TECHNIQUE OF RACE-TRACK MICROTRON INJECTION INTO LINAC

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A new technique of the beam injection into the linac accelerating section of the race-track microtron is considered in this work. The essence of the technique consists in the injection from the outer area of the microtron into the area of the coincided orbits of the first end magnet in such a way that the trajectory of the injected beam has the form of the intersecting loop. It is achieved with the help of the additional displaced field made by the distortion of the scattered fields of both end magnets in the area of the accelerated beam coincided orbit intersection with the border line of interpolar space magnets.

The given figure shows the scheme of charged particle beam injection into the race-track microtron, where 1 - the injected beam trajectory, 2 - the injected beam intersecting loop trajectory, 3 - the end magnet of the microtron, 4 - gradient field area, 5 - the end vertical plane of the magnet poles, 6 - the accelerating section, 7 and 8 - the first and second turns of the circulating beam, 9 and 10 - regions, where the displaced magnetic field is excited.

The realization of the technique may be carried out by active and passive ways. The active way, for example, may be carried out by the pole-face windings of the definite configuration. The passive one may be done by changing the poles' end profile of the field end magnets or by making the ferromagnetic screens with the slot in the scattered fields of the end magnets. Let's consider the latter way in detail.

The field in the median plane of the end magnet, between the magnet and the screen, being at the angle to the front of the magnet, has the following view:

$$B_X = B_Y = 0$$
$$B_Z = B_0\,\varphi/\alpha = (B_0/\alpha)\,\mathrm{arctg}\,X/Y \qquad (I)$$

B_0 - the field in the magnet, the angle φ is counted off from the screen.

Vector potential may be chosen as

$$A_x = A_z = 0$$
$$A_y = (B_0/\alpha)\, y F(\xi)$$

where $\xi = x/y$, $F(\xi) = \xi \,\mathrm{arctg}\, \xi - 1/2 \ln(1+\xi)^2$ (2)

To solve equations of particle movement in the field (1) we assume the approximation on the orbit as $y = y_0 = \text{const}$. Then the vector potential (2) will depend on y and the summarised pulse $\mathcal{P}_y$ will be approximately preserved. In this approximation we get the tra - jectory:

$$\dot{y}/\dot{x} = \frac{dy}{dx} = \frac{\dot{y}_0 - (\Omega y_0/\alpha)F(\xi)}{\sqrt{v^2 - (\dot{y}_0 - (\Omega y_0/\alpha)F(\xi))^2}} \qquad (3)$$

where v - full speed, $\dot{y}_0$ - y - initial speed component, ξ is supposed independent of y $\xi = x/y_0$. The turning angle of the particle flying into the field towards the screen at the angle of $\pi/2 - \alpha$ and leaving it after describing a loop in the scattered field is 2α. Since the full turning angle of the incoming particles is suitable to take as $\pi/2$, the angle α between the screen and the magnet must be equal to $\pi/4$. The distance between the points of particle income and outgoing on the screen is the integral of (3).

$$\Delta y = 2 y_0 \int_0^{\xi_m} \frac{\dot{y}_0 - (\Omega y_0/\alpha)F(\xi)}{\sqrt{v^2 - (\dot{y}_0 - (\Omega y_0/\alpha)F(\xi))^2}}\, d\xi \,, \quad \Omega = \frac{eB_0}{mC} \qquad (4)$$

where ξ_m - is the remotest point of the trajectory from the screen, and is determined from the equation

$$F(\xi_m) = \alpha \frac{v}{\Omega y_0}(1 + \sin\alpha) \qquad (5)$$

The integral (4) has no strict solution, so it can be not only calculated numerically but also approximately integrated.
Then we'll have:

$$\Delta Y = 2Y_0\left[\operatorname{tg}\alpha\,\xi_m/3 - \sqrt{\frac{2\alpha\Omega}{\alpha_m V Y_0}}\,\xi_m^{1/2}\cdot\left(V/\Omega - \frac{\alpha_m}{3\alpha}Y_0\xi_m\right)\right] \quad (6)$$

Equation (5), except the small ξ_m , has no strict solution either:

$$\xi_m \ll 1\ ;\ F(\xi) \approx \xi^2/2\ ;\ \xi_m \approx \sqrt{2V/\Omega Y_0 (1+\sin\alpha)} \quad (7)$$

For the end magnet with the screen to turn the circulating beam by 180°, the following condition should hold:

$$aF_1(X_1) = (Y_0/\alpha)\,F(1) \quad (8)$$

where a - the width of magnet gap, F_1 - the potential of the scattered field without the screen, X_1 - the point, where the scattered field is equal to zero. The potential F_1 is logarithmic: $F_1(x) = \ln(1 + x/a)$. So the distance between the magnet and the screen at the point of outgoing of all the orbits will be:

$$d = Y_0 \sin\alpha = a\,\frac{\alpha F_1(X_1)}{F(1)}\,\sin\alpha \quad (9)$$

The accuracy of all the formulae is estimated in the approximation (7) as:

$$\Delta Y/Y_0 = \sqrt{V/\Omega Y_0}\,f(\alpha)\ ;\quad \Delta Y = \sqrt{\frac{V}{\Omega}Y_0}\,f(\alpha)$$

$$f(\alpha) = 2\sqrt{2/\alpha}\,(1+\sin\alpha) - \sqrt{2\alpha} + 1/3\sqrt{2(1+\sin\alpha)} \approx 2{,}6$$

The numerical example: if β =0,1; γ = 1; H = 10^4; $x_1 = 3a$; $Y_0 = 12{,}6$ cm a = 5 cm, then d = 8,8 cm; ΔY = 2,8 cm; $\Delta Y/Y_0 \approx 20$ %.

Thus the creation of the displacing gradient field at the end sections of the race-track microtron end semimagnets provides the possibility of obtaining the ttajectory of a full intersecting loop by the injected beam.

The setting of the gradient field boundary at the acute angle to the bordering vertical plane poles of the end magnet provides realization of the injection from the outer area of the microtron.

The application of this technique will apparently essentially enlarge the possibilities of construction of the race-track microtrons, simplify the injection system and facilitate the tuning of the beam injection and calculation. All these will ensure safety and high quality of microtron operation.

Literature

1. Technique of charged particle beam injection into the microtron. - Inventor's certificate 1292555, bulletin 40, 1987.

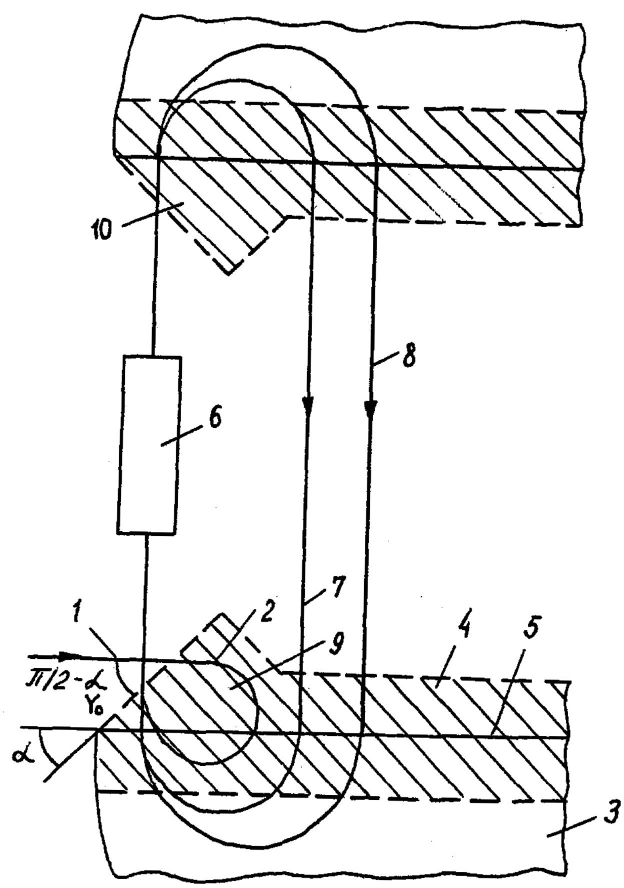

Fig. 1.