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A PULSED ELECTRIC LENS FOR NDCX

by
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- To compress pulse, $v_{tail} > v_{head}$
- This causes a chromatic aberration:

Considerations

Time scale is $\sim$ pulse length ~ 10 ns

Lens works only in vacuum

Lens must be compact (≤ 30 cm)

Voltages ≈ 100 kV

Programmable waveforms

Reasonable cost - look at energy/power

Solenoid $\rightarrow 1.0$ kJ, 10^9 watts

Electric lens $\rightarrow 30$ mJ, 30 kW

Axially symmetric multigap lens system

$$\phi(R, z, t) = \left(\text{Potential at } r=R \right) \approx \frac{V(t)}{2} \left(1 - \cos\left(\frac{2\pi z}{P}\right) \right) \quad \text{inside}$$

$$= 0 \quad \text{outside}$$

$$\text{Length} = nP$$

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

Potential inside the bore ($r < R$)

$$\nabla^2 \phi = 0 \quad (E = -\vec{\nabla} \phi)$$

$$\rightarrow \phi(r, z, t) \approx \phi_0(z, t) - \frac{\partial^2 \phi_0}{\partial z^2} \frac{r^2}{4}$$

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

$$\therefore \text{Solve } \frac{\partial^2 \phi_0}{\partial z^2} - \frac{4}{R^2} \phi_0 = -\frac{4}{R^2} \phi(R, z, t)$$

$$= -\frac{4}{R^2} \frac{V(t)}{2} \left(1 - \cos\left(\frac{2\pi z}{P}\right) \right) \quad (\text{inside})$$

$$\left. \begin{aligned} E_z &\approx -\frac{\partial \phi_0}{\partial z} \\ E_r &\approx \frac{\partial^2 \phi_0}{\partial z^2} \frac{r}{2} \end{aligned} \right\} \text{near axis values}$$

— This can be done analytically —

$z(t)$

VR

$V(t)$

x(t)

$x(t)$

0.005

0.000

0.000

0.000

0.000

0.000

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0.000

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ion starts at 1.0 MS

$x'(t)$

0.005

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To find a focal length start ions
at various times with $x = 10 \text{ cm}$,
 $\frac{dx}{dt} = 0$. (11)

$$f = \frac{x_{\text{initial}}}{\left(\frac{dx}{dt}\right)_{\text{final}}} = \frac{x_{\text{initial}}}{\left(-\frac{x}{v}\right)_{\text{final}}}$$

initial time	final dx/dt	focal length
0	-.00371	8.12 m
.2 μs	-.00716	1.40
.4	-.01163	.860
.6	-.0163	.615
.8	-.0210	.477
1.0	-.0257	.389