Investigations of Wakefields and HOMs in the Tesla-type Cavities at FAST

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FAST Retreat

August 18, 2016

Context

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- Wakefield and HOM proposed studies program described in Feb. 2016 FAST/IOTA mtg. talk.
- At the time we estimated short range wakes due to steering in CC1 and CC2 could be seen in sub-micropulse y-t streak images.
- We expected HOMs would also be generated with dipole mode variation over 10 μs.
- Bunch-by-bunch diagnostics would be needed to detect the variable kicks and positions of the micropulses.

  -rf BPMs for positions in principle, (noise levels)

  -framing mode of the streak camera at X121 could provide position and profile.

  - HOM effects on beam size and emittance at (X107),108

Higher Order Modes (HOMs)

- HOMs are induced by off-center steering in rf cavity.
- Investigate long range deflecting dipole mode acting within the macropulse; ~10-μs range. Vary bunch #.
- The magnitude of the HOMs can be increased by steering transversely off axis in cavity, intentionally or unintentionally, Q dep., and result in emittance growth.
- Commission HOM detectors in CC1 and CC2. (Nathan and Peter plus Ops.) (2)
- Perform initial long range effects search with HOM detectors, various offsets, charges, and beam size/pos. tracking after CC2 in (X107), X108, X121. (Alex, Jinhao, Chip, Dan, Nathan). CC1,CC2 Transfer matrix input? (2)
- Bunch by bunch rf BPM readings requested. CCD gates.

Short-range Dipole Wake Fields

- Investigate short range deflecting dipole mode wake field acting within a single micropulse; 1-20 ps range.
- Use 1-10 micropulses to look for effects initially.
- The magnitude of this wake field can be increased by steering transversely off axis in cavity, intentionally or unintentionally, Q dep., and results in emittance growth.
- Perform initial short range wake field search with (HOM detectors), various offsets, charges, and beam size/pos. tracking after CC2 in (X107), X108, X121. (Alex, Jinhao, Chip, Dan, Randy). CC2 Transfer matrix input? (2)
- X107 slit images would help on emittance evaluation.
- If/when correlated beam size growth with offsets seen at X121, then pursue the streak camera studies to clarify.

Streak Camera Measurements of Dipole Kicks

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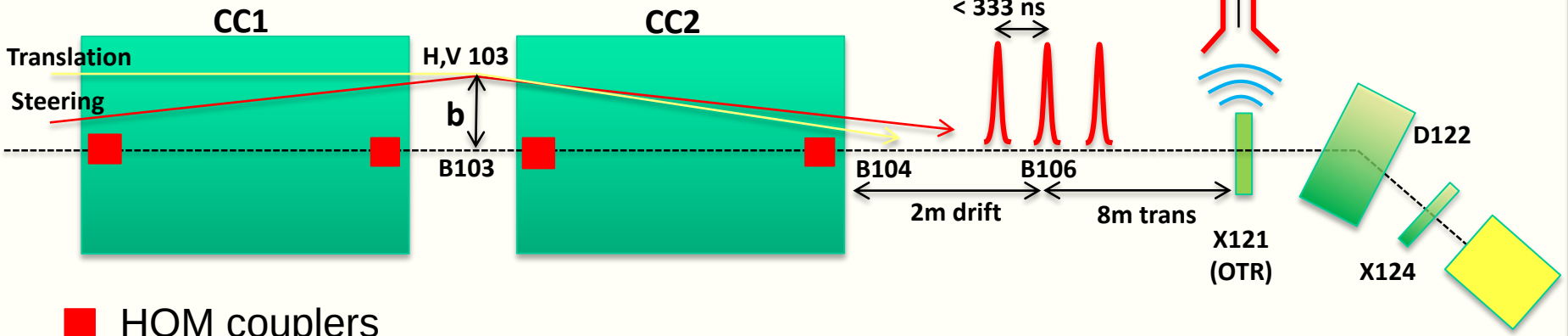
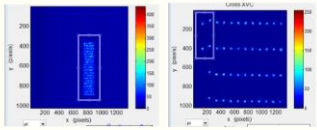
Some Kick and translation options, need b = 0 – 5 mm offsets at B103 between cavities.



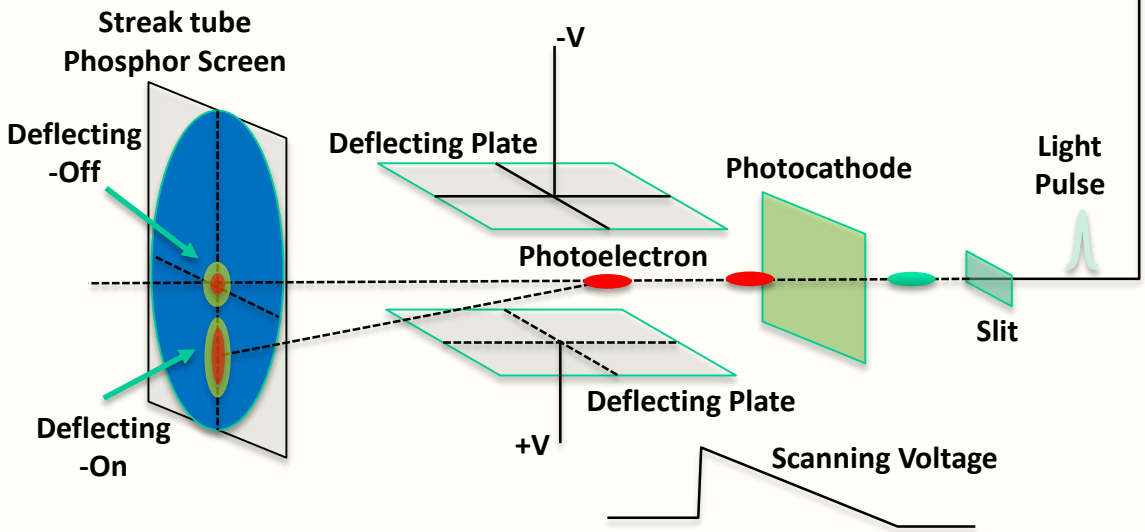
- HOM couplers

Effect	Mode	Temporal resolution	Spatial res. (μm, est.*)	Wake Range
Sub-Micropulse, y-t	Synchroscan,V	1ps	50-100	short
Sub-macropulse, y-t,T	dual sweep,H,V	1ps, H axis selectable	50-100	short
Sub-macropulse, y-T	Slow sweep,V	100 ps	50-100	long
Sub-macropulse, x,y-T	Framing Mode	100 ps	50-100	long

UV laser pulse train demos



*Bunch-by-bunch techniques can be applied to IOTA beam turn by turn.



N.B. Unique Cavity Configuration and Diagnostics capabilities at FAST.

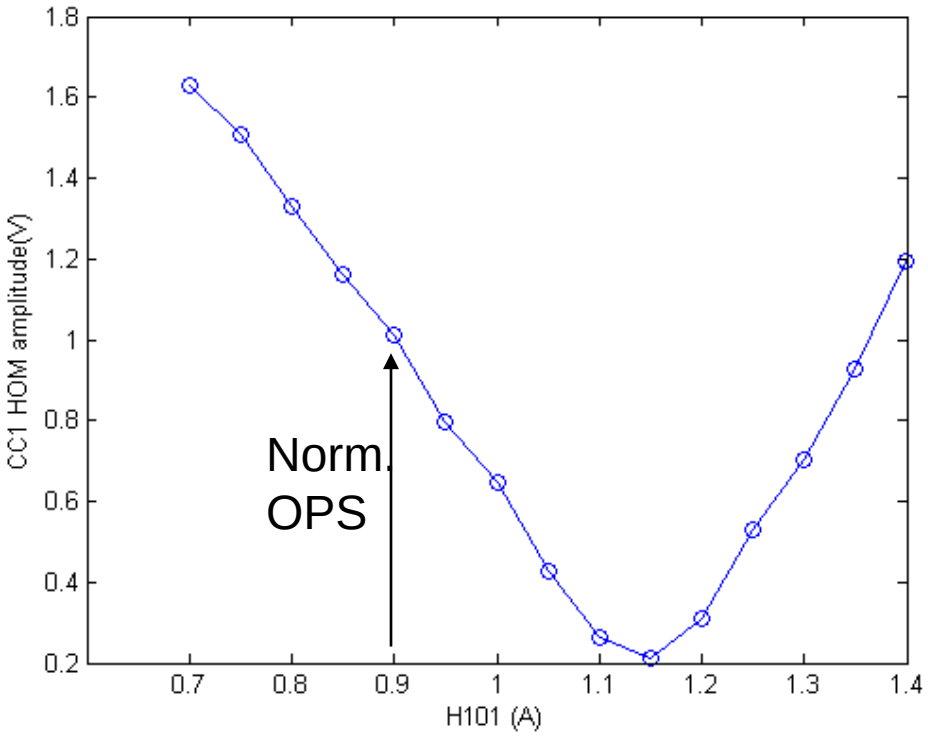
YMS Slide design

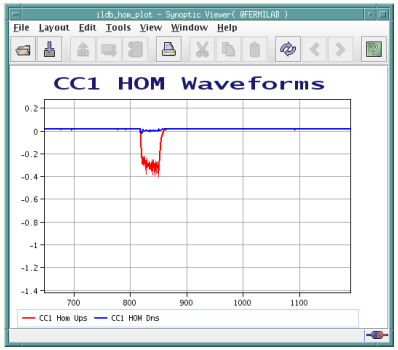
HOM Detector Updates

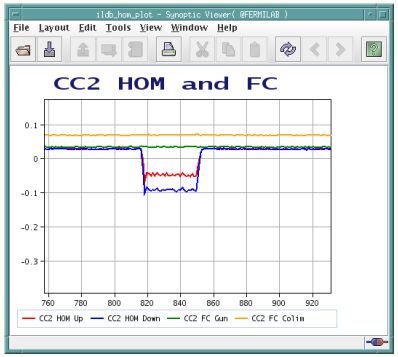
- HOM detector circuits were revised twice by Peter on 7/22/16 from earlier version with beam-based tests.
- With band pass filters available near 1.7-1.8 GHz we targeted the expected HOM dipole modes from Tesla cavities.
- Both CC1 and CC2's upstream and down stream detectors were functioning with the strongest signal in CC1 upstream.
- Jinhao subsequently resteered the beam with H,V101-3 correctors to reduce the CC1 and CC2 HOM signals.
- Emittance reported to be improved by 30% at low charge by Philippe and Jinhao a few days later using reduced HOM setup, but *no* high charge cases done yet.

Preliminary HOM CC1 Det 1 Results

- Initial look at CC1 HOM D1 signals with H101 steering.
- Normal current setting at 0.9 A. (7-22-16 elog entry)







New Steering

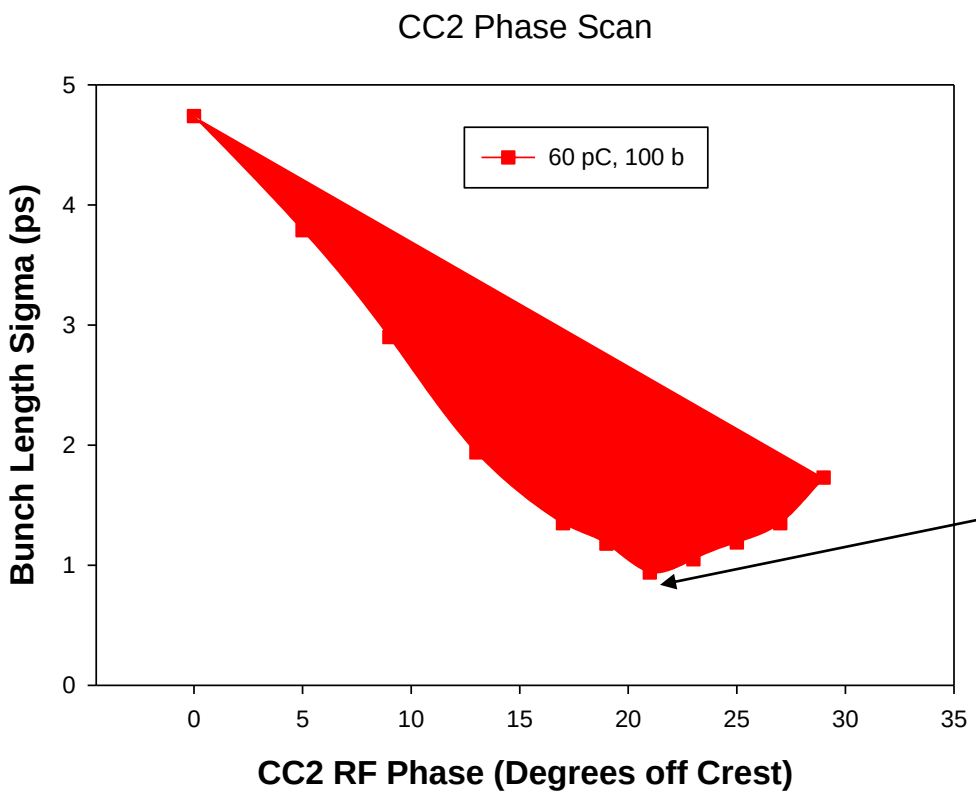
Some Results

- We have obtained clear sub-ps pulse generation and streak camera sub-ps resolution by speeding up R1 and adding a long pass filter (LPF) on OTR input.
- We have obtained clear dual-sweep streak images for looking for short range wakefields. See single bunches at 330 pC/b.
- We have also obtained first semi-framing camera mode for bunch by bunch profile and position with X121 OTR.
- Comparison to images at X121 YAG indicate spatial resolution at about 10 microns, much better than our conservative estimate of last Feb.
- Since beam was apertured to 25 x 135 μm^2 we probably can operate below 200 pC per micropulse if focused.

Electron-beam Compression

- **Comparison of the electron beam bunch length versus CC2 rf phase noted as degrees off crest (DOC).**
- **60 pC micropulse charge, synchronous sum of 100 b.**

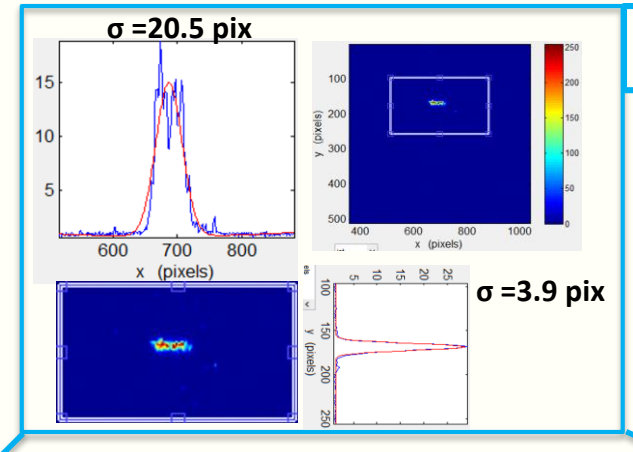
1.New R1 cal:
0.10 ps/pix
2. BandWidth
term subt.
3. 7-13-16 Data



First sub-ps
Bunch length
at FAST

Preliminary Data: Dual-Sweep Streak and Framing Images

YMS Slide design



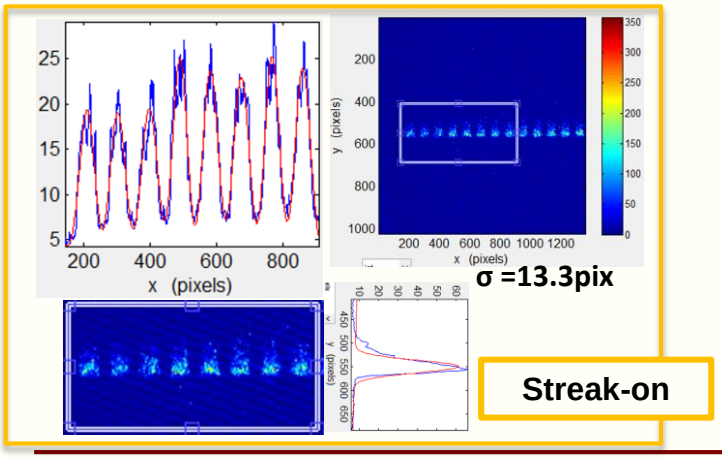
Streak-off, Framing-off

Short Range

Long range

Dual-Sweep Streak Image

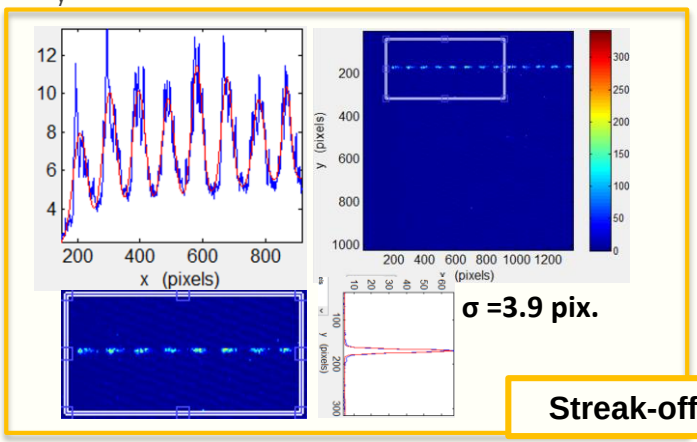
- R1 - 5μs, 330 pC, 13/18b, MCP = 55, CCD-G=10.5 image ave.
- 1.5 degree instr. axis tilt removed. Last bunch at left.
- σ_t = 4.7 ps - Apertured, 25 DOC R1cal=0.38 ps/pix



Streak-on

Horizontal-Sweep Demo for HOMs/IOTA

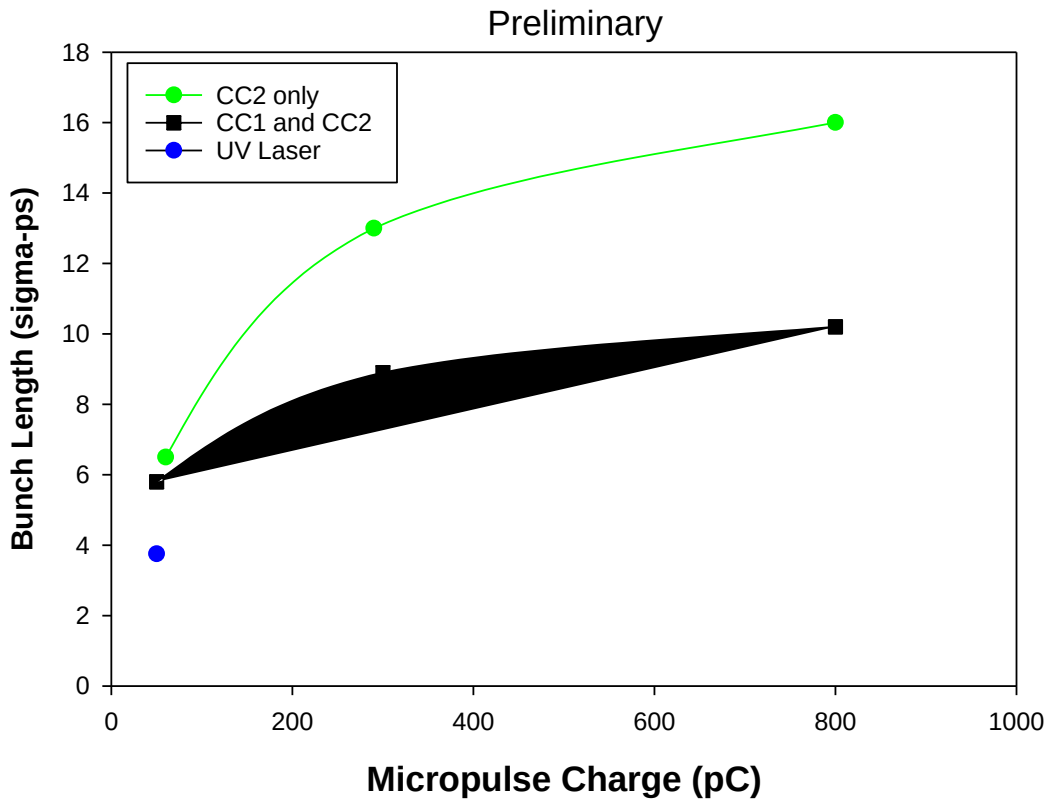
- Focus Mode (L) and Hor.=5 μs (R), 170 and 1000 pC/b, MCP=55, CCD-G=10.
- Focus 3.87 pix. Slit=35 μm (Optics rotated image 90 deg.) @ X121 station
- σ_x = 25 μm, σ_y = 135 μm, X,Y cal = 6.6 μm/pix



Streak-off

Electron-beam Elongation

- **Comparison of the electron beam elongation in z vs. micropulse charge without and with CC1 installed.**
- **Synchronous sum of 20 micropulses except lowest Q.**



*Also should run at 20-25 ps laser pulse lengths for Wakefield studies.

Some Issues-a

- rf BPM bunch-by-bunch mode seemed to cause position-averaging problem, so reverted back to averaging only. Need that former feature and the low noise boards for next run. Look for position vary vs. T.
- Slits at 107 would provide option for alternate emittance measurement technique for assessing HOM effects.
- Studies would benefit from the installed slits and the emittance phase space program being commissioned.
- Framing camera mode at X121 would benefit from the proper trigger in phase with beam from MPS system so can see the beginning of macropulse and with low jitter.
- Steering off-axis through cavities will require trajectory corrections to keep X121 OTR in streak camera slits.

Some Issues-b

- Synchroscan rf tuning unit seems to have more temperature effects with new R1 speed. Tripped on July 26 run. Retuned subsequently.
- Suggested RTD monitor, but actually need small fan or Peltier block to cool unit's vanes in the enclosed box.
- Suggest speed up R2 from 0.68 ps/pix to 0.3-0.4 ps/pix calibration to provide intermediate bunch length coverage and a tuning point closer to the R1 setup.
- HOM detector upgrades planned with a notch filter at 1.3 GHz, low pass filter at 2.4 GHz, and band pass filter at 1.6-1.9 GHz (for dipole modes). Ordered per Peter P.
- HOM CC1 Det2 amplifier needs to be replaced reports Peter.

SUMMARY

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- Successful studies on several counts:
- Demonstrated dual-sweep streak mode for phase and bunch-length tracking bunch by bunch.
- Demonstrated horizontal sweep in semi framing mode to track spatial position and profile bunch by bunch.

  (proposed application to OSR from IOTA ring)
- Demonstrated improved time resolution by speeding up Range 1 deflection circuit and adding 550 nm LPF.
- Observed sub-ps bunches at FAST with improved system. (see e-log) Also should run at 20-25 ps laser.
- Compared results to Martin-Puplett Interferograms.
- Further studies time will be requested for full test program. FAST, LCLS-II, MaRIE, etc. relevance.