The Septum Magnets System of Elettra

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Abstract

Two septum magnets are used to deflect the 2 GeV electron beam coming from the transfer line into a trajectory which is parallel to that of the beam circulating in the storage ring Elettra. The septum magnets will be housed in a UHV vacuum tank, thus avoiding a physical separation between the transfer line and the storage ring vacuum systems. In order to obtain a high injection efficiency, the two magnets will be individually supplied with a high peak pulsed current and their positions can be individually adjusted with an external mechanical system. The design of the whole system, the manufacture and the results of the relevant tests are presented and discussed.

I. THE SEPTUM MAGNETS

The septum magnets main requirements are shown in Table 1. The pulsed high peak magnetic field is produced with a magnetic core made of thin silicon iron laminations. Commercially available 0.18 mm thick laminations have been chosen in order to keep the magnetic field value inside each lamination below saturation .

TABLE 1. Main parameters of the septum magnets

Energy of the electron beam	2 GeV
Deflection	80 mrad
Magnetic length	720 mm
Physical length	760 mm
Peak magnetic field	0.76 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	1.8 kV
Pulse duration	60 μs

To shield the stored beam against the magnetic field produced inside the magnet, a tapered thick copper plate makes the separation between the septum magnet environment and the storage ring vacuum chamber (Figure 1). Eddy currents flowing in the screen are able to reduce the integrated magnetic field below the maximum allowed value of 15 Gauss·m.

Due to the vacuum environment, no glue was used for the laminations: therefore oxide isolated laminations have been assembled in a stainless steel housing. All the components have been designed with UHV criteria to avoid any trapped air and to allow the gas between the laminations to be extracted from the magnet. The coil is made by a parallel of three OFHC copper conductors with ceramic spacers. The magnet has a curved shape with a total length of 760 mm (Figure 2) to keep the inductance at the lowest value.

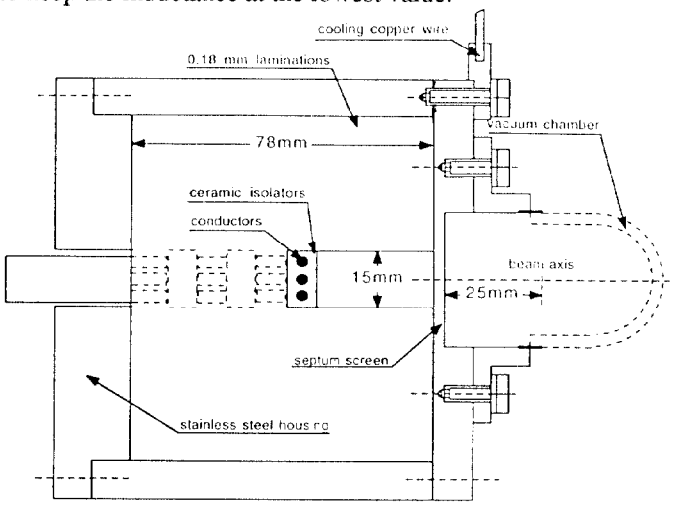

Figure 1. Septum magnet cross section.

The specific degassing rate was measured with a 100 mm long prototype according to PNEUROP specifications. The tests result was:

$$q=6\cdot10 \text{ mbar}\cdot\text{l/sec}\cdot\text{cm}^2$$

The following assembling procedure has been adopted for the magnets:

-US cleaning of all the components and the assembling tools.
-Assembly in clean room, with a grinded tool.
-300 °C bake out in a vacuum oven.
-Dry N_2 protection in an envelope.

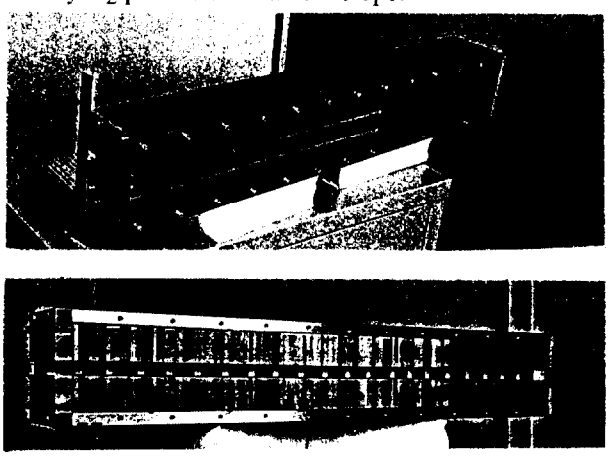

Figure 2. The septum magnet with and without the copper shield.

II. POWER CIRCUIT.

The septum magnets are powered by two independent pulsed circuits, providing a high peak half sine wave current. The circuits (Figure 3) are of the capacitor discharge type, the capacitor bank is made of 20 metallized polypropylene capacitors, 5 μF capacitance each, rated for 2400 VDC. The switch is a fast turn off power thyristor. A recovery of energy is provided by an inductance ten times higher than that of the magnet. The recovery diode and the thyristor have been snubbed, in order to limit the reverse voltage which appears during the turn off (Figure 4). This configuration was tested for several million pulses at a repetition rate of 10 pps with a supply voltage of 1800V and a corresponding peak current of 9000 A.

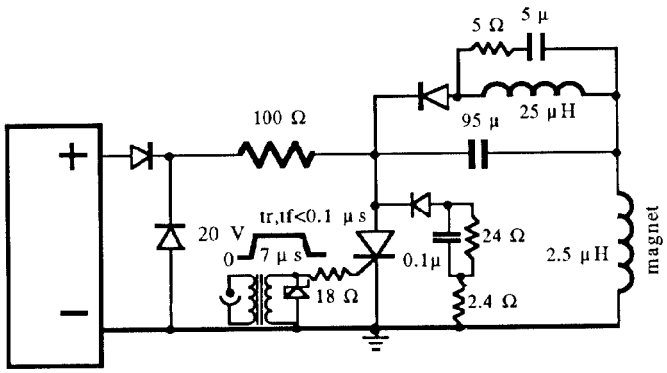

Figure 3. Power pulse circuit

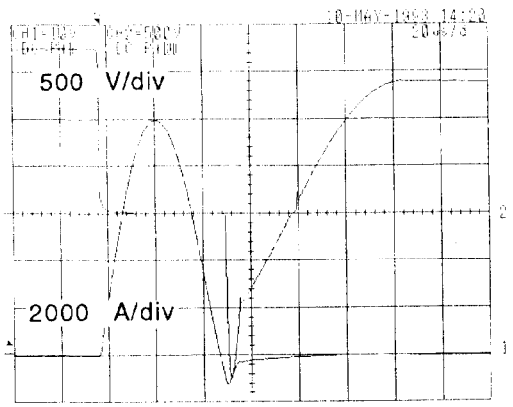

Figure 4. Thyristor voltage and current waveforms.

III. THE VACUUM TANK

The main tasks of the vacuum tank (Figure 6) are:
-to maintain the primary pressure of the Storage Ring;
-to keep the electrical continuity of the vacuum chamber of the Storage Ring: an internal chamber is connected to the side bellows through electrical contacts avoiding sharp variations for beam impedance reasons.
-to allow independent radial adjustment (15 mm) of the two septa (Figure 5);
-to cool the magnets;
-to supply the magnets.

The total amount of losses can strongly be related to the injection efficiency, therefore the magnets are cooled from the copper screen to the upper flange of the vacuum tank through short copper straps. A hollow tube for water cooling from the external side of the vacuum tank (Figure 7) is then fixed to the flange.

The vacuum system is made by:
-one prevacuum turbomolecular oil free pump (500 l/sec);
-two SIP 960 l/sec each;
-two NEG modules 1000 l/sec each;

The "in situ" vacuum procedure will be the following:
a)prevacuum
b)200°C bake out
c)SIP activation
d)NEG activation.

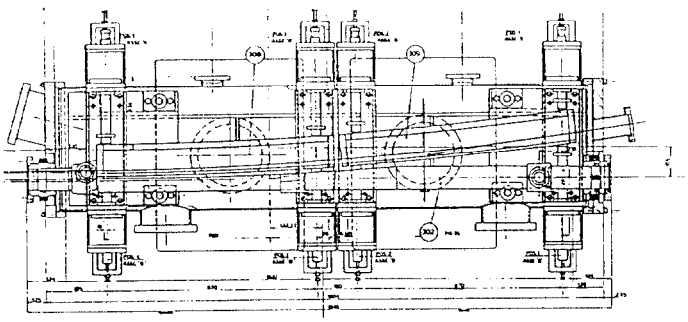

Figure 5. Layout of the septa inside the vacuum tank

Figure 6. The septum magnets vacuum tank.

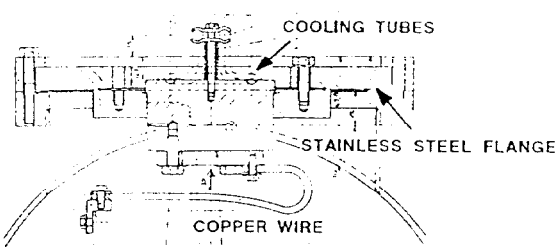

Figure 7. The septum magnets cooling system.

IV. MAGNETIC TEST RESULTS

The linearity of the peak magnetic field versus the peak supply current has been measured by integrating the signal from a coil probe. The results show a perfect linearity within the accuracy of the measurement system (a digital oscilloscope + some electronics) up to the highest field values (Figure 8).

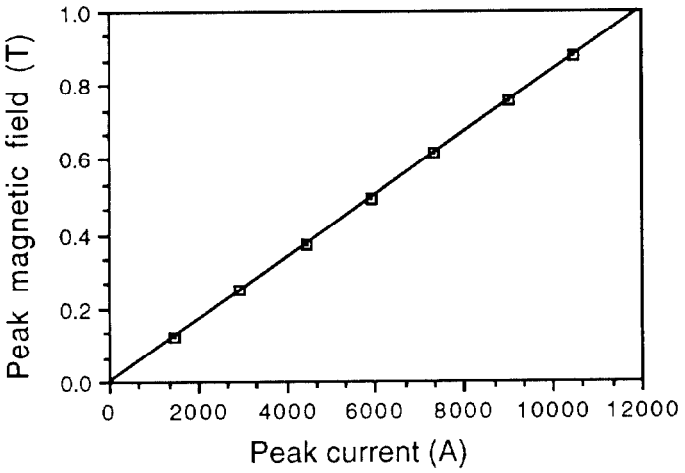

Figure 8. Peak magnetic field vs. peak current.

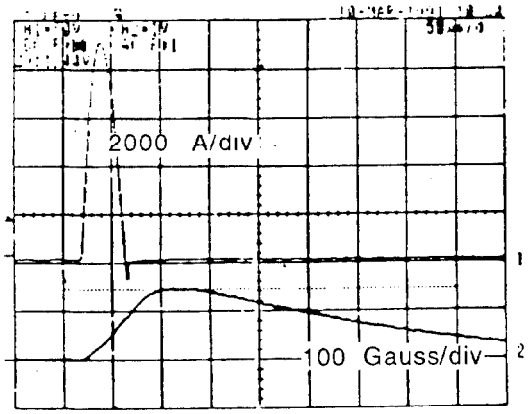

Figure 9. Magnetic field 2 mm far from the septum screen.

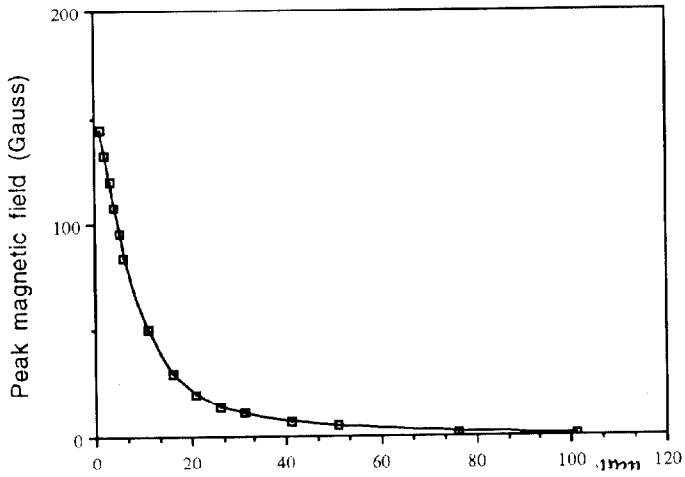

Figure 10. Peak magnetic field vs. distance from the septum.

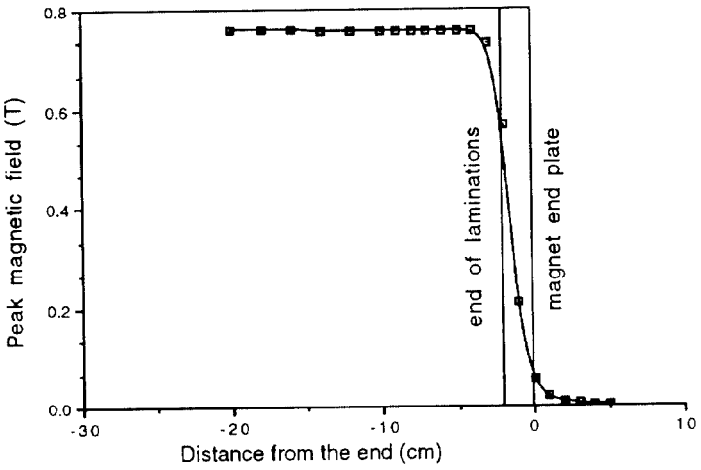

Figure 11. Peak magnetic field along the longitudinal axis.

The behaviour of the magnetic field outside the septum screen at the 2.1 mm thickness location has also been measured (Figure 9 and Figure 10). The longitudinal scan of the peak magnetic field is shown in Figure 11.

V. CONCLUSIONS

The septum magnets that have been installed in the 1.5-2.0 GeV Light Source Elettra presently under construction in Trieste have been described. The magnets will operate in vacuum without direct water cooling, the magnetic field leakage is kept below 15 Gauss·m by using an eddy current screen. The vacuum system has been designed to maintain inside the septa vacuum tank the primary pressure of the Storage Ring, in the range 10^{-9}-10^{-10} torr.

The magnets have been completely constructed and assembled in house, the vacuum chamber was delivered by RIAL (Parma, Italy).