Title
Comments on time-dependent lenses (TDLs)

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Comments on Time-Dependent Lenses (TDLs)

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- TDLs compensate the chromatic effect of tilt in final focus

- TDLs upstream from target $\gtrsim$ 20m for Fusion

  $\Delta\theta(t) \simeq 10 - 30$ mr

- TDLs close to target for HEDP

  $\Delta\theta(t) \simeq 100 - 300$ mr

Where $\Delta\theta(t) = a'/a$ of envelope

Fusion — Simple Solenoid — for TDL

$$\Delta\theta = \left[\frac{B_z}{2(B\rho)}\right]^2 \ell \; a$$

ℓ ↑ magnet length; a ↑ beam radius

Want $\ell \lesssim \ell_{pulse} \approx .5 - 1.0$ m

Example (~250 MeV Ne^{+10})

$(B\rho) = 1.0$ T-m

$\Delta\theta = 10$ mr

$a = .2$ m

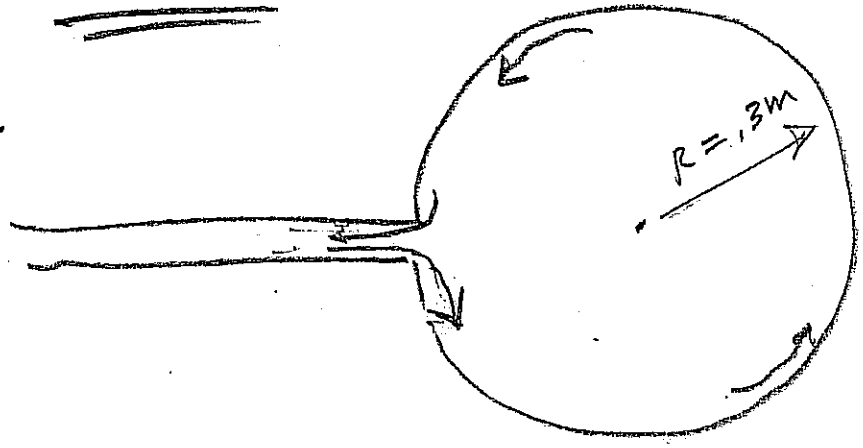
$\ell = 1.0$ m

$$\Rightarrow B_z = 2(B\rho)\sqrt{\frac{\Delta\theta}{\ell a}} = 2 \times 1 \times \sqrt{\frac{.01}{1 \times .2}}$$

$$= \underline{\underline{.45\ T}}$$

Single Turn Solenoid

(Low Impedance)



Solenoid Current $I = \frac{\ell B_z}{\mu_0} = \frac{1 \times .45}{4\pi \times 10^{-7}} = \underline{\underline{358\ kA}}$

Stored Energy $W \simeq \frac{B_z^2 \pi R^2 \ell}{2 \mu_0} = \frac{(.45)^2 \pi (.3)^2 (1)}{2 \times 4\pi \times 10^{-7}}$

$= \underline{\underline{23\ kJ}}$

Inductance $L = \frac{2W}{I^2}$

$= \frac{2 \times (23 \times 10^3)}{(358\,000)^2} = \underline{\underline{3.6 \times 10^{-7}}}$ Henry

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Voltage $V = L \dot{I} = \frac{LI}{t_{rise}}$

Take $t_{rise} = 20\ ns$

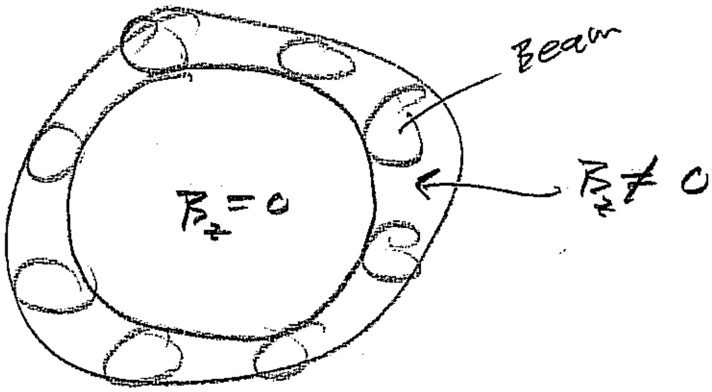
$\rightarrow V = \frac{3.6 \times 10^{-7} \times (358 \times 10^3)}{20 \times 10^{-9}}$

$= \underline{\underline{6.4\ \text{Megavolts}}}$

— Trouble —

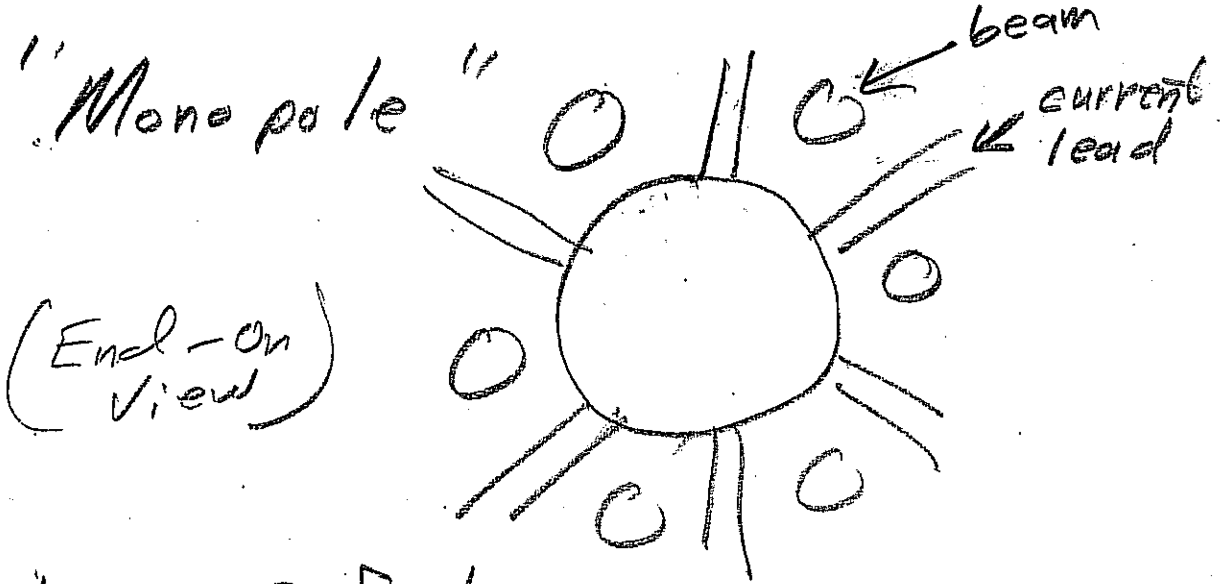
Various Ideas To Reduce V

(1) Annular Solenoid with beams at edge



Highly Non Linear — fringe field gives distorted v_θ —

(2) "Monopole"



— Strong Defection For Low B_θ but Somewhat Non Linear —

(3)''' Time Dependent Dipoles At Merge Point

$$\Delta\theta = \frac{B \cdot l}{(B\rho)}$$

$\Delta\theta = 10.\ mr$
$l = 1.0\ m$
$(B\rho) = 1.0\ T\text{-}m$

$\rightarrow B = .01\ T$ (Good)

This Seems The Best Bet So Far

[Voltage Reduced 10-100]

Diamagnetic Effect (Roger's Problem)

$$\frac{\partial B}{\partial t} \rightarrow E \rightarrow J$$

→ Reversed Component of B

→ Shielding

→ We Cant Pulse Quickly

- This is True for Metal And A Collisional Plasma

- Situation Not Clear Yet For Collisionless Plasma

- Very Low Electron Drift Velocities ⊥ to B Allowed

Example

Merged Main Pulse (to One Side of Target)

$$\begin{cases} 2.5 \text{ MJ} \\ 250 \text{ MeV } Ne^{+10} \\ \ell_p = .5 \text{ m} \\ a_p = .2 \text{ m} \end{cases} \qquad \begin{pmatrix} q = 10 \\ A = 20 \end{pmatrix}$$

$$\begin{pmatrix} \text{Number of} \\ \text{Beam Ions} \end{pmatrix} = \frac{2.5 \times 10^6}{1.6 \times 10^{-19}} \frac{1}{250 \times 10^6} = 6.2 \times 10^{16}$$

$$n_b = \frac{6.2 \times 10^{16}}{\pi \times (.2)^2 \times .5} = \underline{\underline{1.0 \times 10^{18} \text{ m}^{-3}}}$$

Take $n_e = 10 \, q n_b = \underline{\underline{1.0 \times 10^{20} \text{ m}^{-3}}}$

$$\frac{\partial B}{\partial x} \sim \mu_0 n_e e v_{e\perp}$$

$\therefore$ Want $v_{e\perp} << \dfrac{B/a}{\mu_0 n_e e}$

$$\approx \frac{(.01)(.2)}{(4\pi \times 10^{-7})(10^{20})(1.6 \times 10^{-19})} = \underline{\underline{2500 \frac{m}{s}}}$$