

A DIAGNOSTIC KICKER SYSTEM AS A VERSATILE TOOL FOR STORAGE RING CHARACTERISATIONS*

O. Dressler[#], J. Feikes, J. Kolbe, BESSY, 12489 Berlin, Germany

Abstract

For the BESSY II Synchrotron Light Source, two diagnostic kicker systems including current pulsers were developed, allowing vertical and horizontal deflection of the stored beam.

Synchronised with the revolution trigger, simultaneous pulsing of the systems, kicks the stored beam in any transverse direction with a repetition rate of up to 10 Hz allowing a wide range of storage ring investigations. Examples are dynamic aperture measurements and frequency map measurements.

Special efforts were made to assure the demands of high amplitude and time stability for this kind of experiments. The technical concept of the systems and the controlling of the measurements are described.

INTRODUCTION

The BESSY II machine is a dedicated 3rd generation synchrotron light source. Some main machine parameters are collected in table 1.

Table 1: Related machine parameters

Description	Parameter
Momentum, p	up to 1.9 GeV / c
Machine length, l	240 m
Revolution time, t	800 ns
Physical aperture (hor. x ver.)	27 mm x 6 mm

To allow dynamic beam studies by excitation of single bunches or short bunch trains up to the aperture limits in any transverse direction a ‘pinger magnet’ system is a very appropriate tool.

In the special case of BESSY, the pulse length of the system is required to be shorter than twice the revolution time of 800 ns minus the maximal length of the examined bunch train (max. 100 ns), thus 1.5 μ s. So the bunches see the kick only once leaving their dynamic response. The assembly of the magnet and integration of the system into the storage ring had to be done with the least interference to the continuous user operation.

Commencing with the experience gained with the operation of the BESSY II injection kicker system developed at Sincrotrone Trieste [3], similar design rules for the layout of a diagnostic kicker system were applied.

With the beta function at the position of the proposed diagnostic kicker magnet and with the assumed aperture

limit, the maximum necessary deflection angle in vertical and horizontal direction is described by θ_c (Eq. 1).

$$\theta_c = \frac{x_c}{\sqrt{\beta_c} \sqrt{\beta_{\text{Kicker}}}} \quad (1)$$

Together with the momentum p of the machine, θ_c defines the required $\int \bar{B} dl$ kick-strength K (Eq. 2).

$$K[mTm] = \frac{\theta_c [\text{mrad}] * p[\text{GeV}/c]}{0.3} \quad (2)$$

θ_c	Deflection angle [mrad]
β_{Kicker}	Beta function at kicker [m/mrad]
β_c	Beta function at aperture limit [m/mrad]
x_c	Aperture limit

The length of each of the magnets was chosen according to the mechanical space limitation defining the maximum integral field (Table 2). There was a titanium sputtered ceramic beam pipe available with a length of 690 mm, similar to those used in the storage ring injection kickers [3]. Because of the 5 μ m titanium thickness, there is no considerable field reduction due to eddy currents.

Table 2: Pinger system design parameters

Description	Horizontal	Vertical
Deflection angle	5.3 mrad	2.1 mrad
Kick-strength	19.3 mTm	13.2 mTm
Magnet aperture	93mm x 50mm	85mm x 52mm
Magnet length	240 mm	300 mm
Pulse length (max.)	1.5 μ s	1.5 μ s

KICKER SYSTEM DESIGN

While defining the magnet parameters, it was obvious that current pulsers driving different magnets topologies, like travelling-wave kicker magnets or quasi travelling-wave kicker magnets, would be too costly and their development time consuming. Instead, a solution with two lumped inductance magnets was preferred, because of its simplicity.

Two pulser circuits, directly attached to the magnets produce current pulses of half-sinusoidal pulse shape. Their estimated low circuit inductance of about 1 μ H allows short half-sinusoidal current pulses at sufficient current amplitudes of 4.5 kA on the vertical and 3.9 kA on the horizontal magnet.

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#olaf.dressler@bessy.de

Since a sinusoidal pulse is the inherent LC-output, the level of disturbance caused by other frequency components or noise was considered to be low. For excitation of short bunch trains, the pulse maximum has even less deviation from a flat top than a ringing square wave pulse which is typically induced in quasi travelling-wave kicker magnets.

Technical Realisation of Magnets

The main constraints for the diagnostic kicker magnet design were the mechanical length and the requirement not to open the vacuum system. As depicted in Fig. 1, a layout was conceived, where the coils are arranged symmetrically around the beam pipe. The magnets were designed as ferrite window frame magnets, close to the beam pipe; with very low mechanical tolerances, to achieve the most magnetic flux density.

The yoke is made of Ceram Magnetics ferrite (CMD 5005 by Ceramic Magnetics, Inc.) which has sufficient transmission behaviour for this kicker application. The yoke is housed by copper plates to diminish stray fields and for mechanical adjustment.

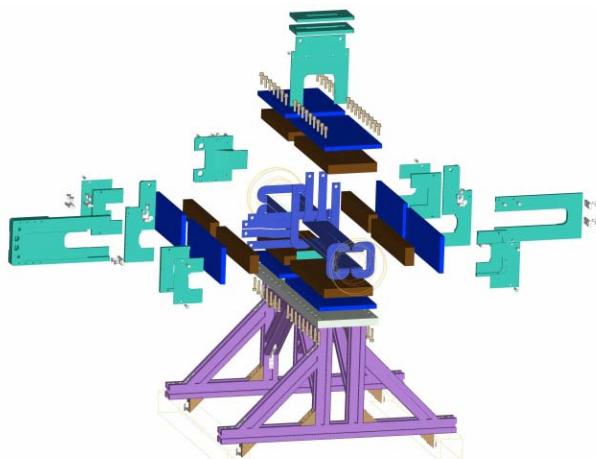


Figure 1: Exploded view of the kicker magnet assembly.

The copper coils are designed as one winding for each magnet, consisting of two symmetrical half-coils. They are bent out of copper sheet metal - to insure low inductance, short and high current pulses with high field uniformity.

Calculations of the magnetic field were made by using POISSON. Especially for this geometry - window frame ferrite core and flat coils - the maximum field deviation is low inside the aperture margins.

Surveying of Magnets

Measurements were performed with an integral probe coil and the final pulser / magnet set up. They show that linearity of kick strength vs. pulse current was achieved over the whole range from lowest to highest values.

No saturation of the core was observed - an important fact for later assessment of acquired machine data (Fig. 2).

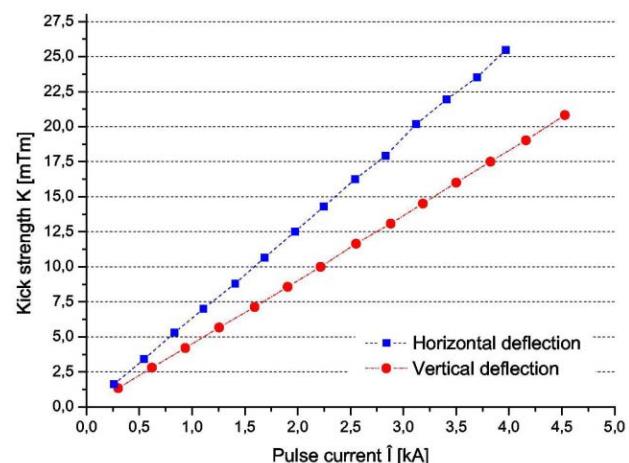


Figure 2: Kick strength vs. pulse current.

Design of Pulser Circuit

For the pulser circuit the ‘classic’ resonant LC-circuit was chosen (Fig. 3). In a PSPICE [6] simulation the ratings of the main components and trimming elements were found, e.g. for damping and pulse manipulation.

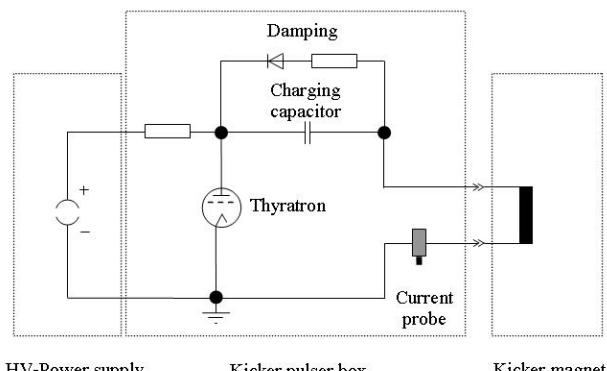


Figure 3: Schematic pulser circuit.

Technical Realisation

The magnets and the pulser systems were realised in-house utilising commercially available components.

The least shift of ignition timing vs. initial trigger and also the change of pulse shape over a wide range can be realised with a thyatron. According to the necessary charging voltage of up to 15 kV for the pulse currents, an E2V CX 1154 thyatron was chosen as the main switch and given preference to a semi-conductor based solution.

Triggered on the current pulse, the pulse shape on the horizontal magnet was measured at different charging voltages (in 3 kV steps, from 3 kV to 15 kV - see Fig. 4).

The kicker pulser was made in a three dimensional layout especially adopted for high voltage durability to insure low inner inductance. By using wrap connexions on the pulser box, the polarity regarding to the magnet can be interchanged.

To insure highest pulse amplitude stability for reproducible measurements, a charging power supply with a stability of 2×10^{-4} was attached to the circuit.

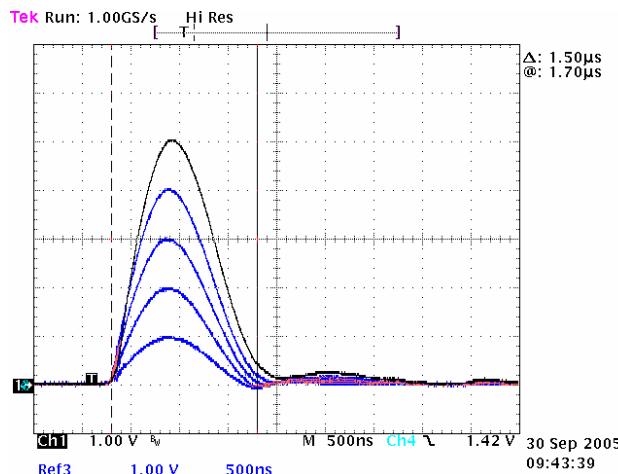


Figure 4: Pulse current on hor. magnet from 3 to 15 kV.

System Operations

While the pulser boxes are situated next to the both magnets inside the storage ring, their control electronics are on top of the storage ring in the service area. Status information and commands from, or into the system are made available. This local control unit provides a link to the BESSY control system by CAN-bus for slow signals.

It also contains a printed circuit board where the trigger condition is realised. Both, the vertical and the horizontal system can be run simultaneously and synchronized - in continuous operation mode with up to 10 Hz repetition rate or in single shot mode. There, a gate signal is given via CAN-bus to enable the next coincident 10 Hz synchronous start trigger, which is initiating the HV start trigger to the thyratron switch (Fig 5).

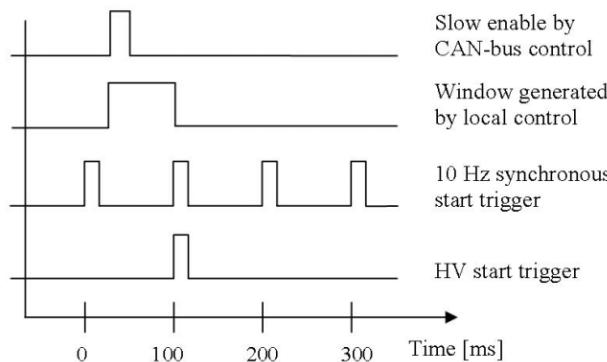


Figure 5: Timing scheme for pulse initialisation.

The fast revolution time of particle beam requires a coincident beam excitation for precise measurements. The 10 Hz start trigger is synchronized with the 1.25 MHz revolution frequency and also with the 50 Hz line beat.

APPLICATIONS

For one particular application, the capability of the system was verified. A beam current of approx. 5 mA was filled into the storage ring at a length of 100 ns. By increasing excitation amplitude of the circulating electron beam with the horizontal pinger system continuously triggered at 10 Hz, a variable aperture limit through a

horizontal scraper was detected by zero beam lifetime criteria. Since the horizontal scraper position is very well defined by a glass ruler reference, this measurement illustrates linearity between charging voltage on the horizontal diagnostic kicker system and a horizontal scraper position. In the range of 36.9 mm to 43.9 mm, the scraper is the aperture limit and the measured points show a nearly linear dependency with only small deviations. These deviations are caused by loss of electron beam during measurements and refills (Fig. 6).

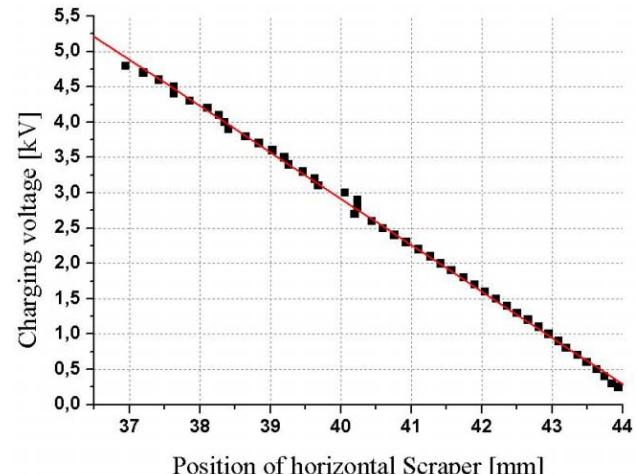


Figure 6: Charging voltage on horizontal kicker vs. horizontal scraper position in continuous trigger mode.

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