A Detector to Measure Longitudinal and Transverse Distributions of a Two Component Ion Beam

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Abstract

A single detector to measure the longitudinal and the transverse distributions of a two component (H^+ and H^-) ion beam is proposed. The operation is based upon rf separation of secondary electrons produced in a wire target by H^+ and H^- ion bunches. To improve the detector parameters the rf deflector is combined with the electrostatic focusing lens.

1 INTRODUCTION

The techniques for measuring the transverse and the longitudinal distributions of a beam are well developed. There are many varieties of profile monitors, likewise, a number of types of longitudinal distribution detectors have been developed [1,2,3,4]. But a method to simultaneously measure longitudinal and transverse distributions is not known. However, a two dimensional transverse and longitudinal distribution is undoubtedly of interest to better understand beam dynamics, to tune an accelerator properly and to obtain precise beam parameters. The problem becomes more complicated if H^+ and H^- ions are accelerated simultaneously, for example, as in the case for both the LAMPF and for the INR linacs.

The method and the technique to measure longitudinal and transverse distributions of a two component (H^+ and H^-) ion beam is proposed. The operation is based upon rf separation of low energy secondary electrons knocked out by ions from a thin wire target. To obtain the required resolution, the longitudinal distribution detectors, using a transverse modulation of the secondary electrons, include an electrostatic lens installed upstream [2,3] or downstream [4] of the rf deflector. We propose to combine the rf deflector with the electrostatic lens.

2 THE BASIC PRINCIPLE OF OPERATION

The schematic diagram of the detector is shown in fig.1. The H^+ and H^- ion beam passes through the thin wire target 1 and knocks out low energy secondary electrons. A negative potential is applied to the target so that the electrons are accelerated by the electrostatic field. Some of them pass through the collimator 2 and get to the rf deflector 3. The frequency of deflecting field ωn (n=1,2,3...) is a multiple of the bunching frequency ω. The displacement of an electron at the distance L (fig. 1) may be written as:

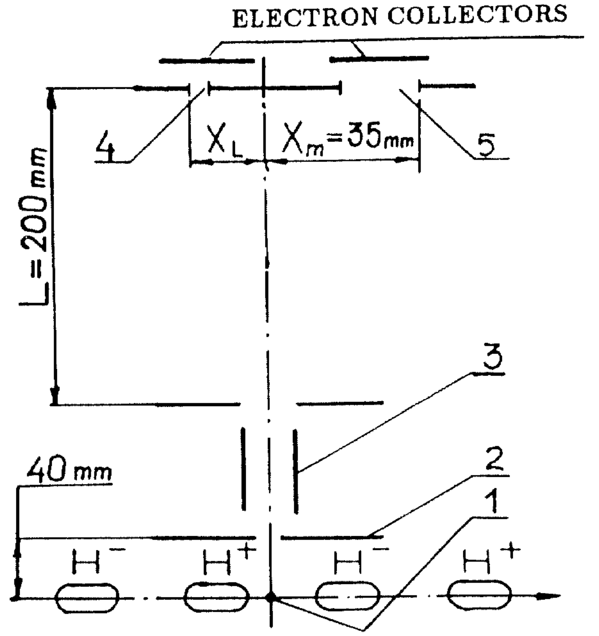

Figure 1: The schematic diagram of the detector.

$$X_L = X_m sin(n\omega t + \psi) \qquad (1)$$

where X_m is a maximum displacement, which depends on the target potential, geometrical parameters and the amplitude of the deflecting field; ψ is the rf phase at the deflector entrance. If n is odd, the signs of displacements X_L for electrons produced by H^+ and H^- ions are opposite. Under certain conditions all the electrons produced by H^+ and H^- ions can be spatially separated. By measuring the intensity of the electrons with positive or negative displacements, one can obtain separate information about H^+ and H^- ions intensity for a fixed target position. It is possible to measure the positively (or negatively) displaced electrons only. The change from H^+ to H^- ions may be done by changing the deflecting field phase by 180°.

The electrons spatial separation depends on X_m, ion bunch length Φ and the position dimension of the nondeflected ($X_m = 0$) electron beam ΔX_L. The condition for the total separation is:

$$X_m sin\frac{\pi - \Phi n}{2} > \frac{\Delta X_L}{2} \qquad (2)$$

To decrease X_m as well as to increase Φ, an additional focusing of the electrons is used, for example by an electrostatic field.

To obtain the transverse distribution of the H^+ and H^- ion beams, the target is moved across the beam. In this case the focusing conditions and the phase at the entrance of the deflector change, so trimming of the focusing field and the phase of the deflecting field is necessary. If the target, the lens and the deflector are moved simultaneously the trimming is not required.

If the intensity of the electron beam is measured at a fixed coordinate X_L, one can measure the longitudinal distribution of the ions in bunches by varying the phase of the deflecting field [1,2,3]. The constituent part of phase resolution $\Delta\phi$ due to nonzero dimension of electron beam ΔX_L is found by differentiating equation 1:

$$\Delta\phi = \frac{\Delta X_L}{n X_m cos\,(n\omega t + \psi)} \qquad (3)$$

The best resolution is obtained when $n\omega t + \psi = \pi n$ ($n = 0,1,2...$). In this case the intensity of electrons must be measured at the axis of the deflector $X_L = 0$. But there is a superposition of signals from H^+ and H^- ions in this case. If $0 < |X_L| < X_m$ and n is odd the superposition does not occur for bunch lengths

$$\Phi = \frac{2}{n} arcsin\frac{|X_L|}{X_m} \qquad (4)$$

The phase resolution $\Delta\phi$ deteriorates and becomes equal to:

$$\Delta\phi = \frac{\Delta X_L}{n\sqrt{X_m^2 - X_L^2}} \qquad (5)$$

If the intensity of electrons is measured at two points X_L and $-X_L$ simultaneously, then one can simultaneously obtain information about the bunch shapes of both the H^+ and H^- ion beams. One could measure the intensity at only one point and still distinguish between H^+ and H^- ions by changing the phase of the deflecting field by 180°.

This principle is used in a transverse and longitudinal distribution detector of a two component ion beam which is under development in the INR linac now. The narrow collimator 4 (fig.1) installed at the coordinate $X_L = -X_m/2$ is used to measure the longitudinal distribution. The dimension of collimator 5 is large enough to pass all the electrons produced by a bunch. The third harmonic (f=594.6 MHz) of the fundamental rf is used to deflect the electrons. Because the third harmonic is used, only a range of 20° (f=198.2 MHz) is measurable. This is enough to make measurements in the high energy part of the INR linac. To measure the beam profile, all the elements shown in fig. 1 are moved simultaneously across the beam.

3 RF DEFLECTOR

When electrons pass from the target to the deflector their temporal structure is distorted and the phase resolution deteriorates. To decrease this distortions, the deflector must be placed as close to the target as possible. In the INR bunch shape monitor [2,3] this distance is relatively large due to electrostatic lens located between the target and the deflector. To decrease the distance and to improve phase resolution the lens may be installed downstream the deflector [4]. But an arrangement of this type requires a higher deflecting field amplitude. We have considered making the deflector be a superposition of the rf deflecting and the electrostatic focusing fields. One might think that the efficiency of the rf deflection in this case would be an average of the efficiencies of the two types of arrangements mentioned above. But the negative focusing potential decreases the kinetic energy of the electrons. The deflection efficiency thus becomes even larger than for the lens followed by the deflector arrangement. There is a small distortion of temporal structure of electron beam due to the decreasing of the kinetic energy of electrons in this case. However we calculated that this effect is negligible.

Fig. 2 shows the geometry of the deflector and the dependence of maximum displacement in case of deflector-lens (curve 1) and in a lens followed by a deflector arrangement (curve 2) vs deflecting plates length for f = 594.6 MHz. The focusing potential for the deflector-lens is taken to have an optimum focusing effect and has been varied from -1865 V up to -1761 V for l=13-31 mm. A simplified diagram of the deflector is shown in fig. 3. The deflector consists of two $\lambda/2$ coaxial coupled cavities 1. The

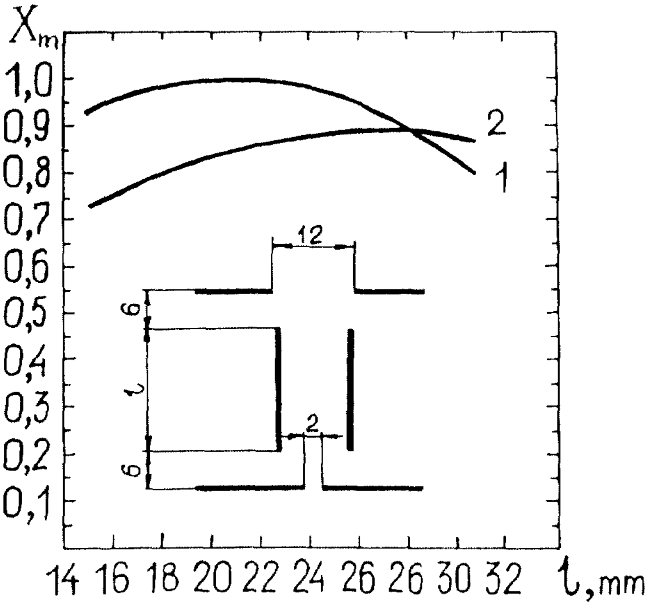

Figure 2: Dependence of maximum displacement for deflector-lens (curve 1) and lens followed by a deflector arrangement (curve 2)

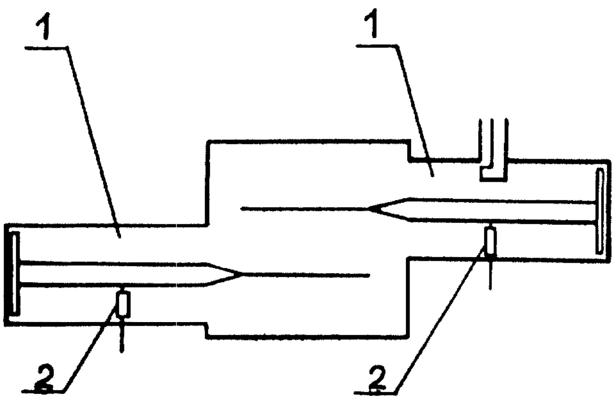

Figure 3: The simplified diagram of the deflector

central electrodes are insulated. The focusing potentials are applied through the resistors 2 near the zero electric field points. The electrostatic potential also prevents resonant rf discharge and provides the possibility to measure the rf amplitude with the help of the secondary electron beam. Since the focusing potentials are applied to the electrodes separately, one can find the optimum focusing field using the slit 4 (fig. 1) and the secondary electron beam. This possibility enables us to eliminate the stage of electron optics tuning with the help of thermal electrons [1,2,3].

The calculations made have shown that the amplitude of rf deflecting voltage between the plates is equal to 650 V (target potential -4 kV). To provide this value of rf amplitude several watts of power is required.

4 CONCLUSION

The method and the technique above provides additional possibilities in a beam study. Both the method and the technique are a further development of bunch shape monitor being used successfully at the INR linac for several years [2,3]. Therefore the authors have no doubt that the detector will be built as proposed.

5 ACKNOWLEDGEMENTS

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