Observations on Submicropulse Electron-Beam Effects From Short-Range Wakefields in Tesla-Type Superconducting Rf Cavities

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Motivation: Assessment of SRW Effects on Beam Dynamics

• It is known that off-axis steering in accelerator cavities can lead to dipolar HOMs that can cause submacropulse centroid slewing and oscillations. (A.H. Lumpkin et al., PRAB 2018).

• In addition, there are short-range wakefields (SRWs) with off-axis steering that result in submicropulse, head-tail centroid kicks (A.H. Lumpkin et al., PRAB 2020).

• We investigate higher-order-modes (HOMs) in a TESLA-type cavity (CC2) and their effects on beam dynamics using bunch-by-bunch rf BPM data taken downstream of CC2.

• CC2 is tuned off-resonance and powered off in these data.

• Beam dynamics that lead to emittance dilution were observed and mitigated.
CC2 HOMs Probed with V103 Scan

- HOM signals for different charges, 500 pC/b and 750 pC/b.
- 1.75-GHz band. Open iris above 500 pC/b. Double VC spot.
CC2 HOM amplitude and phase information. Dipole Modes 7, 14 with diff. frequencies of 267 and 181 kHz with beam harm..
Q118-120 used to Focus Beam at X121 and B121

- The quadrupole focusing effect is shown in the reduced beam submacropulse centroid oscillation from B120PV to B121PV.
- This is summed over in the synchroscan streak image.

![Graphs showing beam oscillation](image)
V103 Scan: X121 Streak Camera Image Effects

• Initial image projections for focus mode and streak images.

  50b.

• Streak R1, 0.5nC/b, 40 images, 38% larger y projection at -1.0 A.

Focus Mode

R1: Ref = 0.0 A

\[ \sigma_y = 407 \mu m \]

\[ \sigma_x = 3.67 \text{ pix} \]

R1: -1.0A, \( \delta y_c = -111 \mu m \)

\[ \sigma_y = 569 \mu m \]

\[ \sigma_t = 10 \pm 1 \text{ ps} \]

\[ \sigma_t = 11 \pm 1 \text{ ps} \]
ASTRA Simulations Performed for SRW

- ASTRA Input Deck for FAST gun and two TESLA-type cavities used.
- Laser spot 0.6 mm rms, Bunch length 4 ps rms.
- (a,b) Head-tail kick for single micropulse calculated with 0- and 5-mm offset.
- (a) Space-charge effects seen in the electron beam bunch length at 500 pC compared to laser.
- (b) Elongation seen as a function of charge.
Summary

- The HOM detectors and rf BPMs were used to evaluate off-axis steering effects and SRWs in a TESLA Cavity at FAST.
- CC1 was powered normally, but CC2 was off-resonance and unpowered.
- Measurable submicropulse head-tail centroid shifts were observed with the streak camera located downstream correlated with steering with V103 into CC2.
- Spectral data show clear near-resonances with a beam harmonic in dipolar modes 7 and 14 in CC2. Combination leads to submacropulse centroid oscillation at ~220 kHz.
- ASTRA simulations show a SRW head-tail effect and space-charge effects on the electron beam bunch length consistent with the experimental results.