HEAVY ION SOURCES AT SATURNE

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As heavy ions were accelerated and extracted from Saturne, it is evident that N7+ or Ne10+ can be produced from Cryebis.

4.10^8 charges of N7+ were accelerated, the Cryebis source providing 3.10^9 charges. The overall efficiency (12,5%) is quite satisfactory and shows that the optical qualities are great. As a comparison, the efficiency is usually 3% and furthermore the results could be improved by a factor of two if we increase the beam energy at the entrance of the Linac.

In this paper, the three years work performed on Cryebis is not detailed but the importance :

a) - Of the electron beam compression and

b) - Of the injected low charge state ion beam quality

is pointed out.

Experimental and theoretical results will be discussed. These two main parameters are under study for Dioné, the new cryogenic EBIS, under construction.

ELECTRON BEAM DENSITY - EXPERIMENTAL RESULTS -

The electron gun cathode diameter was previously 36 mm. The magnetic flux through the cathode is a determinant parameter. Therefore the magnetic field in the cathode region had to be adjusted in the range of + 0.1 G. and the heating current of the cathode to be interrupted during electron emission. The stability and the reliability of the source was very poor.

First, a 7 mm diameter cathode electron gun was set up in Cryebis. The tuning became easier but the compression of the new gun was too large (~50) and the electron beam quality was still found insufficient : 20% of the beam was lost on the anode.

As theoretical calculations allowed to show that strong compression guns do not lead to laminar beams,

a new electron gun with a 4 mm diameter cathode was studied : lower compression (16) lower perveance ($3.7\ 10^{-7}$). Experimental results are encouraging :

- measurements of better current density profiles closer to the uniform distribution than with a 7 mm cathode as shown in Fig.1

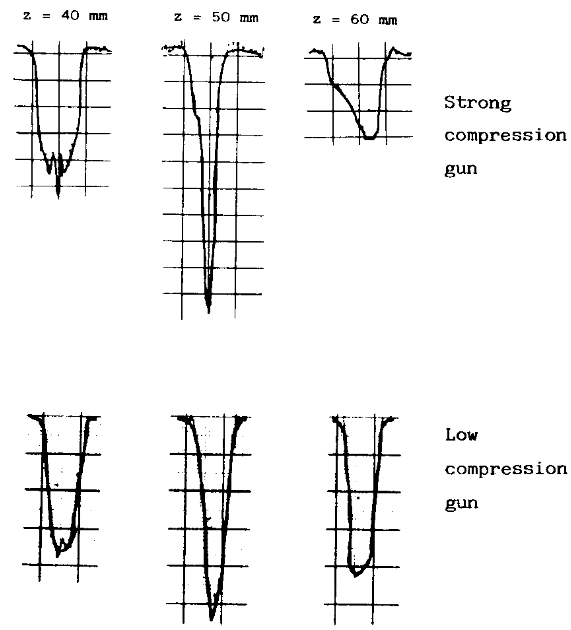

Fig.1 - Measurement of Electron beam profiles for several axial positions

- "perfect beam transmission through the drift tubes from the gun up to the collector (99,99%)

- yet rather low apparent current density (given by the comparison of the charge states evolution with computer calculation) in the range of 100 A/cm² instead of the 1000 A/cm² expected value.

EXPERIMENTAL RESULTS -

Measurements made on Cryebis during February and March 1984 are summarized in the following table :

Ions	Total Intensity charges)	Ion (charges)	Confinement time (ms)
Azote	$5.6\ 10^9$	$3.5\ 10^9$ (N7+)	150
Carbone	$5.2\ 10^9$	$3.8\ 10^9$ (C6+)	150
Neon	$3.7\ 10^9$	1.10^9 (Ne10+)	180
Argon	3.10^9	3.10^7 (Ar18+)	180
		$1.3\ 10^8$ (Ar17+)	
		$1.1\ 10^9$ (Ar16+)	
		etc...	

Ion beam normalised emittance was measured around 1 or 2.10^{-7} m.rd and does not seem to have changed under present conditions.

The electron beam current density is about 150 A/cm^2 with no special behaviour of Argon. According to the cathode magnetic flux we should get 1500 A/cm^2.

As the confinement time τ is known, the relative charge states aboundance allow us to estimate $J\tau$ and then the "apparent" current density J.

Figure 2 shows that the density is decreasing when injected ions intensity increases. This will be discussed further. But, a first explanation may be the poor adaptation between electron and ion beams : one part of the ions is not trapped correctly by the electron beam which is disturbed by ions oscillations.

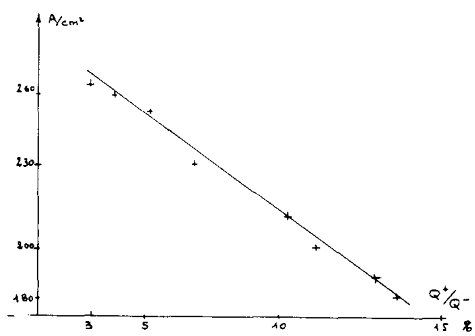

Fig.2 Apparent electronic density versus neutralisation

ELECTRON BEAM DENSITY - IMPROVEMENTS IN THE FUTURE

Suppose that a 10.000 A/cm^2 electron density is required, that is, about a 0.1 mm diameter beam for 1A intensity. The electrostatic compression inside electron gun will be followed by magnetic compression up to high intensity magnetic field (3 or 6 T).

Calculations performed so far show that :

a) - The electrostatic compression has to be limited in order to get a laminar beam with uniform density. If C is the compression factor defined as :

$$C_e = \left(\frac{r_k}{r_f}\right)^2$$

it has to be lower than 4. $\qquad C_e \leq 4$

rk : cathode radius

rf : beam radius after electrostatic compression.

i.e. initial beam radius at 1500 G before magnetic compression.

b) - If the magnetic compression starts from a too low magnetic field value, it occurs without good adiabaticity and then the beam scallops. So we impose a minimum B value of 1500 G.

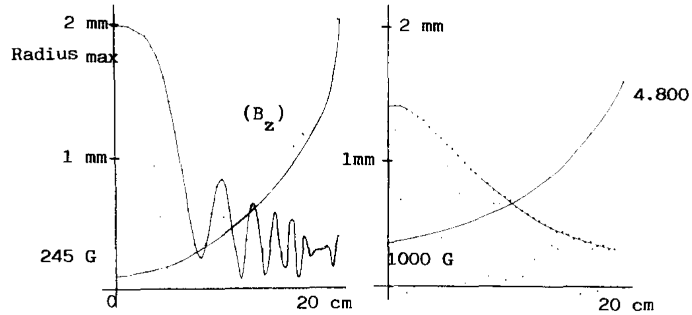

Fig.3 - Magnetic compression comparison between 245 G and 1000 G for a 0.5A;20 kV electron gun

Hence, the magnetic compression $C_M = \left(\frac{B_{max}}{B_{min}}\right)^2$ equals 1600 under these conditions :

B min = 1500 G in the gun field matching coil

B max = 6 T in the cryogenic solenoid $\qquad [C_M = 1600]$

THE NEW ELECTRON GUN COMPROMIZE FOR DIONE -

The cathode radius and the cathode anode voltage are the cathode-anode remaining parameters of the electron gun.

Figure 4 shows the variation of r versus B min for different cathode-anode voltages values.

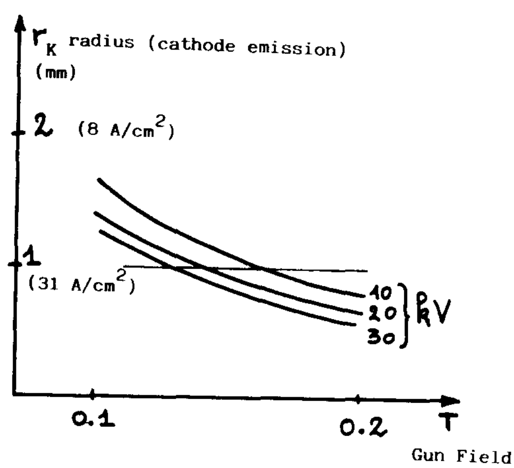

Fig.4 - 1 A electron gun

The following parameters will be adequate for the future version of the electron gun :

- *2 mm cathode diameter*
- *30 kV anode voltage,*
- *1 A intensity.*

The required emission density becomes 30 A/cm^2 leading to use LaB6 as an emissive material.

LOW CHARGE STATE IONS INJECTION -

This injection process has been previously described /1/. The existing set up behaviour is not satisfactory. As said before, the "apparent" electron beam density does not reach the expected value and decreases when the injected ions quantity increases. It seems to exist a mechanism of continuous feeding in low charge states ions during the confinement time.

We can suspect two main reasons :

- optical : the injected ion beam emittance is too large ($\varepsilon > 10^{-7}$ norm.m.rd) or there is a misalignment between the electron beam and the ion beam.

- Physical : - It exists a distribution of several charge states which are simultaneously injected (different gyration radii and differential trapping time in the electron beam).

- Presence of a residual gas in the source. This is particularly true in the case of species more difficult to pump, the neon for instance. A 0.1% residual density with regards to the initial density of injected ions in the electron beam can reduce by half the production of completely stripped ions according to the calculation models.

Therefore it seems necessary to get a better process of injection from the external source in quantity as well as in quality. This not only to obtain a "cleaner" and more reliable operation, a more versatile use when the ion species is changed, but also in hopes of improving the electron beam density and therefore the performances of the source : the yield in completely stripped ions.

Consequently, we will take for DIONE the following options :

- cryogenic pumping on the external source injection line.(in addition to the superfluid liquid helium cryopumping system of Dioné itself). This in order not to pollute the Ebis source itself and to avoid having to warm it up to the ambient temperature.

- getting a better emittance in improving the extraction and the optical line of the beam coming from the external source (E.S.) (the present conditions are not optimum because of the lack of means and time) :

. in increasing the extraction energy of the E.S. ion beam.

. in focusing the ion beam nearer from the E.S.; better optics in general.

. in studying external sources with good emittance (Thermoionic solid emission sources, multicups ion sources).

- magnetic selection of charge states.

SUMMARY -

As a conclusion, for Dioné, particular efforts will be devoted to :

- the electron gun : new technology of strongly emissive cathode,

- the external source : beam brightness and careful adaptation in regards with the direction and the acceptance of the electron beam.

DIONE CHARACTERISTICS - Cryostat - Winding -

Maximum field..................6 teslas
Nominal current .... 145 A
Length + 1% field .... 1 M
Winding length .... 1.248 m
Interior diameter of winding .... 93 m
Stored energy .... 198.8 kJ
Overall length .... 1.954 m
Exterior diameter .... 0.556 m
Weight .... about 1.100 kG
Separate vacuum regions for superconductor and electron beam mandrel :
- interior diameter .... 80 mm
- straightness .... 10 µm
Helium consumption : one 500 l dewar per week

DIONE - OPTIONS -

Magnetic field :	*6 Teslas uniform*
Electron gun :	*30 kV; 1 A*
	Compression < 20
Injection :	*External source*

DIONE - OBJECTIVES -

1. *Completely stripped ions up to Ar 18+*
2. *Confinement time of the order of 10 ms or less up to Ne 10+*
3. *Of the order of 10^{11} charges per pulse*
4. *For heavier ions, the highest charge state possible, consistent with the results obtained on Cryebis and with reliable technology.*

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