INJECTION AND FAST EXTRACTION IN THE ESR

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Introduction

The design of the 'Experimental Storage Ring' (ESR) [1], which is under construction at GSI, has to fulfill - among many others - the following requirements:

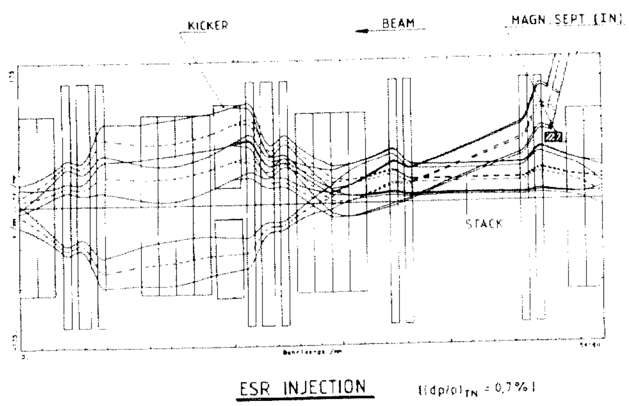
a) Injection of the beam from the heavy ion synchrotron SIS [2] with a maximal emittance of 20πmm mrad.

b) Injection of secondary beams from the 'Fragment Separator' with a maximal momentum spread of $\pm$0.35% and a transverse beam emittance of 20πmm mrad.

c) Fast extraction of the beam back to SIS.

The main component for these injection-/extraction procedures is the fast kicker magnet, which will be used both for injection and extraction and which also allows injection while a cooled stacked beam is circulating in the ring (accumulation).

The most crucial operating mode with respect to the design of the kicker is the injection of the beam from the fragment-seperator.



ESR INJECTION ((dp/p)$_{TN}$ = 0.7%)

Fig. 1

The injection procedure works in the following way: The central closed orbit will be bumped near the septum magnet. The beam to be injected passes through the gap of this septum magnet, performs approximately 3/4 of a betatron oscillation and, finally, is inflected to its closed injection orbit by the kicker magnet (Fig. 1). Then, emittance and momentum spread of the beam are reduced by stochastic pre-cooling before it is stored by rf-stacking. As the stack shall not be disturbed by the deflecting field of the kicker magnet the active area of this magnet covers only a part of the horizontal acceptance.

As the phase advances between the magnetic inflection septum and the kicker and that of the magnetic extraction septum and the kicker are close enough to 270^0 the same kicker magnet can be used for both injection and fast extraction. Similar to injection, the closed orbit has to be shifted before ejection into the kicker gap either by reducing the field of the main dipoles or by accelerating the beam.

Design of the Kicker magnet

As mentioned above, for beam injection a kicker is required, that affects only a part of the horizontal acceptance. The yoke of this magnet is C-shaped. The time required for rf-stacking is about 20 ms. As the cirumference of the SIS is exactly twice that of ESR, the ESR-ring is completely filled with 1/2 of the SIS beam; the second part of the SIS beam shall be injected into the ESR as soon as possible; therefore a second injection shot has to be possible after 20 ms. This short time interval prevents to use a mechanical shutter for the screening of the circulating stack from the magnetic field of the kicker magnet.

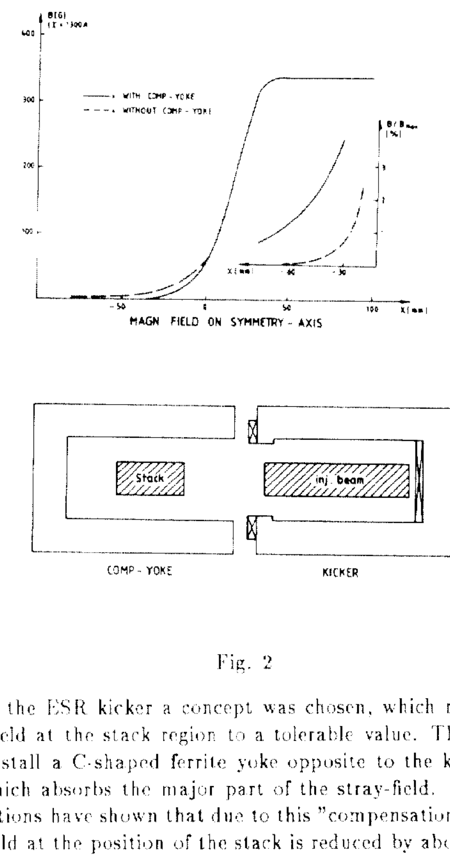


Fig. 2

For the ESR kicker a concept was chosen, which reduces the stray field at the stack region to a tolerable value. This concept is to install a C-shaped ferrite yoke opposite to the kicker magnet, which absorbs the major part of the stray-field. POISSON-calculations have shown that due to this "compensation"-yoke the strayfield at the position of the stack is reduced by about a factor of ten. (Fig. 2) The kicker is subdevided into 3 modules. In the following table 1 the essential parameters for one magnet-module are listed:

Tab.1

ESR-Kicker	Parameter	units
magnet type	lumped	
kicker aperture (width * height * length)	100 * 44 * 450	mm
aperture of comp. yoke	100 * 50 * 450	mm
ferrite material	8C11 (Valvo)	
impedance of term.-resist.	25	Ω
number of current-windings	1	
max. current	1400	A
B_{max}(kicker-gap)	390	G
max. magn. rigidity	10	Tm
max. deflection angle	1.9	mrad
inductance	1.4	μH
field rise-/fall-time	110	ns
flat-top duration	0-3000	ns

Electric circuit

Due to the maximal current of 1.4 kA and the chosen impedance of 25 Ω a maximal voltage of about 40 kV has to be applied to the magnet.

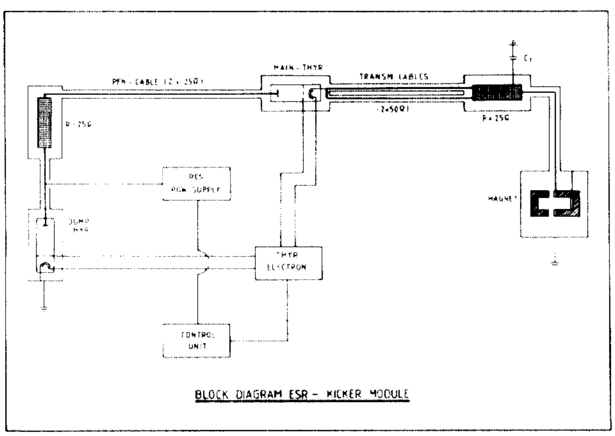


Fig. 3

Fig. 3 shows the block diagramm of the set-up for one module [3]. A high voltage load cable with an impedance of 25 Ω is charged by a 'resonant power supply'. The charge is switched to the magnet by the thyratron (Main Thyr.) by two paralleled 50 Ω RG220-transmission-cables. Variable pulse flat-top duration, which is required because of different particle revolution times, is achieved by an appropriate switching of a 'Dump'-thyratron, which discharges the HV-cable to the opposite side. This 'Dump'-thyratron also absorbs the strong reflections from the lumped magnet. Because of these reflections hollow-anode-type thyratrons (1671, EEV) are used.

Both sides of the load cable are terminated by high power 25 Ω resistors located in an oil filled coaxial aluminium housing. The resistor on the Main-switch side is located before the magnet; due to this design the magnet is on ground potential during the flat-top duration, which reduces the probability of voltage break-throughs.

The 'resonant power supply' works as follows: two primary condensor banks (12 mF) are charged by two power supplies to a maximum voltage of 220 V. This charge is switched to an high voltage transformer by high power SCRs; the high voltage connector of this transformer is connected to a cascade of diodes, that prevents a discharge of the load cable.

The charging of the load cable lasts 4 ms; the peak charging current is about 600 A. All housings for the thyratrons, the terminating resistors, the diode cascade and the high voltage measurement deviders are filled with oil, used for HV-insulation and cooling of these components.

The grids of the thyratrons are supplied by a 'Trigger Amplifier' unit, that delivers very steep switching pulses with amplitudes of about 3 kV. The jitter of the thyratron switching time may be optimized by an appropriate setting of the 'reservoir'-heating, that influences the gas pressure inside the tube.

The switching of the HV-thyratrons is synchronized with the phase of the accelerating RF-cavity; the required variable delay-times due to various particle revolution times are realized by presettable fast digital counters.

Injection-/Extraction channels

Three short straight sections of the ESR contain identical magnetic septa for beam injection and fast-/slow extraction. As these septa have to be located close to the adjacent bending dipoles both the injected and the extracted beams lead through the strayfield of the C-shaped bending magnets. 3-dimensional beam tracking calculations show that due to these strayfields both an additional bending angle of about 8° and a blow-up of the horizontal beam diameter has to be taken into account. In order to correct the bending effect of the dipole-strayfield an additional septum-type bending magnet ("matching"-septum) will be installed in the injection- and slow-/fast extraction beam line.

The following table contains some essential parameters of both magnet types:

Tab. 2

	Inj. Sept.	Match. Sept.	units
max. magn. rigidity	10	10	Tm
bending angle	4.2	8.0	degrees
gap width	150	200	mm
gap height	60	60	mm
gap length	1200	1000	mm
no. of windings	8	55	
no. of cooling ch.	8	10	
max. current	3600	500	A
max. DC-power	80	30	kW

The injection-/extraction septa will be connected in series to the ESR main dipoles in order to save costs for additional power supplies. A parallelled "bypass"-power supply will compensate for saturation effects in the main dipoles at high currents and allows a steering possibility. The "matching" septa will be supplied by independent power supplies.

References

[1] B. Franzke, Nucl. Inst. Meth. B24/25 (1987) 18-25

[2] K. Blasche, D. Böhne, B. Franzke, H. Prange, IEEE NS-32 (5) (1985) 2657

[3] our gratitude to the CERN PS-Kicker Division for the support during the kicker construction