Beam Test of a Harmonic Kicker Cavity

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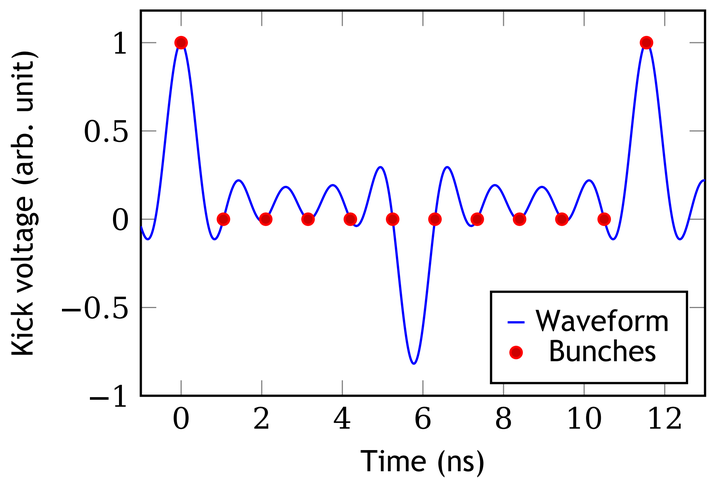
Cavity principle and application

An injection/extraction kicker designed for high bunch frequency

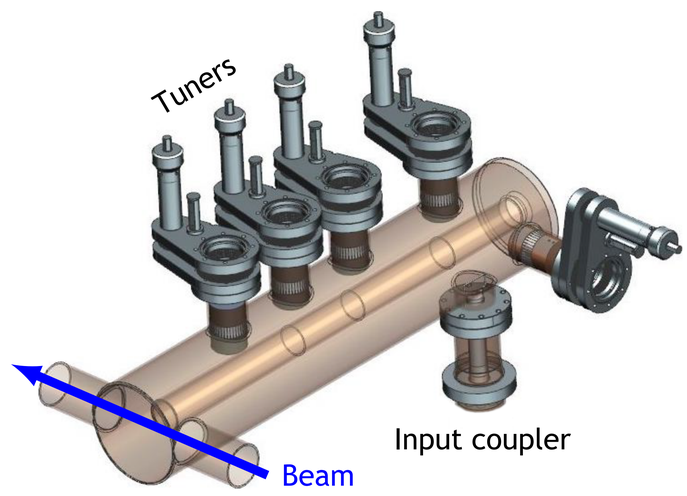
- Transverse deflecting cavity excited at multiple frequencies at the same time
- Fourier synthesis of deflection waveform that acts on every nth bunch only
- Pulsed RF drive minimizes impact on stored beam
- Very short rise/fall times determined by harmonics:

$$V(t) = \sum_{i=1}^{5} A_i \cos\left[(2i-1)\omega t - \phi_i\right]$$

- Note: QWR-type cavity with shorted end supports only odd harmonics

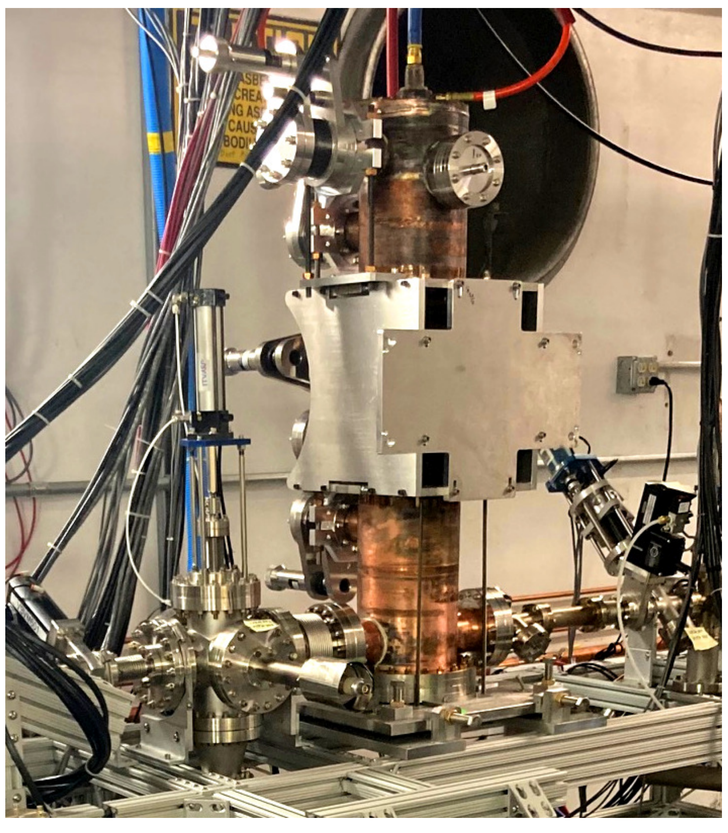


Example: all A_i equal, all $\phi_i = 0$. $f_{\mathrm{HK}} = 86.6\,\mathrm{MHz}$; all 11 buckets filled at a bunch frequency of $11 f_{\mathrm{HK}} = 952.6\,\mathrm{MHz}$.

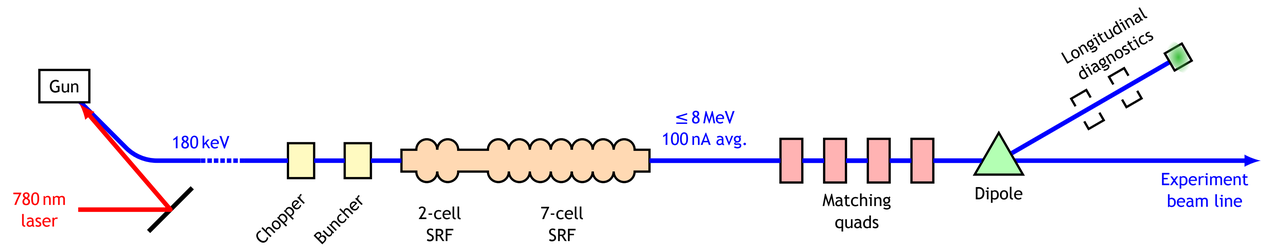


- Single input coupler, single field probe
- Design power: 6 kW for 2.5 mrad kick at 55 MeV (JLEIC)

Beam test at the Upgraded Injector Test Facility (UITF)

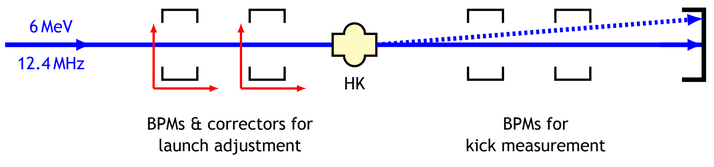


UITF: compact polarized e⁻ photoinjector with SRF booster at Jefferson Lab

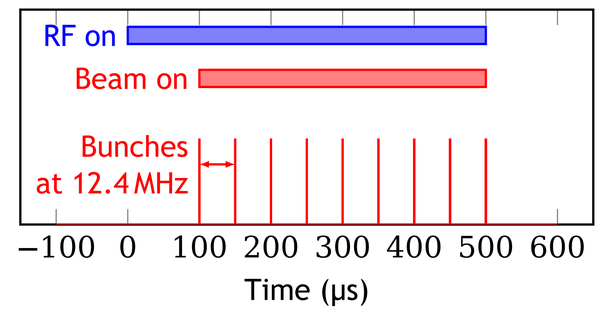


- Flexible bunch timing determined by laser
- Short bunch length: < 1 ps
- Machine frequency: $f_0 = 1497\,\mathrm{MHz}$

Kicker test beam line



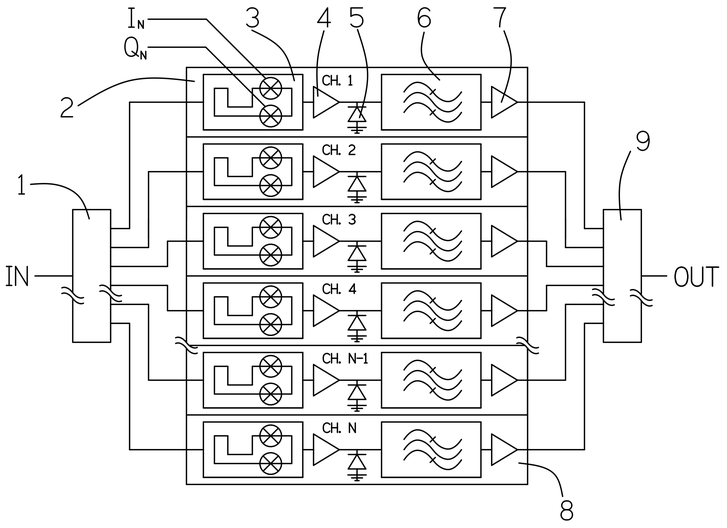
Macropulse synchronization



- Bunch frequency: $f_{\mathrm{HK}}/7 = f_0/121 \approx 12.4\,\mathrm{MHz}$
- All bunches arrive at same cavity phase

Generation and measurement of the deflection waveform

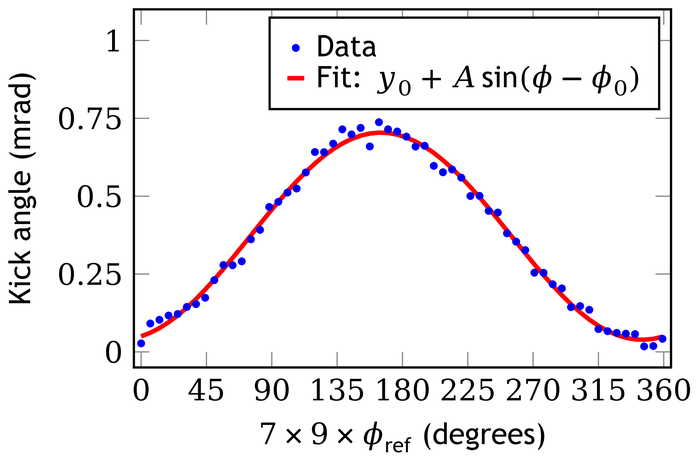
Harmonic Arbitrary Waveform Generator (HAWG)



1: Signal divider
2: Channel 1
3: I/Q modulator
4: Amplifier
5: Harmonic generator
6: Band-pass filters
7: Amplifier
8: Channel N
9: Harmonic combiner

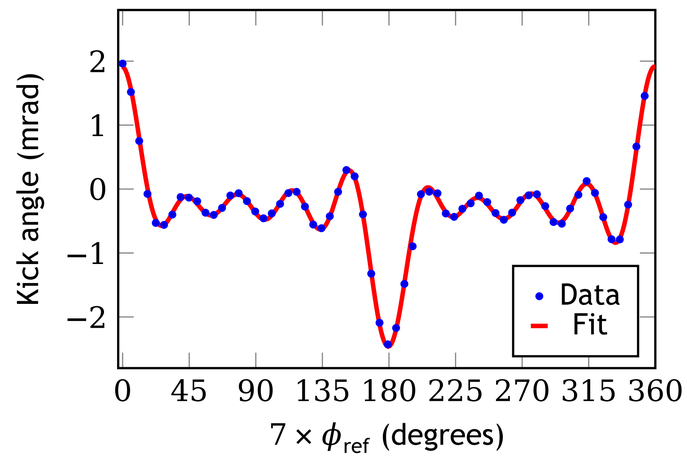
- HAWG reference phase scanned to obtain waveform
- Kick measured by downstream BPMs

Highest mode only



- Mode-by-mode calibration for phase and amplitude reference
- Clean sinusoidal deflection

All five modes powered



- Resulting waveform close to theory
- Phase errors caused by detuning (open loop)

Successful proof of concept!

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