CHOPPER FOR INTENSE PROTON BEAMS AT REPETITION RATES UP TO 250 kHz*

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Abstract

A chopper system for high intensity proton beams of up to 200 mA and with repetition rates of up to 250 kHz is under development at IAP to be tested and applied at the Frankfurt Neutron Source FRANZ.

A Wien filter-type E×B configuration consisting of a magnetic deflector field and a pulsed electric compensation field perpendicular to the B-Field and the ion velocity is described. Field calculations and beam transport simulations through the chopper are presented.

A high voltage pulse generator will be used to produce the electric field required to compensate the magnetic deflection. Preliminary results for serial and parallel transistor arrays are discussed.

DESIGN OF CHOPPER SYSTEM

Introduction

The chopper system will be installed in the Low Energy Beam Transport (LEBT) section of the Frankfurt Neutron Source FRANZ [1,2]. A scheme of the neutron generator is depicted in Fig. 1.

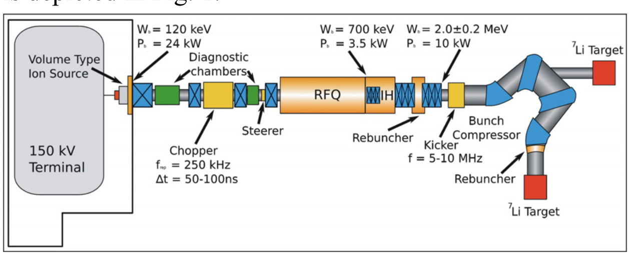

Figure 1: Scheme of the Frankfurt Neutron Source FRANZ.

The chopper will produce 50 to 100 ns pulses by deflecting the beam while maintaining a straight trajectory only for the pulsed beam transported to the RFQ.

E×B Chopper System

Magnetic and electric kicker systems were studied [3]. A magnetic kicker with high repetition rate would entail high power consumption. The field energy required to deflect a 120 keV proton beam with a magnetic kicker is three orders of magnitude higher compared to an electric kicker. The disadvantage of electric deflection systems, especially in combination with intense ion beams, is their risk of high voltage breakdowns caused by beam losses.

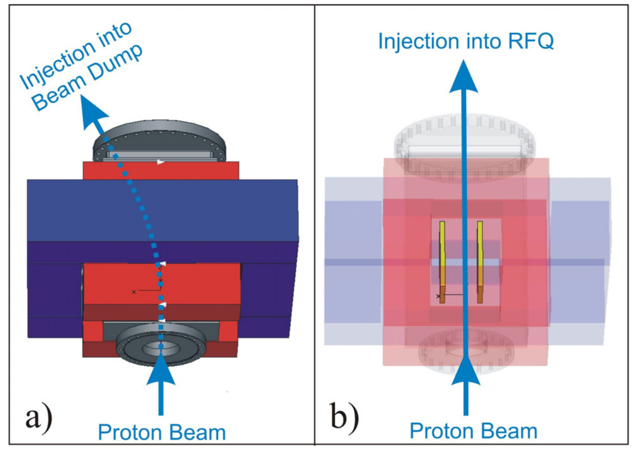

Figure 2: E×B chopper system: The static magnetic deflection (a) is compensated during a short pulse by an electric field between deflector plates inside the dipole gap (b).

Therefore a chopper system with a Wien filter-type E×B configuration [4,5] is being developed (Fig. 2). A static magnetic dipole field will transport the beam to a septum magnet and further to the beam dump. Deflector plates located within the dipole gap will create an electric field to compensate the magnetic deflection during a short 100 ns pulse. The low duty cycle for the electric field minimizes the risk of high voltage breakdowns. A possible layout is shown in Fig. 3 and the main chopper parameters are given in table 1.

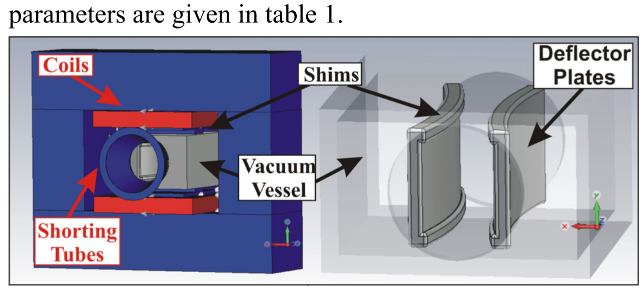

Figure 3: Magnetic dipole and electric deflector layout.

Table 1: Chopper parameters

Magnetic Dipole	Deflector Plates
B_{max} = 60 mT	E_{max} = 300 kV/m
l_{dipole} = 15 cm	l_{defl} = 15 cm
h_{gap} = 13 cm	d_{gap} = 3-5 cm
Θ_{mag} = 6000 ampere-turns	V_{gap} = 9 kV

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Field Calculations

The beam can pass the chopper without deflection, if the Wien condition is satisfied along the system:

$$\int \vec{F}_{defl}\ dz = \int q \cdot (\vec{E} + \vec{v}_p \times \vec{B})\ dz = 0 \quad (1)$$

But a local mismatch between both fields can still lead to a transverse offset. This effect will be minimized by installing shims and shorting tubes at the dipole while the electric deflector will utilize curved plates and shims. The calculated deflecting forces for on-axis particles travelling in longitudinal direction are presented in Fig. 4. Electric and magnetic fields were computed using CST EMS [6].

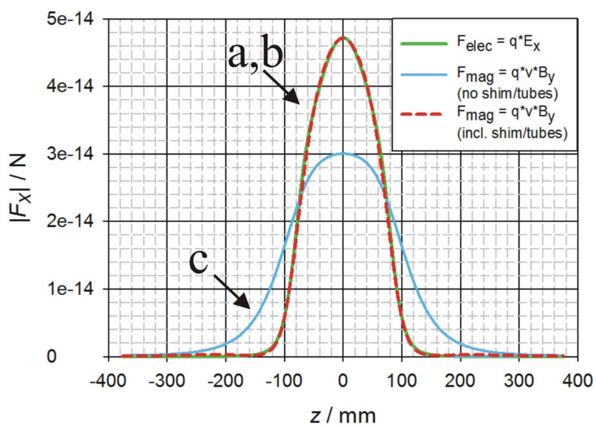

Figure 4: Calculated deflecting forces for on-axis particles (Curve a,b: matched case, c: without shimming).

PIC-SIMULATIONS

The transport of a 120 keV, 150 mA proton beam through the chopper system was simulated using a Particle-in-Cell (PIC)-Code developed at IAP. The field data was imported from CST EMS. The input distribution is reproduced in Fig. 5.

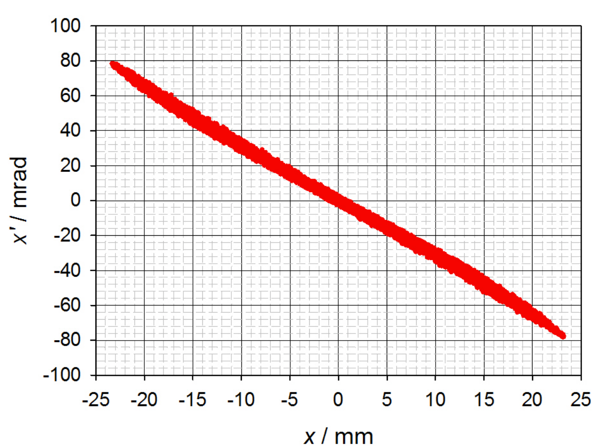

Figure 5: Chopper input distribution.

The magnetic dipole field leads to a deflection of 10 degrees which is in full agreement with the analytical calculations. When the electric field is used to compensate the magnetic force, the beam maintains its straight trajectory.

The output distribution of the chopper in the horizontal plane is shown in Fig. 6. No significant angular or transverse offset is observed in the simulations.

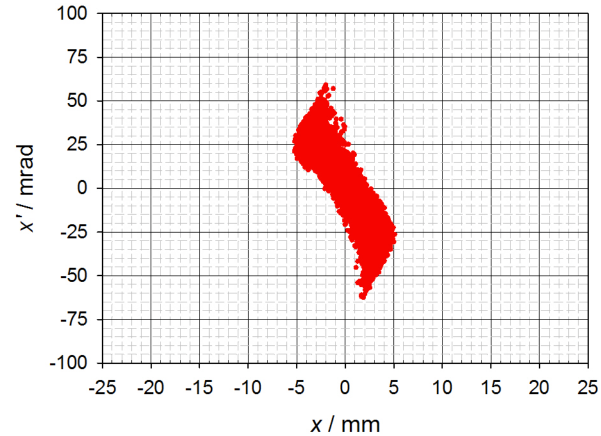

Figure 6: Chopper output distribution.

DRIVER FOR FAST KICKER

A high voltage pulse generator will produce the electric field required to compensate the magnetic deflection. It will employ fast transistor technology in the primary circuit, while at the secondary circuit the high voltage is provided around a transformer core. A pulse repetition rate of 250 kHz and a flat top duration of 50 to 100 ns is needed.

Different setups are currently being tested. Pulses of 15 kV had been achieved with a first setup using a nanocrystalline tape wound core from *Hitachi Metals* (Fig. 7) and two IGBTs from *Toshiba* in push-pull configuration [7]. The repetition rate was limited to 10 kHz due to the switch behaviour and high power deposition.

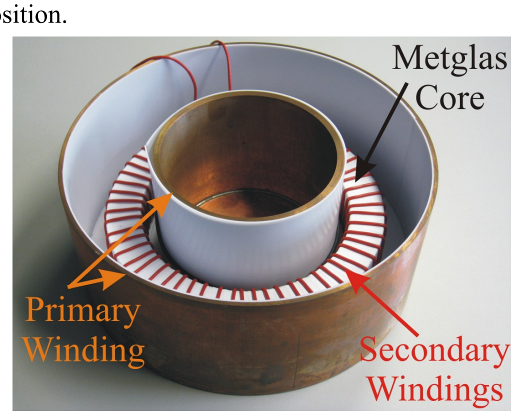

Figure 7: Nanocrystalline Tape Wound Transformer Core.

A switch array for higher repetition rates using the same transformer core is shown in Fig. 8. Four times ten MOSFET power transistors are installed in a coaxial setup where a copper vessel acts as primary winding. Four parallel MOSFET power transistors are applied to distribute the current in the switches as well as the magnetomotive force in the transformer core. Ten arrays of four switches are triggered consecutively to lower the individual repetition rate for each transistor. Pulses of 5 kV with a global repetition rate of 250 kHz could be measured. Post-pulse oscillations due to parasitic capacitance were observed.

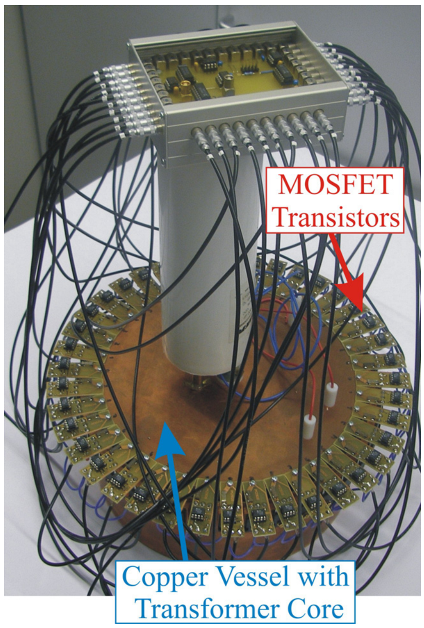

Figure 8: Parallel transistor array for fast kicker.

An alternative option is the stacking of smaller transformer cores. A possible pulse for the first stacking stage realized with a transformer core from *Thomson* is reproduced in Fig. 9. A pulse amplitude of 1.3 kV can be achieved with a repetition rate of more than 250 kHz.

Figure 9: Pulse with 1.3 kV at 260 kHz repetition rate for first stacking stage.

CONCLUSION

An E×B chopper system will be constructed in the LEBT section. In a Wien filter-type configuration the static magnetic deflection will be compensated during a short 100 ns pulse by an electric field. An E×B chopper combines the higher reliability of a magnetic deflector with the lower power consumption of an electric kicker. Additionally, the filter properties might be used to purify the proton beam by separating the remaining H_2^+- and H_3^+-fractions.

At the dipole and the deflector plates shims and shorting tubes will be installed to ensure the local matching of the electric and magnetic deflection forces and minimize the transverse offset downstream of the chopper system. Particle transport simulations through the chopper system show no significant angular or transverse offset of the pulsed beam.

Different setups for the high voltage pulse generator (250 kHz, 100 ns) are being tested. They are based on fast transistor technology in the primary circuit, while the high voltage is provided at the secondary circuit around a transformer core. A parallel array of four times ten MOSFET switches in coaxial geometry shows encouraging results with respect to amplitude and repetition rate. Undesired post-pulse oscillations have to be reduced. A serial array of more compact transformer cores is also being studied. Experimental results for the first stacking stage are promising.

ACKNOWLEDGEMENTS

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