An update on the Odin ALE code

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Introduction

In order to simulate Inertial Confinement Fusion (**ICF**), and other High Energy Density Physics (**HEDP**) experiments, an Arbitrary Lagrangian Eulerian (**ALE**) Radiation-hydrodynamics code, *Odin* [1], is being developed at the University of Warwick with collaborators based at other institutions. ICF experiments are limited by laser technology and cost. Recently, there have been significant developments in the functionality of the *Odin* code, specifically new refractive ray-tracing and hot-electron routines, which have expanded its ability to accurately simulate experiments that have happened at laser facilities, such as **OMEGA** and **NIF**.

The *Odin* ALE code

Odin is a radiation-hydrodynamics ALE code for studying laser fusion. It has the following features:

- ALE: Computational grid moves with the fluid as long as possible, before remapping to a smother grid and restarts in Lagrangian mode. This is essential to accurately track the ∼30 times radial collapse of the DT fuel pellet.
- Multi-material with arbitrary EoS and opacity. This, combined with ALE, is essential to prevent numerical mixing of the different layers of the target. Targets are usually multi-layered with CH, doped CH, solid DT and gas DT layers.
- Thermal conduction and multi-group radiation transport handled implicitly using PETSc[2].
- 3D laser ray-tracing and energy deposition (developed as part of this AWE project).
- 3D hot-electron transport (developed in another AWE project - Duncan Barlow). Hot-electrons are generated by 3-wave parametric instabilities driven by the laser. They must be modelled as they can pre-heat the core stopping ignition.

Applications

- Using these new routines we can perform simulations of real experiments in 2.5D.
- By using the experimentally utilised laser profiles of each of the 60 beams on OMEGA, we can investigate the 3D asymmetries of the implosion due to laser power imbalance.
- We will use synthetic diagnostics and compare the results of the simulation with the experimental diagnostic measurements.
- A synthetic x-ray radiography diagnostic has been developed and more will be created as part of this study.
- Study the impact of hot-electrons and corresponding target pre-heat, on NIF and other ICF implosions.
- Verify what conversion of laser energy to hot-electrons can be expected during these experiments.

Acknowledgements

We would like to acknowledge funding from: AWE, and EPSRC grants EP/P026486/1, EP/R029148/1 and $EP/M011534/1$.

Refractive Raytracing Routine

- The rays of the laser beam travel into the plasma and are refracted in 3D according to the vector form of Snell's law[3], which is applied at the cell boundaries:

$$\vec{v}_{\text{refract}} = r\vec{l} + \left(rc - \sqrt{1 - r^2\left(1 - c^2\right)}\right)\vec{n} \tag{1}$$

- The rays deposit their energy via inverse bremsstrahlung[4] at, or prior to, the critical density:

$$k_i = \frac{\overline{\nu_{el}(t)}}{c}\left(\frac{n}{n_c}\right)\left(1 - \frac{n}{n_c}\right)^{-\frac{1}{2}} \tag{2}$$

- Multiple beams with distinct laser power profiles are able to be added to the simulations.
- Beam parameters and locations can be read in from the *Visrad* software package.
- Due to laser-plasma instabilities (LPIs), a proportion of the laser energy is not delivered to the target. LPI can result in incoming laser energy being transferred to an electron plasma wave (EPW) and a scattered electromagnetic (EM) wave (SRS), or two EPWs (TPD). As these EPWs Landau damp, suprathermal electrons are produced.

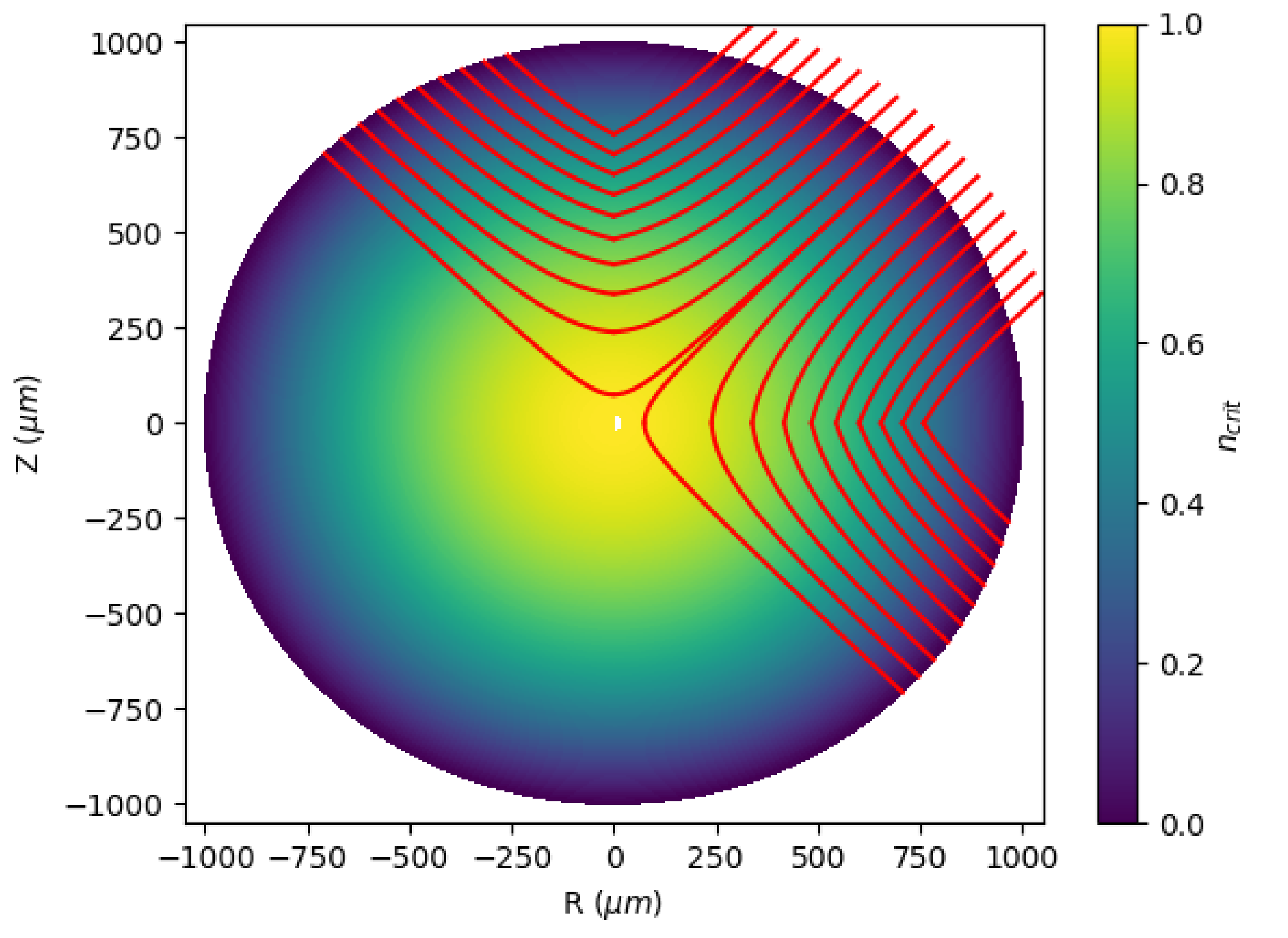

Figure 1: The paths of a small subset of the multiple beams entering a spherical capsule and being refracted due to a linear density profile.

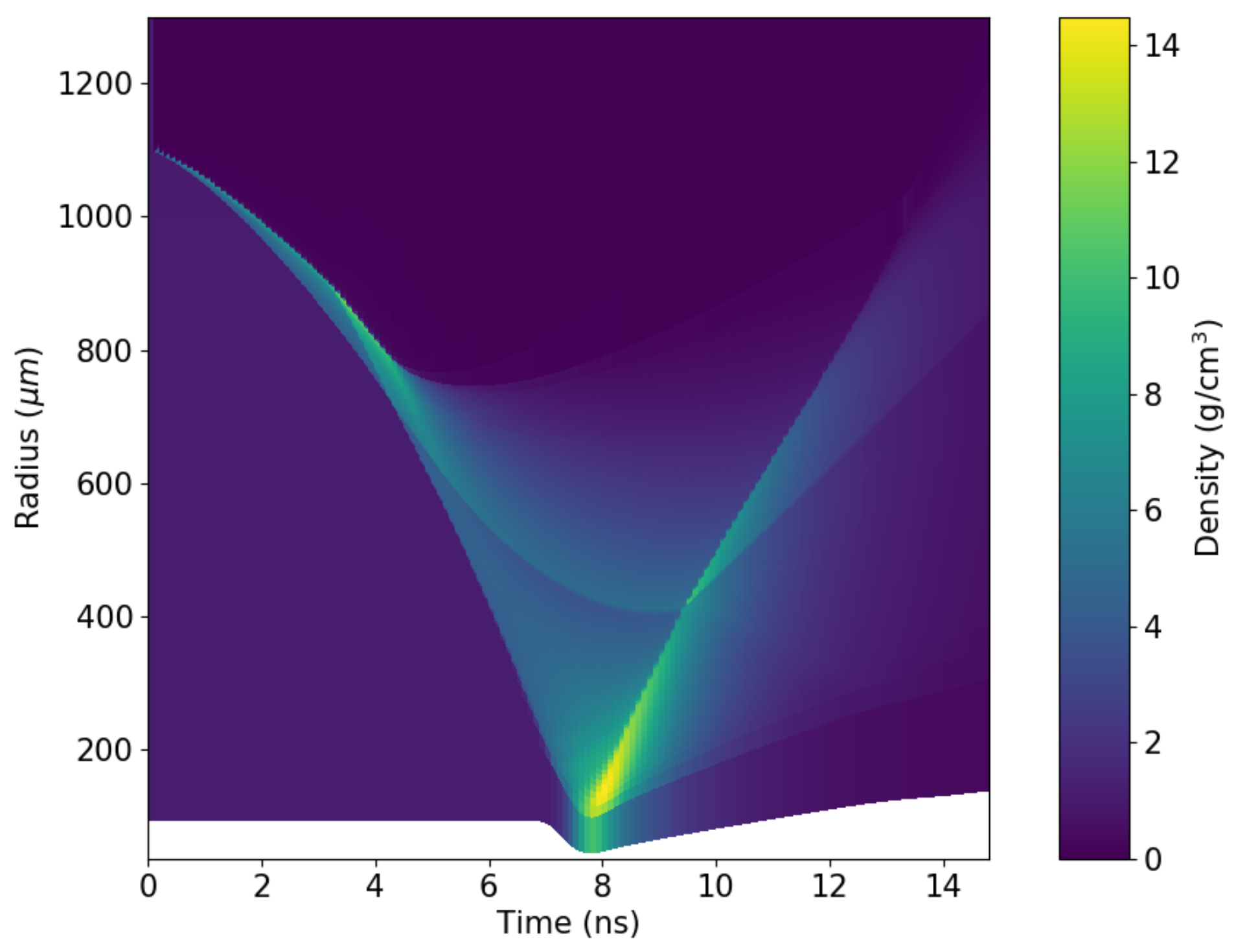

Figure 2: An R vs t plot from a solid capsule Odin simulation. The density is shown in the z-axis.

Hot Electron Routine

- Hot electrons are generated at the $n_{crit}/4$ density. This routine acts as a simplified LPI model
- The electrons move in 3D and are subject to scattering and reflux.
- Energy deposition is given by the stopping model as described in [5].
- Binary collisions and plasma wave excitation effects are the mechanisms for the slowing down of hot electrons.

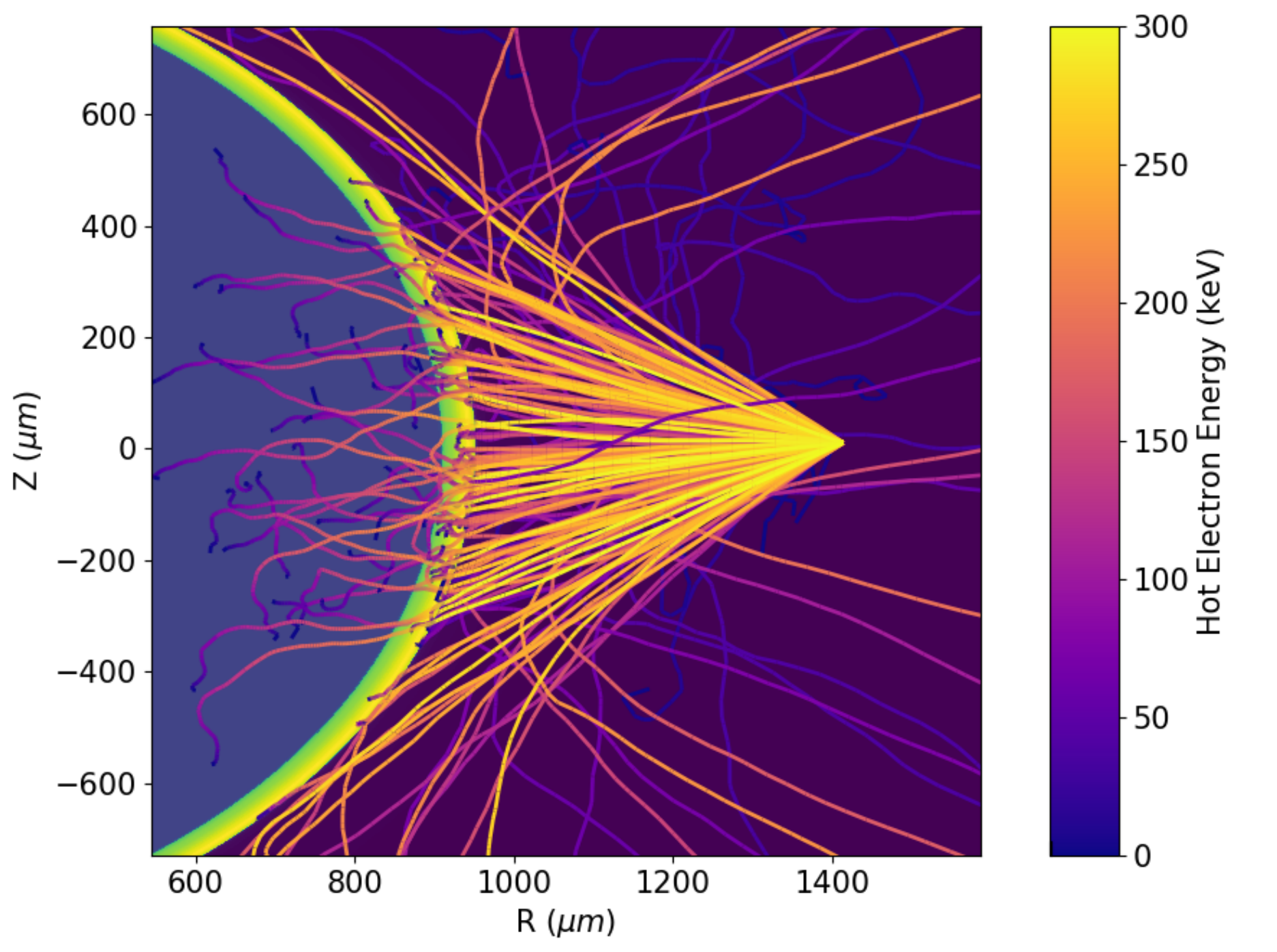

Figure 3: A sample of the simulated paths of hot electrons, generated in the ablated plasma of a solid NIF capsule.

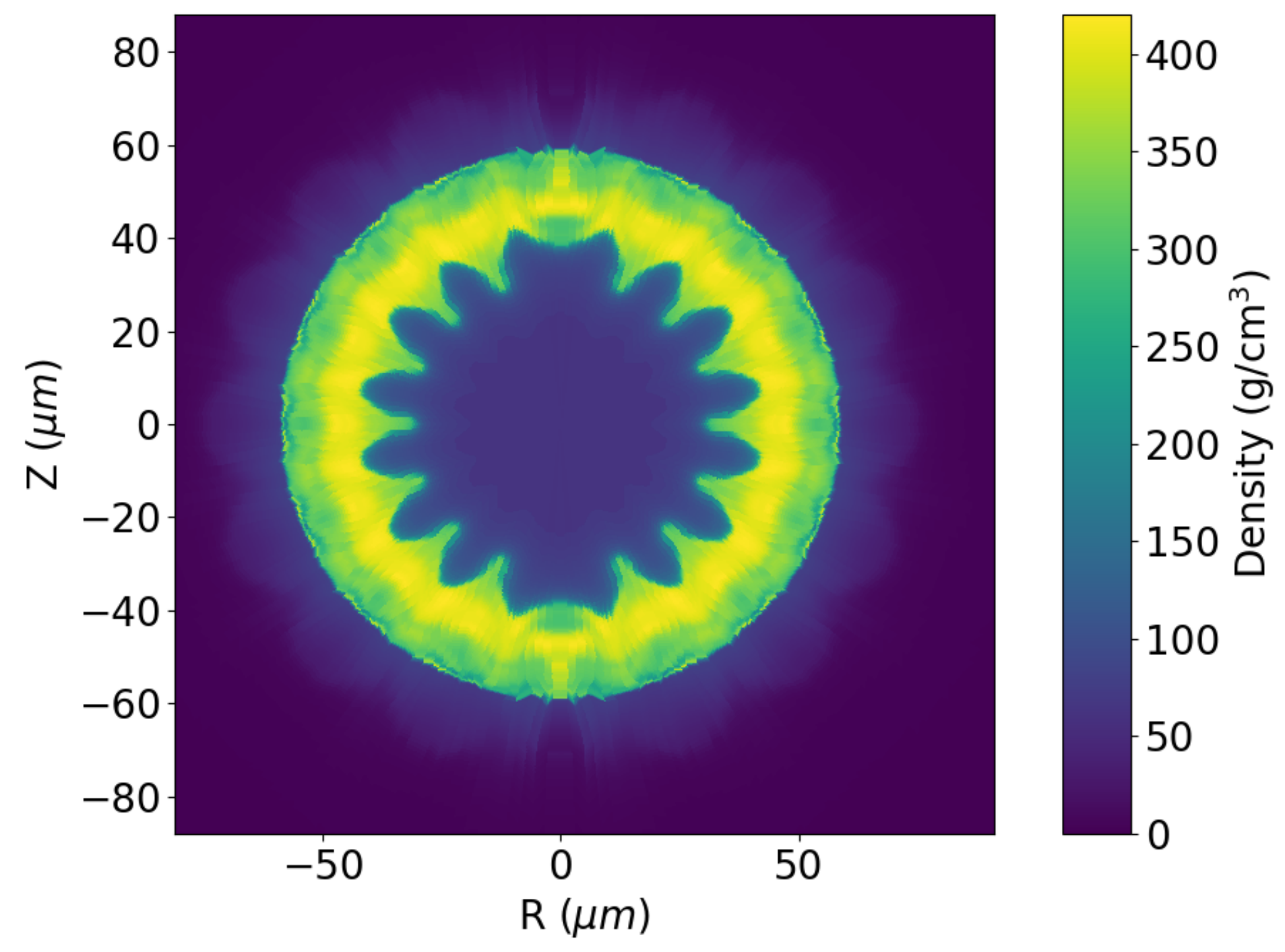

Figure 4: Full solid NIF capsule demonstrating the possible asymmetries caused by a non-uniform hot electron drive.

References

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