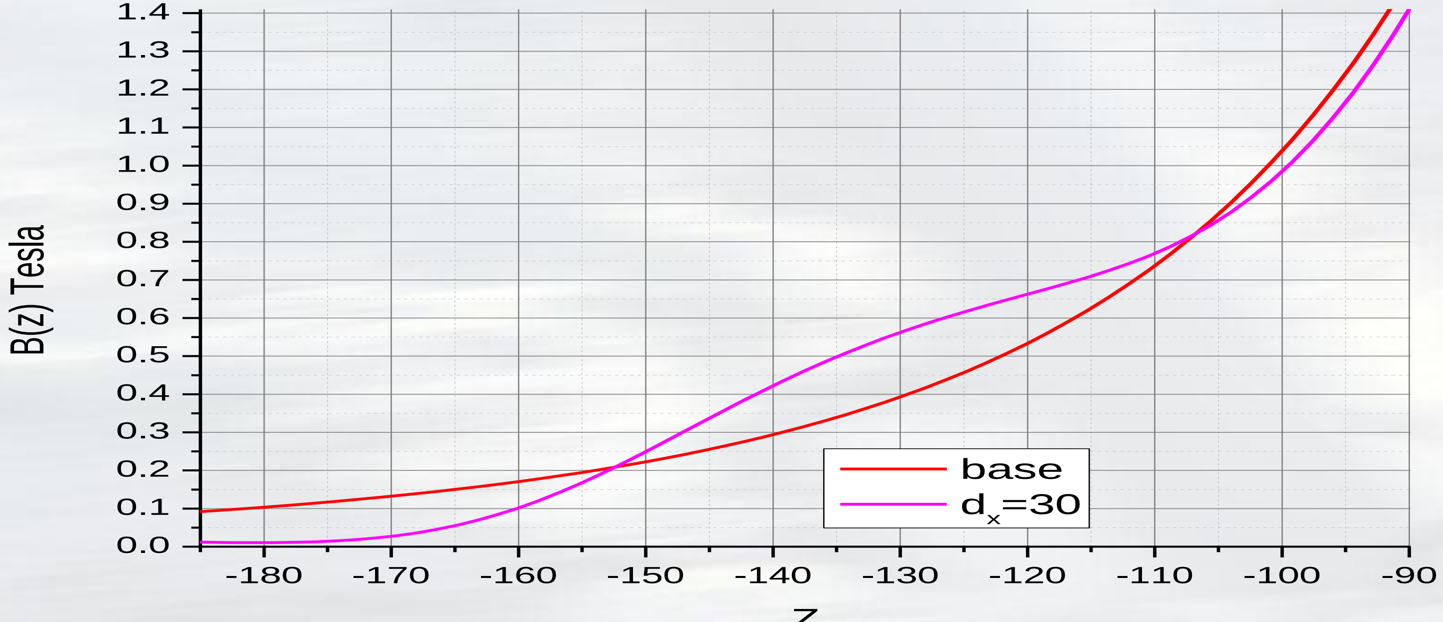


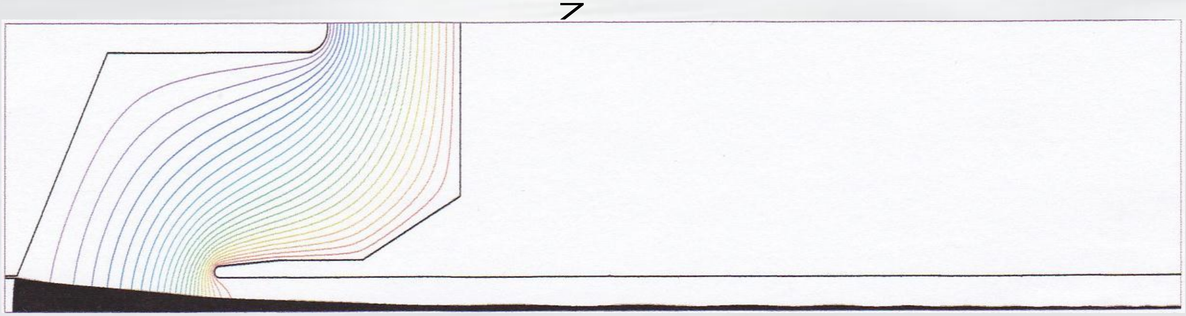
Cathode diameter – 6mm
Electron voltage - 100kV
Electron current - 1.0 A
P_m = 0.03 microAmps/$V^{3/2}$

Electron Gun
150 kV

(1991-1993) RSE 120 keV – 200 mA

Magnetic Compression into Brillouin Flow from Low Perveance High Voltage Pierce Gun.





Magnetic Compression into Brillouin Flow from Low Perveance High Voltage Pierce Gun.