

PULSED MAGNETS FOR INJECTION AND EXTRACTION AT LSB*

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ABSTRACT

A synchrotron light source is being designed in Barcelona. The injection to the booster at 0.1 GeV is made with a septum-kicker ensemble as well as the extraction from the booster at 2.5 GeV . The injection to the storage ring requires two septum magnets and four fast bumper magnets[1]. The septum magnets (0.85 m of magnetic length) are eddy current type, they are water cooled and they are placed inside a vacuum vessel. The yoke will be made of 4% silicon-iron laminations. They are excited with a $50 \mu\text{s}$ half sine wave. The kicker magnets (0.4 m of length) in the booster are window frame type with a ferrite core. The vacuum chamber made of ceramic is placed inside the window. The excitation current has a flat top of 100 ns and a ramping time of 320 ns . The four bumpers (0.4 m of length) in the storage ring are window frame magnets with the yoke made of ferrite. The excitation current is a half sine wave of $6.62 \mu\text{s}$. All these magnets are fed with special purpose current supply circuits.

1 INTRODUCTION

At the LSB there are two septum magnets, two kicker magnets and four bumper magnets to be designed for the injection and extraction processes: one septum and one kicker for the injection to the booster, one kicker and two septa for the extraction from the booster, and two septums and four bumpers for the injection into the storage ring.

The preaccelerator provides 50 bunches, 2 ns each, every 0.1 s and the magnets have to produce a constant field the time the bunches go through. For the good performance of the injection, the maximum relative magnetic error $\Delta B/B$ has to be under 10^{-3} . Simplicity, price and reliability are the main goals to be achieved.

The magnetic simulation has been made with the finite elements code OPERA-2d[®]. Analytical models are used to estimate the heat losses and the required cooling.

The conceptual design of the magnets takes into account the circuit for pulse generation which are at present under design.

2 SEPTUM MAGNETS

A septum magnet (septum1) will be designed to transfer from the preaccelerator to the booster.

Four identical septum magnets (septum2) are designed: two for extraction from the booster and two for injection into the storage ring at both ends of the transfer line. The two septum magnets are placed one after the other in a common vacuum tank. The vacuum tank will be a stainless steel cylinder (1 m of length for septum1 and 2 m of length for the two septum2). The vacuum chamber of the ring will be inside the tank in order to keep the beam wall-currents unaffected and to keep the vacuum in the chamber unchanged. The pressure in the chamber of the storage ring will be 10^{-9} Torr while the pressure in the tank will be 10^{-8} Torr . At the point where the particles enter the storage ring both pressures are in contact through a hole of relatively high vacuum impedance.

Septum1 and 2 are eddy current type. The main parameters of both magnets are listed in table 1. We have chosen the same cross section for both magnets (septum 1 and 2) (fig.1) for simplicity and to reduce manufacturing costs.

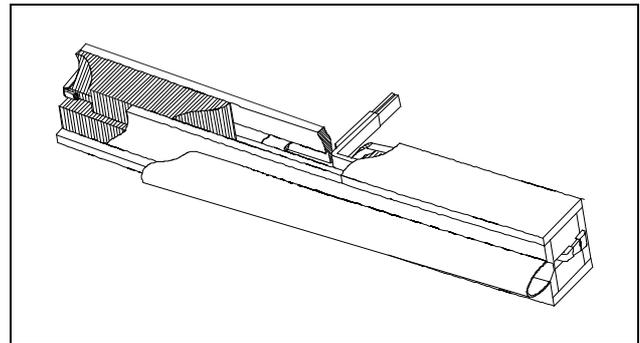


Figure 1. CAD design of the septum magnets involved in transfer processes at LSB.

The yoke will be made of 4% Si-Fe laminations 0.2 mm thick. *Carlite* will be used as isolant between laminations to preserve a good vacuum level in the tank[2]. Magnets are curved to reduce self-inductance, and with parallel end faces for ease construction.

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Table 1. Main parameters of the septum magnets at LSB.

| | Septum 1 | Septum 2 |
|-----------------------------|----------------------|----------------------|
| Beam energy [GeV] | 0.1 | 2.5 |
| Deflection [mRad] | 270 | 81.5 |
| Length [m] | 0.3 | 0.85 |
| Field [T] | 0.3 | 0.8 |
| Pulse width [μ s] | 50 | 50 |
| Septum foil thickness [mm] | 3.0 | 3.0 |
| Aperture [mm ²] | 20Hx12V | 20Hx12V |
| Self-inductance [μ H] | 0.56 | 3.53 |
| Peak current [kA] | 2.4 | 7.64 |
| Peak Voltage [kV] | 0.084 | 1.7 |
| Total losses [W] | 10 | 270 |
| Force on septum [N/mm] | 107 | 2600 |
| Field variation in 10mm | 10^{-3} | 10^{-3} |
| Integrated stray field [Tm] | 1.5×10^{-5} | 0.5×10^{-5} |

The conductor will be made of solid copper (5Hx10Vmm²), with a channel for water cooling (1mm²) for the septum2. The conductor out of the cavity has bigger cross section area (5Hx20Vmm²). The conductor will be isolated from the yoke by ceramic pieces. Magnetic forces push the conductor towards the iron yoke, thus no tight support for the cable will be needed.

The septum sheet will be 2.5 mm thick and a 0.5 mm screen of *permalloy* will be assembled to further reduce stray field. Calculations show that the integrated stray field stays below the safety value of 10^{-3} Tm. The copper cover around the magnet acts as a pulsed magnetic field screen, and as a closed circuit for the eddy currents in the septum[3], and reduces the field distortions at the ends[4].

The field calculation is made with OPERA-2d[®]. The field stability in 10mm in the aperture is better than 10^{-3} . The stray field is delayed with respect to the field in the aperture and lasts for some hundreds of microseconds. The maximum value is 1.8×10^{-5} T, and if there is no permalloy screen the maximum stray field is 5×10^{-3} T which would be too harmful for the stored beam.

The heat losses in septum2 are important (270 W). The heat load in the yoke (100 W) will be removed by a water channel weld around the magnet. The conductor will be water cooled to remove the heat (130 W) from the eddy currents and transport current. Both cooling channels are connected in parallel to the same circuit which provides a water flux of 3.6 l/min to keep ΔT below 10 K.

The exciting current will be a half sine pulse 50 μ s long which provides a maximum field stability at the top better than 10^{-5} during the 100 ns.

Care has been taken to maintain the voltage of the magnet under 1.7 kV to be able to use commercial thyristors for the current supply circuit, which is under

investigation at present. Septum2 can work at 120%, but power losses would be at the limiting upper value.

3 KICKER MAGNETS

A kicker magnet will be designed to accept the beam into the booster (kicker1), and another to extract it (kicker2). Both are window frame type and have the same cross section for simplicity (fig.2). The aperture is fixed by the booster vacuum chamber size. The main parameters for both kicker magnets are listed in table 2.

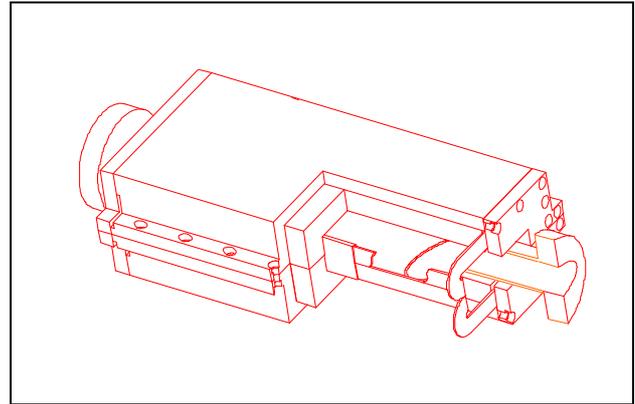


Figure 2. CAD design of the kicker magnet in the booster.

Table 2. Main parameters of the kicker magnets at LSB.

| | Kicker 1 | Kicker 2 |
|-----------------------------|--------------------|--------------------|
| Beam energy [GeV] | 0.1 | 2.5 |
| Deflection [mRad] | 6 | 5.17 |
| Length [m] | 0.4 | 0.4 |
| Field [T] | 0.005 | 0.108 |
| Aperture [mm ²] | 65Hx45V | 65Hx45V |
| Self-inductance [μ H] | 0.77 | 0.77 |
| Peak current [kA] | 0.18 | 3.86 |
| Peak Voltage [kV] | 0.43 | 3.95 |
| Ramping time [ns] | 320 | 320 |
| Total losses [W] | 0 | 10 |
| Field variation in 10 mm | 2×10^{-4} | 2×10^{-4} |

The yoke will be made of Ferrite. The conductor will be made of copper (4Hx45Vmm²) insulated from the yoke with *kapton*. The vacuum chamber will be made of ceramic material (98% Al₂O₃) to prevent eddy currents screening the field inside. The inside part of the vacuum chamber will be covered with a metallic layer (2-4 μ m of Titanium [5]) thinner than the skin depth of the field but thicker than the skin depth of the particles signal, to keep the beam wall currents unaffected. A 10 mm thick copper layer will be around the magnet to screen magnetic field and as mechanical support. Low heating is foreseen, and the cooling will be through the surrounding air and supporting structure.

The field quality in the aperture is guaranteed by the reliable design if the ferrite is not saturated. Calculations give a stability of 2×10^{-4} in 10 mm around the center of the aperture.

The current pulse has to be shorter than the revolution time into the booster (420 ns). We chose a ramp and flat top current signal. The ramp takes less than 320 ns and the flat top more than 100 ns . We are at present investigating the best solution for the electric circuit to produce the required pulse. These magnets can produce a good field up to 0.25 T but the current circuit would need changes.

4 BUMPER MAGNETS

Four equal bumper magnets are designed to be placed in a straight section of the storage ring to bump the central orbit and accept the bunches coming from the transfer line (fig.3). The four bumpers work approximately at the same field. The main parameters are listed in table 3.

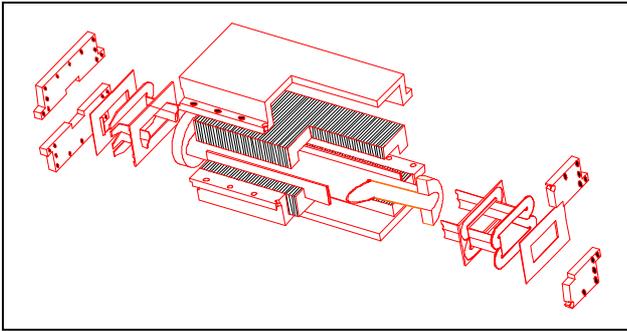


Figure 3. CAD design of the bumper magnet to inject into the storage ring.

The design of the bumper magnets is rather similar to that of the kicker magnets. The main differences are the pulse shape and duration, and the field strength. Here the pulse will be a half sine wave $6.62 \mu\text{s}$ long.

Calculations show that the relative field variation in 10 mm in the aperture is 5×10^{-5} , and the relative field variation in 50 ns is 3×10^{-5} , which are both far under the maximum allowed.

The current supply will be similar to that for the septum magnets but the voltage across the bumper will be bigger and this will introduce some changes in the circuit and elements. The signal of the four bumpers will be delayed from one bumper to another the time the bunches take to go from one to the other (8 ns , 15 ns , and 8 ns respectively). The bumper magnets can be pushed to 0.25 T without problems, but the current circuit must be readapted.

Table 3. Main parameters of the bumper magnets at LSB.

| | Bumpers 2, 3 | Bumpers 1, 4 |
|------------------------------------|--------------------|--------------------|
| Beam energy [GeV] | 2.5 | 2.5 |
| Deflection [mRad] | 7.84 | 10.37 |
| Length [m] | 0.4 | 0.4 |
| Magnetic field [T] | 0.16 | 0.21 |
| Aperture [mm ²] | 80Hx40V | 80Hx40V |
| Self-inductance [μH] | 1.05 | 1.05 |
| Pulse duration [μs] | 6.62 | 6.62 |
| Peak current [kA] | 5.09 | 7.24 |
| Peak Voltage [kV] | 2.5 | 3.6 |
| Power Losses [W] | 20 | 35 |
| Field variation in 10 mm | 5×10^{-5} | 5×10^{-5} |

5 SUMMARY AND CONCLUSIONS

We have presented the conceptual design of the pulsed magnets involved in injection/extraction processes at LSB. The field calculations ensure a good field quality for all magnets. We have reduced the number of designs to the minimum: 1 design for the two kicker magnets in the booster, 1 design for the septum magnets, and 1 design for the four bumper magnets.

Heat production is important in septum2, and water cooling is designed to keep temperature under reasonable values. A permalloy screen in the septum is recommended to reduce the stray field.

We have taken into account during the design of the magnets the current supply circuits, which are at present under investigation. The magnets here presented can work at 120% (if there are injection demands) if the current circuit is adapted.

ACKNOWLEDGEMENTS

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REFERENCES

- [1] J. Campmany, M. Traveria. *Injection and extraction schemes of the LSB booster and storage ring*. These proceedings.
- [2] R. Fabris, A. Favari, D. Tommasini. *A high current passive septum magnet for Elettra*. Proceedings of EPAC'94, pp 1460. 1992.
- [3] F. Rohner. *Eddy current septum magnet for the ESRF*. CERN internal note AT/MA/90-08. Geneva, 1990.
- [4] M. Giannini, D. Corso, et al. *Design, construction and installation of the Elettra injection system*. Proceedings EPAC'92, pp 2352. 1994.
- [5] E. Karantzoulis. *On the resistive coating of the kicker ceramic chamber*. Internal note Sincrotrone Trieste ST/M-TN-92/1, 1992.