PULSED SEPTUM FOR THE LNLS INJECTOR

A.R.D. Rodrigues[†] , R. H. A. Farias, M. J. Ferreira, F. S. Rafael and G. Tosin,
LNLS Laboratório Nacional de Luz Síncrotron - LNLS/CNPq
Caixa Postal 6192 -- 13081-970 Campinas - SP - Brazil.

Abstract

The design and construction of a pulsed thin septum for the LNLS UVX injection system are presented. The injection system uses two septa and three kickers to inject the 120 MeV electron beam from the Linac into the storage ring. The present system uses two d.c. septa. A pulsed thin septum is under construction in order to reduce the septum wall thickness from the present 5.5 mm to 1.5 mm, thus improving the injection efficiency. A prototype has been built with a 1.5-mm-thick copper septum wall which is now being measured. The magnet is driven by a 1.6-kA half-sine wave current pulser. It is constructed of a 0.4 m manganese-zinc ferrite yoke and is being tested in passive and active configurations. The magnet will be housed inside vacuum and has been designed to operate at up to 200 MeV.

1 INTRODUCTION

The injection system of the LNLS 1.37 GeV electron storage ring consists of an underground 120 MeV Linac operating at 2856 MHz and a 20.03 metre long transport line [1]. The storage ring has a wide dynamic operational range: the electrons are injected at 120 MeV, stacked and then ramped to the final energy.

At the end of the transport line, the final deflection of the injected beam towards the storage ring is carried out by two septa deflecting the beam in the plane of the stored beam orbit. Both septa are conventional non-staggered laminated C-core d.c. magnets. The thin septum has an active shielding provided by a four-turn water cooled coil. At 120 MeV the current density is 11 A/mm^2 and the coil shows good thermal behaviour. However, for higher injection energies the cooling system of the coil has inevitably to be improved. The total septum thickness, composed of the coil, the cooling system and the vacuum chamber of both the storage ring and the transport line, amounts to 5.5 mm. The thick septum is a non-cooled passive-like dc magnet built to work at an injection energy injection up to 250 MeV. Shielding is accomplished by properly wrapping the storage ring vacuum chamber with low-carbon iron laminations.

The replacement of the present thin septum by a pulsed one is motivated by the increase of the Linac energy to 170 MeV, to be performed during the last quarter of 1997. Since an extra effort ought to be applied to the development of a new refrigerated coil, the substitution of the current septum by a new pulsed one has been decided. Besides allowing the injection at the increased energy, the new septum can be made considerably thinner. In fact, a prototype has been built and is now under measurement with a total 1.5 mm thick septum wall. With the reduced septum thickness an increase in the injection efficiency is expected. Another reason is the huge dependence of the stray field upon the accuracy in the manufacture and positioning of the coil in the present septum. Even though the effects of the dc leakage fields on the beam can be partially corrected by using the steering magnets the effect of the multipolar components are hazardous to the dynamic aperture and can not be compensated.

In this paper the design and the preliminary measurements of the new pulsed septum are presented. At a first stage the present thick septum is not going to be substituted but just repositioned in order to fit the optical characteristics of the transport line. A new active water-cooled dc thick septum, based on the same principle of current sheet, has been designed notwithstanding.

2 PULSED THIN SEPTUM

The main characteristics of the pulsed thin septum are shown in table 1. To choose between a passive ‘eddy current’ and an active ‘current sheet’ septum, a prototype has been built allowing both configurations. These configurations are easily interchangeable and measurements are now under way.

In the design of the septum the usual requirements have been aimed at: the thinnest septum, low leakage

Deflection angle (mrad)	52.4
Physical length (m)	0.4
Aperture height (mm)	22
Aperture width (mm)	45
Nominal Field (T)	0.09
Nominal Excitation Current (kA)	1.6
Maximum repetition rate (Hz)	7.5
Pulse width (µs)	10
Self-inductance (µH)	1
Septum wall thickness (mm)	1.5

Table 1 - Main characteristics of the thin septum (@200 MeV)

[†] Also at Departamento de Física de São Carlos, Universidade de São Paulo.

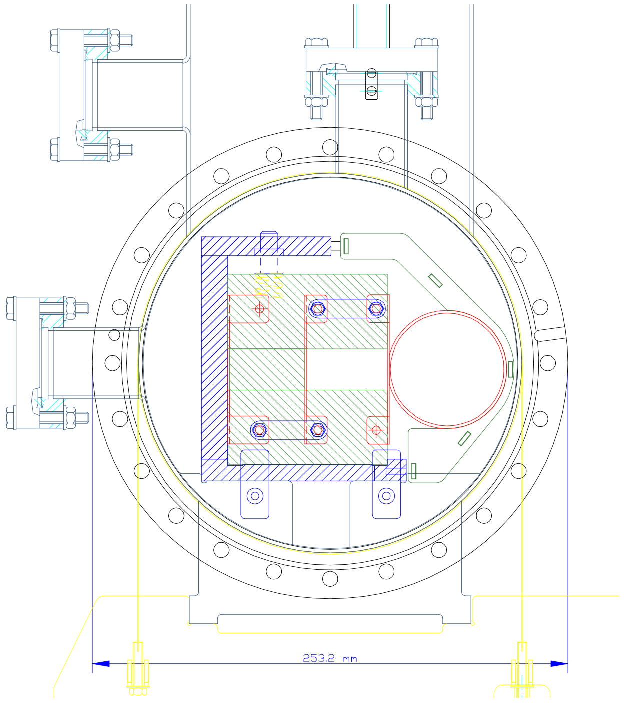

Figure 1 - Section of the thin septum magnet inside the vacuum tank

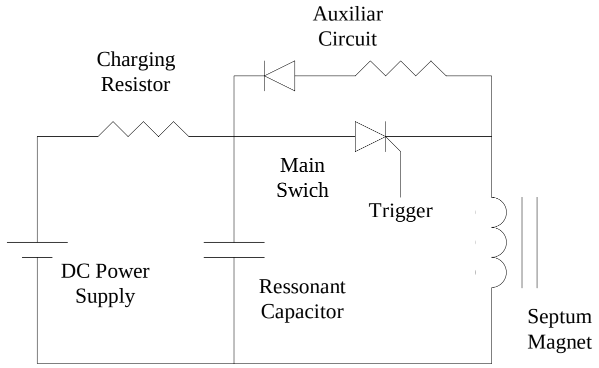

Figure 2 - Diagram of the septum magnet pulsed power supply

field, good field homogeneity along the gap. Some additional constraints have also been set out. The use of a solid state based power pulse circuit limited the peak voltage of the pulser to below 1.8 kV. To avoid using a ceramic chamber it was decided to put the septum in vacuum. This makes a thinner septum easier to be achieved but special care has to be taken so as to attain u.h.v. quality in the vacuum tank. The magnet should be able to work at a maximum beam energy of 200 MeV. Moreover, any cooling system should be avoided.

The main requirement refers to the leakage field. The 120 MeV beam is very sensitive to any spurious field. An integrated leakage field of 2 Gauss·m along the septum wall deflects the beam by 0.5 mrad. Beam optics considerations show that keeping the integrated field in the ‘field free’ region below 0.4 Gauss·m @120 MeV (0.1% of the field in the gap) is a quite safe threshold.

Figure 1 shows a cross section of the septum magnet inside the vacuum tank. The vacuum tank includes both the septum and the storage ring vacuum chamber. In the storage ring side a copper tube is allocated to minimize impedance effects and also to provide an additional shielding to the leakage fields. Pumping slots have been introduced in the tube.

The magnet is constructed of a manganese-zinc ferrite yoke. A stainless steel housing is used to keep the ferrite blocks in the required position. The shielding is provided by a 1.0 mm thick indented copper plate. The storage ring copper tube is tapered in the point it leans against the shielding to a minimum thickness of 0.5 mm. The insulation is provided by a 20 μm thin kapton layer placed in between the tube and the copper plate.

In both passive and active configurations a single turn coil is used. In the passive case both the winding conductor in the gap and the external return conductor have the same cross section (20×1mm²). The ‘eddy current’ shield is a 1 mm thick indented copper blade (skin depth ≈ 0.3 mm). In the active configuration, the indented blade is the active septum with an effective 20×1mm² cross section. In both cases forced cooling is not necessary due to the low power dissipation (the average power is 0.4 W at the most demanding operational condition).

At the very end of the transport line the pulse duration of the beam coming from the Linac is about 150 ns. For a 10 μs current pulse the ‘flat top’ of the magnetic field in the aperture is 300 ns for 0.1% field homogeneity.

3 SEPTUM POWER SUPPLY

The septum is driven by a sub-damped resonant circuit, the impedance and the pulse duration of which are basically determined by the magnet self-inductance. The main characteristics of the circuit are:

- Maximum charging voltage	1.6 kV
- ½-sine pulse width	10 μs
- Peak current	2.0 kA

The charging supply is formed by a high voltage d.c. power supply and a charging resistor. Such configuration can be used due to the low repetition pulse rate applied to the magnet (7.5 LINAC PRR) and the resulting low power dissipation in the charge.

The auxiliar circuit attached to the main thyristor switch makes the resonant circuit overdamped. The backswing reaches 35% of the main pulse amplitude and dies out after 10 μs.

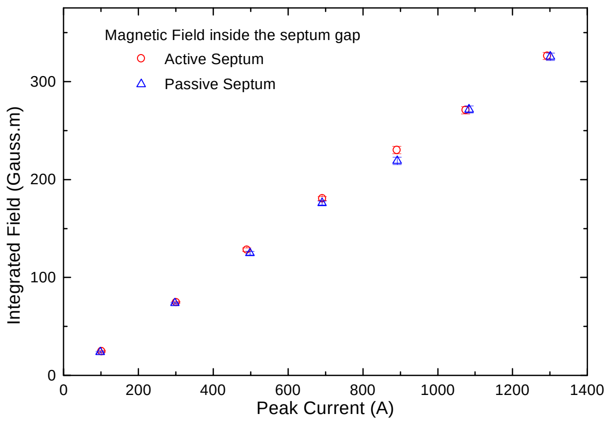

Figure 3 - Integrated magnetic field along the septum aperture(i_p = 1.1kA, B_{int}=280 Gauss.m).

4 MEASUREMENT RESULTS

Magnetic field measurements have been performed using an assembly consisting basically of a Fluke osciloscope PM3382A and a geometrically well known measuring coil. The field is obtained by numerical integration of the voltage induced in the sensitive coil. The time interval for each signal acquisition is 40 ns. Preliminary measurements have been made of the septum in both the active and passive configurations. Up to now, the septum has been measured up to the present injection energy (120 MeV).

The peak magnetic field in the central region of the gap has been measured with a 99.80×19.65 mm single turn rectangular coil. The integrated field in the gap region has been measured with a 40.41×600.0 mm single turn coil in order to include the end fields (Figure 3). The mapping of the field in the gap region has shown good field homogeneity (1% in the region 7-35 mm inward the core).

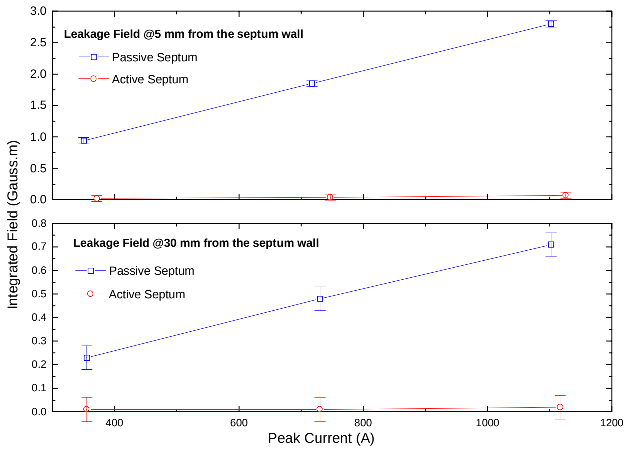

Figure 4 - Integrated leakage field at two points in the stored beam region(i_p = 1.1kA, B_{int}=280 Gauss.m).

In order to measure the integrated leakage field a 698×10.13 mm 10-turn search coil has been used. The field was measured close to the septum wall (@5 mm) and in the centre of the vacuum chamber (@30 mm). Due to the weak induced voltages special care had to be taken so as to minimize the effects of high-frequency oscillation signals induced over the averaged signal.

As expected, the shielding provided by the active configuration is by far more efficient. Close to the septum wall the leakage field is 40 times smaller in the active configuration for 1.1 kA peak current (Figure 4). In that case the integrated field in the gap region is about 280 Gauss·m in both configurations. At 5 mm from the septum wall the field is atenuated to 1% of its value in the gap in the passive configuration and to less than 0.05% in the active case. For the active septum the required 0.1% leakage field has been achieved. For the passive septum the field is 10 times stronger and modifications in the septum wall are necessary in order to improve the shielding efficiency. Two possible choices are to increase the septum thickness or to introduce a magnetic shield.

5 CONCLUSIONS

Preliminary measurements carried out on the prototype of the thin septum now under construction at LNLS shows that the active “current sheet” configuration delivers the level of performance which is demanded of it. Due to the low repetition rate and relatively low peak current the average power dissipated in the septum wall is small and no special cooling system is required. Parallel to the tests performed on the septum prototype the vacuum tank is already projected and under construction.

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REFERENCES

[1] R. H. A. Farias, Liu Lin and G. Tosin “*Magnetic Design of the LNLS Transport Line*”, PAC95