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A PINGER MAGNET SYSTEM FOR THE ALBA SYNCHROTRON LIGHT SOURCE

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Abstract

A pinger magnet system consisting of two short kickers, one for each transversal plane, has been recently commissioned at the ALBA Synchrotron Light Source. The kickers excite large betatron oscillations on the electron beam in order to probe the linear and non-linear beam dynamics regime together with the turn by turn capabilities of the BPMs. The kickers are mounted around a single Ti coated ceramic vacuum chamber, have a length of 0.3 m each and provide a half sine pulse with an approximate pulse length of 1.5 us at an amplitude of 1.60 mrad in the horizontal plane and 1.15 mrad in the vertical plane. The pulser unit is based on solid state technology. This report summarises the steps followed from its design until its installation, electric and magnetic characterisation in the laboratory, and the first results with beam.

INTRODUCTION

To probe the non-linear regime of beam dynamics, a pair of pinger magnets have been designed, built in house and installed in the ALBA storage ring.

A single electron train will be kicked transversally by means of the pinger magnets, resulting in the excitation of betatron oscillations around the reference orbit. If the kick is strong enough the oscillations can reach the boundary of the non-linear region where the magnetic fields of the optics exhibits strong non-linearities.

The evolution of the dynamics of the electron train is then sampled; turn after turn, by beam position monitors (BPM). The pulse width must be such that the electron beam is kicked only once, all through the dynamic range of the pinger magnets. Beam dynamic results from the first studies performed with the pinger magnets are reported also in this conference [1,2] and the analysis of the impedance change due to the installation of the pinger magnets has also been evaluated [3].

MAGNETS SPECIFICATIONS

The maximum kick to be provided by the pinger magnets to the electron beam was specified as 1.60 mrad in the horizontal plane and 1.15 mrad in the vertical plane by the Beam Dynamics group. Under these kicks the dynamic aperture can be probed up to the physical limits of the vacuum chamber. The pinger magnets have been installed in a short straight section where the beta functions are 9.17 m and 5.14 m in the horizontal and vertical plane respectively. The pulse width is required to be smaller than twice the revolution time (896 ns) and the goal was to stay below 1.5 us for the whole range.

DESIGN OF THE MAGNETS

The design of the magnets is based on a window shaped magnet made with ferrites, CMD5055, from Ceramic Magnetic Ltd and a single turn coil. The main magnets parameters are presented in Table 1.

Table 1 Main Magnets Parameters

Parameter	Units	HOR	VER
Gap	mm	38	94
Ferrite length	mm	300	300
Max kick	mrad	1.60	1.15
Max field	T	0.053	0.038
Intensity	A	1614	2869
L_{magnet}	uH	1.00	0.16

The magnets have been installed around an existing ceramic chamber with inner dimensions 24x80 mm and a length of 780 mm, as shown in Figure 1.

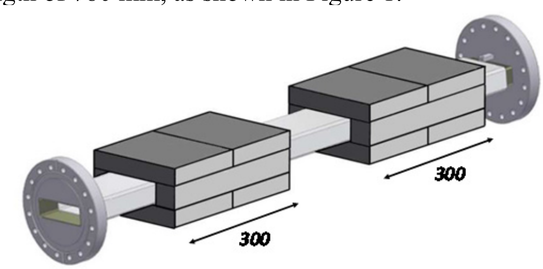

Figure 1: Installation of the magnets around the ceramic vacuum tube. Ferrite length in mm.

The chamber has a 0.4 µm Ti coating, which allows the circulation of the image current and it is thin enough not to generate significant eddy currents which might distort the magnetic pulse [4]. This ceramic chamber is the same that has been used for the ALBA storage ring injection kickers. Figure 2 shows the cross section of both magnets.

Magnetic simulations have been performed with OPERA-2d to ensure that the ferrites do not saturate. A field homogeneity of $\pm 5 \cdot 10^{-4}$ has been achieved over ±25 mm. Figure 3 shows the magnetic field lines as obtained with OPERA-2d [5].

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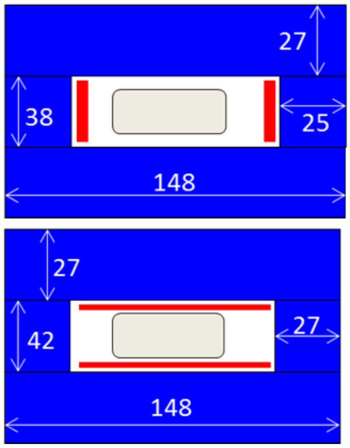

Figure 2: Cross section sketch of the HOR (upper) and VER (lower) pinger magnet. Dimensions in mm.

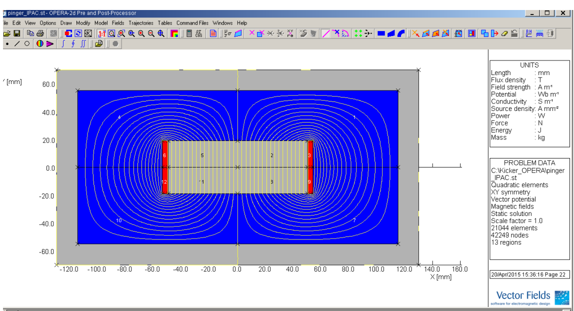

Figure 3: OPERA 2d simulation of the HOR pinger magnet.

DESIGN OF THE ELECTRICAL CIRCUIT

The high current peak is generated through an LC oscillator circuit, as shown in Figure 4.

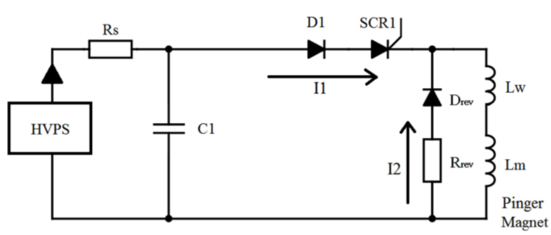

Figure 4: Schematics of the pulser unit.

The HVPS charges the capacitor array (C_1), and once the trigger closes the thyristor (SCR1), the capacitors are discharged through the coil. To avoid the negative reverse pulse, a fast recovery diode (D1) is included behind the thyristor. In addition, a flyback diode (D_{rev}) is installed to protect D1 and SCR1 from high voltages when turning off. The pulser unit has been installed under the magnet inside the tunnel to minimise cable inductance while the high voltage power supply has been placed outside the tunnel.

The theoretical pulse width is given by,

$$T_p = \pi \sqrt{L \cdot C}$$

Where T_p is the pulse width, L the total inductance of the circuit and C the capacitance. Once the capacitance is chosen, the charging voltage can be calculated as,

$$U = I \sqrt{L / C}$$

Where I is the required maximum peak current.

The initial calculations for the capacitance were done to obtain a 1.5 us pulse at the maximum kick, but we found during the initial tests that the pulse width grows with decreasing pulse current due to the V-I non-linear characteristics of the switch and the diodes. Since there is an interest in using the pinger magnet over a wide kick range, the capacitance of the circuit was reduced with respect to the original design to remain within the 1.5 us for all the voltage settings.

The final capacitances used for the pinger magnets have been 66 nF and 120 nF for the horizontal and vertical pinger magnets respectively. The electrical circuit has been simulated with PSPICE.

TECHNICAL REALISATION

The selected high voltage PS is from FuG Elektronik, type HCK 400-12500, providing 12.5 kV-60 mA and with a long term stability of $\pm 1 \cdot 10^{-3}$. Film capacitors with a nominal voltage of 3 kV from AVX were chosen.

Once the pingers were assembled, the current pulse was measured as a function of the voltage and the pulse amplitude, width and delay from trigger to peak current was recorded for different settings between 1 and 10 kV. Figure 5 shows the peak amplitude and width versus HV.

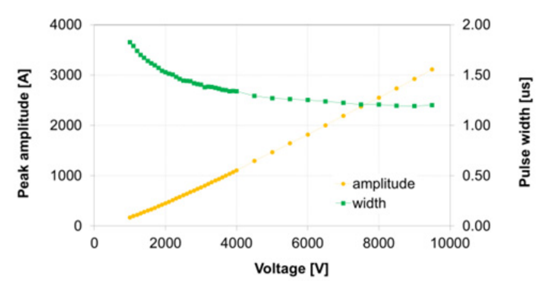

Figure 5: Peak amplitude and pulse width for the VER pinger as a function of HV setting.

As switch, an array of thyristors from Behlke, model HTS 120-500-SCR, which provides 5kA in direct mode and supports up to 12 kV in inverse mode for less than 100 µs has been selected. Diodes (D_1, D_{rev}) are also from Behlke, model FDA 160-450. They can support a maximum peak reverse voltage of 16 kV and a peak forward current of 4500A up to 10 µs.

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For a voltage setting of 9 kV, the peak current achieved is 1620 A for the horizontal pinger magnet and 2925 A for the vertical pinger magnet.

The pinger magnets are triggered at 3.125 Hz through the ALBA timing system and are synchronised with the 500 MHz RF frequency. There is an adjustable delay to synchronise the peak with the passage of the beam which is set through the control system.

MAGNETIC MEASUREMENTS

Magnetic measurements were performed with a 1 turn long coil for integral field measurements and a short coil for local field measurements intended to obtain information on the homogeneity of the magnetic field along the pinger magnet. The induced voltage on the coils was measured on a digital scope DSOX3104A from Agilent Technologies and the magnetic field integrated with the same scope. Figure 6 shows a typical snapshot of the scope screen.

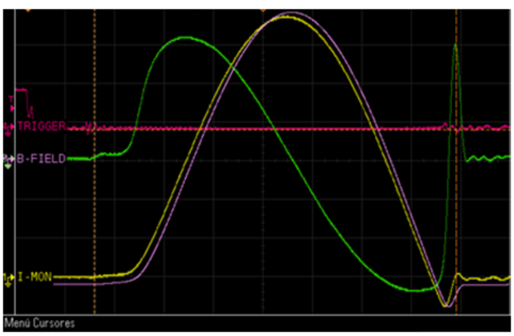

Figure 6: Image from magnetic measurements. Yellow trace is the current pulse, green is the induced voltage pulsed and purple is the integrated magnetic field.

Figure 7 shows the linear dependence of the measured magnetic field with the peak current for both pinger magnets. The data indicates no saturation of the ferrites even at high current.

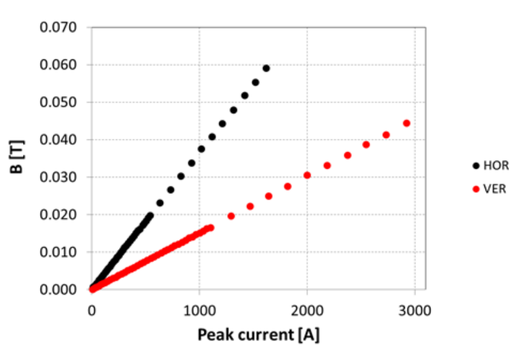

Figure 7: Magnetic field linearity with current pulse.

The magnetic field measured for a voltage setting of 9 kV is 59 mT for the horizontal and 44 mT for the vertical pinger respectively.

The measurements with the short coil indicate that the magnetic field is homogeneous within ±0.5% inside the magnet, except at the ends, where the contribution from the end coil can be observed.

PINGER MAGNET SYNCHRONISATION WITH BEAM

The pinger magnets have to be synchronised with the passage of the beam. For this purpose a single train (64 ns) was injected into the SR and the pinger magnet delay varied until the maximum beam oscillation was observed. The data shows a good agreement with the data already recorded on the laboratory. See the results plotted in Figure 8 for the vertical pinger.

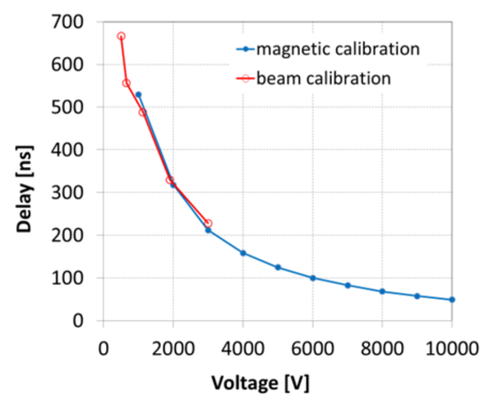

Figure 8: VER pinger magnet synchronisation.

CONCLUSION

A pair of pinger magnets has been designed for the ALBA storage ring. The units, designed and built in house have been installed in the ALBA storage ring and fulfil the requirements to provide insight into the non-linear dynamics of the storage ring.

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