FINALIZED DESIGN OF THE PULSED MAGNETS AND THEIR PS FOR SESAME RING INJECTION

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Abstract
The design of the SESAME† storage ring injection pulsed magnet systems have been improved in order to take benefit of the most recent realizations in synchrotrons. These pulsed systems are optimised for the injection into the 2.5GeV storage ring of the 800 MeV electrons beam prepared by the Booster. The septum magnet is based on a direct driven septum technology, out of vacuum, with a thin vacuum chamber of rectangular cross section permitting to get a good field transverse homogeneity. The four kicker magnets will be of the window frame geometry, around a racetrack alumina vacuum chamber, integrating a forced air cooling in order to avoid significant thermal heating due to the stored beam. These magnets can be opened for backup and will be completely CEM shielded. Their pulsed power supplies will be built based on solid-state HV switches, even for short half-sine pulses generation.

INTRODUCTION

The injection process from the 800MeV booster to the 2.5GeV storage ring unlike the original Bessy-I, takes place in the horizontal plane[1]. The microtron and booster are installed inside the main ring, so the injected beam comes from the inner side of the straight section. The injection scheme (four kickers closed orbit bump) foresees the septum with two kickers in a long straight section, while the other two kickers will be positioned in the two adjacent short straights. The design of kicker magnets and pulsed power supplies are identical and close to the SOLEIL design.

SEPTUM MAGNET

Fast deflection of the beam from transferline to the ring is accomplished with a thick septum followed by a thin septum just after 1m. The thin septum magnet is a direct driven and out of vacuum with a rectangular vacuum chamber for the incoming beam. The EM transient analysis shows a better field homogeneity in the good field region for a rectangular vacuum chamber in comparison with the round pipe chamber. The magnet yoke is laminated steel in order to avoid the effects of eddy current losses during the 250µs pulse. The injection point is defined to be at the downstream end of the thin septum, where the injected beam is parallel and 32mm from the nominal orbit. The distance between the injected beam and the bumped beam is 12 mm, and the effective septum thickness is 3mm. The thin coil thickness is 2.5mm at the upstream and it smoothly decreases to 1mm at the septum downstream end. Static electromagnetic analysis is performed by the codes OPERA and POISSON, giving similar field homogeneity in the good - field region of septum chamber $\Delta B/B$ better than 1.5×10^{-3}. Transient analysis is performed by OPERA and the results show the field homogeneity in the good field region better than 0.37%. The field attenuation of 250µs field pulse, due to the 0.5mm thick vacuum chamber is at most 4%. The transient analysis shows the stray field without any magnetic shielding has a RMS value of 1.7% of the maximum peak field which is equivalent to 0.02 T.

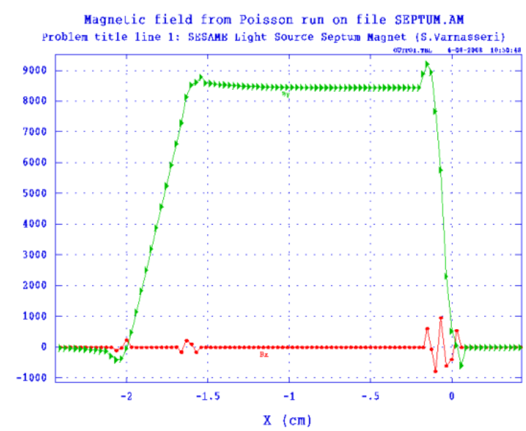

Figure 1: Static analysis of the septum fields on axis y=0 , Bx(red) and By(green).

Table 1: SESAME injection septum specifications.

Deflection angle(degree)	9
Field Strength(T) @ 800MeV	0.84
Stray Fields (max.)	0.017
Magnetic Length (m)	0.5
Septum Thickness(mm)	2.5
Magnet Aperture(mm^2)	11×30
Pulse Duration (us)	250
Conductor Resistance(mΩ)	0.98
Inductance(µH)	1.3
Peak Current(A)	7360
Peak Power(kW)	56
Average Power(W)	7
PS Voltage(V)	350

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† Synchrotron-light for Experimental Science and Applications in the Middle East is an independent intergovernmental organization developed under the auspices of UNESCO. It involves at present the following member states: Bahrain, Cyprus, Egypt, Islamic Republic of Iran, Israel, Jordan, Pakistan, Palestinian Authority and Turkey.

KICKER MAGNETS

Four kicker magnets are required for injection process into the SESAME storage ring. The magnets have identical specifications and are expected to produce identical magnetic fields. Therefore they have the same electrical, mechanical and magnetic design. Each kicker magnet is to produce a maximum field of 0.031T in order to make a nominal transverse horizontal kick of 3.5 mrad. Since the design of the pulsed power supply and the connection cable length is an integrated part of the magnets specifications, so the maximum length of the cables is taken into account. The current pulse shape will be half sine wave with repetition rate of 1 Hz. Fig.2 shows the layout of injection kickers in the storage ring for a 20 mm horizontal bump.

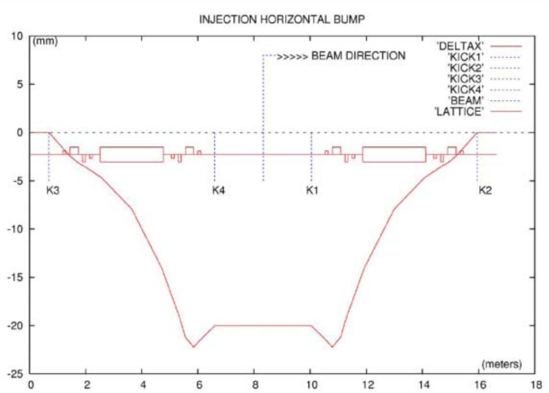

Figure 2: SESAME injection horizontal bump scheme.

The kickers strengths for a 20 mm bump are given in table.2 for the linear (without sextupole) and nonlinear (with sextupole) cases. The maximum kick required for kicker K3 is 3.46 mrad which is the base for the design of identical kicker with strength of 3.5 mrad.

Table 2: Injection kickers strength for 20 mm bump.

Strength (mrad)	K1	K2	K3	K4
Without sextupole	-3.16	-3.39	-3.39	-3.16
With sextupole	-3.09	-3.46	-3.46	-3.09

Kicker magnets are one turn coil with ferrite yoke, with a window frame shape adapted from the SOLEIL design[2]. Ferrite yokes are made of 8C11 C-shape pieces, which constitute two half symmetric magnet yokes, located each one on a plate which can be opened. To get a good matching of all the kicker magnets, it is necessary to have specific attention on the transverse dimensions and tolerances, the positioning of the ferrite cores and the coil parts (insulated and maintained by dielectric machined C parts). With these arrangements the control of parameters of the four kickers, like the transverse field homogeneity and leakage inductance, will be achievable. The design of the magnet also includes a free gap (2 mm) around the alumina needed for the air cooling. Such a cooling needs a regular free gap, but not a too wide gap in order to distribute the air around the ceramic in turbulent flow. It is foreseen not to use forced air due to the low temperature raise during the operation of kickers (maximum 48^{o}C), but there is the possibility to include an air forced cooling, in the vertical plane, to avoid any overheating of the ceramic due to the beam image current. The vacuum chamber is made of ceramic with 2μm Ti coating. The optimization of the coating thickness has been carried out in order to be thick enough for the thermal issues and thin enough not to attenuate and ill-shape too much the magnetic field [1,3].

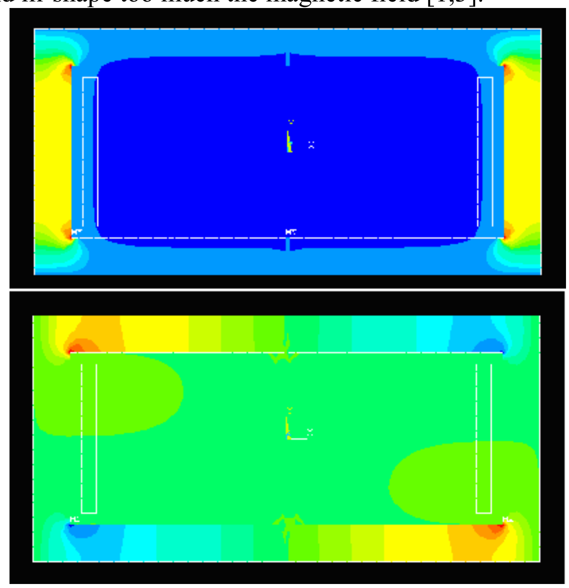

Figure 3: Magnetic field density, Bx(lower) and By(upper) of the kicker magnet.

Study on using short pulse width also has been carried out with close collaboration with SOLEIL, due to the eddy currents attenuation on the penetrating field from the vacuum chamber. The intention was to use an optimised pulse period based on optics requirements and experience of solid state high voltage technology already available at SOLEIL. Fig.4 shows the attenuation of the magnetic field for various pulse durations.

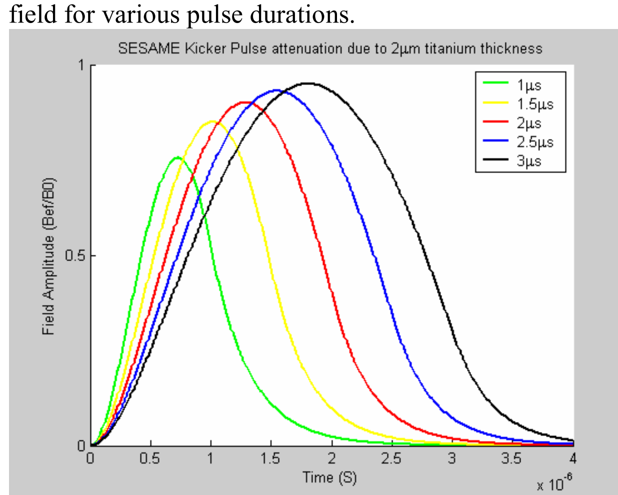

Figure 4: Field attenuation for various pulse durations.

The whole magnet will be enclosed in an electromagnetic shield, in order to avoid any EM perturbations to the side-equipments. The magnet design is also considered taking into account the electric design and SPICE simulations of the whole system, including pulser, coaxial transmission and magnet. These simulations permit to determine suited value of pulse correcting RC components. Tab.3 shows the kicker systems specification based on a design similar to SOLEIL kickers.

Table 3: Identical injection kicker parameters.

Deflection angle (mrad)/max	3.5/3.9
Magnetic field (T)	0.035
Magnetic length (cm)	30
Current pulse duration (µs)	1.5
Magnet material	Ferrite yoke/ ceramic chamber
Aperture dimension (mm^2)	56.5×120
Conductor dimension (mm^2)	5*40
Magnet resistance (mΩ)	0.1
Magnet inductance (µH)	0.92
Current (A)	1814
Charging voltage (kV)	4.55

SEPTUM PULSED POWER SUPPLY

The half-sine wave field pulse with duration of 250µs and repetition rate of 1 Hz will be generated by a pulsed circuit based on LC resonant discharge. The stored energy in the capacitor will be switched by a high current rate thyristor to the septum magnet inductance. One charging power supply with rating of 350V-10A will be used. Fig.5 shows the simplified electrical circuit for the septum magnet.

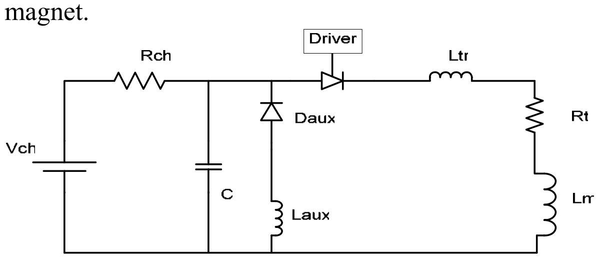

Figure 5: Simplified septum pulser electrical circuit.

To get good operation and maintenance conditions, we intend to locate the pulsed power supplies out of the storage ring tunnel. This choice is done for septum and kicker pulsers due to the high possibility of damages for solid-state switches under radiation. The connection between pulser and septum magnet will be made of a 15m coaxial cables bundle to ensure the stable shape and low level EM perturbation.

KICKER PULSED POWER SUPPLY

Similar to the septum pulser, the kicker pulsed power supplies are based on the classical LC resonant discharge circuit. The half-sine wave current pulse with the duration of 1.5µs is required. For the choice of switch, the solid state modules manufactured by BEHLKE GmbH, IGBT switch in series with HV diode will be used.

The transmission of power pulses between pulsers and magnets will be accomplished by means of parallel coaxial cables RG-214U. The maximum length between pulsers and kicker magnets is considered to be 8.5m. Fig.6 presents a simplified electric circuit of the kicker magnetic system.

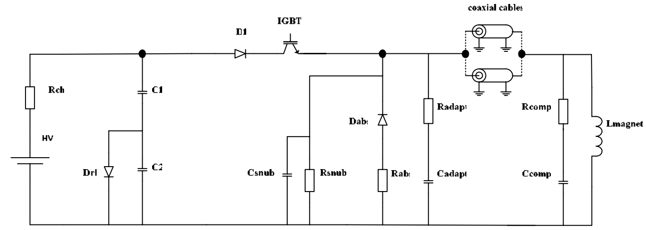

Figure 6: Kicker electrical pulsed circuit

ALLOCATION OF PULSED PS'S

Due to nature of pulser circuits for pulsed magnets it is necessary to have them as close as possible to the magnets. In the other hand in order to have a reliable system, far from direct radiation and easy maintenance conditions for the electrical system of the pulsers, they should be allocated outside the storage ring tunnel in the service area. There will be one opening in the shielding wall at a point which has the same distance to the two kickers after septum. For the kicker before septum and also septum itself, the main opening for the cooling and transferline cables will be used; while for the remaining first kicker there is one small separate opening. The longest cable in this configuration does not exceeded 8.5m.

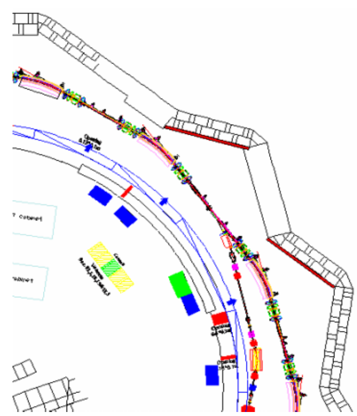

Figure 7: The allocation of pulsed power supplies in the service area.

In fig.7, blue boxes correspond to the kicker pulsers and the red signs on the shielding correspond to the openings.

REFERENCES

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