Ions in LCLS2 Linac, gun and Cavity

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Outline

• Update Ions at Linac (simulation with more macro-particles)
• Cathode ion bombardment:
  - Gun fields
  - Ions trajectory
  - Ions reaching the cathode
• Ions in the 1.3GHz cavity
100pC

Vacuum Model

S<1000m, P=1nTorr, Temperature=10k
S>1000m, P=10nTorr, Temperature=300k
90% h2
7% CO
1% CO2
1% CH4
1%H2O
Bunch amplitude at the end of linac for a long bunch train (100pC, with more particles)

Simulation includes
- Multiple gas vacuum
- Optics
- Trapping effects (bunch spacing, ...)
- Nonlinear effect
- 5 millions particles

Similar as before, there is a linear growth, instead of exponential one
- Non-coherent motion found due to the long bunch spacing (not deep trapped) and short linac
- Linear theory doesn’t apply here

Density $1.2 \times 10^{12}$

Similar growth in X and Y

CO period is about 5 bunch spacing
300pC

- Slightly faster than 100pC case
What are the assumptions in linear theory

- The bunch spacing is much shorter than the ion oscillation period (coasting beam)
- Linear force between two beams
- Long linac
Test with a long linac with FODO cell

Bunch spacing 2ns
H2 ion frequency=0.7MHz
About 700 bunches in one ion period
Discussion

- Large number of ions can be accumulated due to the attractive force even with a long bunch spacing. However there is a lack of coherent motion between ion and e-beam due to the long bunch spacing and short linac.

- A analysis model is proposed here and will be used to benchmark the simulation
A simple model

Assumptions
(1) Ion line density are constant along the linac
(2) The beam size varies accordingly
(3) The kicker from ions is linear
\[ \Delta y' \propto (y_b - y_i) , \quad y_i = 0, \text{yb0 random} \]
(4) Bunch receives single kicker from each element and then drift to next element
(5) Random amplitude and A linear dependence is found which agree with simulation

\[ \text{scale_cor0} = 1.0e7 \]

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One better model

\[ \Delta y' \propto (y_b - y_i) \]

\[ y_i = y_b \times (0.5 - \text{rand}) \times \text{cof} \]
Cathode ion bombardment with APEX GUN
Gun fields

- Gun parameters (100pC):
  - Frequency: 187MHz
  - Cavity field: 21MV/m
  - rf phase: -8 degree
  - Solenoid: 0.042Tesla
  - Beam energy at gun exit: 0.75MeV
- 2D gun field (CW model)
- 1D solenoid
- 3D calculation with arbitrary particle and field;
  Field solver is also available
Electron beam detail

Ions are uniformly generated along the e-beam path (Note: ionization cross section has strong dependence on the e-beam energy at low energy <1MeV)
With 100pC configuration

- Tracking 180k particles
- Only near cathode particles (z<1cm) can hit the cathode
- 7% ion can hits cathode (actually more ions can hits the cathode when the cross section effect is included)
- 2% is still stay inside the cavity
Distributions at cathode

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Effect of Ionization cross section (H2)

With cross section

7% ion can hits cathode

More than 37% ion can hits cathode

Given 1nTorr pressure, 300pC, H2 ion hitting per rf period less than 1
Strong dependence on the rf phase

18% ions can reach the cathode with an rf phase of -20 degree (compared 7% at -8 degree)

- A positive phase cause ion drift away from the cathode $\overline{v}_{z,0} \propto \sin(\phi_0)$
- On the other hand, a large negative phase ([-90 0]) make more chance for ion to hitting the cathode

rf phase -20 degree
summary

- The low rf frequency gun makes it unique:
  - High ion energy; less chance to hit the cathode; easy to control the ion bombardment (rf phase)
- Short cavity: low ion production
- The field profile (single cell cavity) reduce the ion bombardment
- We can reduce the ion bombardment by choosing rf phase $\rightarrow 0$
- It is not a issue given so low bombardment rate?

Next:

- Get more information about the cross-section of other type ions
- include laser effect, expect more chance to hit the cathode
- Cornell GUN
BC2 energy effect vs RW wake field de-chirp

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De-chirp by RW wake

\[ \langle E \rangle = 0.250 \text{ GeV}, \ N_e = 0.062 \times 10^{10} \]

After BC1

\[ \langle E \rangle = 1.600 \text{ GeV}, \ N_e = 0.062 \times 10^{10} \]

After BC2

\[ \langle E \rangle = 4.009 \text{ GeV}, \ N_e = 0.062 \times 10^{10} \]

After L3

\[ \langle E \rangle = 4.000 \text{ GeV}, \ N_e = 0.062 \times 10^{10} \]

Before HXR Undulator
Increase the energy at BC2 to ease the sensitivity to the strong de-chirper from RW wake

Advantage at higher BC2 energy

- Provide more correlated energy spread (More RWW possible)
- Reduced LSC effect due to high beam energy
- More flexible Linac design;

Bottom line: keep BC2 energy at 1.6 GeV, varies BCs configurations!

Assumptions:
- Constant RF phase \( \varphi_{L2} = -21^\circ \)

\( \sigma_z1 = 0.283 \text{ mm} \) (post BC1 bunch length)

24%@2.2GeV

\( \sigma_z1 = 0.15 \text{ mm} \)

16%@2.2GeV

BC2@1.6GeV

R56= -59.0mm/-37.5mm

LCLSII Physics meeting, 07/17/2014, L. Wang