A PULSED ELECTRIC LENS FOR NDCX

by
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A pulsed electric lens for NDCX

Ed Lee
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- To compress pulse, \( \frac{v_{\text{Tail}}}{v_{\text{Head}}} \)
- This causes a chromatic aberration:

\[ \text{Hodg Focus} \]
\[ \text{Tail Focus} \]

- Place fast pulsed lens here to compensate velocity "tilt"

Strong Lens (Solenoid)

Considerations

Time scale is ~ pulse length ~ 60 ms
Lens works only in vacuum
Lens must be compact (~ 30 cm)
Voltages ~ 100 kV
Programmable waveform
Reasonable cost - look at energy/power
Solenoid \( \approx 1.0 \text{ kJ} \), \( 10^9 \text{ watts} \)
Electric lens \( \approx 30 \text{ mJ} \), 30 kV
**Axisymmetric multigap lens system**

\[ \phi(r, z, t) = \left( \text{Potential per gap} \right) \approx \frac{V(t)}{2} \left( 1 - \cos \left( \frac{2\pi z}{L} \right) \right) \]

- Inside: \( r = R \)
- Outside: \( r = 0 \)

Length: \( n \Delta P \)

\( n = \# \text{ of periods} \) \( (=3 \text{ in drawing}) \)

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**Potential inside the bore \( r < R \)**

\( \nabla^2 \phi = 0 \) \( (E = -\nabla \phi) \)

\[ \phi(r, z, t) = \phi_0(r, t) - \frac{\partial \phi_0}{\partial z} \frac{r^2}{4} \]

\( \phi_0(r, t) = \text{on-axis potential} \)

\[ \text{Solve} \quad \frac{\partial^2 \phi_0}{\partial z^2} - \frac{1}{r^2} \frac{\partial \phi_0}{\partial r} = -\frac{V(t)}{2} \left( 1 - \cos \left( \frac{2\pi z}{L} \right) \right) \]

Outside:

\[ E_r = -\frac{\partial \phi_0}{\partial r} \]

Near axis values:

\[ E_r = \frac{\partial^2 \phi_0}{\partial z^2} \]

- This can be done analytically...
Solve for ion orbits

\[
\frac{d\gamma(t)}{dt} = \gamma(t)
\]

\[
\frac{d\gamma(t)}{dt} = -\frac{e\gamma}{M} \frac{d^2}{dt^2} (\zeta(t) \gamma(t))
\]

\[
\frac{d\lambda(t)}{dt} = \lambda(t)
\]

\[
\frac{d\lambda(t)}{dt} = \frac{3e}{2M} \frac{d^2}{dt^2} (\zeta(t) \lambda(t)) \lambda(t)
\]

**Worked case:**

\[V(t) = (950 \text{ keV}) \sqrt{\frac{t}{10 \mu s}}\]

\[n = 4 \text{ periods}\]

\[R = 2 \text{ cm}\]

\[P = 6 \text{ cm}\]

\[300 \text{ keV} \quad K^7 \quad (m_0 = 38.96 \text{ gm u})\]
\[ t = 1.0 \mu s \text{ for all} \]
ion starts at 1.0 μs
To find a focal length start ions
at various times with $x = 10 \text{cm}$
$
\frac{dx}{dt} = 0 \text{,}
$

$F = \frac{x_{\text{initial}}}{(\frac{dx}{dt})_{\text{final}}}$

<table>
<thead>
<tr>
<th>Initial time</th>
<th>Final $x$</th>
<th>Focal length</th>
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<tbody>
<tr>
<td>0</td>
<td>-0.0321</td>
<td>3.12 m</td>
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<tr>
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<tr>
<td>2.0</td>
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<td>1.389</td>
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</tbody>
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