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A NEW CHOPPER SYSTEM WITH LOW EMITTANCE GROWTH FOR PNC HIGH POWER CW LINAC

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ABSTRACT

A new chopper system is developed for PNC high power CW linac. It has low emittance growth. There is only one RF cavity in the chopper system. When the beam passes through the cavity, there is no field for the part of the beam which will pass through the chopper slit; but there is a deflecting magnetic field for the remainder part of the beam which will be stopped at the chopper slit.

1. INTRODUCTION

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

Some laboratories [2),3)] use two RF cavities with a slit and a solenoid system shown on Fig.1. When the part of beam, which will pass through the slit, passes through the first cavity, the particles with different longitudinal phase will be added different transverse momentum. The slit is like a mirror. Passing through slit the particles will be focused to the axis at the second cavity . If the second cavity has the same amplitude as the first one and opposite phase , their transverse momentum can be cancelled in ideal case.

This conception is that some transverse momenta are added to the beam for deflecting by the first cavity, then are cancelled by the second cavity after beam passing through the slit.

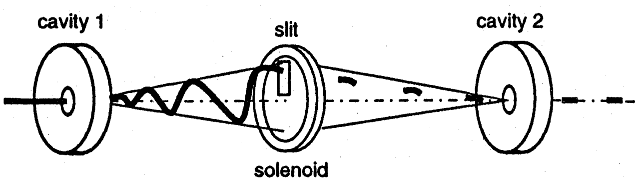

Fig. 1, Double cavity chopper system

A 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 passing 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.2. 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.

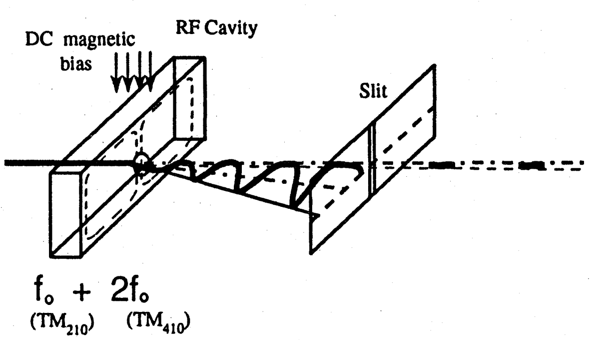

Fig. 2, New chopper system

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2. CAVITY DESIGN

Fig. 3 shows a composed magnetic field added by three magnetic fields that are a RF magnetic field with fundamental frequency (B_{f_0}), a RF magnetic field with second harmonic frequency (B_{2f_0}) 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.

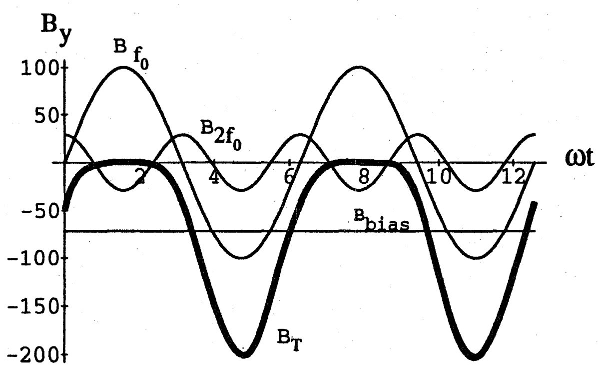

Fig. 3, composed magnetic field in cavity

In the rectangular cavity one will choose TM_{210} mode for the chopping fundamental mode. According to the MAFIA calculation, if the frequency of the TM_{210} mode is f_0, the frequency of the TM_{410} mode is not equal to $2f_0$. Only the frequency of the TM_{420} mode is equal to $2f_0$, but this mode can not be used for this purpose. Fig.4 shows the magnetic fields of the TM_{110} mode, TM_{210} mode, TM_{410} mode and TM_{420} mode in the cavity.

According to the perturbation theorem, if a variable stub tuner is located at the maximum electric field of TM_{210} mode and the maximum magnetic field of TM_{410} mode, the frequencies of the TM_{210} mode and the TM_{410} mode will be tuned in the opposite direction. So it is possible to make the ratio of the frequencies of the TM_{410} mode and the TM_{210} mode exactly two.

By means of this method one can realize this new idea. A test chopper cavity is shown on the Fig.5. There are four variable stub tuners (ST_{11}, ST_{12}, ST_{13} and ST_{14}) on the XZ planes to tune the fundamental frequency, other four variable stub tuners (ST_{21}, ST_{22}, ST_{23} and ST_{24}) on the XY planes to tune the frequency ratio of the TM_{410} mode and the TM_{210} mode and two magnetic coupler loops ($C\,f_{210}$ and $C\,f_{410}$) on the YZ planes to excite the TM_{210} mode of f_0 frequency and TM_{410} mode of $2f_0$ frequency fields, respectively.

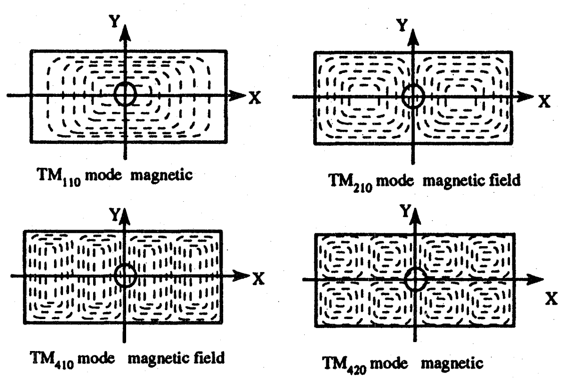

Fig. 4, Magnetic fields of the TM_{110} mode, TM_{210} mode, TM_{410} mode and TM_{420} mode

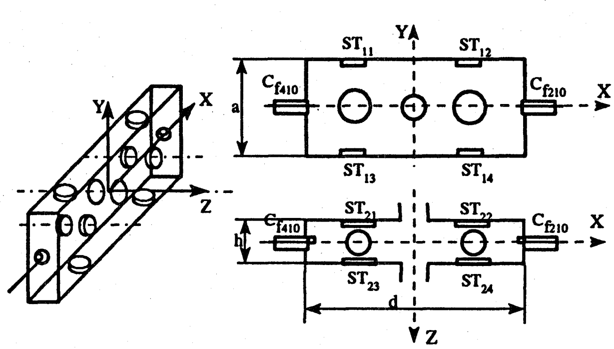

Fig. 5, Test chopper cavity

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. 6 shows the magnetic fields of the TM_{210} mode and the TM_{410} mode in the chopper cavity. Fig. 7 shows the electric fields of the TM_{210} mode and the TM_{410} mode in the chopper cavity.

Table 1. Results of calculation by MAFIA

* calculating quality factors for a range of modes *

* mode range from 1 to 10 *

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	4.819838972E-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	

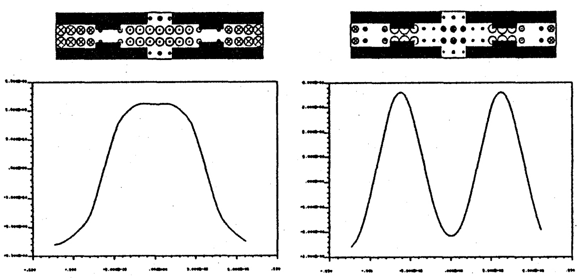

Fig. 6, Magnetic fields in the chopper cavity.

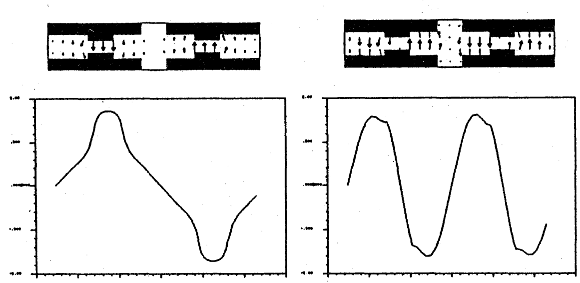

Fig. 7, Electric fields in the chopper cavity

3. 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, $B_{TM_{210}}$ = 25 gauss, one of the TM_{210} mode, $B_{TM_{410}}$ = 9.755 gauss and DC bias magnetic field B_{bias} = 15.25 gauss on the beam center line. The maximum electric field near the stub tuners E_{max} = 2.0MV/m. So there is no discharge problem. The chopper system is shown on Fig.4. The chopper slit needs special design because of very high power dissipation.

Using MAFIA TS3 code (the particle-in-cell-code) the results of simulation are shown on Fig.8.

Now the test chopper cavity is under construction.

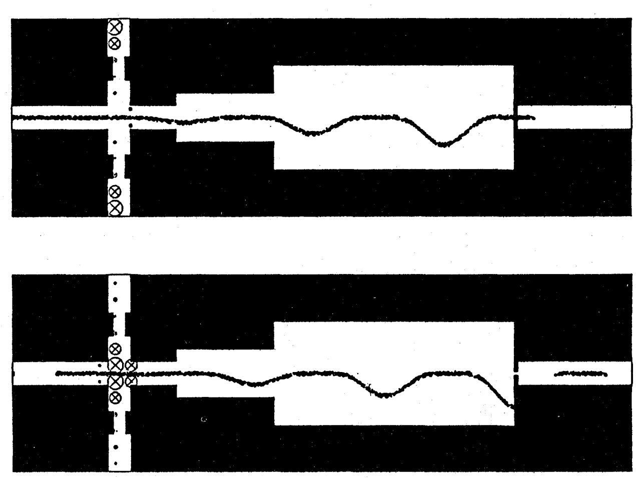

Fig. 8, Chopper system simulation by MAFIA

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