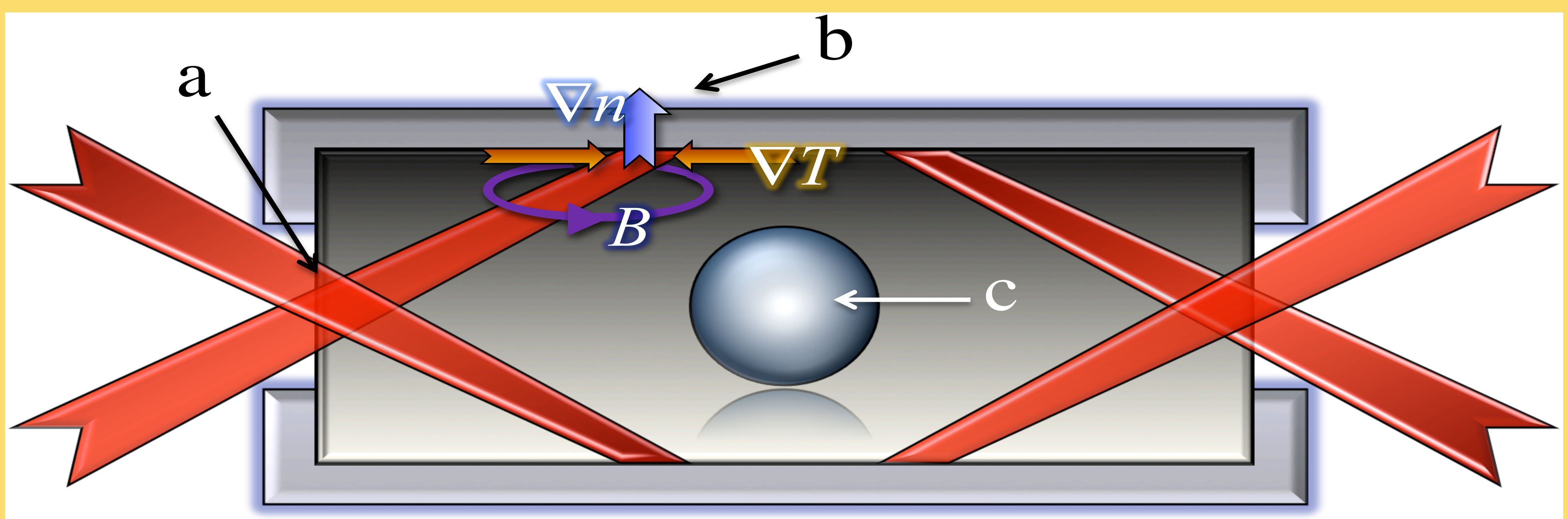
# Vlasov-Fokker-Planck modeling of plasma near hohlraum walls heated with nanosecond laser pulses calculated using the ray tracing equations

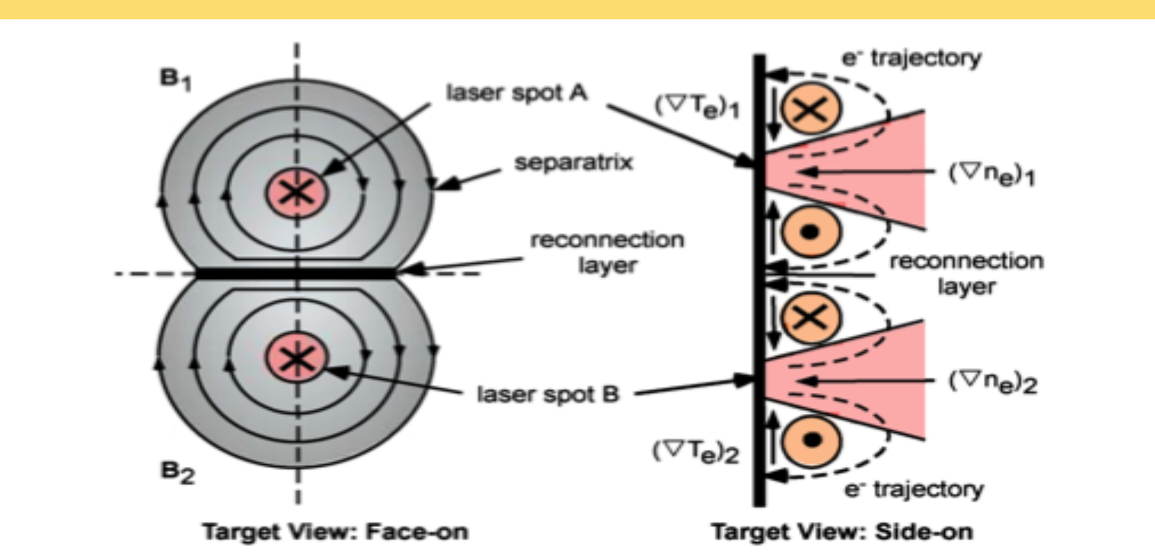
A. S. Joglekar, A. G. R. Thomas
*Center for Ultrafast Optical Sciences, University of Michigan, Ann Arbor, MI, USA*

## Abstract

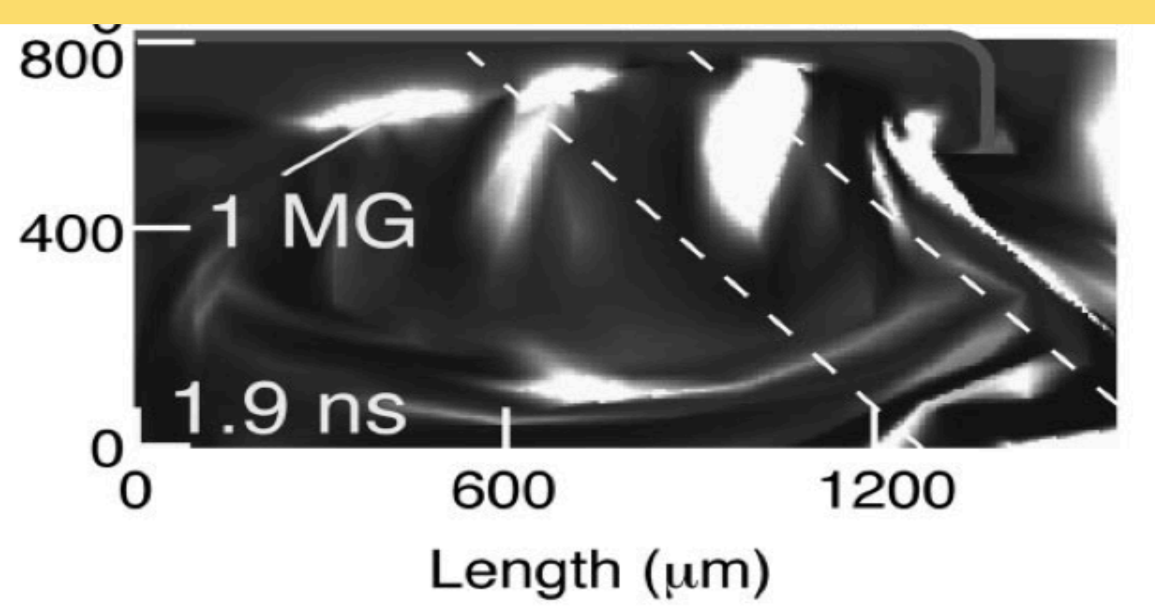
Here, we present 2D numerical modeling of near critical density plasma using a fully implicit Vlasov-Fokker-Planck code, IMPACTA, which includes self-consistent magnetic fields as well as anisotropic electron pressure terms in the expansion of the distribution function, as well as an implementation of the Boris CYLRAD algorithm through a ray tracing add-on package. This allows to model inverse brehmsstrahlung heating as a laser travels through a plasma by solving the ray tracing equations. Generated magnetic fields (eg. the Biermann battery effect) as well as field advection through heat fluxes from the laser heating is shown. Additionally, perturbations in the plasma density profile arise as a result of the high pressures and flows in the plasma. These perturbations in the plasma density affect the path of the laser traveling through the plasma, and modify the heating profile accordingly. The interplay between these effects will be discussed in further study.

## Magnetic Field Generation




P.M. Nilson, Magnetic Reconnection and Plasma Dynamics in Two-Beam Laser-Solid Interactions, PRL **97**, 255001 (2006)




S. H. Glenzer,† W. E. Alley, K. G. Estabrook, et. al, Thomson Scattering from Laser Plasmas, *Phys. Of Plamas* May 1999, VOLUME 6, NUMBER 5

Using Faraday's Law along with a Ohm's Law:

$$\mathbf{E} = \frac{\nabla p_e}{e n_e} + \ldots$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

Substitute:

$$\frac{\partial \vec{B}}{\partial t} = \nabla \times \frac{\nabla p_e}{n_e e} = -\frac{\nabla n_e}{n_e^2 e^2} \times \nabla(n k_B T) \sim \nabla T \times \nabla n_e$$

## Ray Tracing

- Fermat's Principle:

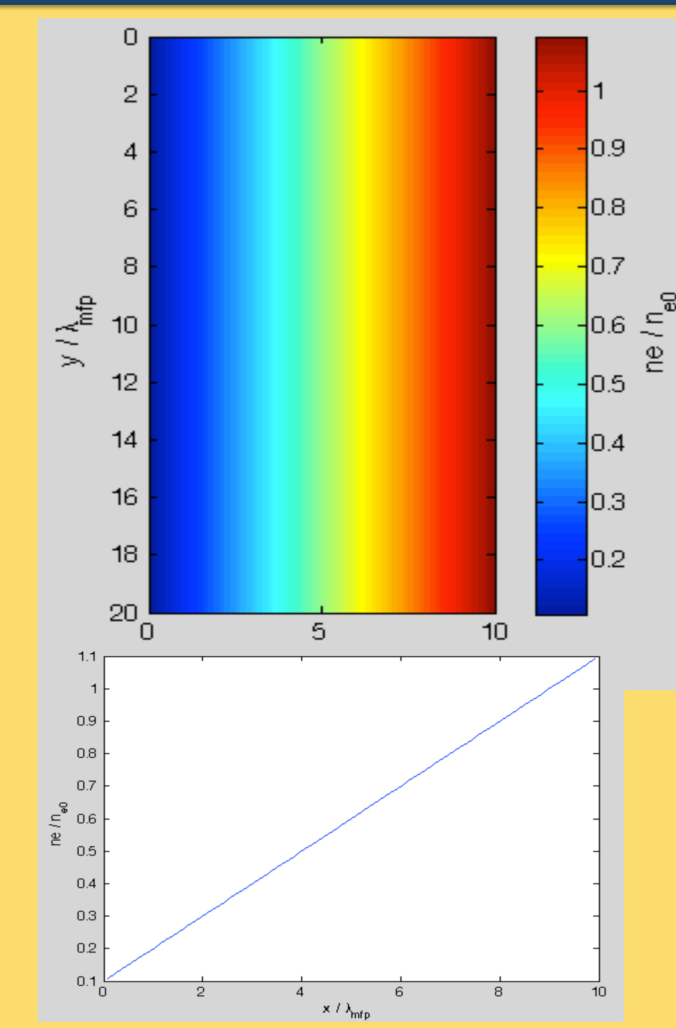
$$\delta \int_a^b n(\mathbf{r}) ds$$

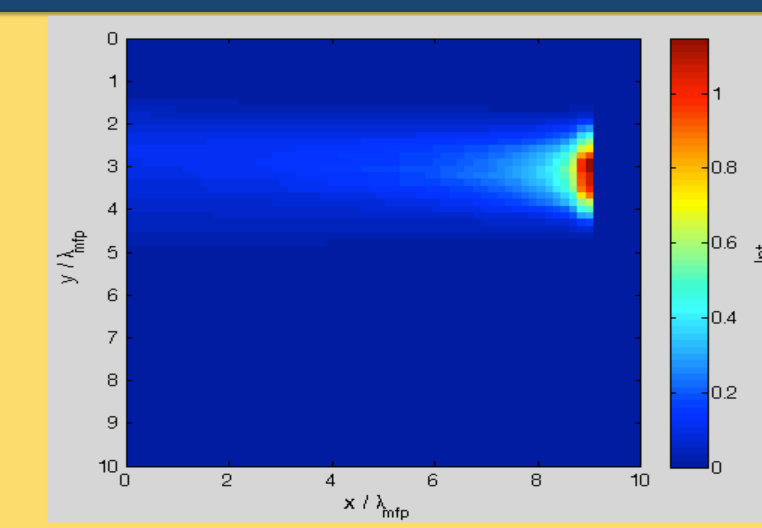
- Workable form to develop into algorithm:

$$\frac{d\mathbf{r}}{ds} = \mathbf{v}$$

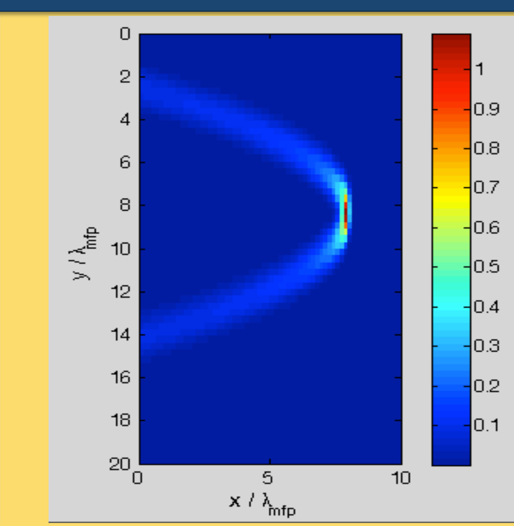
$$\frac{d\mathbf{v}}{ds} = \mathbf{v} \times \left( \frac{\nabla n}{n} \times \mathbf{v} \right)$$

- Simple test: Ray-Tracing over a linear density ramp. Path equation can be easily solved.
- Shown are four solutions for different initial angles.

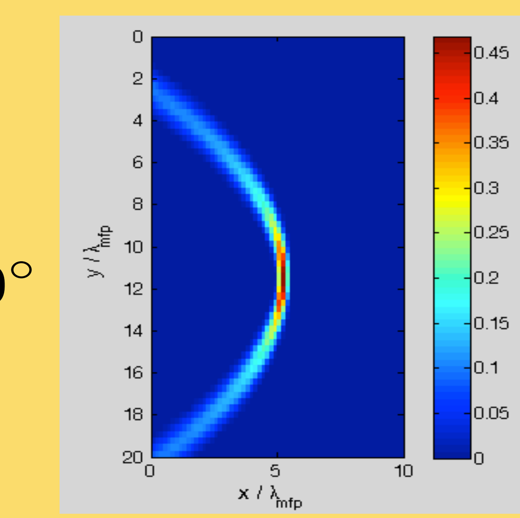




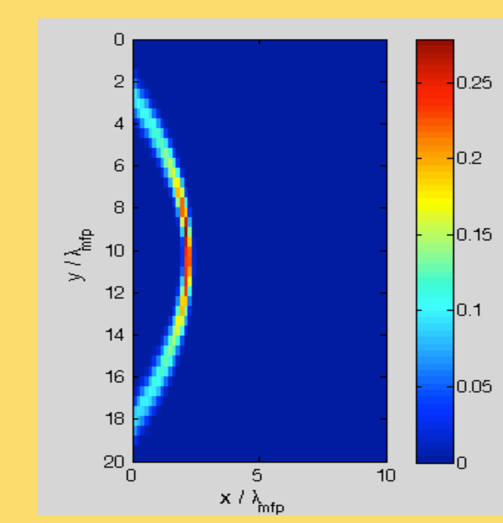
$\theta = 2^\circ$



$\theta = 20^\circ$

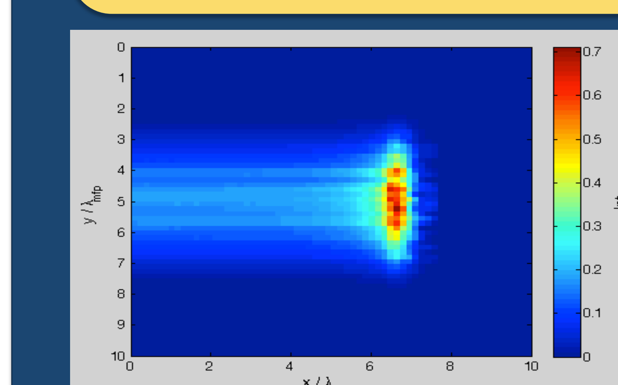


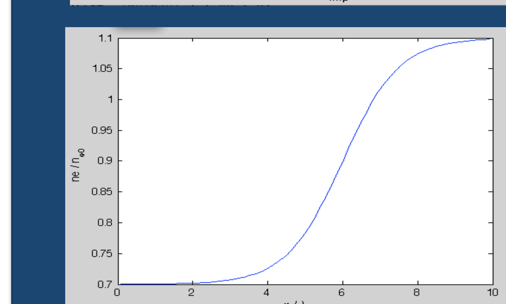
$\theta = 40^\circ$



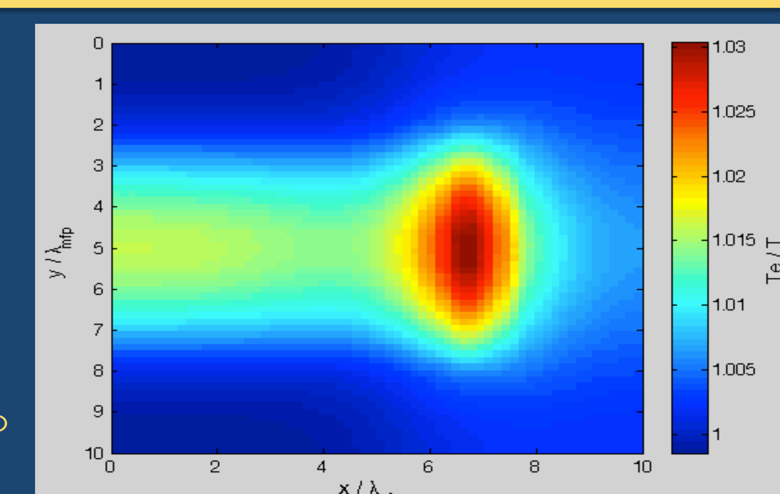
$\theta = 60^\circ$

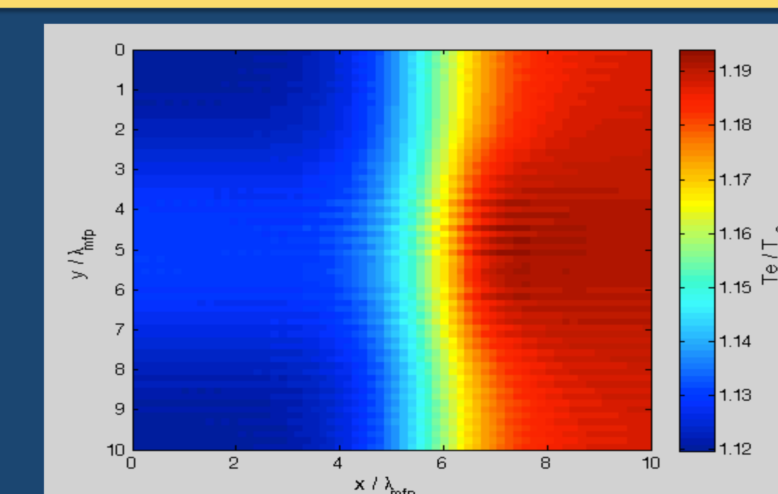
## Vlasov Fokker Planck Modeling Results

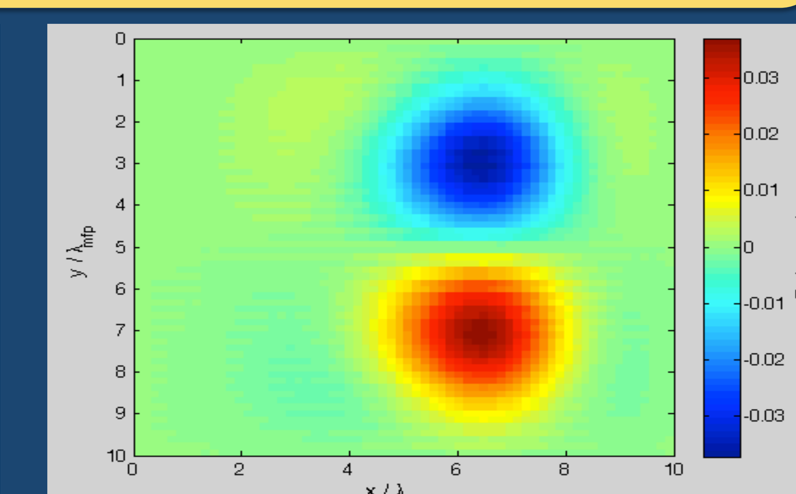




$\theta = 0^\circ$

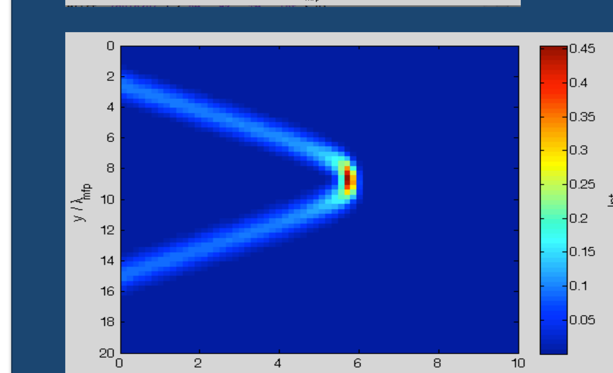


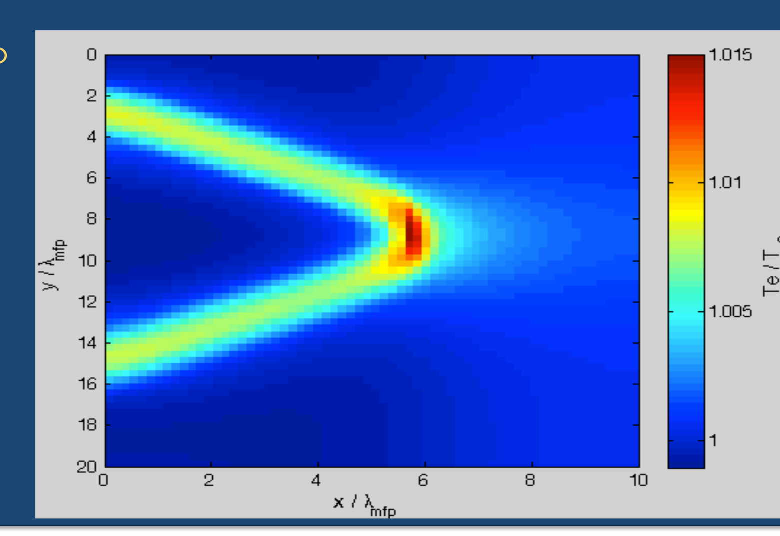


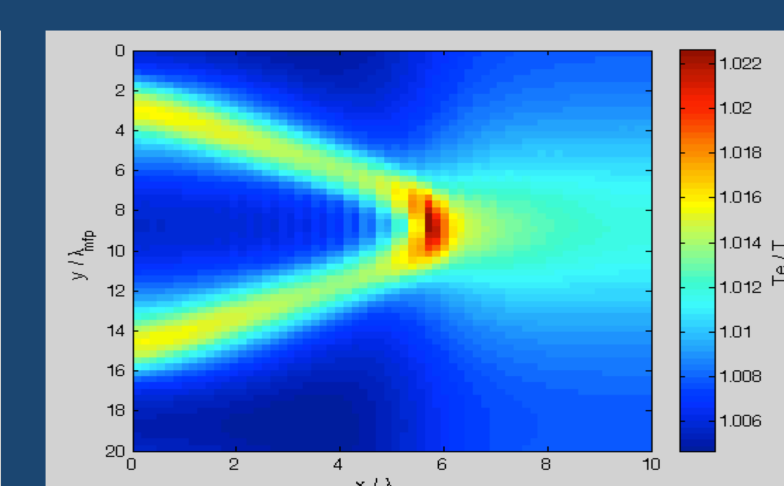


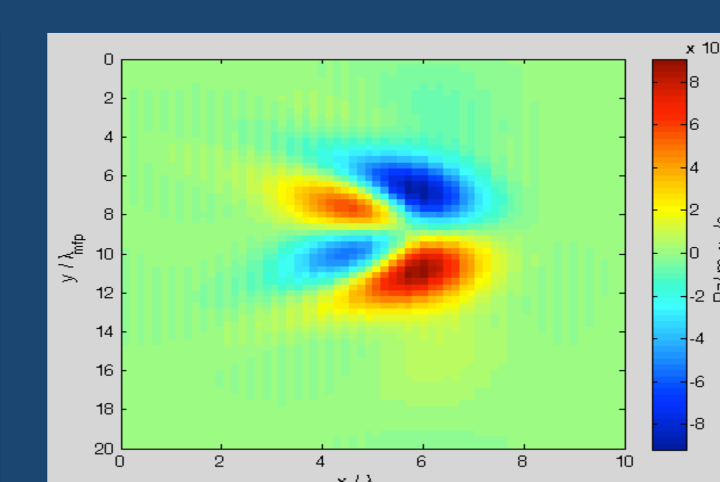
$t = 100\tau_{ei}$

$\theta = 40^\circ$









## Conclusion

This shows the implementation of an in-plane ray-tracing mechanism within a Vlasov-Fokker-Planck code with self-consistent field generation. This allows to model laser plasma interactions, such as those at the walls of a hohlraum. This allows to generate magnetic fields out-of-plane. When reconsidering the geometry, one can envision the development of a magnetic reconnection configuration with opposite magnetic fields approaching one another.

Future work will be focused on using different dispersion relations for the laser frequency to observe changes in the intensity mapping due to variation in not only the density profile, but also the magnetic field.