BEAM EMITTANCE MEASUREMENT ON ELECTRON GUN

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Summary

The beam emittance of the electron gun with the direct emitting has been measured in our laboratory.

The experimental apparatus and measurement method will be described and some results of the emittance measurements will be discussed.

Introduction

A 8Mev medical linac and a 5Mev industrial electron linac were designed and manufactured in our laboratory. In order to improve the characteristics of these machines, to measure the emittance of the gun and to evaluate the contribution of different factors to emittance growth are important. The experimental apparatus and mathematical procedure are described. Some results of emittance measurement are given.

Principle of the measurement method

If we assume that the beam distribution in the phase space is elliptical and the quadrupole is thin lens, then the emittance is[1,2]

$$\varepsilon = \frac{r_{min}(r^2 - r_{min}^2)^{\frac{1}{2}}}{L^2(\frac{1}{f} - \frac{1}{f_o})} \qquad (1)$$

or

$$\varepsilon = \frac{r_o r_{min}}{L} \qquad (2)$$

wher r_o - radius of the beam at the quadrupole,
L - Distance from the quad to the fluorescent screen,
f - focul length of the quad,
f_o - focul length which minimizes beam spot at the screen,
r_{min} - Minimum beam radius at the screen.

Sometimes we couldn't treat the quad as a thin lens, for example, when the electron enengy is very low. In that case the emittance formula for thick lens will be used instead of the above,

$$\varepsilon = \frac{r_{min}^2}{R_{12}} \sqrt{\left(\frac{r_0}{r_{min}}\right)^2 - \left(\frac{R_{12}'}{R_{11}R_{12}' - R_{12}R_{11}'}\right)^2} \qquad (3)$$

where $R_{11} = \cos kl_0 - kL\sin kl_0$

$R_{12} = \frac{1}{k}\sin kl_0 + L\cos kl_0$

$R_{11}' = -l_0\sin kl_0 - L\sin kl_0 - kl_0 L\cos kl_0$

$R_{12}' = \frac{l_0}{k}\cos kl_0 - (Ll_0 + \frac{1}{k^2})\sin kl_0$

l_0 - the effective width of the quad,

$$k^2 = \frac{ec}{(E^2 - E_0^2)^{\frac{1}{2}}} \frac{dB}{dr}$$

Experimental apparatus

The assembly is represented in Fig.1. The magnetic quadrupole lens is adjustable to very the beam size at the screen. A fluorescent screen and a camera are used for the beam radius measurement (Fig.2).

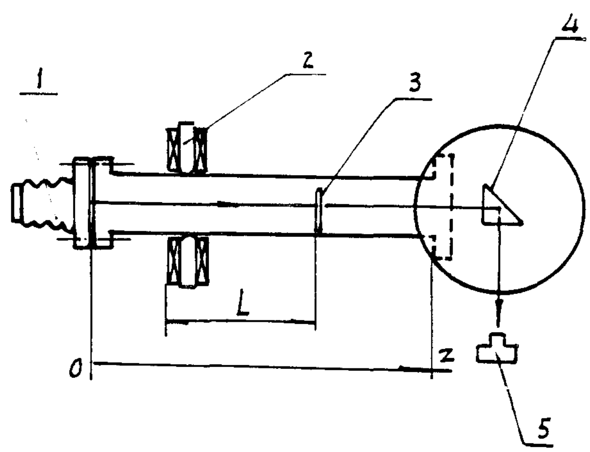

Fig.1. Emittance measurement set-up

1 - Electron gun
2 - Magnetic quadrupole lens
3 - Fluorescent screen
4 - Triangular mirror
5 - Camera
6 - Vaccum chamber

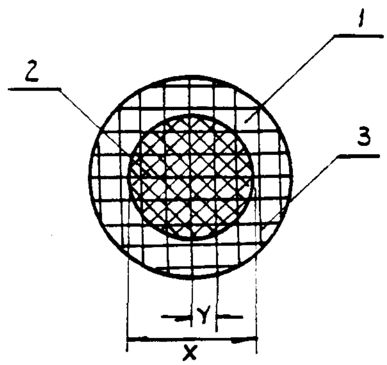

Fig.2. Fluorescent screen
1 - Fluorescent screen
2 - beam spot
3 - mesh

Emittance measurement

We measured the r_0 and r_{min} at low energy 2-5kev and calculated the emittances[3]. Table I shows results of measurements performed for four different electron voltages and currents, where we kept the cathode current constant.

Table I

V(kv)	I(ma)	$2r_0$(mm)	$2r_{min}$(mm)	$\varepsilon(m_0c\text{-cm})$
2	250	5.2	4.2	$0.66 \cdot 10^{-3}$
3	335	6.0	4.3	$1.0 \cdot 10^{-3}$
4	400	6.2	4.7	$1.31 \cdot 10^{-3}$
5	440	6.3	4.8	$1.49 \cdot 10^{-3}$

Conclusion

A method has heen described to measure the radii r and r_{min} of the electron gun beam at two positions, one is at the entrance of the quad, the other is at the fluorescent screen, which is located behind the beam waist. This experimental device is very simple.

From measurement results it seems that the beam emittance of the gun depends upon both the beam current and energy for a gun with a direct emitting cathode.

References

1, G.Mavrogenes, SLAC-PUB-2560, 1980
2, K.L.Brown, SLAL-PUB-2370, 1980
3, Gao Wei, Research Report, Tsinghua University, 1984