

A Novel Chopper System with Very Little Emittance Growth

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Abstracts

It is well known that a RF chopper system can remove a part of unusable beam in a RF period with penalty of emittance growth. The important thing is how to reduce its emittance growth. A new idea is that the chopper cavity does not add or adds very small transverse momentum to the part of the beam passing through the chopper slit. The key point of this idea and the simulation results by MAFIA TS3 code are mentioned in this presentation. The test chopper cavity is under construction with this concept.

1. INTRODUCTION

In the low energy electron linac, even though using a prebuncher and buncher most particles can be bunched into narrow phase, there are some particles like a tail that will bring about some troubles to increase beam loading, increase energy spread and decrease BBU start current. The chopper system can cut the tail to improve the beam characteristics. But it will add transverse momentum to make emittance grow up.

The important thing is how to make the chopping system very little emittance growth. For basic chopping system it consists of a RF chopping cavity and a slit showed on Fig 1. The rectangular cavity with TM_{210} mode is usually used for the chopping cavity. The beam bunch-length depends on the RF power into the cavity, width of the slit and distance between the cavity and slit. This system has two disadvantages: one is very large transverse momentums added to the beam; other is one RF period having two beam bunches.

If a DC magnetic bias [1,2] is added on the cavity range, there is only one beam bunch in one

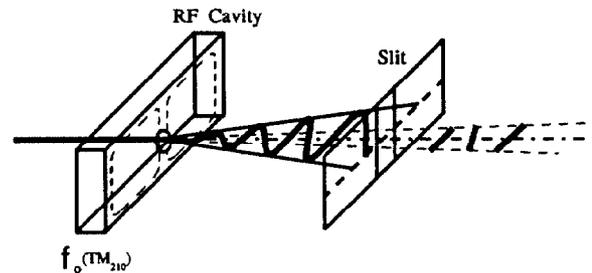


Fig. 1, Basic chopper system

RF period, and beam transverse momentums added to beam become small. It shows on Fig.2. But it is not enough small for low emittance accelerator yet.

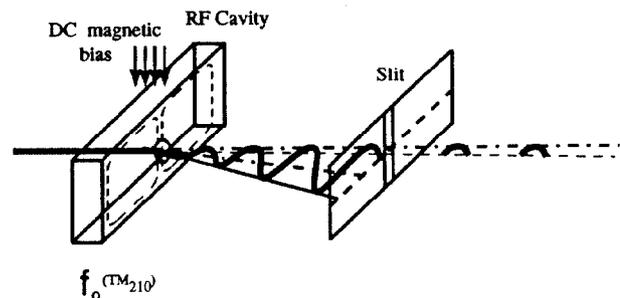


Fig. 2, Chopper with DC magnetic bias system

Some laboratories [3,4] use two RF cavities with a slit and a solenoid system shown on Fig.3. 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 the 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.

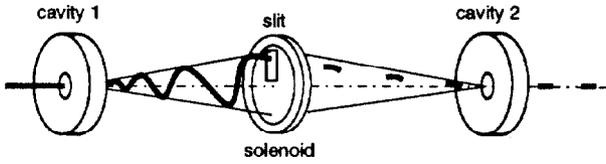


Fig. 3, Double cavity chopper system

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 the beam transporting a distance.

2. NOVEL IDEA

A novel idea is that when the beam passes through a chopper cavity, the cavity does not add (in ideal case) or adds a 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 on the chopper slit. It means that the fields in the chopper cavity are zero when a part of beam passes through the chopper slit, so this part of beam will pass through the chopper slit without any additional transverse momentum from the cavity; but there is a deflecting field in the cavity when the remainder part of beam during one RF period passes through the cavity, and the remainder part of beam will stop at the chopper slit. It is showed on Fig.4.

The key point of this new idea is how to generate above-mentioned field.

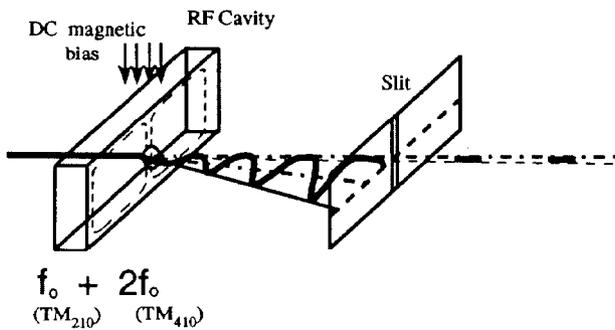


Fig. 4, A novel chopper system

3. SPECIAL CAVITY

Fig.5 shows a composed magnetic field (B_T) added by three magnetic fields that are a RF magnetic field with the fundamental frequency (B_{f_0}), a RF magnetic field with the 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 amplitude and phase of each field, the length of flat part can be changed.

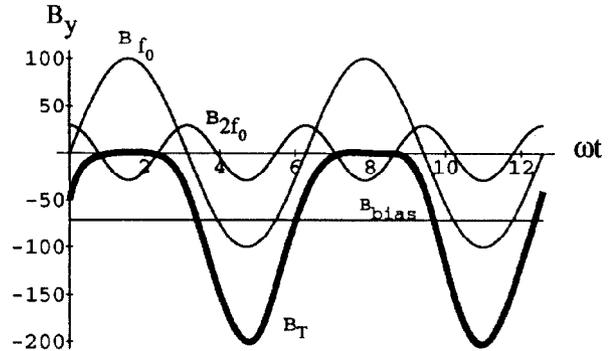


Fig. 5, Magnetic fields in the chopper cavity

In the rectangular cavity if one chooses TM_{210} mode for the chopper 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.6 shows the magnetic fields of the TM_{110} mode, TM_{210} mode, TM_{410} mode and TM_{420} mode in the cavity. The beam hole is located at the cavity center.

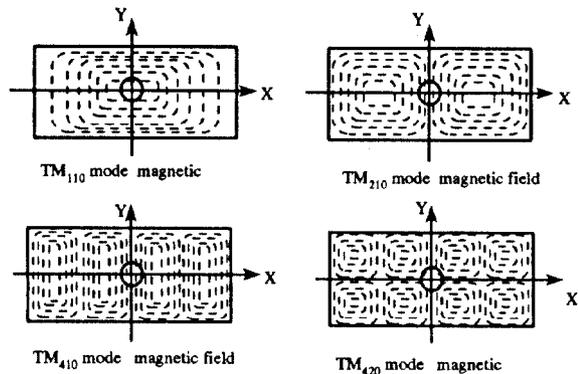


Fig. 6, Magnetic fields of the TM_{110} mode, TM_{210} mode, TM_{410} mode, and TM_{420} mode

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. Table 1 lists the results of calculation by MAFIA. There are frequency, Q value, store energy, power loss and magnetic field of each mode. Fig.7 shows the magnetic fields of the TM_{210} mode and the TM_{410} mode 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 *
.....
mode  f(GHz)  Q  energy(J)  loss(W)  By(Tesla)
.....
1  TM110  0.837531626  9689  6.002060112E-16  3.259610915E-10
2  TM210  1.248342084  12247  3.665386054E-16  2.349247186E-10  1.1073E-09
3
4
5
6  TM410  2.497986794  16392  1.393084383E-15  1.333810062E-09  -2.1576E-09
7
8
9
10  3.116830826  19071  1.151081412E-15  1.181979292E-09
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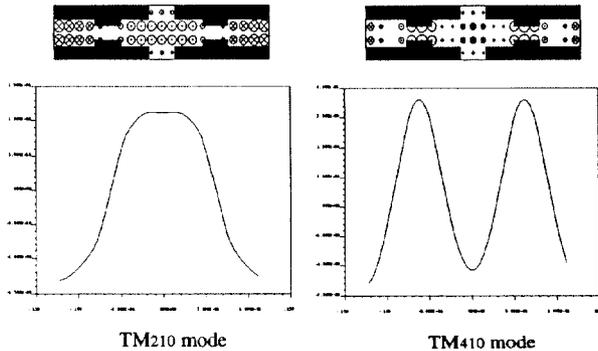


Fig. 7, Magnetic fields in the cavity calculated by MAFIA

4. 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 $dd = 40mm$, the 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, $BTM_{210} = 25$ gauss, one of the TM_{410} mode, $BTM_{410} = 9.755$ gauss and DC bias magnetic field $B_{bias} = 15.25$ gauss on the beam center line. The chopper system is shown on Fig.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.

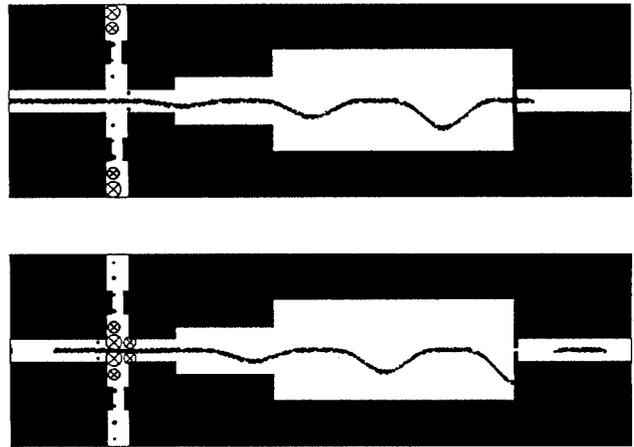


Fig. 8, Chopper system simulation by MAFIA

5. REFERENCES

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