Injection into the Elettra Storage Ring

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Abstract

The Elettra storage ring will be filled with a 2 GeV electron beam from its full energy linear accelerator. Two pulsed septum magnets will be housed in a vacuum tank and four identical fast kicker magnets in air, with an internal ceramic vacuum chamber, will be symmetrically placed around the mid-point of a single straight section. The layout of the injection section, the design of the main individual components, their manufacture and the results of the relevant test are presented and discussed.

I. INTRODUCTION

The design of the layout of Storage Ring Injection has been already described and discussed in a previous paper [1]. All the injection components are now constructed, tested and installed in the storage ring. The injection elements (Figure 1) consist in:

-a vacuum tank housing two septum magnets;
-four kicker magnets symmetrically placed around the mid-point of a single straight section
-four ceramic tubes as vacuum chamber for the kickers;
-the power pulsers for the kickers and the septa.

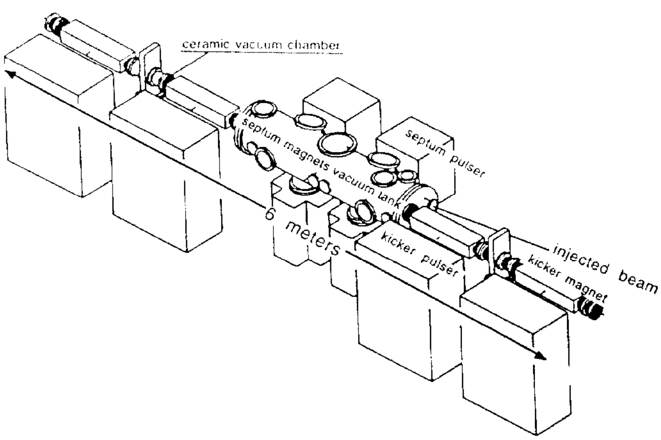

Figure 1. Layout of Storage Ring Injection.

II. KICKERS

A. Magnet

The kickers (Table 1) are window frame magnets, with a free window 90 mm wide and 48 mm high (Figure 2). The magnetic core is made by 0.1 mm thick laminations, which are able to provide the required 0.22T peak, 5 μs duration, half sine wave pulsed magnetic field with a repetition rate of 10 pps.

TABLE 1. Main parameters of the kicker magnets.

Energy of the electron beam	2 GeV
Deflection	22 mrad
Peak magnetic field	600 mm
Magnet inductance	1.5 μH
Peak current	8.5 kA
Peak voltage	15 kV
Pulse duration	5 μs

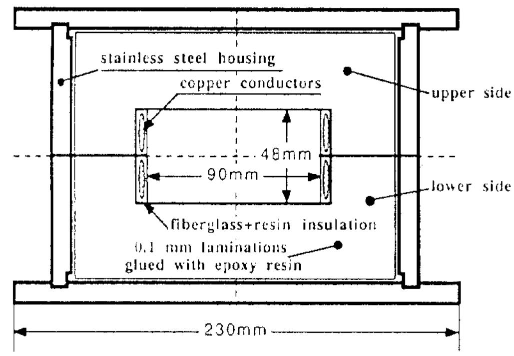

Figure 2. Kicker magnet cross section.

The magnet is splittable into two parts to allow the insertion of the ceramic vacuum chamber. The coil is made by two half coils connected in parallel, the insulation is a fiber glass tape impregnated under vacuum with a standard epoxy resin type bisphenol A (Araldit F) with anhydride hardener and amine-substituted phenol-type accelerator.

The kicker support (Figure 3) is made to position and fix two adjacent magnets, with the possibility of lowering the bottom side of the support for the ceramic vacuum chamber bake out.

Figure 3. Half kicker magnets on the support.

B. The pulse power circuit.

The pulse circuit [Figure 4] is of the capacitor discharge type, with a resistive recovery path. The capacitor is charged to the peak voltage, then the thyratron is fired when the pulse is required and the anode voltage falls to its conduction value. In order to keep the negative anode voltage after the forward conduction at the lowest possible value the recovery resistance has been carefully chosen. The reverse arcing, in the thyratron which is still highly ionized due to the very high peak current pulse, causes circuit ringing [2] and, due to the evaporation of the cathode emissive coating, causes severe damage to the electrodes surface [3], thus shortening the lifetime of the tube.

The use of a low value recovery resistor resulted in a smoothing of the current pulse (Figure 5), limiting the negative anode voltage after conduction below 1000 V.

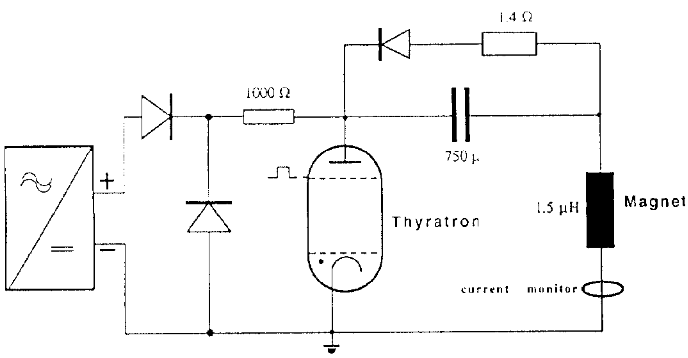

Figure 4. Kicker magnet power pulse circuit.

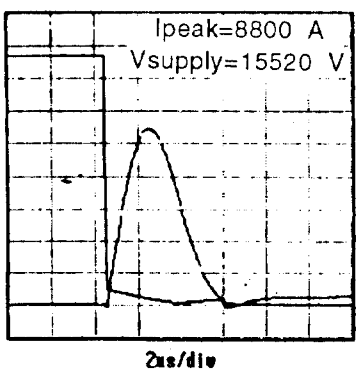

Figure 5. Anode voltage-current waveforms.

The pulsers are placed close to the magnets to minimize the total discharge circuit inductance. The thyratron filaments are supplied by two step-down transformers housed in a metallic box which acts also as a support and a forced air cooling system for the thyratron itself (Figure 6). All the main control and monitoring electronics are placed in the service area, behind the concrete shielding blocks where people is allowed to access for maintenance during the operation of the machine. The trigger grid signals are then transmitted with a coaxial cable from the service area directly to the thyratron.

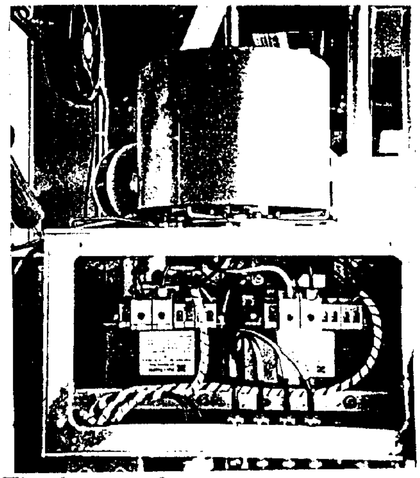

Figure 6. The thyratron box.

C. Test results.

Extensive tests have been made on the pulser [4], to verify the ability to operate at 10 pps without fault fires and with an acceptable lifetime. More than 2 million pulses have been fired up to now in a well monitored prototype pulser with excellent results and without any significant degradation of the thyratron.

The behaviour of the laminated magnetic core of the kickers was also first verified with a 200 mm long prototype, supplied by a 3 μs duration half sine-wave pulse; then all the four series magnets have been tested to measure the magnetic field inside the magnets and the linearity current-magnetic field. The behaviour of the magnetic field along the longitudinal axis is shown in Figure 6.

The residual magnetic field was also measured along the magnetic axis, an integrated value of 9.6 Gauss·meter was obtained after having supplied the magnet at the maximum peak current for several pulses. The same integral was obtained for the four different magnets, resulting in a negligible total integrated magnetic field for the four magnets when operating in the straight section.

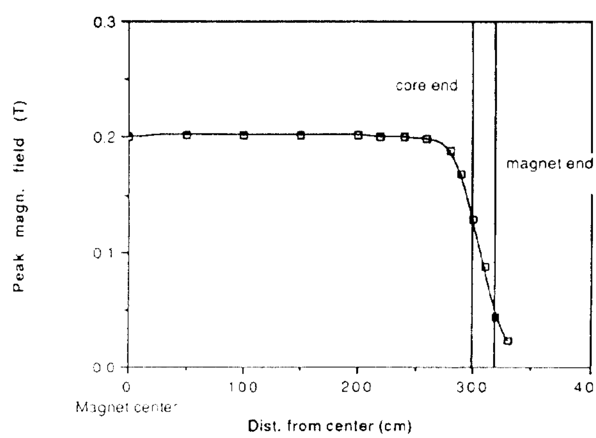

Figure 6. Behaviour of the magnetic field along the longitudinal magnet axis.

D. Ceramic Vacuum chamber

The vacuum chamber inside the kicker magnets (Figure 7) is made of ceramic in order to let the pulsed magnetic field pass through the wall of the chamber. The inside of the chamber is coated with a 3 μm thick titanium layer to provide a conducting path for the image charges [5]. As most of the image currents flow close to the beam in the centre of the chamber, it was possible to decrease up to 1.5 μm the thickness of the coating in the curved parts of the vacuum tube. Titanium was chosen for its very good reactivity and adhesion with ceramic, due to chemical bounds to the silicon phase of the alumina [6].The vacuum chamber is a monolithic tube 710 mm long with a minimum thickness of 3.5 mm, maximum 5.0 mm, 72 mm wide and 34 mm high. To achieve the highest mechanical strength the chamber was isostatically pressed. The external surface was grinded and the inside was fired at the final roughness of 0.8 μm. The ceramic tube was braised to a covar ring, then welded to a stainless steel bellow and to a CF flange. The continuity of the vacuum chamber shape between the ceramic side and the stainless steel side through the bellow was obtained by inserting RF contacts (Figure 8).

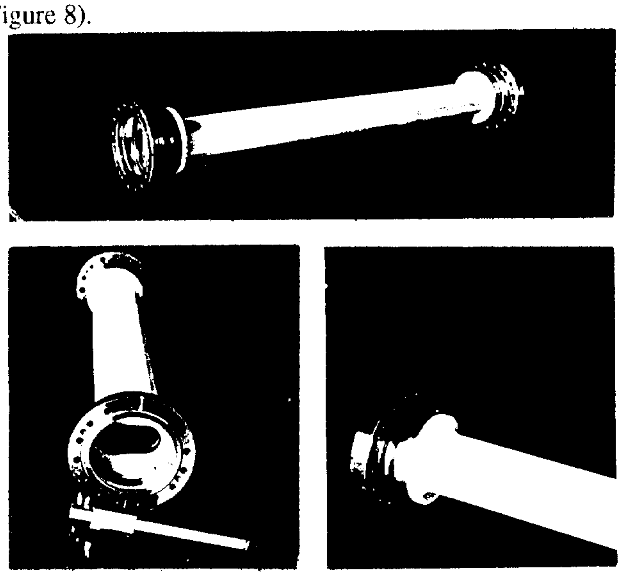

Figure 7. The ceramic vacuum chamber.

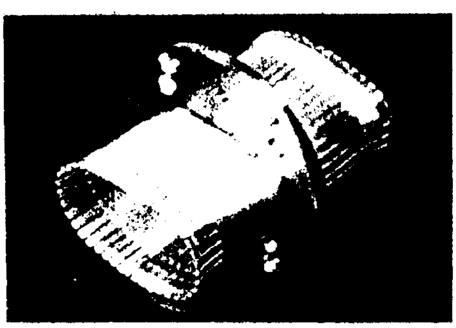

Figure 8. The RF contacts.

III. SEPTA AND VACUUM TANK

A detailed description of the injection vacuum chamber (Figure 9) and of the two septum magnets can be found elsewhere [7].

The chamber allows the primary storage ring pressure of 10^{-9} torr to be maintained and the septum magnets to be individually displaced to optimize the injection precess.

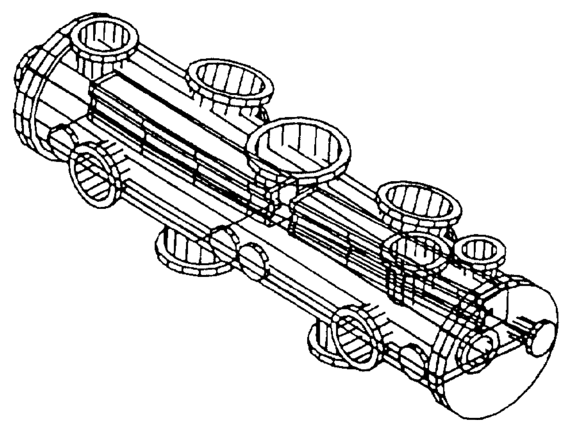

Figure 9. Septum magnets vacuum chamber.

The septa are two laminated 760 mm long magnets with a curved shape to keep the inductance at acceptable values.

The magnets are of the eddy current type, i.e. the septum screen acts against the magnetic field leakage thank to the rapid variation of the pulsed magnetic field which is produced by discharging a capacitor into the magnet coil. The magnets are cooled by copper straps connected to the vacuum tank, then externally water cooled.

IV. REFERENCES

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