



Faraday Rotation Imaging of X-Pinch Implosion Dynamics

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 Assuming a current of 400 kA goes through a 10 μm neck/hot spot plasma with no losses:

$$p_{mag} = \frac{\mu_0 I^2}{8\pi^2 r^2} = \frac{\mu_0 (400 \ kA)^2}{8\pi^2 (5 \ \mu m)^2} \approx 1 \ \text{GBar}$$





- Insertable CuW electrodes supports multiple X-pinch configurations
- Adjustable electrode gap via return posts

- Ag, Mo, W wires
 - $\overline{m} \approx$ 0.2-0.4 mg/cm
 - 25µm 2-wire x-pinches
 - 50µm hybrid x-pinches



Imaging Faraday Rotation Diagnostic



[2] G. F. Swadling et al., Review of Scientific Instruments, (Nov. 2014).









- Peak current 188 kA @ 270 ns
- At time of Faraday image:
 - 133 kA @ 97 ns of current rise
 - ~75% of peak current rise time
 - ~70-85% of peak current



Extracting the Magnetic Field from Rotation Angle

• Faraday Rotation:

$$\Delta \varphi = \frac{e^3 \lambda^2}{8\pi^2 \varepsilon_0 m_e^2 c^3} \int_{-\infty}^{\infty} n_e(r) B(r) \cdot dz$$

• Abel Inversion for B(r):

$$B(r) = \frac{8\pi^2 \varepsilon_0 m_e^2 c^3}{e^3 \lambda^2 n_e(r)} \left[\frac{-1}{\pi} \int_r^\infty \frac{d(\Delta \varphi)}{dx} \frac{dr}{\sqrt{r^2 - x^2}} \right]$$



- Too noisy or asymmetric for Abel inversion
- Approximation using average parallel magnetic field and manually measured fringe shifts:

$$B_{||}(x) = \frac{8\pi^2 \varepsilon_0 m_e^2 c^3}{e^3 \lambda^2} \frac{\Delta \varphi}{\int n_e dz} \qquad \longrightarrow \qquad I_{encl}(r) \simeq \frac{2\pi r}{\mu_0} B_{||}(x)$$

$|\mathbf{M}| 2\pi$ Error of Average Enclosed Current Profile



- Rotation profile shows characteristic positive and negative (i.e. bright and dark) rotations
 of roughly equal magnitude on opposite sides of the X-pinch neck
 - This implies a roughly azimuthally symmetric field profile around the neck
- A simulated profile agrees well in amplitude and decay but implies a more extended density profile than purely gaussian.
 - Gaussian density normalized to 1E18 cm^-3 at neck edge, Full current of 133 kA in neck

$|\mathbf{M}| 2\pi$ Error of Average Enclosed Current Profile



- The enclosed current profile approximated by the areal rotation and phase gives currents of only about 20 kA, which is insufficient for the observed X-pinch dynamics
- Corrected profile suggests that between 70-100% of current measured by Rogowski coil is within a radius of 150-200 μm
- Better light collection, higher laser energy, and higher MAIZE current will all reduce noise and improve measurement



- An imaging Faraday rotation diagnostic has been designed and fielded on the MAIZE LTD and provides measurements of rotation and density around x-pinch necks
- \bullet The extracted enclosed current profiles appear to be giving currents almost exactly 2π smaller than the known driver current
- Current and Future Goals:
 - Determine whether the 2π factor difference is physical or a processing error
 - Determine a method to computationally reduce the various noise sources to allow for a greater number of usable images
 - Better determine if the density and magnetic field are approximately azimuthal to allow for Abel inversion