LCLS S-band Structure Coupler

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Outline

• Motivation
• Modeling tool
• S3P model of S-band coupler
• Field analysis
• Beam analysis

Discussions
Motivation

• To understand effects of multipole fields on beam dynamics in single-feed coupler
• Work on alternative designs if necessary
Parallel EM Codes On Unstructured Grids

Generalized Yee Grid

- Tau3P/T3P
- Time Domain Simulation With Excitations

Omega3P
- Frequency Domain Mode Calculation

S3P
- Scattering Matrix Evaluation

Finite-Element Discretization

Track3P – Particle Tracking with Surface Physics

V3D – Visualization/Animation of Meshes, Particles & Fields
LCLS S-Band Coupler – S3P Model

- Dimensions directly from drawings
- Reflection about 0.05
- Should be ok for this study

For field symmetry
Field Asymmetry In Coupler Cell - Ey

Ey:
- Snapshot
- Contour plot
Field Asymmetry
Fields On Axis

On-axis $E_y$ and $B_x$ are non-zero in the coupler region
Beam Dynamics

• Equation of motion:
\[ \frac{d(\gamma \beta)}{dt} = \frac{e}{m_0 c} (\tilde{E} + c \beta \times \tilde{B}) \]

• Transverse momentum
\[ \Delta \tilde{P}_{m \perp} = -\frac{je}{\omega} \nabla_{\perp} \int E_z (r, \theta, z, m) e^{j \omega t - j \zeta z} dz d\zeta \]

\[ E_z (r, \theta, z, \zeta z) = \sum_{m=0}^{\infty} A_m J_m (\eta_r r) \cos (m \theta) e^{-j \zeta z} + \sum_{m=0}^{\infty} B_m J_m (\eta_r r) \sin (m \theta) e^{-j \zeta z} \]

where \( \eta_r^2 + \zeta_z^2 = \frac{\omega^2}{c^2} \)

• To the first order
\[ \Delta \tilde{P}_{\perp} = -\frac{je}{\omega} \left( -\frac{\eta_r A_0}{2} (x\hat{x}_0 + y\hat{y}_0) + \frac{\eta_r A_1}{2} \hat{x}_0 + \frac{\eta_r B_1}{2} \hat{y}_0 + \frac{\eta_r A_2}{4} (x\hat{x}_0 - y\hat{y}_0) + \frac{\eta_r B_2}{4} (y\hat{x}_0 + x\hat{y}_0) \right) \]

- focusing
- dipole
- quad
- skew quad


\( \gamma \) Dependence Of Momentum Multipoles

- \( 1/\gamma \) dependence for azimuthal focusing (full structure - back-back coupler in our case)

\[ \gamma(\infty)\beta_r(\infty) = \gamma(-\infty)\beta_r(-\infty) \left( 1 + \frac{I_{01}}{\gamma} + \frac{I_{02} - I_{03}}{\gamma^2} \right) - r(a) \left( \frac{I_{11}}{\gamma} + \frac{I_{12} - I_{13} + I_{14}}{\gamma^2} \right) \]

where \( I_{nn} \) are integrals of \( E_z \) field

- Dipole and quadrupole are \( \gamma \) independent.
Azimuthal Focusing

- Full back-back system simulation
Dipole & Quadrupole

- Effect of input coupler
- Integrate through half of the model

Dipole & Quadrupole v.s. RF Phase

- Dipole x
- Dipole y
- Quad/mm

Beam (phase?)
Head-Tail Effect

- “Zero” phase is not accurate since only a few cells are included in the present model – phase slippage and coupler effect significant
- Amplitude of dipole and quadrupole OK
- Bunch spans ±10 degrees in RF phase
- If beam on crest, head to tail $\Delta(\gamma\beta_{\perp})$ is
  - Dipole: 0.005
  - Quadrupole: 0.0015/mm (focusing)