Improvements to the LHC Injection Kickers Beam Screen

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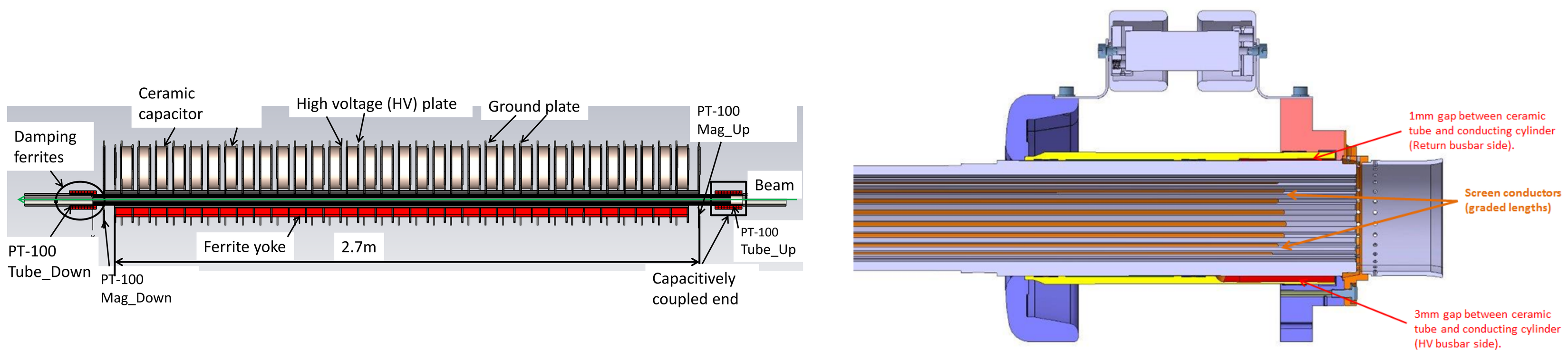
Abstract

The LHC injection kicker magnets (MKIs) experienced strong heating during the initial operation of the LHC up until the beginning of LS1 in 2013, sometimes necessitating cooling periods of 2-3 hours between fills. This heating was found to be caused by beam-induced heating due to beam-driven wakefields in the kicker magnets due to insufficient screening of the ferrite yoke by the beam screen within the yoke, originally necessitated due to concerns of HV breakdown on the beam screen. Recent studies proposed improvements to the beam screen which are to be implemented for LS1, which allows better screening of the ferrite yoke whilst improving HV behaviour. Further studies are under way to allow the MKIs to operate with HL-LHC parameters without experiencing negative effects due to beam-induced heating. Improvements to the resonant coaxial wire method, which permit greater frequency resolution, are also discussed.

Introduction



(a) (b)

Figure 1: (a) The structure of the MKI and (b) the internal structure of the beam screen.

- During operation of the LHC in 2011 and 2012, high temperatures were observed in the LHC injection kicker magnets (MKIs), becoming higher as the bunch intensity was increased to reach higher luminosities [1].
- The heating was determined to be caused by beam-induced heating due to the circulating beam interacting with the real component of the longitudinal beam coupling impedance in the magnet. The hottest magnet before technical stop 3 (TS3), MKI8D, was replaced with a new beam screen in TS3 to improve the screening of the ferrite yoke (structure shown in Fig. 1(a)).
- The improved screening was shown to be highly effective, strongly reducing the temperature of MKI8D, seen in Fig. 2, where it can be seen MKI8D changes from being the hottest magnet at IP8 to the coldest after TS3 [2].

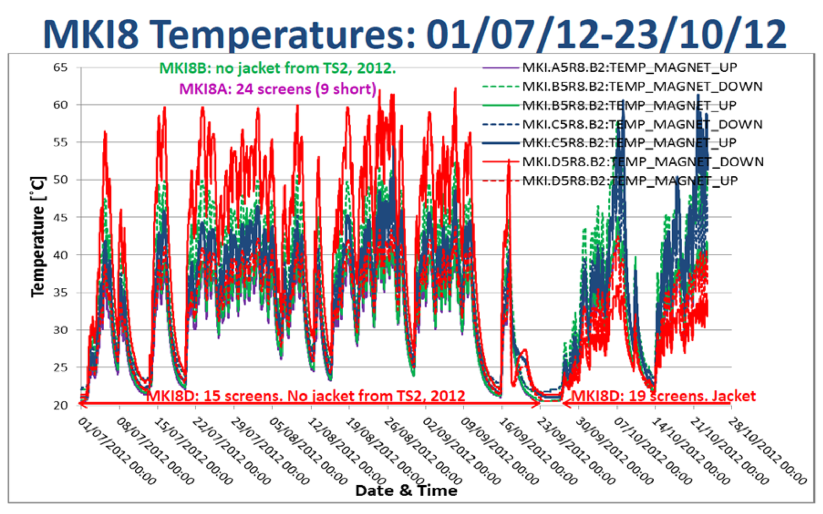


Figure 2: Heating of the MKIs at IP8 before and after TS3.

New Beam Screen Design

- A new screen design has been proposed [3] for installation in the MKIs during long shutdown 1 (LS1) which aims to include 24 screen conductors in the design, whilst lowering the surface electric field on the ceramic tube during kicker pulsing, shown in Fig. 1(b).
- The capacitively coupled end is significantly changed:
  - The external metallization is replaced by an external metal tube which steps away from the ceramic tube near the ends of the screen conductors. This reduces the surface electric field on the ceramic tube significantly. Tapering the length of the conductors also helps this reduction.
  - This reduction allows 24 screen conductors to be placed back in the beam screen, greatly improving the screening of the ferrite yoke from the beam.
- In addition the thermal emissivity of the inside of the vacuum tank is planned to be increased to help improve heat evacuation from the tank.

References

1. E. Métral *et al.*, *Beam-Induced Heating/Bunch Length/RF and Lessons for 2012*, LHC Performance Workshop, Chamonix 2012, CERN-ATS-2012-069
2. M.J. Barnes *et al.*, *Beam Induced Ferrite Heating of the LHC Injection Kickers and Proposals for Improved Cooling*, IPAC2013, MOPWA031
3. M.J. Barnes *et al.*, *Upgrade of the LHC Injection Kicker Magnets*, IPAC2013, MOPWA030
4. T. Kroyer, F. Caspers, and E. Gaxiola, *Longitudinal and Transverse Wire Measurements for the Evaluation of Impedance Reduction Measures on the MKE Extraction Kickers* CERN, Geneva, CERN-AB-Note-2007-028, Jul 2007
5. Hugo Day, PhD Thesis, June 2013

Impedance Measurements of New Design

- The beam coupling impedance for all MKIs with the new beam screen design is measured before bake out and HV conditioning to ensure consistency between magnets and to foresee any possible problems with regards to heating
- Measurements is typically done using the coaxial resonant method due to it's sensivity to low impedances. Additional measurements with the classical coaxial method are done as time allows

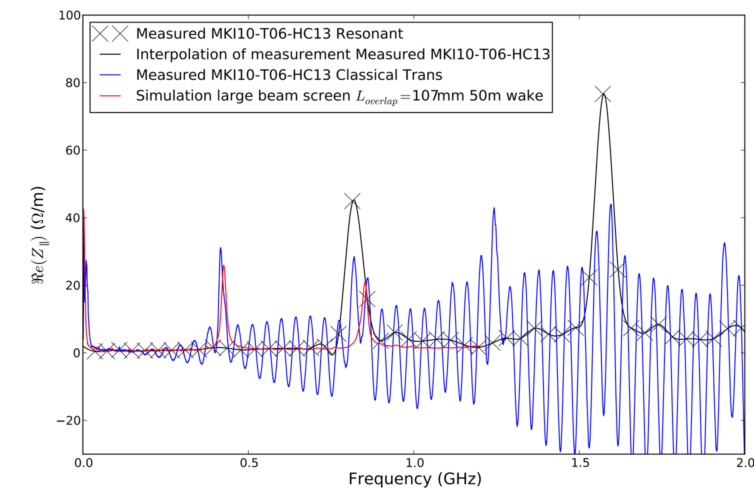


Figure 3: Impedance measurements of one MKI using the resonant coaxial wire method and the classical coaxial method, with comparisons to impedance simulations of the new design.

Table 1: Beam parameters for power loss calculations

Running Mode	N_b 10^{11}	$n_{bunches}$	bunch length (ns)	Bunch separation (ns)
Pre-LS1	1.6	1380	1.2	50ns
Post-LS1	1.15	2808	1.0	25ns
HL-LHC 25ns	2.2	1380	1.0	25ns
HL-LHC 50ns	3.5	2808	1.0	50ns

Table 2: The power loss expected in the MKIs for the magnets measured so far. All power losses are given in W/m.

Screen Design	Pre-LS1	Post-LS1	HL-LHC 50ns	HL-LHC 25ns
New Design	21-35	34-52	151-240	125-191
15 screen conductors	68	117	538	432
Old MKI8D (twisted)	168	N/A	N/A	N/A
19 screen conductors	52	76	N/A	N/A

Resonant Coaxial Impedance Measurements

- The resonant coaxial impedance measurement method turns the device under test (DUT) in a coaxial resonator by running a coaxial line through the device and weakly capacitively coupling the device to the VNA circuit.
- Measurement of the Q factor of this resonance very accurate measurement of the losses of the system can be made and the impedance measured.
- Drawbacks are that resonant frequencies are dependant on the length of the DUT meaning frequency resolution can be poor for short devices.

$$f_0 = \frac{nc}{2L} \tag{1}$$

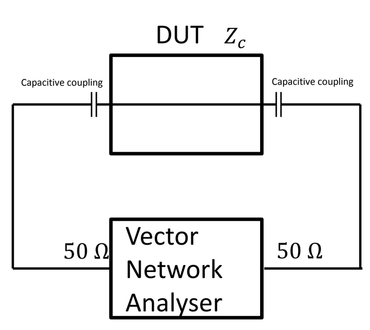
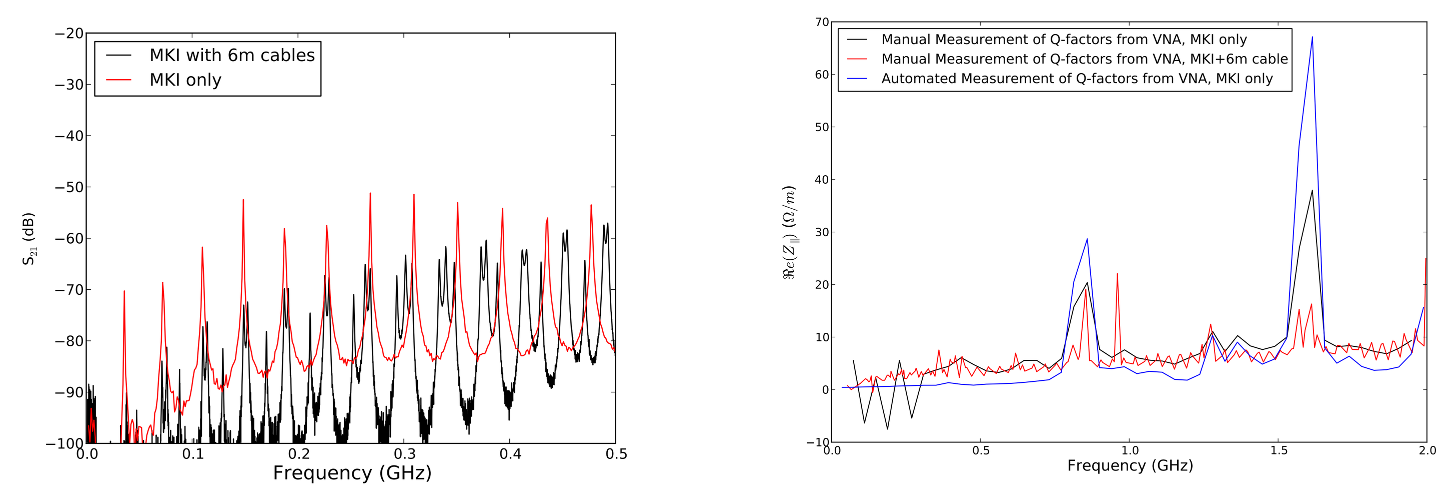


Figure 4: Schema of the measurement setup for the coaxial resonant wire method.

- Length can be increased by artificially lengthening the structure - the use of low loss coaxial cables being a solution (their losses are well characterised and the length known). Other solutions may be possible also (inductances or capacitances to increase the electrical length) however these would make measurements of the imaginary impedance of the device complicated.
- More details of the analysis technique can be found in [4] and [5]



(a) (b)

Figure 5: (a) S_{21} and (b) impedance measurements of a number of configurations for measurement setups for an MKI with the new screen design.

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