A NOVEL CHOPPER SYSTEM FOR HIGH POWER CW LINAC

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Abstract

For PNC high power CW linac, a new chopper system with very little emittance growth is being developed. The new idea is that when the beam passes a chopper cavity, the cavity does not add or adds very small transverse momentum to the part of the beam passing through the chopper slit. This idea is realized by a rectangular cavity with three fields superposed. The simulation results by MAFIA TS3 code (the particle-in-cell-code) is mentioned and some influential factors are discussed.

Introduction

A new chopper system is developed for PNC high power CW linac [1,2] The important thing is how to make the chopping system very little emittance growth.

The previous conception [3,4] is that when the beam passes through the chopper cavity, in the one RF period, RF magnetic field will give some transverse momenta to the beam for deflecting, a part of beam will pass through the chopper slit; then let this part of beam pass through a second cavity to cancel their transverse momenta.

The novel idea is that when the beam passes through a chopper cavity, the cavity does not add (in ideal case) or adds very small transverse momentum to the part of the beam which will pass through the chopper slit; the transverse momenta are only added to other part of beam, which will be stopped at the chopper slit. It is showed on Fig.1. It means that the fields in the chopper cavity are zero when a part of beam passes through the chopper cavity, so this part of beam will pass through the slit straight and without any additional transverse momentum from the cavity; but there is a deflecting field in the chopper cavity when the remainder part of beam during one RF period passes through the cavity, and this remainder part of beam will stop at the slit.

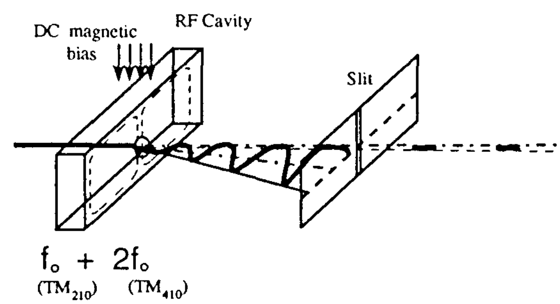

Fig. 1, A novel chopper system

Cavity Design

Fig. 2 shows a composed magnetic field added by three magnetic fields that are a RF magnetic field (B_{f_0}) with fundamental frequency fo, a RF magnetic field (B_{2f_0}) with second harmonic frequency 2fo and a DC magnetic bias field (B_{bias}). The composed magnetic field has a flat part which field is equal to zero. Tuning each field amplitude and phase, the length of flat part can be changed.

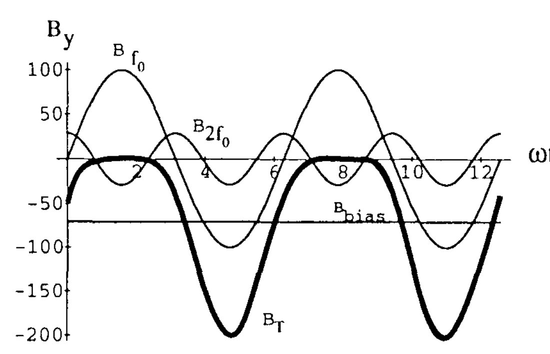

Fig. 2, Composed magnetic field in cavity

One can realize this new idea by means of a rectangular cavity added variable stub tuners. The cavity can be resonated at the TM_{210} mode with f_0 frequency and TM_{410} mode with $2f_0$ frequency.

Fig. 3 shows the magnetic field B_{f_0} at the TM_{210} mode with f_0 frequency and B_{2f_0} at TM_{410} mode with $2f_0$ frequency in the cavity. Table 1 lists the results of the calculation by MAFIA. There are frequency, Q value, store energy, power loss and magnetic field of each mode.

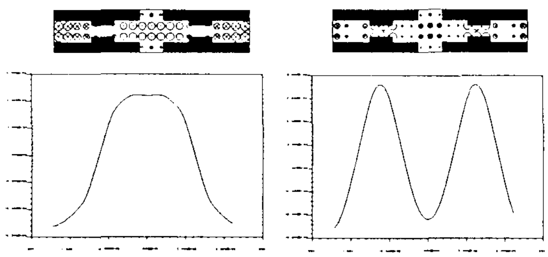

Fig. 3, Magnetic fields in the chopper cavity.

Table 1. Results of Calculation by MAFIA

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* calculating quality factors for a range of modes *
* mode range from          1     to      10        *
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mode		f(GHz)	Q	energy(J)	loss(W)	By(Tesla)
1	TM110	0.837531626	9689	6.002060112E-16	3.259610915E-10	
2	TM210	1.249342084	12247	3.665386054E-16	2.349247186E-10	1.1073E-09
3		1.806570530	14367	3.198437437E-16	2.526887866E-10	
4		1.949722171	14753	7.662335215E-16	6.362320115E-10	
5		2.087855577	15125	5.557318051E-16	4.019638972E-10	
6	TM410	2.497986794	16392	1.393084383E-15	1.333810062E-09	-2.1576E-09
7		2.521357536	16889	5.850735558E-16	5.488078880E-10	
8		2.975537777	16491	3.641353877E-16	4.128012099E-10	
9		3.036289454	18421	1.111540690E-15	1.151149509E-09	
10		3.116830826	19071	1.151082412E-15	1.181979292E-09	

Some Influential Factors

Beam transit time effect

In general speaking, when the field in the cavity is changing sinusoidally with time the transit time factor is equal to $\mathrm{Sin}(\pi L/\lambda o)/(\pi L\lambda o)$. But for the field $B_T(t)$ shown on the Fig.2, the length of the flat part will depend on the transit angle (transit angle $\alpha=2\pi L/\beta\lambda o$) shown on Fig.4. The larger transit angle the smaller flat part. B_T is total magnetic field in the chopper cavity, B_I is the magnetic field that the beam passing through the chopper cavity suffers with different input phase.

As following:

$$B_T= B_{f_0}\,\mathrm{Sin}(2\pi z/\beta\lambda o)+B_{2f_0}\,\mathrm{Sin}(4\pi z/\beta\lambda o+\pi/2)$$

$$B_I =\int [\, B_{f_0}\,\mathrm{Sin}(2\pi z/\beta\lambda o+\phi o) + B_{2f_0}\,\mathrm{Sin}(4\pi z/\beta\lambda o+\pi/2+2\phi o)\,]\,\mathrm{Sin}(\pi z/L)\, dz$$

where β is the beam relative velocity, λo wave length, ϕo input phase, α transit angle, L the length of the cavity and integration from 0 to L.

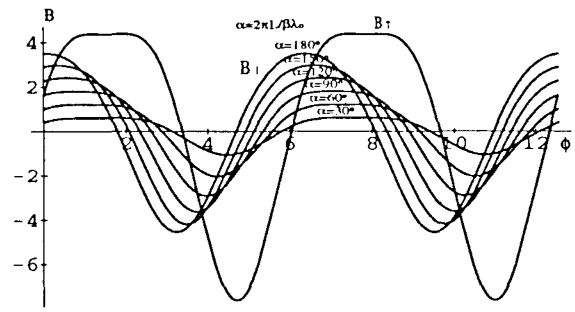

Fig. 4, Beam transit angle effect

It is found that for a fixed transit angle (α=100°) changing the amplitude ratio of the magnetic fields between B_{f_0} and B_{2f_0} can change the length of the flat part. Fig.5 shows that on :

a), B_{2f_0} / B_{f_0} = 0.29, during 90° length, the spread dB_T/B_T=1.9%, the spread dB_I / B_I = 9.6%;

b), B_{2f_0} / B_{f_0} = 0.33, dB_T/B_T =5.63%, dB_I / B_I =5.58%;

c), B_{2f_0} / B_{f_0} = 0.38, dB_T/B_T =13.1%, dB_I / B_I =1.90%;

d), B_{2f_0} / B_{f_0} = 0.41, dB_T/B_T =18.1%, dB_I / B_I =4.09%.

It is shown that case "c" is the optimum.

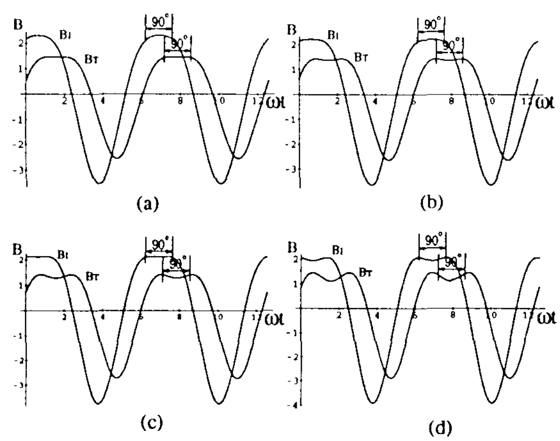

Fig.5, Radio of $B2f_0$ / Bf_0 effects

Beam size effect (edge effect)

At above discussion it is assumed that the beam size and slit size are very small. If the beam diameter is not so small, for example, 5mm, then choosing slit width is the same size of beam diameter. In this case, the edge effect will become important. Fig.6 shows the edge effect. The edge parts will add some transverse momenta. In principle, using two slits can cut the edge parts.

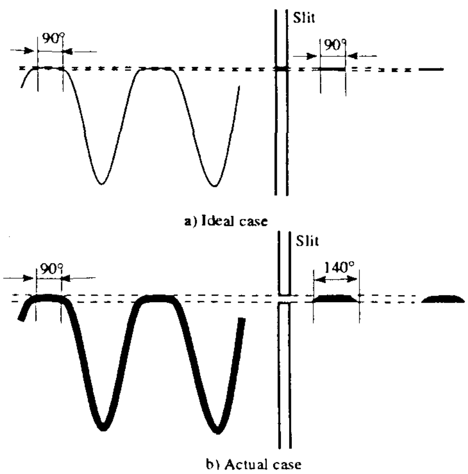

Fig. 6, Beam size effect

Chopper System Design and Simulation

According to the calculated data chopper system can be designed, suppose that the length between the chopper cavity and slit s = 0.5m, the width of slit is equal to the beam diameter(5mm), the maximum deflecting distance dd = 40mm, input power P_{f_0}= 1234W for f_0, and P_{2f_0} = 280W for $2f_0$ is necessary. The maximum magnetic field of the TM_{210} mode, B_{f_0}= 25 gauss, one of the TM_{210} mode, B_{2f_0}= 9.755 gauss and DC bias magnetic field B_{bias} = 15.25 gauss on the beam center line. The chopper system is shown on Fig.1. The chopper slit needs special design because of very high power dissipation.

Using MAFIA TS3 code (particle-in-cell -code) the results of simulation are shown on Fig.7. On the Fig.7 (a), there is no field on the beam line in the chopper cavity, so the part of the beam will pass through the slit straight. On the Fig.7 (b), there is a deflecting magnetic field, so this part of the beam will be deflected and stop at the slit.

Now the test chopper cavity is under construction.

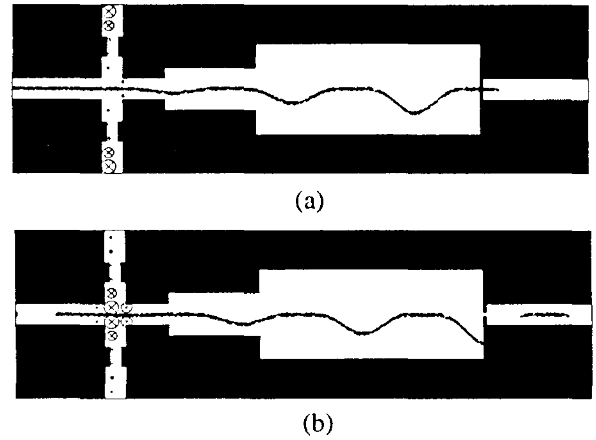

Fig. 7, Chopper system simulation by MAFIA

References

[1], Y.L. Wang, et al. "A Novel Chopper System with Very little Emittance Growth."
Proceedings of the 4th European Particle Accelerator Conference, in London, June 1994.

[2], Y.L. Wang, et al. "A New Chopper System with Low Emittance Growth. for PNC High Power CW Linac"
Proceedings of the 19th Japan Linac Conference , in Tokai, July 1994

[3], L.M.Young and D.R.Keffeler, "The RF Power System for the Chopper Buncher System on the NBS-Los Alamos RTM", IEEE, Trans. Sci. NS-32, 2165, 1985

[4],H.Braun, H.Heringhaus and A.Streun, "The Gun Chopper System for the MAINZ Microtron." Proc. of EPAC, Rome, June, 1988