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## **The Stripline Kicker Prototype for the CLIC Damping Rings at ALBA: Installation, Commissioning and Beam Characterisation**

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### Abstract

The extraction system for the CLIC Damping Rings has very tight specifications. Therefore a full characterization of the behaviour of the stripline kicker under conditions as close as possible to the expected working conditions will be very valuable. To that end the CLIC stripline has been installed in the ALBA Synchrotron Light Source to be characterised with beam. Prior to its installation, the effect of the stripline kicker on the machine impedance has been assessed. The installation has required the design of an absorber to screen the electrodes of the stripline from synchrotron radiation and additional BPMs have been installed for a better kick angle determination. The commissioning of the stripline with beam has been performed following closely beam parameters, pressure and temperature. The studies with beam include the determination of the longitudinal and transverse impedance of the kicker, the field homogeneity when excited with a DC field and the field ripple when pulsed. This contribution reports on the first experience with the stripline kicker for the CLIC DR in the ALBA storage ring and presents the results of the initial beam characterisation.

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# THE STRIPLINE KICKER PROTOTYPE FOR THE CLIC DAMPING RINGS AT ALBA: INSTALLATION, COMMISSIONING AND BEAM CHARACTERISATION

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## Abstract

The extraction system for the CLIC Damping Rings has very tight specifications. Therefore a full characterisation of the behaviour of the stripline kicker under conditions as close as possible to the expected working conditions will be very valuable. To that end the CLIC stripline has been installed in the ALBA Synchrotron Light Source to be characterised with beam. Prior to its installation, the effect of the stripline kicker on the machine impedance has been assessed. The installation has required the design of an absorber to screen the electrodes of the stripline from synchrotron radiation and additional BPMs have been installed for a better kick angle determination. The commissioning of the stripline with beam has been performed following closely beam parameters, pressure and temperature. The studies with beam include the determination of the longitudinal and transverse impedance of the kicker, the field homogeneity when excited with a DC field and the field ripple when pulsed. This contribution reports on the first experience with the stripline kicker for the CLIC DR in the ALBA storage ring and presents the results of the initial beam characterisation.

## INTRODUCTION

High energy electron-positron colliders, such as CLIC, would be a powerful tool to perform searches for new physics. To achieve high luminosity at the interaction point, it is essential that the beams have very low transverse emittance: the Pre-Damping Rings (PDRs) and Damping Rings (DRs) damp the beam emittance to extremely low values [1]. The injection and extraction from the PDRs and DRs will be carried out using stripline kickers, with remarkable kick stability requirements. The stripline consist of two electrodes housed in a conducting cylinder; each of the electrodes is driven by an equal but opposite polarity pulse. The geometric cross-section of the electrodes defines the field homogeneity and the characteristic impedance.

A first prototype of the extraction kicker for the CLIC DR has been designed, built and studied without beam in previous works [2]. In order to complete its characterization, the stripline kicker has been installed in the ALBA Synchrotron to be tested with beam. The results of the in-situ tests and measurements of the beam coupling impedance, transversal field homogeneity and flat-top ripple will be compared to the simulations to validate the final design.

## INSTALLATION

One of the medium straight sections of the ALBA storage ring with a free length of  $L=4.3$  m has been adapted to host the stripline [3]. In normal operating conditions the stripline will kick the beam in the horizontal plane, however, to avoid synchrotron radiation hitting the electrodes it was decided to install the assembly rotated by  $90^\circ$ . In this way, a distributed absorber designed and installed upstream of the stripline, for its protection, did not become the limiting horizontal aperture in the storage ring.

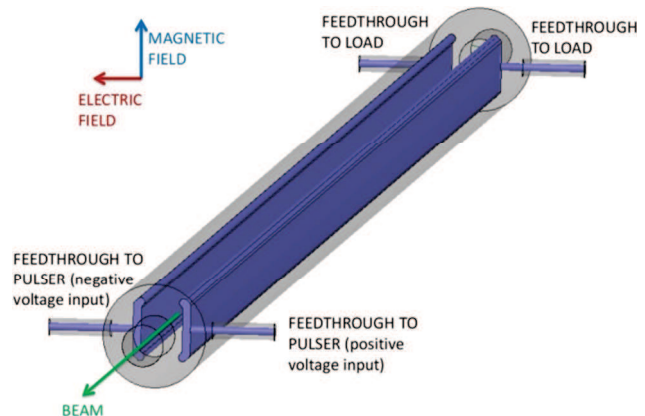


Figure 1: Stripline prototype.

To be able to perform the beam measurements additional BPMs were added. In this way a set of 4 BPMs are available for measurements of the beam position, two upstream and two downstream of the stripline. The storage ring BPMs are equipped with four buttons-type capacitive pickups and connected to a Libera Brilliance+ unit.

The stripline was baked at  $150^\circ\text{C}$  and the rest of the straight was baked at  $250^\circ\text{C}$ . After the bake-out the stripline and the chambers were installed in the storage ring.

## BEAM CONDITIONING

Figure 2 shows the evolution of pressure (in blue) as the electron beam current (in grey) was slowly increased in the storage ring. In this case the stripline was terminated with four  $50 \Omega$ , 100 W loads from Diconex, one per feedthrough, to terminate the electrodes and dissipate the

power induced in the electrodes by the electron beam. During conditioning of the electrodes, when the circulating beam increased from 125mA to 135mA, an increment of pressure,  $\Delta P=3 \cdot 10^{-8}$  mbar, was observed, together with a 20% vertical beam blow up and a vertical tune shift of  $2 \cdot 10^{-4}$ . These results are compatible with ion instabilities, in this case produced by larger atomic masses as indicated by the presence of masses 52 and 80 in the Residual Gas Analyser (RGA) situated next to the stripline.

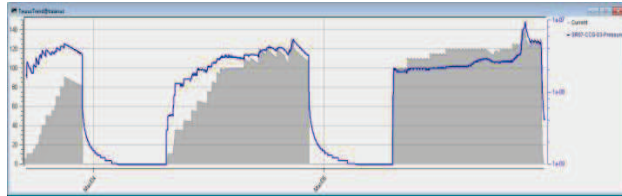


Figure 2: Pressure evolution (in blue) as a function of current in the storage ring (in grey).

Since the operation of the stripline under these conditions was not compatible with users operation, the stripline was removed from the ring. A visual inspection showed evidence that the synchrotron radiation had hit the two last MACOR rings used to keep the electrodes in position. In addition we found traces of glue (Loctite 406) that the manufacturer had used for fixing the screws that lock the position of the electrodes to that of the MACOR rings. These traces of glue are compatible with the large masses mentioned above.

New MACOR rings, with larger horizontal clearance were designed and produced. In parallel the glue was removed using chloroform.

With the new rings, the stripline was again installed in the storage ring. However, while now there were no traces of contamination on the RGA, the pressure did not decrease sufficiently to ensure adequate operating conditions for the light source. Therefore the stripline was removed for the second time. In this case the MACOR rings came out clean and no sign of contamination was found either on the electrodes or on the rings. The unexpected behaviour of the pressure, which might be related to ion instabilities, requires further studies

Finally it was decided to install the stripline when there is no users operation and perform the measurements at currents which are a compromise between having an adequate pressure in the storage ring and having a good signal to noise ratio for the measurements performed.

## HV CONDITIONING

For beam extraction from the CLIC DRs, each electrode will be driven by a voltage pulse of 12.5 kV; for this reason, HV conditioning is necessary prior to the tests with beam. The HV tests have been performed using two DC HV power supplies, which are low current with a relatively small output capacitance. The stripline was first pumped down to a final pressure of  $2 \cdot 10^{-9}$  mbar and then the electrodes powered differentially.

Figure 3 shows the pressure evolution as a function of the HV conditioning: the green trace is the vacuum pressure and the red and blue traces are the applied positive and negative electrode voltages, respectively: a vacuum “spike” is indicative of a HV breakdown. The maximum voltage achieved was 11.5 kV before installation in the storage ring. For a given DC voltage, the number of breakdowns decreased with time, demonstrating a conditioning effect.

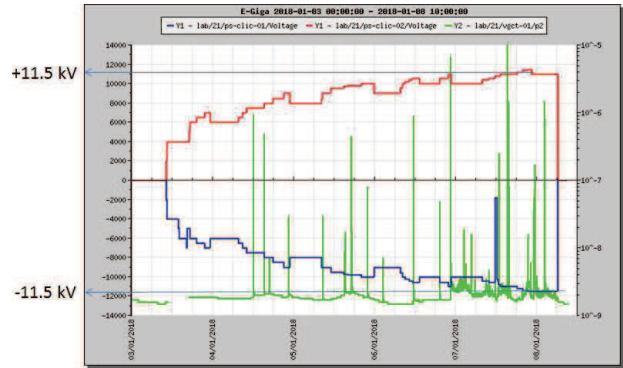


Figure 3: Vacuum breakdowns during HV conditioning.

## MEASUREMENTS WITH BEAM

The most important requirements for the extraction kicker system are collected in the Table 1 for the Damping Ring design at 2 GHz [1]. Significant challenges, for the extraction system, include the stability ( $\pm 0.02\%$ ), flat top repeatability ( $\pm 0.01\%$ ) and the field uniformity ( $\pm 0.01\%$  over a radius of 1.0 mm). In addition, the specification for the beam coupling impedance (not shown in Table 1) is very challenging.

Table 1: Stripline Kickers Specifications

Kicker parameters	DR	Units
Energy	2.86	GeV
Deflection angle	1.5	mrad
Aperture	20	mm
Eff length	1.7	m
Extraction stability	$\pm 2 \cdot 10^{-4}$	
Flat top reproducibility	$\pm 1 \cdot 10^{-4}$	
Field rise and fall time	100	ns
Pulse flat top	900	ns
Extraction uniformity	$\pm 0.01$ ( $r=1.0$ mm)	%

### Beam Coupling Impedance

The transverse contribution of the stripline has been estimated from the change on TMCI threshold and detuning slope measured before and after the stripline installation.

The measurements have been performed using the nominal ALBA lattice as well as a specifically designed lattice that maximises the beta function at the location of the stripline to enhance its contribution to the global impedance of the ring.

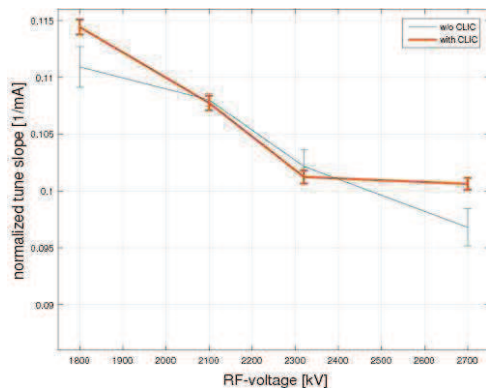


Figure 4: Detuning slope as a function of RF voltage with the stripline installed (orange) and without it (blue).

The detuning slopes [4] are sensitive to different machine parameters (i.e. vertical chromaticity), and the machine reproducibility is one of the main limitations of this method. For this reason, the detuning slopes shown in Figure 4 were taken at different RF voltages (and hence different bunch lengths), and also with the in-vacuum undulators open and closed.

The impedance ( $\beta_y=1.88$  m) inferred from the average measurements carried out before and after the stripline installation is  $Z_{\text{eff}}=3.1$  k $\Omega$ /m, which has to be compared with the value of the simulations of 6.20 k $\Omega$ /m. Nevertheless the rms error associated with the measurements is very large (15 k $\Omega$ /m), which stems from the difficulties associated to reproduce the machine conditions (i.e. zero chromaticity for instance). The repetition of the measurement with a larger  $\beta$ -function did not lead to a better result.

### Transverse Field Homogeneity

The stripline kick is determined by measuring the beam angle difference at the entrance and the exit of the stripline, using two pairs of BPMs: two upstream and two downstream of the stripline.

Using the machine corrector magnets, the beam position is scanned in a region 1 mm around the nominal trajectory to determine the field homogeneity. Figure 5 depicts the kick variation while scanning the beam position in the horizontal (left) and vertical (right) plane, when each electrode is powered to 3.5 kV DC, but of opposite polarity. In order to protect the HV DC power supplies from beam induced currents, a filter box has been designed and assembled: each box is connected between the output of the DC supply and its corresponding electrode. First results show a variation of  $\sim 10^{-3}$ , and we expect to decrease it further by carrying out a larger number of measurements per position. The measurements in figure 5 were limited to 3.5 kV and 10 acquisition/position because partial beam losses due to an incomplete HV conditioning of the electrodes together with the beam.

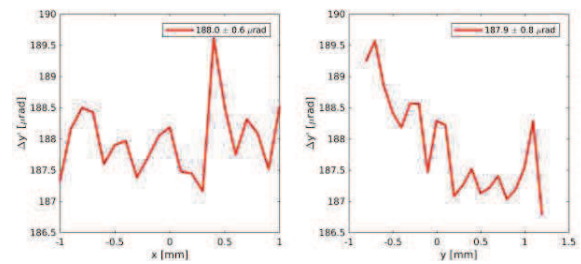


Figure 5: Kick produced when the beam is scanned horizontally (left) and vertically (right).

### Pulsed Measurements

The beam extraction from the CLIC DRs requires the stripline to be operated in pulsed mode with a repetition rate of 50 Hz. The pulser units, based on inductive adder technology [5] are under development at CERN. Once delivered to ALBA the field flat top ripple can be determined by measuring kick differences while scanning relative positions between the pulse flat top and a single bunch with steps of 8 ns. For that purpose, the turn-by-turn amplitude at each one of the 122 BPMs will be measured right after the stripline pulse and averaged over sufficient samples to obtain the desired precision.

## CONCLUSION

The installation of the CLIC stripline at ALBA has been successfully performed, although the conditioning with beam has been more challenging than expected and it is not yet fully understood. First results with beam have been presented and shown its potential to provide useful information about the fulfilment of the stripline tight specifications. An additional installation of the stripline is foreseen in the near future to complete the transverse field homogeneity tests and to characterise the inductive adder pulse generator under development at CERN.

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