The ELETTRA fast magnets

D.Tommasini
Sincrotrone Trieste,Padriciano 99,34012 Trieste,Italy

Abstract

The design of the fast magnets to be used to inject the electron beam into the 2 GeV storage ring Elettra is presented and discussed. Injection makes use of two types of fast magnets: the septa and the kickers. There are two identical septa magnets of the so called "eddy current" type, which will be housed in a vacuum tank. The orbit bump is generated by four identical kicker magnets symmetrically placed around the mid-point of a single straight section: they will be in air with an internal vacuum chamber. Extensive electric and magnetic tests have been performed on prototypes, and the relevant results are presented and discussed.

1. INTRODUCTION

The Elettra electron storage ring will be filled at the energy of 2 GeV from its linear accelerator. Injection takes place in the horizontal plane of the machine, in a single straight section. The injection system consists in two septum magnets and four kicker magnets. The septa are used to deflect the electron beam coming from the transfer line into a direction which is parallel to that of the stored beam. Two identical septa will be housed in a vacuum tank, where the storage ring vacuum pressure has to be maintained (Figure 1).

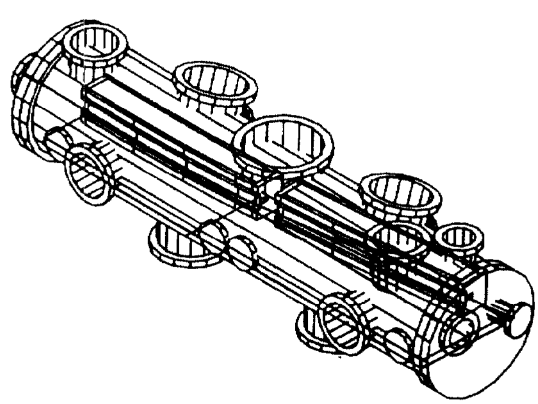

Figure 1. Septum magnet vacuum tank

The four kickers are symmetrically placed around the mid-point of a single straight section (Figure 2): this solution allows us to have four identical magnets. They are in air, with an internal vacuum chamber. The vacuum chamber (Figure 3) will be made of ceramic, in order to let the magnetic field produced by the kickers pass through the wall of the vacuum chamber. The inside of the chamber will be coated with a metallic material, in order to provide a conducting path for the wall currents.

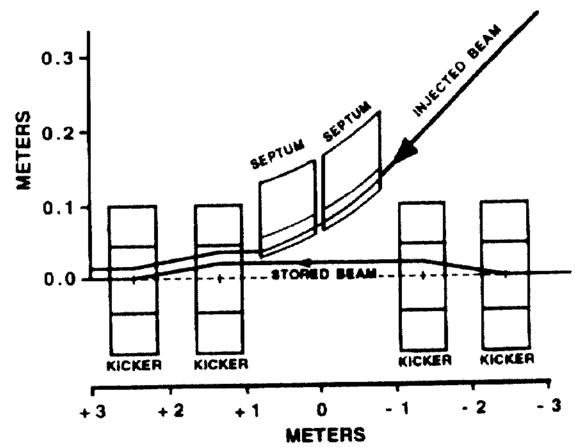

Figure 2. Layout of storage ring injection

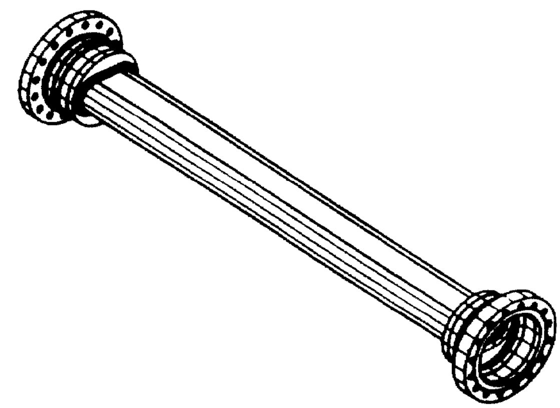

Figure 3. Ceramic vacuum chamber

2. SEPTUM MAGNETS

The septum magnets main requirements are shown in Table 1. As these magnets must produce a pulsed high peak magnetic field, the magnetic core must be made of thin silicon iron laminations in order to maintain the magnetic field value in each lamination below saturation. Theoretical calculations [1], taking into account the behavior of the pulsed magnetic field inside the laminations, allowed us to chose commercially available 0.18 mm thick laminations. As the magnets will be put in vacuum, Carlite insulated laminations have been used. To shield the stored beam against the magnetic field produced inside the magnet, a tapered thin copper plate makes the separations between the septum magnet environment and the storage ring vacuum chamber. Eddy currents flowing in the screen are able to reduce the integrated magnetic field leakage below the maximum allowed value of 10 Gauss·m.

To produce the required current pulse a capacitor discharge like circuit has been designed (Figure 4), which makes use of an inductive recovery path able to recuperate the reverse voltage of the capacitor after the current pulse. In order to limit the electrical inductance value, therefore the applied voltage, a curved shape, following the trajectory of the beam, has been chosen for the magnet. This solution allowed us to make use of solid state devices as switches to produce the required high current fast pulse.

A detailed description of the magnets, the electric circuit and the tests which have been made on prototypes can be found elsewhere [2].

Table 1. Main parameters of the septum magnets.

Energy of the electron beam	2 GeV
Deflection	80 mrad
Magnetic length	720 mm
Peak magnetic field	0.8 T
Free aperture	30Hx15V mm
Nominal distance septum-closed orbit	25 mm
Minimum thickness of the septum sheet	2.1 mm
Magnet inductance	2.5 μH
Peak current	9.0 kA
Peak voltage	2.0 kV
Pulse duration	60 μs

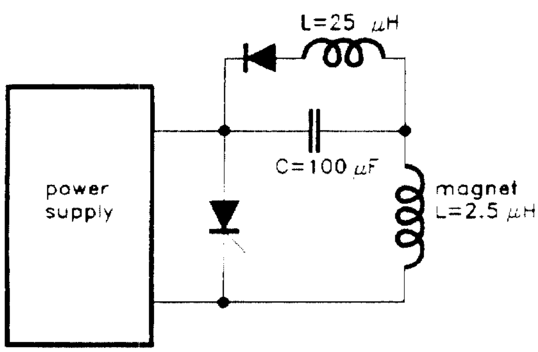

Figure 4. Septum power pulser circuit

3. KICKER MAGNETS

The kicker magnets main parameters are given in Table 2. Due to space limitations, very strong kickers are needed for Elettra. The kickers are window frame magnets, with a free window 90 mm wide and 48 mm height (Figure 5).

Table 2. Main parameters of the kicker magnets.

Energy of the electron beam	2 GeV
Deflection	22 mrad
Magnetic length	600 mm
Peak magnetic field	0.22T
Free aperture	90Hx48V mm
Magnet inductance	1.5 μH
Peak current	8.5 kA
Peak voltage	15.0 kV
Pulse duration	4 μs

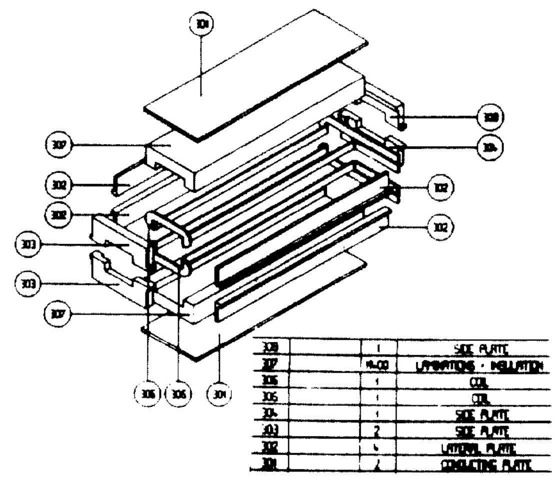

Figure 5. Kicker magnet exploded view.

The high peak magnetic field which is required is still feasible with ferrite cores, but ferrite would be close to saturation. Moreover, the need of making the magnets splittable into two parts, in order to allow the insertion of the vacuum chamber, would have forced to make an expensive construction if ferrite were used. The possibility of making a laminated magnet, even for such fast pulse, was therefore investigated. A theoretical approach showed that the required magnetic field pulse could be produced with thin enough commercially available laminations. Therefore a low cost prototype magnet making use of 0.1 mm thick oriented silicon-iron laminations was made and tested. The relevant results (Figure 6) showed the ability of such a magnet to produce the required magnetic field. To avoid the possibility of having a high remanent magnetic field when the magnet is switched off, the use of Permalloy-C instead of silicon iron was also investigated. The results obtained with a full scale magnet were very good, so the final four kickers which will be installed in the injection section will be made of such laminations.

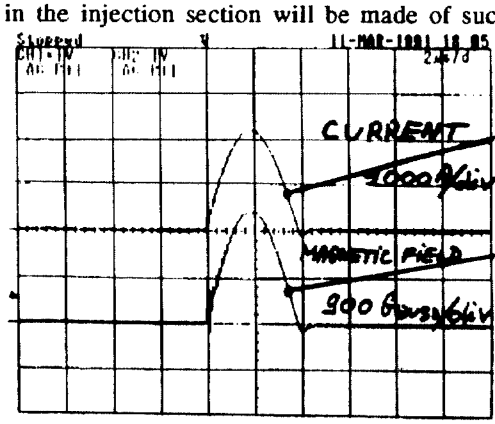

Figure 6. Current and Magnetic field waveform produced by the kicker prototype, the current was measured with a fast transformer, the magnetic field by integration of the induced voltage in a 31x31 mm rectangular coil. The waveforms were taken with a digital oscilloscope.

As the magnets are in air, a critical part of the design was the electrical insulation of the coil. According to the experience of CERN [3], a reasonable compromise combining good processing and operational properties with sufficiently high radiation resistance can obtained with a standard epoxy resin type bisphenol A (Araldit F) with anhydride hardener and amine-substituded phenol-type accelerator. A fiber-glass taped coil, impregnated under vacuum with such a resin, showed the ability to sustain a 25 kV D.C. voltage applied for 5 minutes, which was fixed as our acceptance test for the coils. The isolation between the laminations was obtained by means of the same resin compound.

The kickers are supplied by a capacitor discharge-like circuit. The very high current to be produced represents one of the most hard challenges in this activity, and a detailed study of this problem can be found elsewhere [4].

4. CERAMIC VACUUM CHAMBER

Due to the pulsed magnetic field, the vacuum chamber which will be installed inside the kickers will be made of ceramic. According to the experience of LEP [5], a 97.5% Al_2O_3 grade was chosen. A covar ring will be braised directly to the ceramic, then two small bellows and the stainless steel flanges will complete the assembly. The small bellows are required to prevent the break of the ceramic during mounting, while bigger bellows have been foreseen in the injection section for linear dilatations during the bake-out.

The inside of the ceramic will be metallized with a 3μm thick layer of titanium. Titanium was chosen for its very good reactivity and adhesion with ceramic. The thickness of the layer was chosen after a detailed study of the beam effects on the metal+ceramic system [6].

5. CONCLUSIONS

The prototypes of all types of magnets which are required for the injection of the 2 GeV electron beam into the storage ring Elettra have been constructed and tested. All magnets will be made of iron laminations and will be supplied by means of capacitor discharge-like circuits.

The final construction of the septa magnets will be made within September 1992 in our workshops.

The final version of the four kicker magnets will be ready in Trieste by the end of July.

The delivery of the ceramic vacuum chambers with the internal metallisation is foreseen within the end of 1992.

Extensive routine long term tests will start in September; the injection system will be ready for installation within March 1992.

6. ACKNOWLEDGEMENTS

The support of dr.M.Giannini for the mechanical design of the injection system was of primary importance. The construction of the first kicker prototype was supervised by dr.A.Fabris.

7. REFERENCES

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