HARMONIC STRIPLINE KICKER FOR MEIC BUNCHED BEAM COOLER*

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Abstract

In the current MEIC design, the ion collider ring needs to be cooled by a bunched electron beam of up to 200 mA 55 MeV, with the possibility to upgrade to 1 A. Although it’s not impossible to design and build an ERL to provide such a beam, the technical risk is important and cost associated with such an ERL will be very high. An alternative is to recirculate the electron bunches in a ring to up to 25 turns until the bunch’s quality is degraded, reducing the beam current in the ERL by a factor of 25. This scheme requires a pair of fast kickers that kick one in every 25 bunches. In this paper, we will analyze the electrodynamic properties of a harmonic stripline kicker for this circulating ring, and compare to the harmonic resonator kicker.

Circulator Ring for MEIC Bunched Electron Cooler

Electron beam will be accelerated to 55MeV in the ERL, injected into the circulator ring by kicker I, circulates M times (M=25 in this case) in the circulator ring and perform cooling, then extracted back to the ERL by kicker II, decelerated and dumped. The bunch repetition rate in the ERL (and the gun/breeder) will be reduced to 1/25 of that in the cooling channel, as well as the beam current. The kicker rise/fall time is required to be <1 ns, and repetition rate needs to be 19 MHz. This set of parameters will be prohibitive for switching DC pulse kickers, but could be achieved with harmonic kickers. A simplified version of kicker with M=10 and repeats at 47.6MHz will also be used in the discussion.

Harmonic Kicker and Waveform Synthesis, with FFT

A harmonic kicker utilizes the harmonic alternating EM field to synthesize the desired periodic waves. For a particle with different initial position, the phase when the particle arrives at the kicker is the total kick it receives from the M times bunches.

Waveform Synthesis with Constraint Method

Minimum Number of Modes

We can’t, and don’t have to make a perfect square wave with finite harmonics modes. For a waveform that kicks one in M bunches, the synthesized wave only need to meet constraints (shown below) at the center of each bunch, plus an optional flat top requirement near the kicked bunches.

Zero-Gradient Waveform

We can also use M/2 RF modes to construct the waveform and apply additional zero gradient constraints at the bunches, avoiding the emittance growth due to cavity (TVAUD04).

Single Mode Transverse Shunt Impedance in a Stripline Kicker

For TEM modes in a stripline, traveling wave propagates opposite to the beam, and has speed of light with E=-iB. If the electron travels close to speed of light and opposite to the wave propagation direction, the electric force and the magnetic force will be equal and add up, F=±E. The transverse E-field of one traveling harmonic with amplitude E and angular frequency ω is a function of time and position E=cos(ωt−kx). Particle location is a function of time x=ct−z. Total kick field (E-field equivalent) from the traveling wave for the particle at location z is

The kicking voltage of single mode is the field integral along z axis

For the center of 9th bunch with z=20m (arrival at center of kicker at t=0 and “on phase”),

The wall loss is negligible as most of the power is dumped into the load. RF power needed to excite that mode will be

The resulting transverse shunt impedance for single mode on the kicked (0th) bunch is

Benchmark Impedance calculation with CST MWS

CONCLUSION

We analyzed the dynamics of the stripline RF kicker and derived the analytical equation to estimate the shunt impedance; the result well agrees with numeric simulation. We are able to optimize the length of each kicker, so that the RF power needed to construct a waveform using certain set of harmonics can be minimized. To generate 55kV kick in every 25 bunches with 12 modes in the MEIC recirculating electron cooler, the power needed is 11.6kW for a kicker scaled from the PEP-II feedback kicker to 70mm beampipe. To generate 55kV “zero gradient” kick with 24 modes, the power increases slightly to 13kW. The power requirement for the stripline kicker is 2-3 orders of magnitude higher than a set of resonant kickers, but is not prohibitive. The shunt impedance of the stripline kicker can be further improved with higher characteristic impedance, if we can match with the loads and sources.

REFERENCES


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