

**ELECTRON BEAM DENSITY OF
CRYEBIS FRECH 2 ELECTRON GUN**

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Abstract.

This report gives a method to calculate by computer -programming the FRECH II- electron beam density. This method consists in taking current measurements on a 1/10 mm tungsten-wire, to determine the electron-beam density profile.

Résumé.

Ce rapport décrit la méthode employée pour trouver la densité du faisceau électronique issu du canon FRECH II. Il décrit le programme de calcul réalisé qui, à partir des mesures du profil de faisceau sur un fil de 1/10 mm, permet le calcul de la densité.

I. Apparatus.

In this study we use the Frost-type electron gun (1) scale 2. It consists of a cathode, a focusing electrode (Wehnelt) and an anode as shown in figure (1). This gun is magnetically shielded. The distances between gun-shielding and cathode-wehnelt could be adjusted by sensitive micrometers.

Around the cathode there is a small coil for cancelling residual magnetic field. The gun and its support (A) Fig.(2) are placed in front of a solenoid (B) that gives more than 5200 gauss for electron beam confinement.

The electron current is measured on a Faraday cup (C) with wires that can be moved in the three dimensions.

The vacuum is obtained by two cryogenic pumps that uses liquid He or N_2 . The two pumps (D and E) have pumping speeds of 300 and 400 litres/sec respectively. On using liquid helium the apparatus operates four days while for liquid nitrogen it works one and half day only. After continuous operation for three weeks the pressure reaches $5 \cdot 10^{-10}$ mm Hg when the cathode is cold and $2 \cdot 10^{-9}$ mm Hg under operation.

The filament is heated by a 20 KHz 7.1V-13A supply. The cathode temperature reaches 1100°C.

For electron beam extraction, a pulse generator (2) with amplitudes of 10 KV-2 A and pulse width 20 μ s is used on the cathode. The anode is kept at zero potential. The wehnelt is at the cathode potential.

The beam tester as shown in figure (3) consists of a diaphragm in front of two wires of thickness 0.1mm perpendicular to each other and a cooled collector put at the end of a rod that moves in the three directions by micrometers. The study of the electron beam profile is made by the use of the two wires. An x-y recorder is used to draw the electron beam profile by moving one wire across the beam axis.

The electron currents on the diaphragm, the two wires and the collector are measured through a 10 Ω resistance on an oscilloscope. The wires are polarized with respect to the collector Fig.(4) to avoid the secondary electrons emissions.

II. DENSIT program.

First of all, we control that the vertical and the horizontal wires give the same profile. Then, we can calculate the density. If the profile is not exactly symmetrical which is the general case, then we calculate the density for each half part of the profile. This is made by the DENSIT computer program that we now briefly describe.

1. In this program, we calculate the average electron density in electron beam cross-section (BJBAR). The experimental electron density distribution profile do not gives the true value since the beam is distributed along the length of the wire.

By using the experimental profile, we calculate its total area by using simpson's rule

$$\text{Area} = \frac{h}{3} (Y_0 + 4Y_1 + 2Y_2 + 4Y_3 + 2Y_4 \dots + 2Y_{n-2} + 4Y_{n-1} + Y_n)$$

where $Y_0, Y_1, Y_2 \dots Y_n$ are Y values corresponding to equal displacement h in the X-direction.

2. In this method the profile Fig. (5) is divided into vertical elements by the lines $Y_1, Y_2, Y_3 \dots Y_n$.

The ratio between each small area and the total area multiplied by the total electron current gives the current distribution in each element. To eliminate mistakes due to the reading, we utilise the mean value between two successive points (B1 or B2) which are called BM1 and BM2 which corresponds to the values before and after the maximum value (NMAXI) respectively. The values BM1 and BM2 are arranged for computer calculations, and called BI(IA) where IA = 1, 2, 3, ..., NMAXI.

3. The second part of this program divides the cross-section of the electron beam into small areas which are calculated and has special indices to be arranged in a matrix.

First the cross-section is divided into vertical areas as shown in Fig. (6) which are called S(N,NMAX). SS(N,NMAX) is the area of the sector.

In calculation of the next vertical element the area of the first element is subtracted which is called (SIG) where

$$\text{SIG} = \text{SIG} + \text{S}(\text{N}, \text{NMAX})$$

$$\text{SS}(\text{N}, \text{NMAX}) = \frac{r^2}{2} \left(\frac{\pi\alpha}{180} - \sin \alpha \right) \quad \text{Ref. (3)}$$

$$\text{S}(\text{N}, \text{NMAX}) = \frac{\pi r^2}{2} - \frac{r^2}{2} \left(\frac{\pi\alpha}{180} - \sin \alpha \right) - \text{SIG}$$

where $\frac{\pi r^2}{2}$ is the total area, α the angle of the sector. $\text{SIG} = 0$ in the first calculation.

4. The next step is to subdivide the cross-section area into circular areas in a manner as shown in fig.(7) each surface element is called $A(I,J)$.

The area $A(I,J)$ is calculated by subtraction between two successive columns in the same vertical element e.g. $A(1,6) = S(1,6) - S(1,5)$.

The arrangement of elements of area $A(I,J)$ are changed to the arrangement $B(IR, JRZ)$ as shown in fig.(7).

5. By using the values of B and the currents $BI(IA)$ the UNIVAC subroutine $\text{SEQL}(\text{NMAX}, B, BI)$ solve the following system of linear equations

$$I_1 = J_1 B_{11} + J_2 B_{12} + J_3 B_{13} + J_4 B_{14} + J_5 B_{15} + J_6 B_{16}$$

$$I_2 = J_2 B_{22} + J_3 B_{23} + J_4 B_{24} + J_5 B_{25} + J_6 B_{26}$$

$$I_3 = J_3 B_{33} + J_4 B_{34} + J_5 B_{35} + J_6 B_{36}$$

$$I_4 = J_4 B_{44} + J_5 B_{45} + J_6 B_{46}$$

$$I_5 = J_5 B_{55} + J_6 B_{56}$$

$$I_6 = J_6 B_{66}$$

This system of linear equations has this arrangement up to the value of NMAXI in the program. In these equations I_1, I_2, \dots represents $BI(IA)$ and J_1, J_2, J_3, \dots represents $BI(II)$ SEQL inverse the B -matrix, and give the calculated solutions of the density in $BI(II)$ where $II=1, \text{NMAXI}$.

6. The area of the circular sections $\text{SAB}(1), \text{SAB}(2), \dots$ are calculated. These areas are added successively and called $\text{SINT}(1), \text{SINT}(2), \dots$ as shown in Fig.(8).

where

$$\begin{aligned} \text{SINT}(1) &= \text{SAB}(1) \\ \text{SINT}(2) &= \text{SAB}(1) + \text{SAB}(2) \\ \text{SINT}(3) &= \text{SAB}(1) + \text{SAB}(2) + \text{SAB}(3) \\ &\vdots \\ \text{SINT}(\text{NMAXI}) &= \frac{\pi R^2}{2} \end{aligned}$$

For calculation of the average electron density we use the equation

$$\text{EJBAR}(\text{NJ}) = \frac{\text{EJBAR}(\text{NJMI}) \cdot \text{SINT}(\text{NJMI}) + \text{SAB}(\text{NJ}) \cdot \text{BI}(\text{NJ})}{\text{SINT}(\text{NJ})}$$

where EJBAR is the average electron density
SINT(NJMI) is the area corresponding to (NJMI)
SAB(NJ) is the circular area corresponding to (NJ)
BI(NJ) is the calculated density BI(IX)
NJMI = NJ-1

With this program the average electron density is calculated for each half part of the profile.

III. Results.

The electron distribution profile of the electron beam extracted from the electron gun FRECH II is measured by a beam tester and drawn on a X-Y recorder Fig. (9) shows the electron average density (A/cm^2) on the two sides of the beam calculated by the UNIVAC computer.

The experimental conditions for the electron beam profile are

$$\begin{aligned} v_{\text{ex}} &= 10 \text{ KV} \\ I &= 2.15 \text{ A} \\ B &= 5200 \text{ gauss} \\ 2B_1 &= 50 \text{ gauss} \end{aligned}$$

The difference between the two curves shows a small dissymetry of the beam which has to be corrected by a small displacement of the gun.

Conclusion.

The DENSIT program, which gives rapidly the density in the center of the beam, and the density on its both sides, is a good way to study and to optimize the electron guns.

References

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- 2) Ch.Goldstein, A.Serafini (Bilan des essais sur le canon FRECH1 et définition du canon FRECH2 de la source CRYEBIS). IPNO-76-07, Orsay (1976).
- 3) I.N.Bronstein (Aide-mémoire de mathématiques), p.250 (1963).

JOB R 021731 00040

DELE R 021733 VALMAX

0000 R 021553 XY

DDDD R 12161

000 P 000144 2

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 3* ..... DIMENSION Y(100),Z(100),C(150),S(150),R(150),B(100)
 5* ..... 10Z(100)+54E(100)+SINT(100)+PJRA(100)+PRR(100)+6*(21+23)+RT(100)
 6* ..... 20M(100)+27(100)+X(100)+Y(100)
 8* ..... READ 10,40,60,80,90,PWAY
 9* ..... DEAF 50(100)+70(100)
10* ..... PRINT50 (Y(100),Z(100))
11* ..... J=1
12* ..... 50
13* ..... 10
14* ..... 10
15* ..... 10
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570      DO 91 I=1,NV
571      QZ(I)=Z(I)-TA*I
572      DO JY 92,12*(I)
573      CONTINUE
574      MKM=MINMAX
575      DO 91 I=1,NV
576      RM(I)=1/(Z(I)+QZ(I)+I**2)
577      PRINT 98,RM(I)
578      91 CONTINUE
579      NM=1+NM*V
580      Y(I)=RM(I)
581      DO JY 101,12*(I)
582      CONTINUE
583      L=1
584      DO 20 I=1,NM*V
585      VJ(I)=I**2
586      IF(TA>0) DO TO 100
587      101 DO JY 102,12*(I)
588      CONTINUE
589      20 CONTINUE
590      100 CONTINUE
591      DO 12 I=1,12
592      IAC(I)=I*V
593      IF(I<6) 91(12-I) QZ(I)=Y(I)
594      IFC(I)=I*V
595      IF(I<6) 91(12-I) QZ(I)=X(I)
596      DO JY 111,12*(I)
597      CONTINUE
598      12 CONTINUE
599      111 DO JY 112,12*(I)
600      CONTINUE
601      112 DO JY 113,12*(I)
602      CONTINUE
603      113 DO JY 114,12*(I)
604      CONTINUE
605      114 DO JY 115,12*(I)
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607      115 DO JY 116,12*(I)
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609      116 DO JY 117,12*(I)
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611      117 DO JY 118,12*(I)
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627      125 DO JY 126,12*(I)
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996      CONTINUE
997      310 DO JY 311,12*(I)
998      CONTINUE
999      311 DO JY 312,12*(I)
1000     CONTINUE

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1179      *MAYENMAX=J
1184      IF(MAX,PT,1) GO TO 3
1191      C   CALCUL DES SURFACES TROUSSES AII,JI
1196      C
1199      0   DO 1 I=1,MMAXY
1204      M1=MMAXI+2*I
1211      0   DO 2 J=MMAXI-I+1
1216      JM=J-1
1221      M2=M-1
1226      IF(I,FS,JI) GO TO 9
1231      A1=K*F1ESIT,JI-DET,JK
1236      F11,FF,MMI, PD TO 2
1241      M2=J-1
1246      0   IF(I,MI,ESIT,JK)
1251      PD TO 2
1256      0   A1=MI*ESIT,JI
1261      CONTINUE
1266      F   CONTINUE
1271      PD 40 I=1,MMAXY
1276      I=I+1
1281      PD 41 J=1,MMAXY
1286      J=J+1
1291      0   IF(J,FF,IP2
1296      F11,FF,MMI,MMAXI) GO TO 41
1301      M1=J+J-1+I+1,JI
1306      0   CONTINUE
1311      60  CONTINUE
1316      PD 42 I=1,MMAXY
1321      PRINT I,FS,I
1326      PRINT I,FS=I,KS,A(I,KS),O1,KS),KDE(MMAXY,JI)-1
1331      02  CONTINUE
1336      PRINT I,FS,IPR(I,JI),O1(I,JI),J,JI,MMAXY)
1341      C   SE REPRESENT LA VALEUR NORMALISEE DES DECPANTS
1346      CALL SCL(MMAXY,MMI)
1351      PRINT I,FS=I,II=I,III=I,II,MMAXY)
1356      C   SE REPRESENTE ICI LES QUANTITES CALCULEES
1361      C
1366      C   UN RESEAU EST REPRESENTE PAR   IIP=IIP*CONSTANTE
1371      PD 21 I=1,MMAXY
1376      S0=0.
1381      PD 22 I=1,MMAXY
1386      PD 23 I=1,MMAXY
1391      IF(I,FS,I,II) GO TO 23
1396      F11,FF,MMI,MMAXI) GO TO 23
1401      IF(I,II+J-I,II-I,II),I,FS,JI) GO TO 24
1406      PD TO 24
1411      24  S0(I,II)=S0+(I,II,I)
1416      S0=SRN(I,II)
1421      22  CONTINUE
1426      21  CONTINUE
1431      PD 24 I=1,MMAXY,SRN(I,MMI),MMI,MMAXY)
1436      C   VERIFICATION DES SURFACES INTERMEDIAIRES
1441      SUPR=0.
1446      PD 26 I=1,MMAXY
1451      SUPR=SUPR+S0(I,II)
1456      SINT(I,II)=SUPR

```

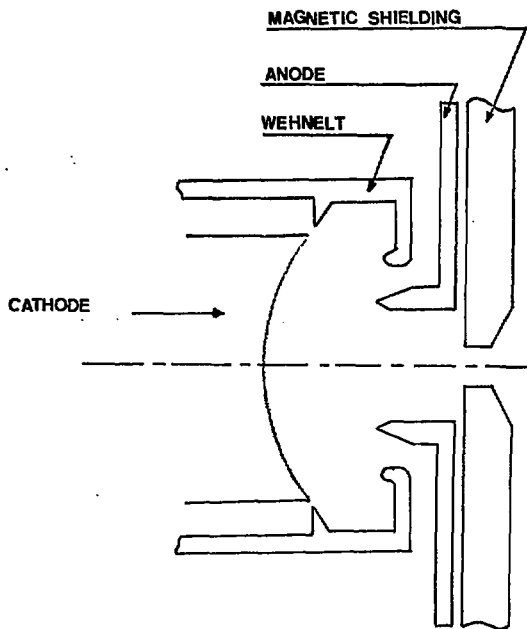
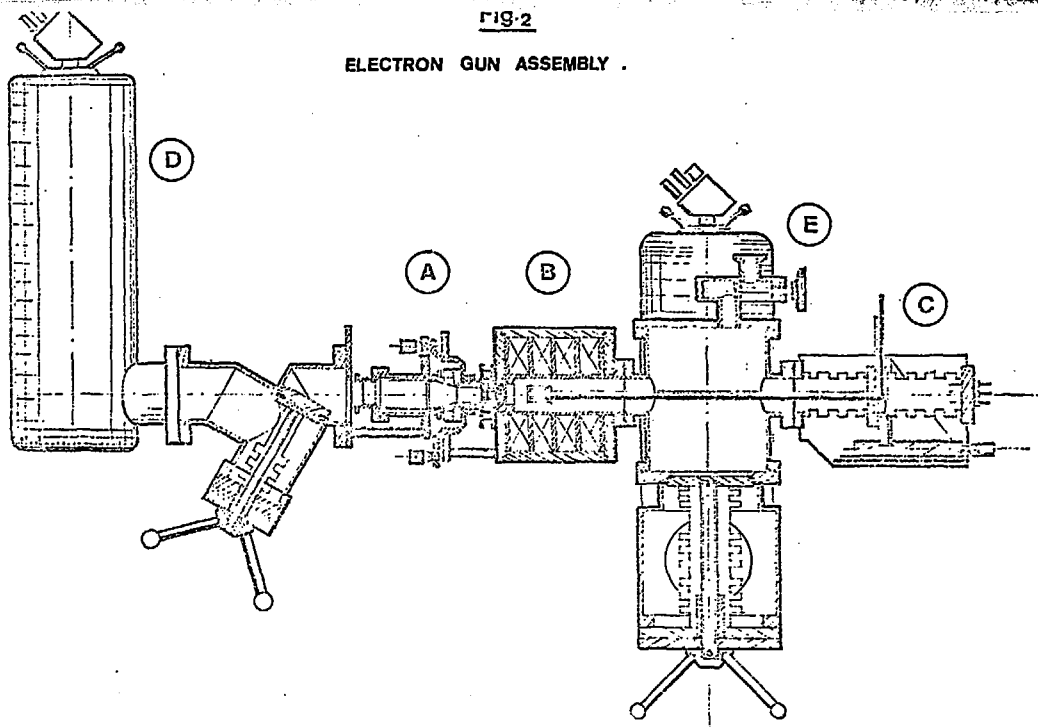
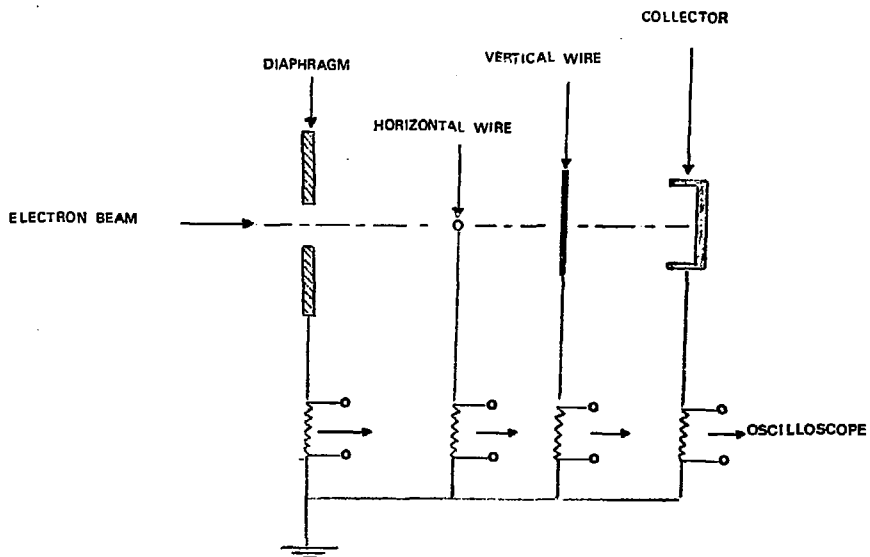



FIG. 1 ELECTRON GUN*FRECH2*

FIG. 2

ELECTRON GUN ASSEMBLY .





13

FIG.3_BEAM TESTER

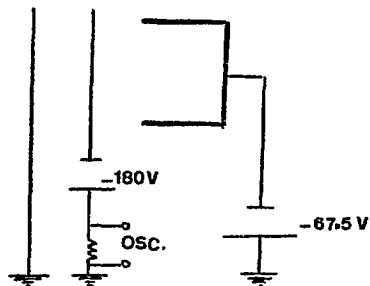


FIG.4 FARADAY CUP POLARISATION .

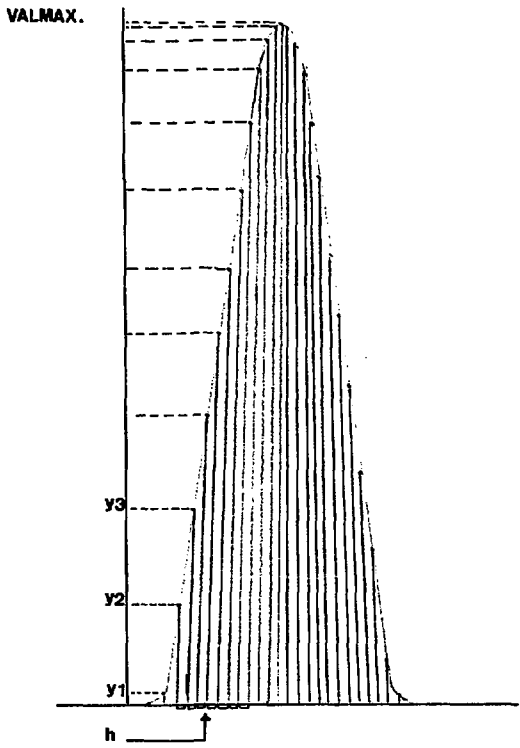


FIG.5 EXPERIMENTAL ELECTRON BEAM PROFILE.

$$A(1,6) = S(1,6) - S(1,5)$$

A(1,6)

S(1,6)

S(1,5)

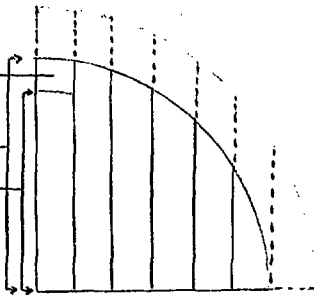


FIG.6 CALCULATION OF A(I,J)

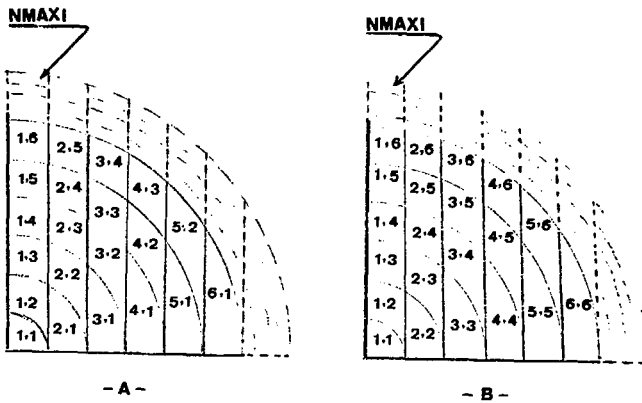


FIG. 7. A(I,J) AND B(IR, JRZ)

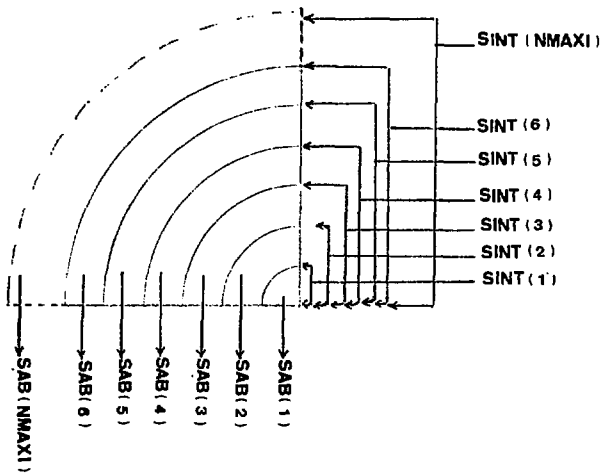


FIG.8 — RELATION BETWEEN SAB[IA] & SINT [IA]

**FIG. 9 AVERAGE ELECTRON DENSITY DISTRIBUTION CALCULATED
BY COMPUTER FORTRAN IV.**

