The update on the status of harmonic kicker development for the Circulator Cooler Ring (CCR) in JLEIC

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Abstract

An effort to develop the second prototype of the harmonic kicker for the CCR of JLEIC is under way. After beam dynamics study and RF design of the kicker [1], further progress has been made on coupler (loop) design, tuner ports, multipacting study, and mechanical design. On the beam dynamics aspect, the effects of multipoles was investigated and scheme to cancel the effects was developed.

Introduction

- A harmonic kicker is a RF device that transits electron bunch into/ out of the CCR of JLEIC by deflecting kick.
- A new kicker system, based on the quarter wave resonator (QWR), is being developed with the updated beam parameters. The base beam dynamics study and RF design of the cavity is already done [1] and further progress toward fabrication of the prototype is reported here.

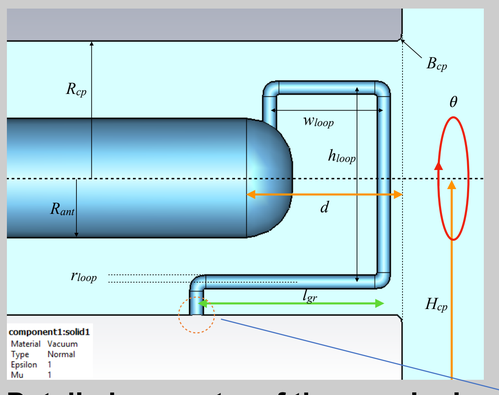
The updated beam parameters if the JLEIC CCR

Beam parameters	Unit	Value
Beam energy	MeV	110
Kick angle	Mrad	2.5
Turns	-	11
Kick freq.	MHz	86.6
Bunch freq.	MHz	476.3
Bunch charge	nC	1.6
Bunch length	cm	2
Energy spread	-	2E-03
Emittance	mm-mrad	36
α		0
β	m	120

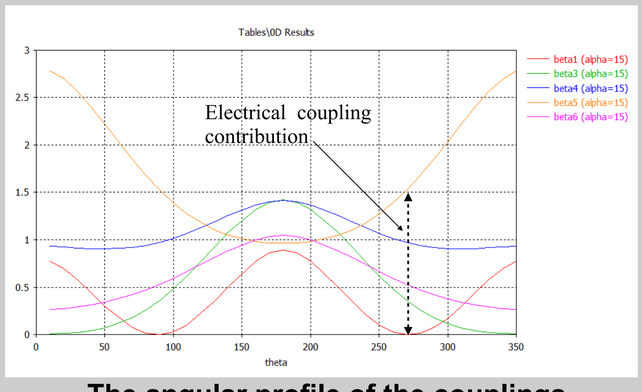
The RF parameters of the harmonic kickers [3]

Cavity design

- A single loop coupler was designed to supply 5 harmonic modes into the cavity near critical coupling.



Detailed geometry of the coupler loop. Each parameters were optimized for critical couplings.



The angular profile of the couplings.

The loop is anchored to the rotatable flange for further adjustment of coupling during the installation.

Figures	f	β	P_g	Q_0	Q_e	Δ_{dB}
Unit	MHz	-	kW	10^4	10^4	kHz
1	86.6	0.74	0.62	0.57	0.78	26
2	259.8	1.21	0.77	0.95	0.86	57
3	433	1.23	1.11	1.31	1.06	74
4	606.2	1.20	1.56	1.55	1.29	86
5	779.4	1.26	2.47	1.70	1.35	103

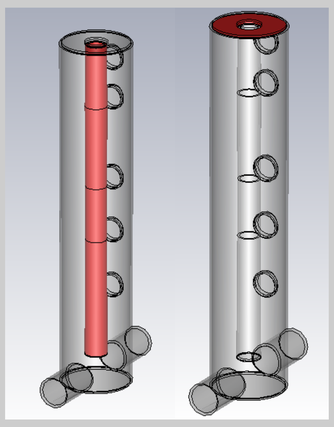
Figures of merit of the kicker cavity

- Tuner port design

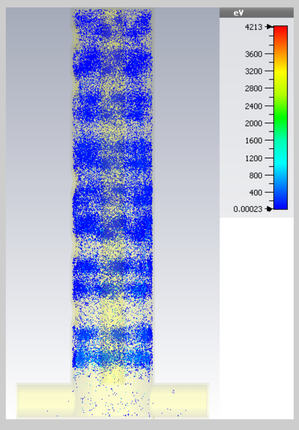
For the motion of the stubs in the tuner ports with some margin for misalignment, gap of 1mm is introduced. The RF fingers are installed to block the RF leakage through the gap. Also the length of the tuner ports was determined for the minimum power loss.

- Multipacting study

- Two-point multipacting takes place between outer and center conductor
- No multipacting takes place on the top plate.

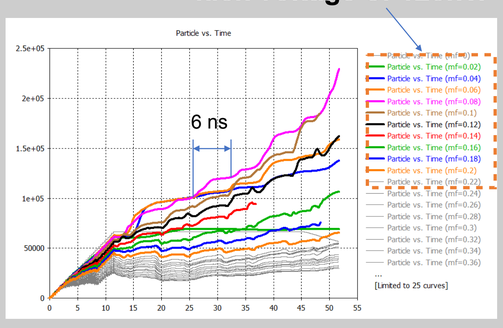


The expected regions for multipacting



The electrons in multipacting

2.5~25kV bandwidth is much lower than operation kick voltage of 125kV.



The number of the electrons vs. time for multipacting between the outer and center conductor.

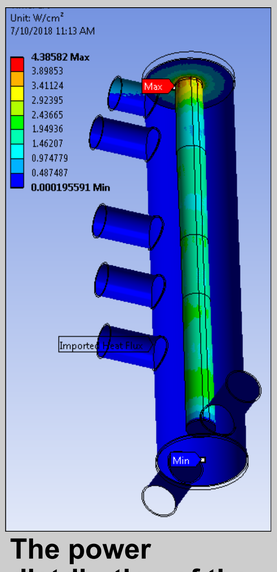
- Thermal analysis was done by using ANSYS

- The expected power dissipation for the operation is below 6.5kW including generic tuning motion of the stubs.

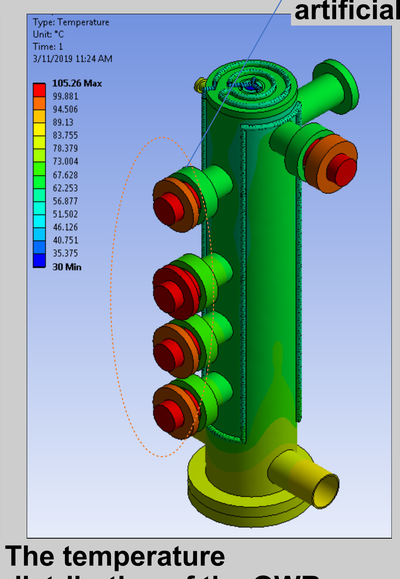
- For extensive cooling, the water cooling channel was introduced into the center conductor, around outer conductor, top plate, and at the root of the stubs.

- The final temperature does exceed 80C with extensive cooling channel installed. This would lead to $\delta f/f \sim 0.6\times10^{-3}$ (for all the modes) well within the tuning range of the tuner ($\delta f/f \sim 0.75\times10^{-3}$).

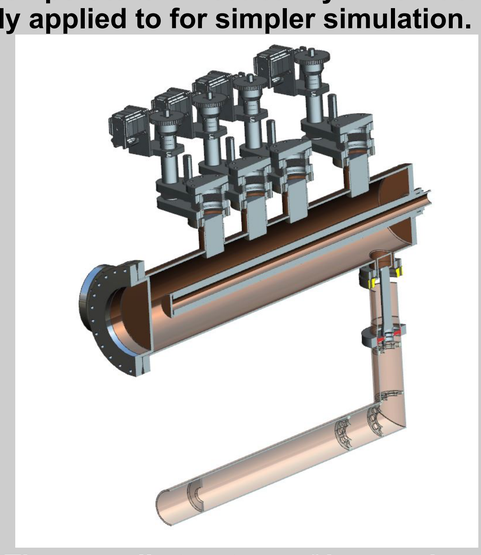
Not the temperature of real cavity. This was artificially applied to for simpler simulation.



The power distribution of the QWR



The temperature distribution of the QWR

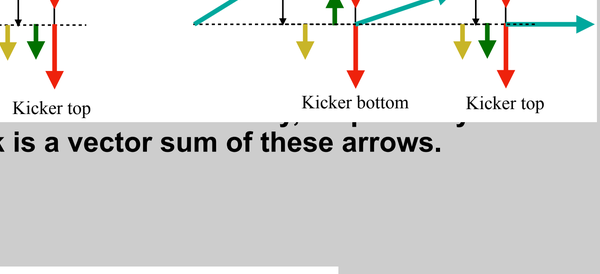


The overall structure of harmonic kicker

The effects of multipoles on beam dynamics

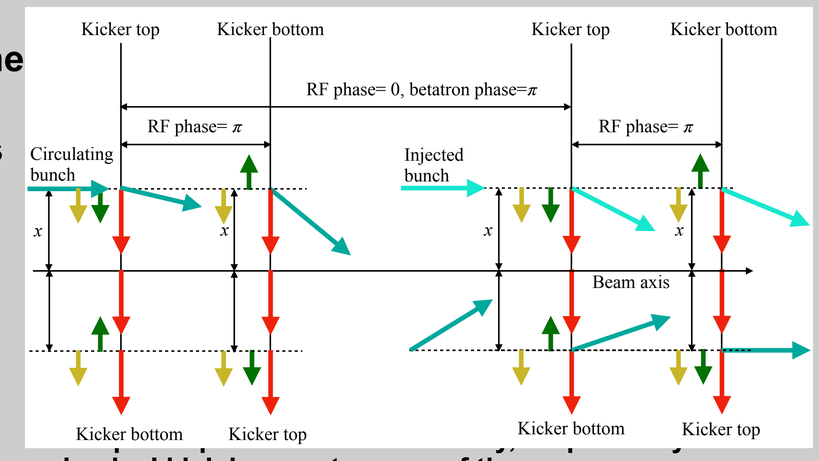
- The QWR cavity has multipole fields other than "monopole" (the designed kick constant over transverse plane), whose effect on the dynamics in the CCR turns out (by ELEGANT simulation) to be detrimental.

- In the CCR of proton energy of 200 GeV, injection electron energy is 110 MeV and a pair of the kickers for each injection (IK) and extraction (EK) kicker.



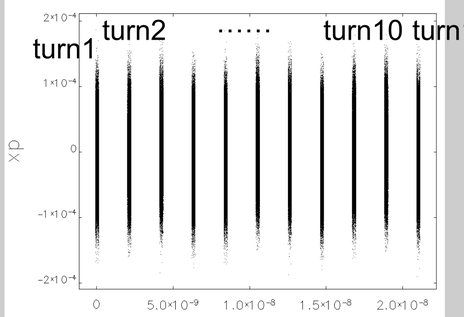
- Cancellation scheme

The slope generated after extraction kickers is inverted by betatron phase advance of π and vertical location also moves down to -x at IK, where the same kick (as EK) is applied and cancels the slope.

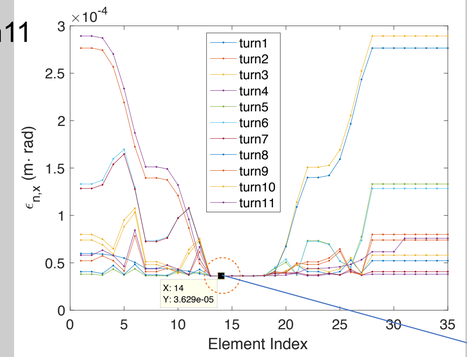


physical kick is a vector sum of these arrows.

- Simulation results



Slope profile at the cooler



Normalized emittance

cooler

References

[1] G. Park, S. Wang, J. Guo, R. A. Rimmer, J. Henry, M. Marchlik, and H. Wang, in Proceedings of IPAC2018, Vancouver, Canada, April 2018.

[2] S. Benson, in Proceedings of IPAC2018, Vancouver, Canada, April 2018

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