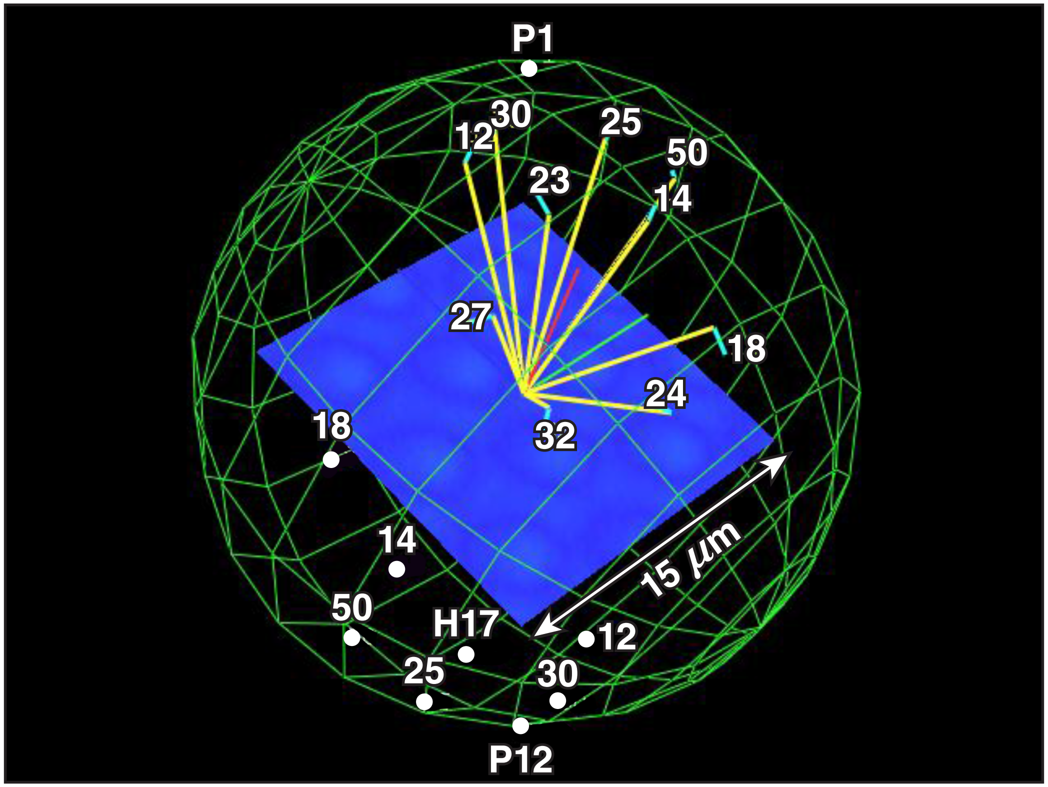
A Numerical Investigation of Two-Plasmon–Decay Localization in 60-Beam Spherical Implosion Experiments on OMEGA



J. F. Myatt
University of Rochester
Laboratory for Laser Energetics

44th Annual Anomalous Absorption Conference
Estes Park, CO
8–13 June 2014

Summary

Three-dimensional calculations demonstrate the spatial localization of two-plasmon decay (TPD) in spherical implosions

- Multibeam laser–plasma instabilities (LPI's) have to be studied in three dimensions
- The laser–plasma simulation environment (LPSE) code describes TPD in 3-D
  - fast, makes efficient use of memory, and extensible
  - includes 3-D visualization tools
  - three-dimensional calculations can be performed in ~1 h
- LPSE calculations show TPD localization in spherical targets that is consistent with experimental observations

Collaborators

J. Shaw, J. Zhang, A. V. Maximov, R. W. Short,
W. Seka, D. H. Edgell, and D. H. Froula

University of Rochester
Laboratory for Laser Energetics

D. F. DuBois and D. A. Russell

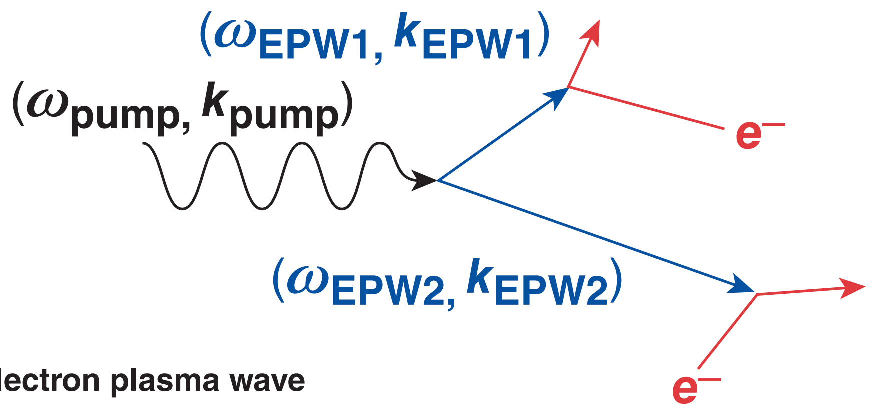
Lodestar

H. Vu

UCSD

It is important to know the stability of direct-drive–implosion designs with respect to multibeam TPD

- We want to construct "in-line" models of TPD that can be implemented in hydrocodes
  - quantify the effects of TPD on time-dependent drive
  - account for hot-electron preheat
- A model that can be used to search for and test TPD mitigation strategies is required
  - linear threshold*
  - nonlinear saturation



EPW: electron plasma wave

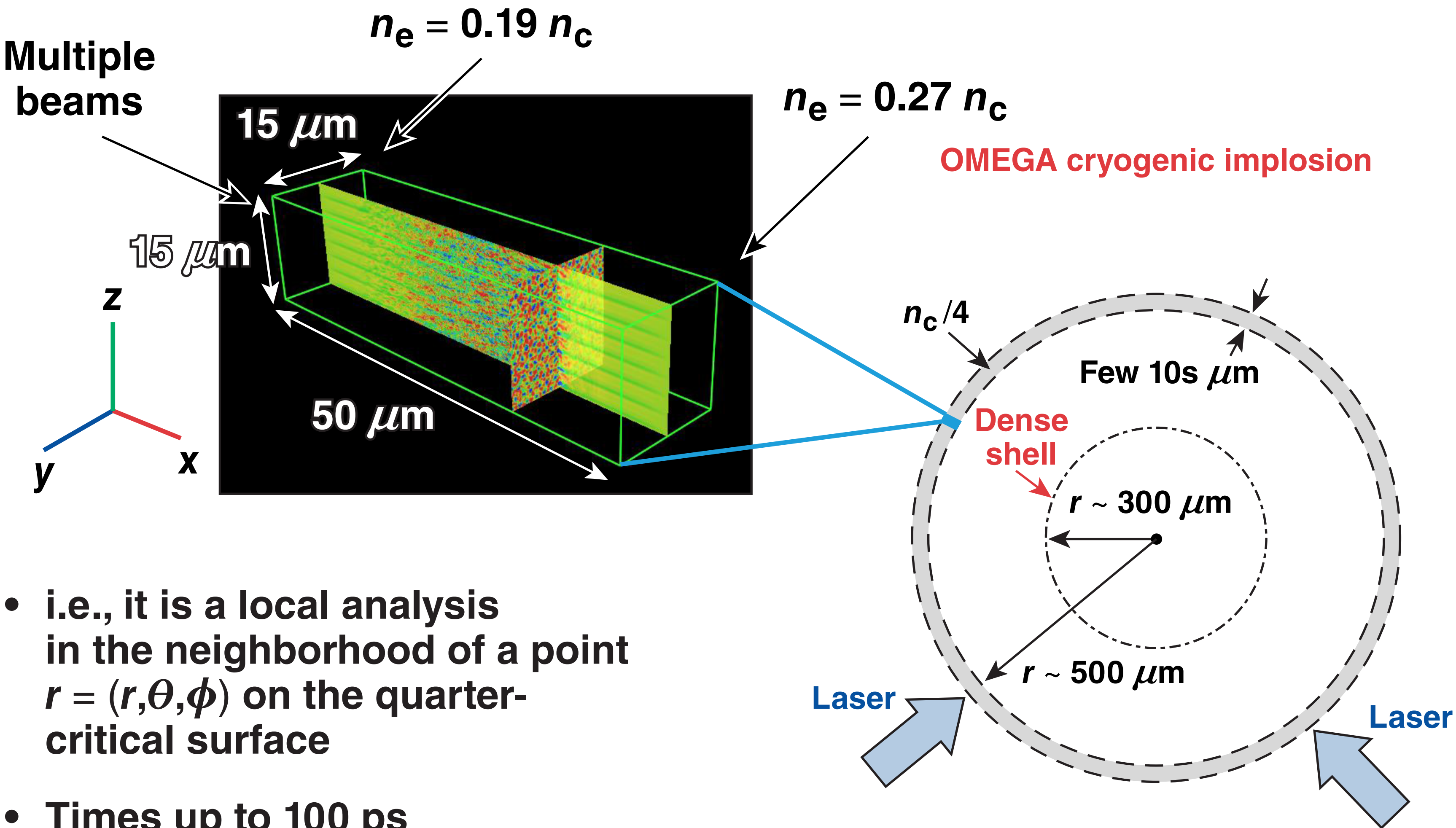
TC11296

*R. W. Short, J. F. Myatt, and J. Zhang, this conference.

LPSE is a practical model that is being used to address these questions

- It solves the fundamental TPD equations for linear response in an arbitrary hydrodynamic profile (density, temperature, velocity) with an arbitrary number of beams
- LPSE includes nonlinear saturation mechanisms that are related to the coupling of Langmuir waves (LW's) to low-frequency density fluctuations
  - performance (one run in ~1 h on 96 Intel cores)
  - setup (either planar or spherical target simulations are automated)
  - connected to experiment via "diagnostics" package
  - tools for the exploration/visualization of large 3-D data sets
- LPSE is extensible!

The simulation volume is determined by the density scale length and the Langmuir wave correlation length

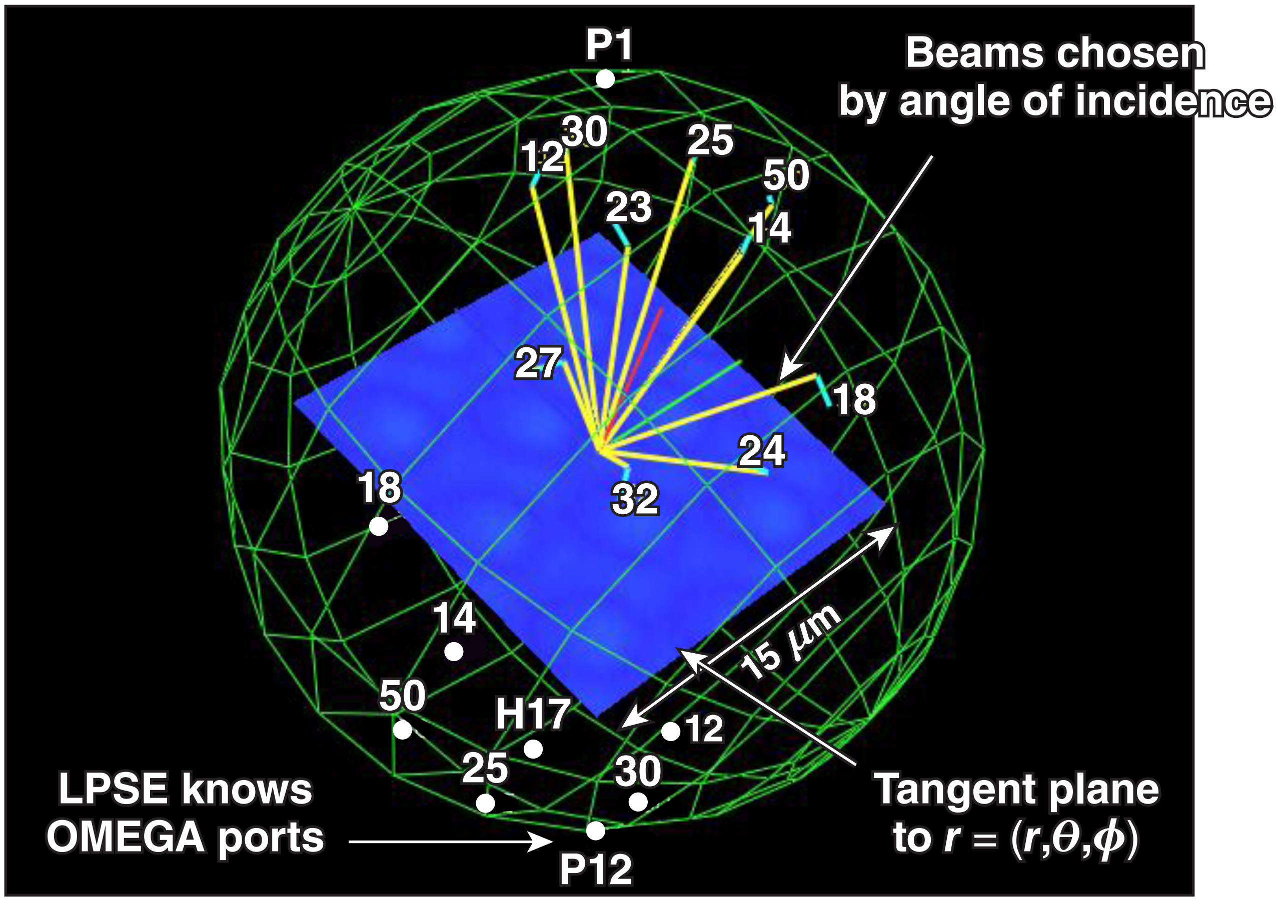


- i.e., it is a local analysis in the neighborhood of a point $\boldsymbol{r} = (r,\theta,\phi)$ on the quarter-critical surface
- Times up to 100 ps

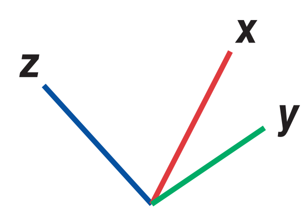
TC11243a

The “laser package” automatically sets up the laser beams according to a location (r,θ,ϕ) on the $n_c/4$ surface

- **Phase plates and polarizations [including distributed polarization rotators (DPR’s)] can be specified**



3-D Cartesian LPSE coordinate system:

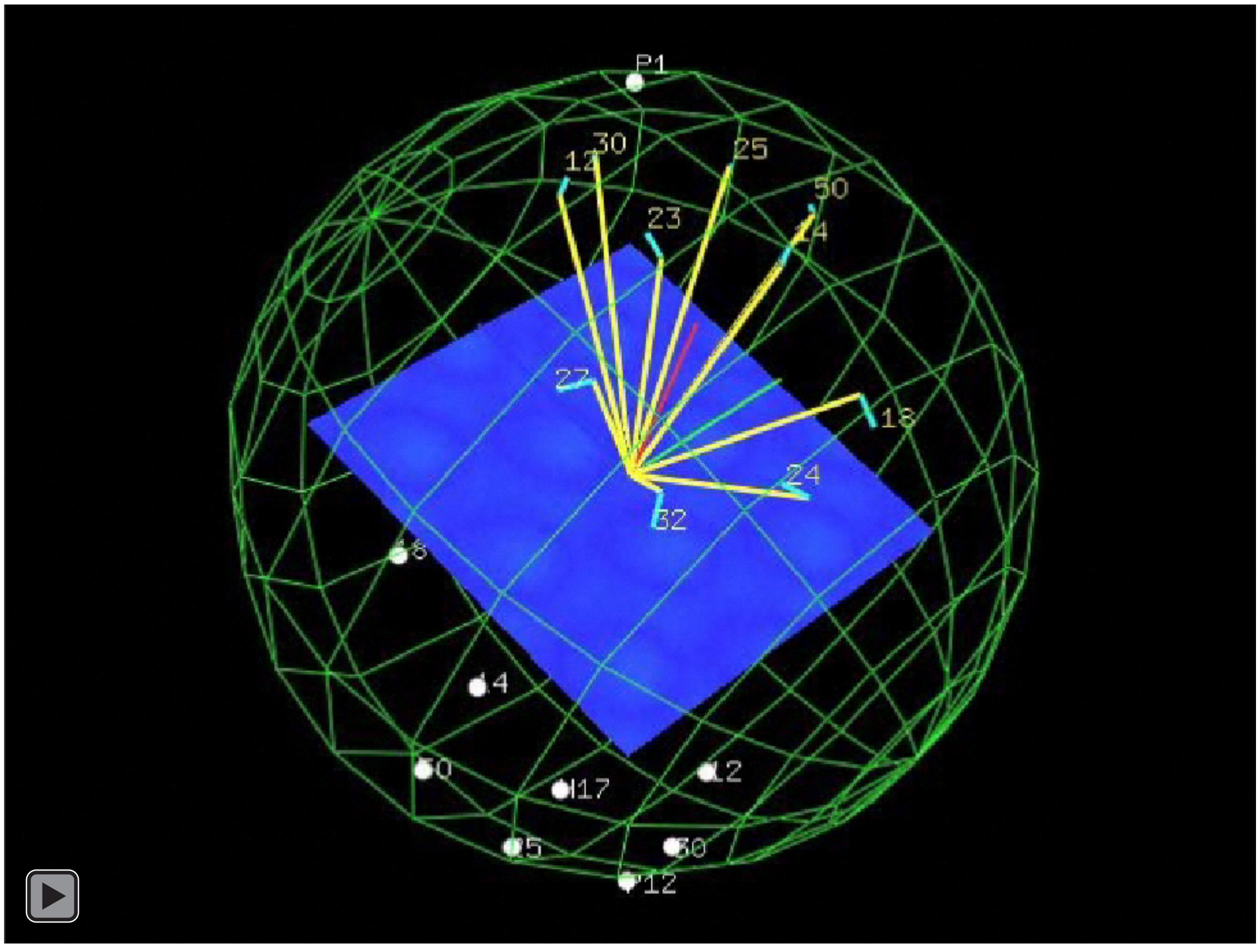


Hydro variables must be specified

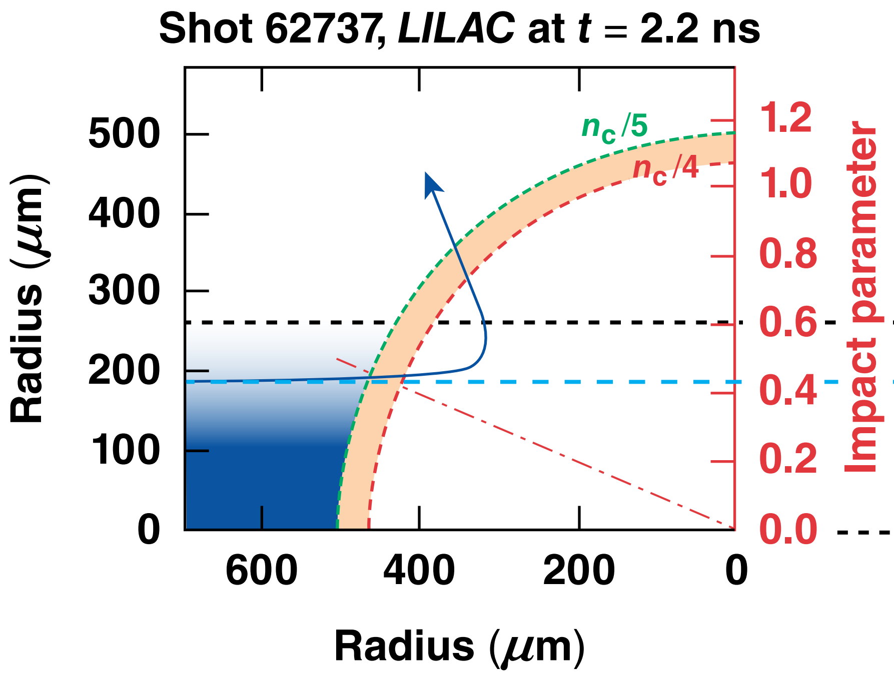
TC11298

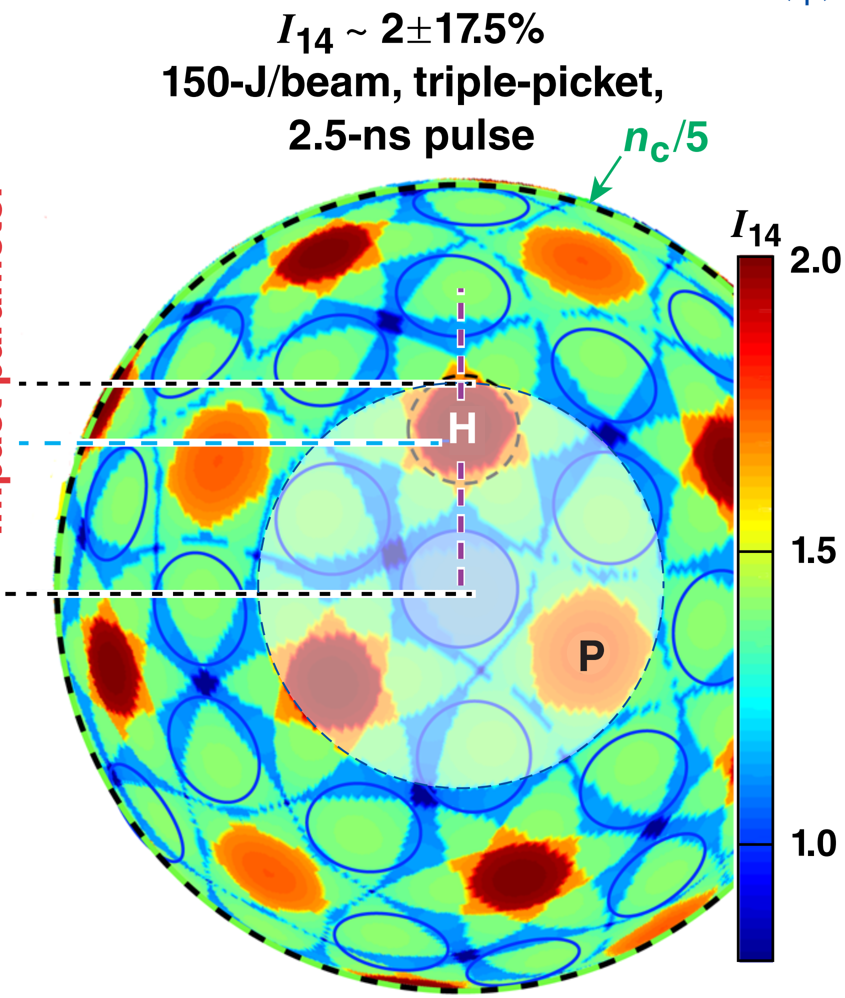
Visualized with LPSE plotter

The “laser package” automatically sets up the laser beams according to the (r,θ,ϕ) location on the $n_c/4$ surface



The reasons for TPD spatial dependence can be understood by considering a sample path

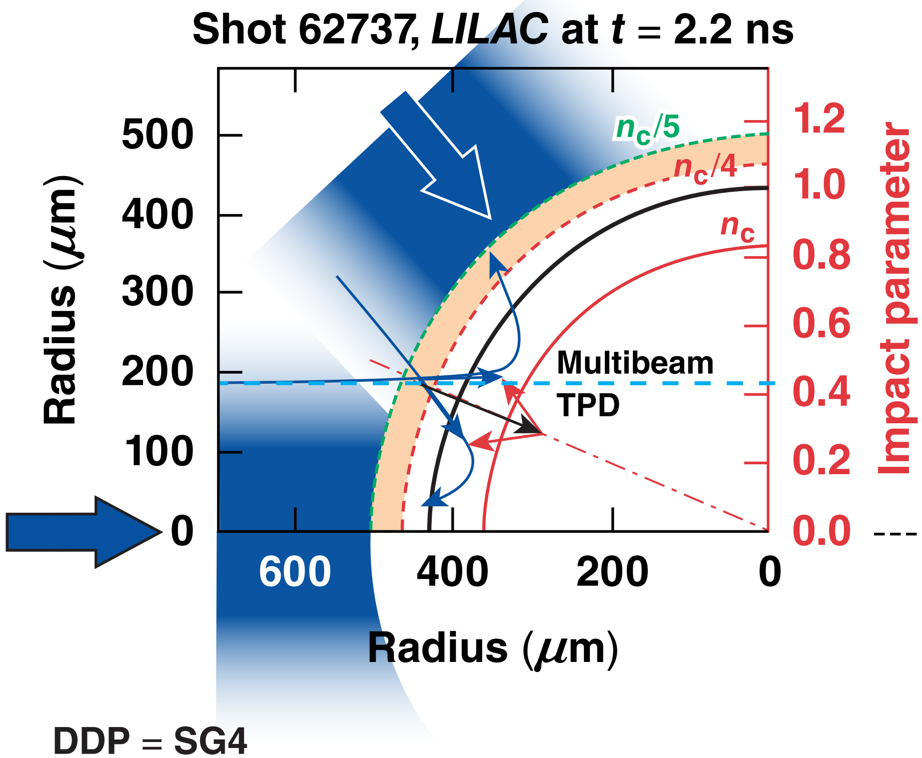


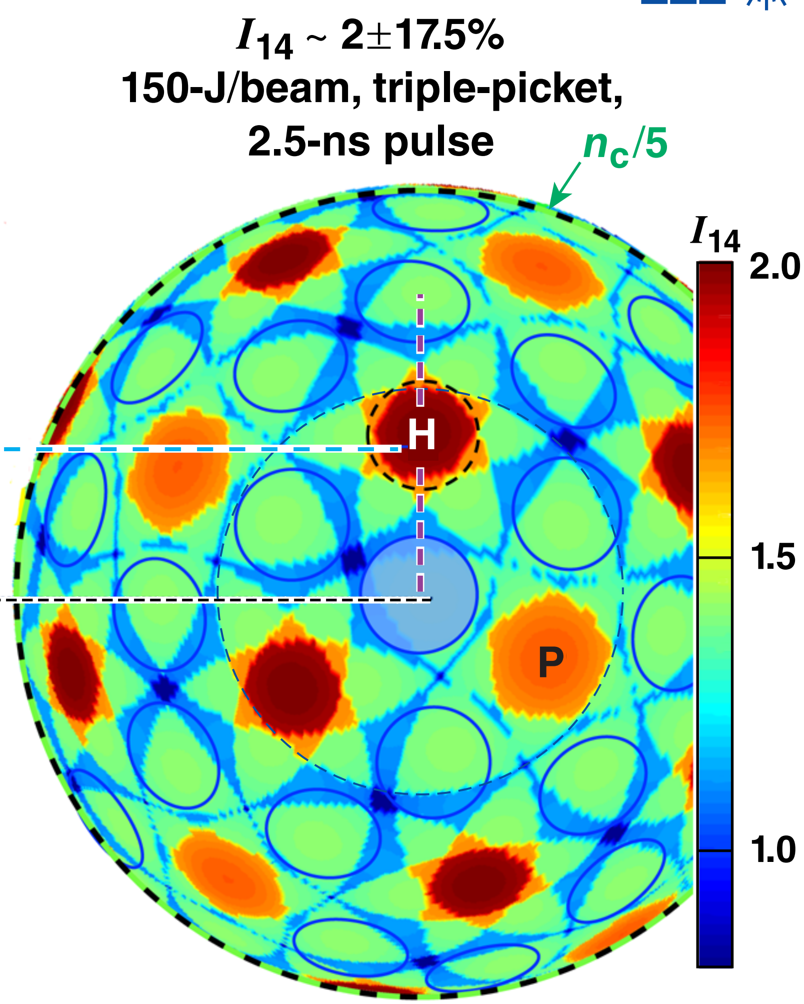


DDP = SG4

- Multibeam TPD favors symmetry
  - bisectors of beam pairs
  - centers of HEX or PENT ports

Six beams can cooperate at the hex center, while fewer beams contribute at other locations

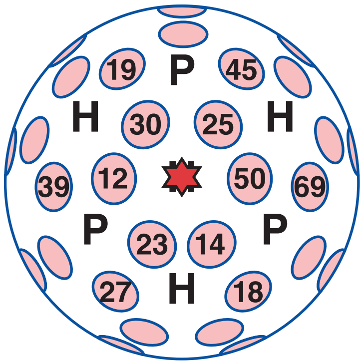


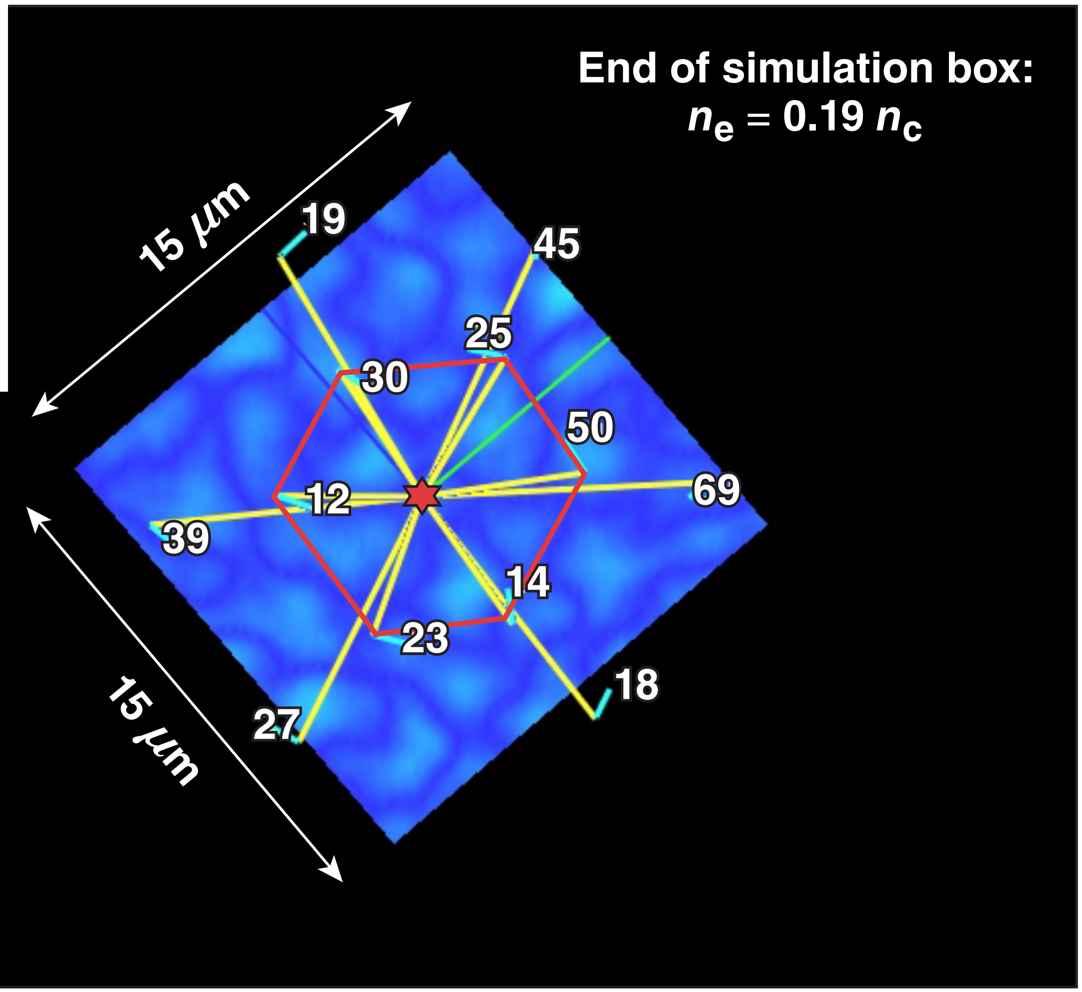


DDP = SG4

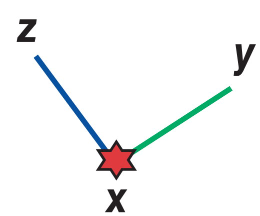
- Multibeam TPD favors symmetry
  - bisectors of beam pairs
  - centers of HEX or PENT ports

A series of runs computed the effects of an excursion across H17 with both large (SG4) and small (SG2) spot phase plates



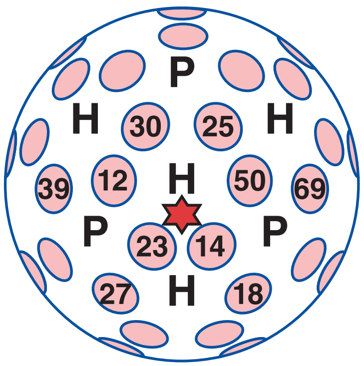


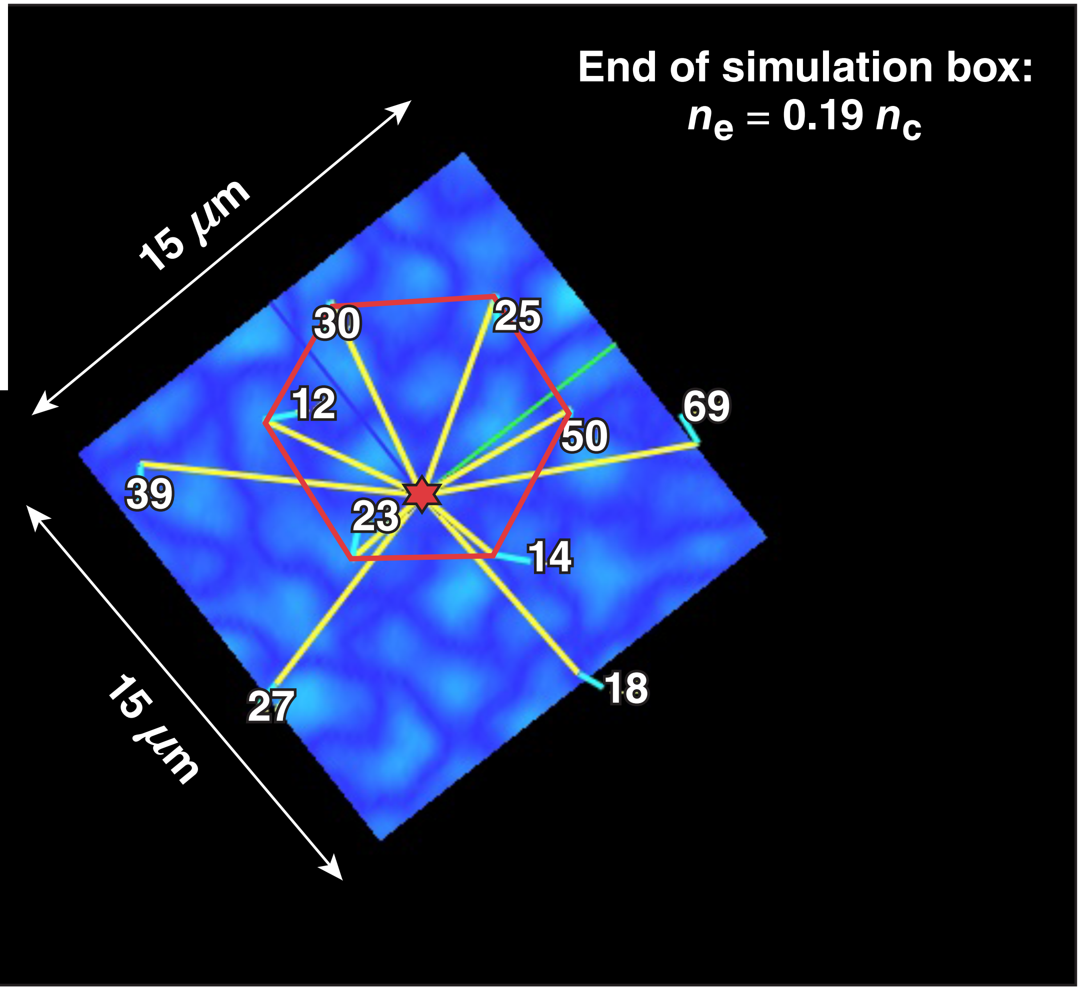
$R = 500\ \mu m$
$\theta = 142.6°$
$\phi = 54.0°$



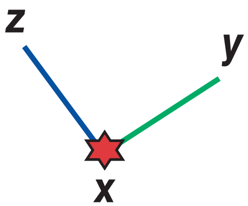
TC11300

A series of runs computed the effects of an excursion across H17 with both large (SG4) and small (SG2) spot phase plates



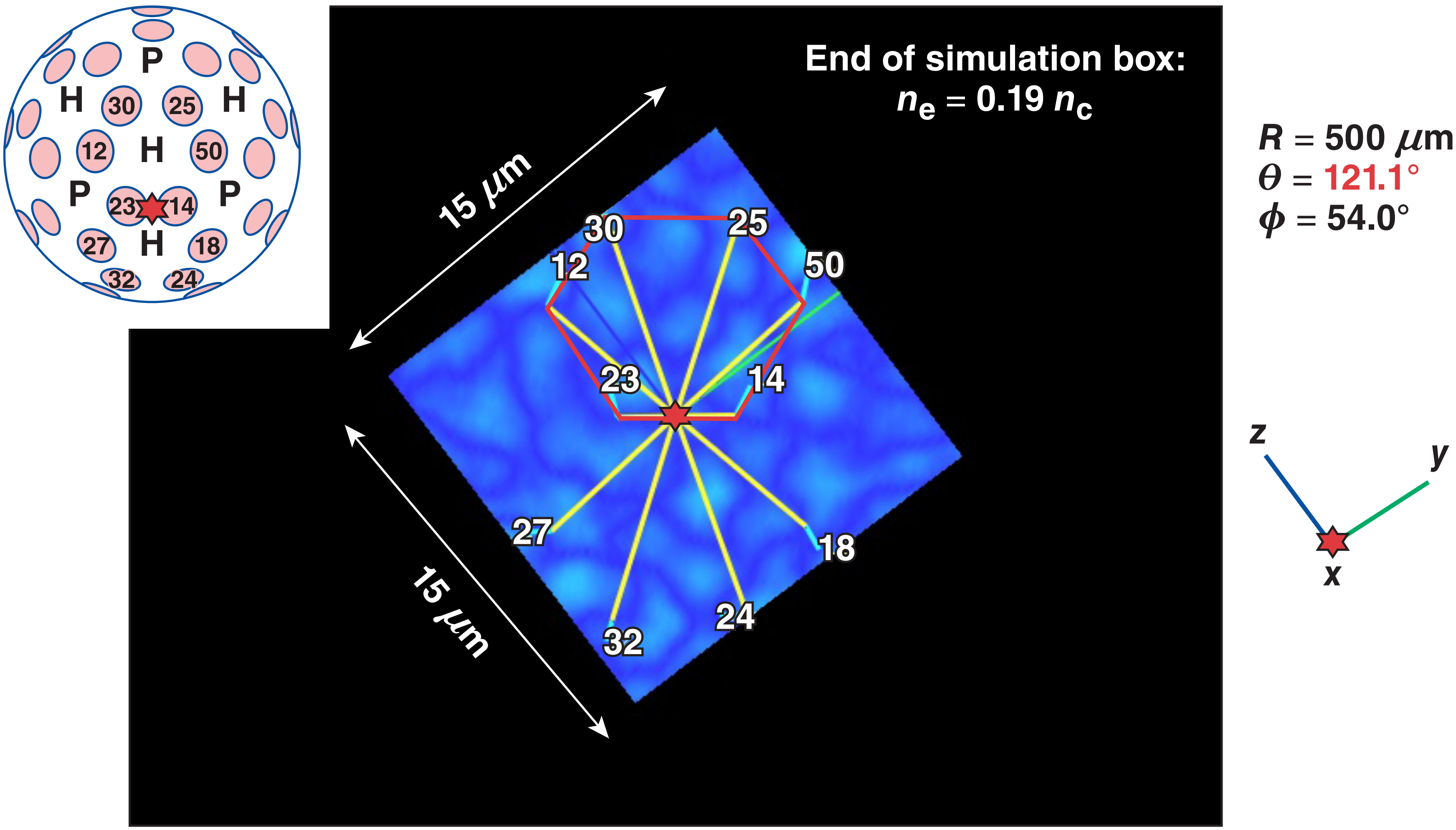


R = 500 μm
θ = 131.9°
ϕ = 54.0°



TC11300a

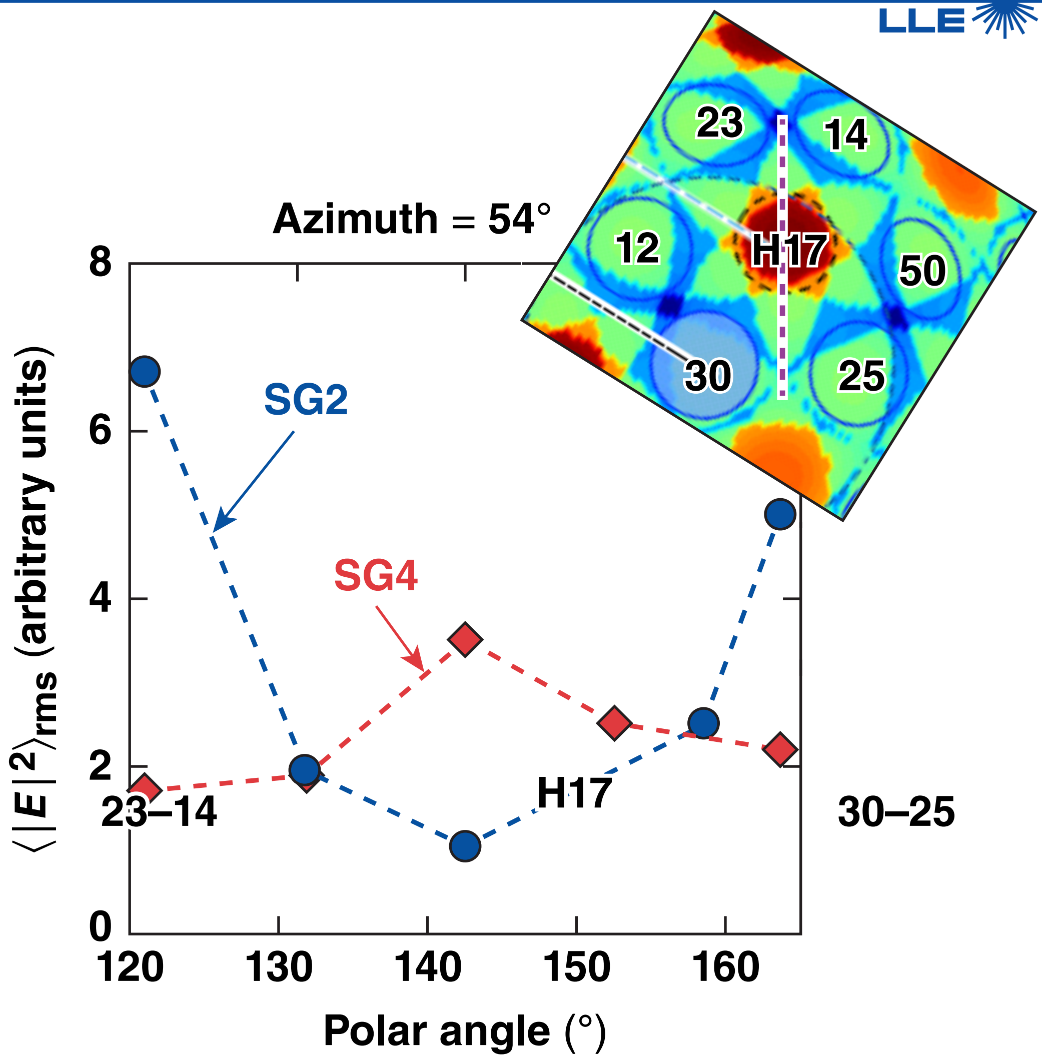
A series of runs computed the effects of an excursion across H17 with both large (SG4) and small (SG2) spot phase plates



TC11300b

The LPSE simulations show that TPD depends on the beam spot shape (at constant power and hydrodynamics)

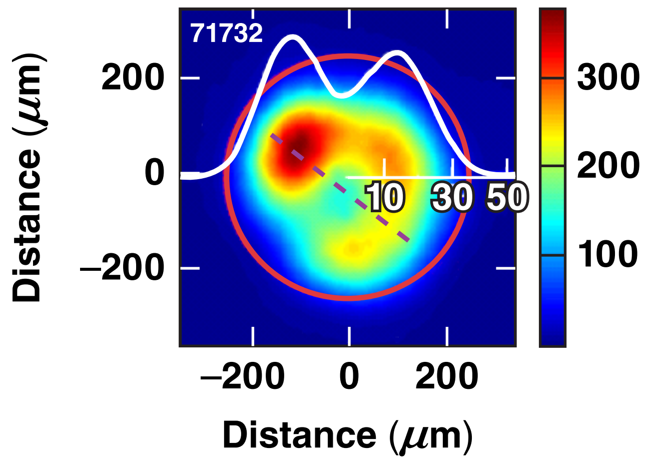
- The plot shows the dependence of the saturated LW rms (root-mean-square) energy density on the position of the $n_c/4$ surface
- SG4 phase plates have a focal spot that is close to the target diameter in size; SG2 phase-plate spots are roughly half the diameter
- Can be compared with the observations of local temperature "islands"*



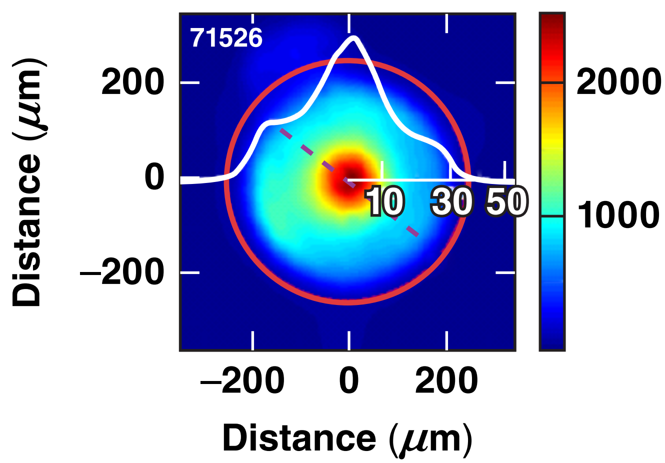
TC11244a

*W. Seka *et al*., Phys. Rev. Lett. 112, 145001 (2014).

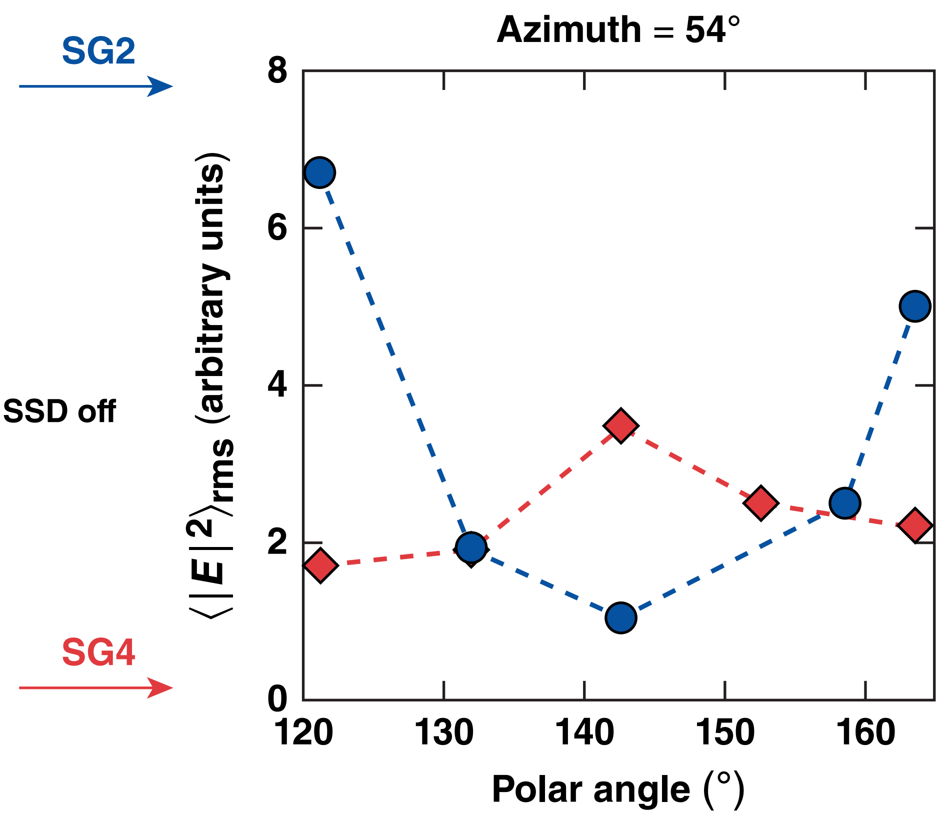
The LPSE simulations predict a similar structure to that observed in half-harmonic images through a hex port*



Room-temperature CH target (880-μm diam), SG2, SSD off



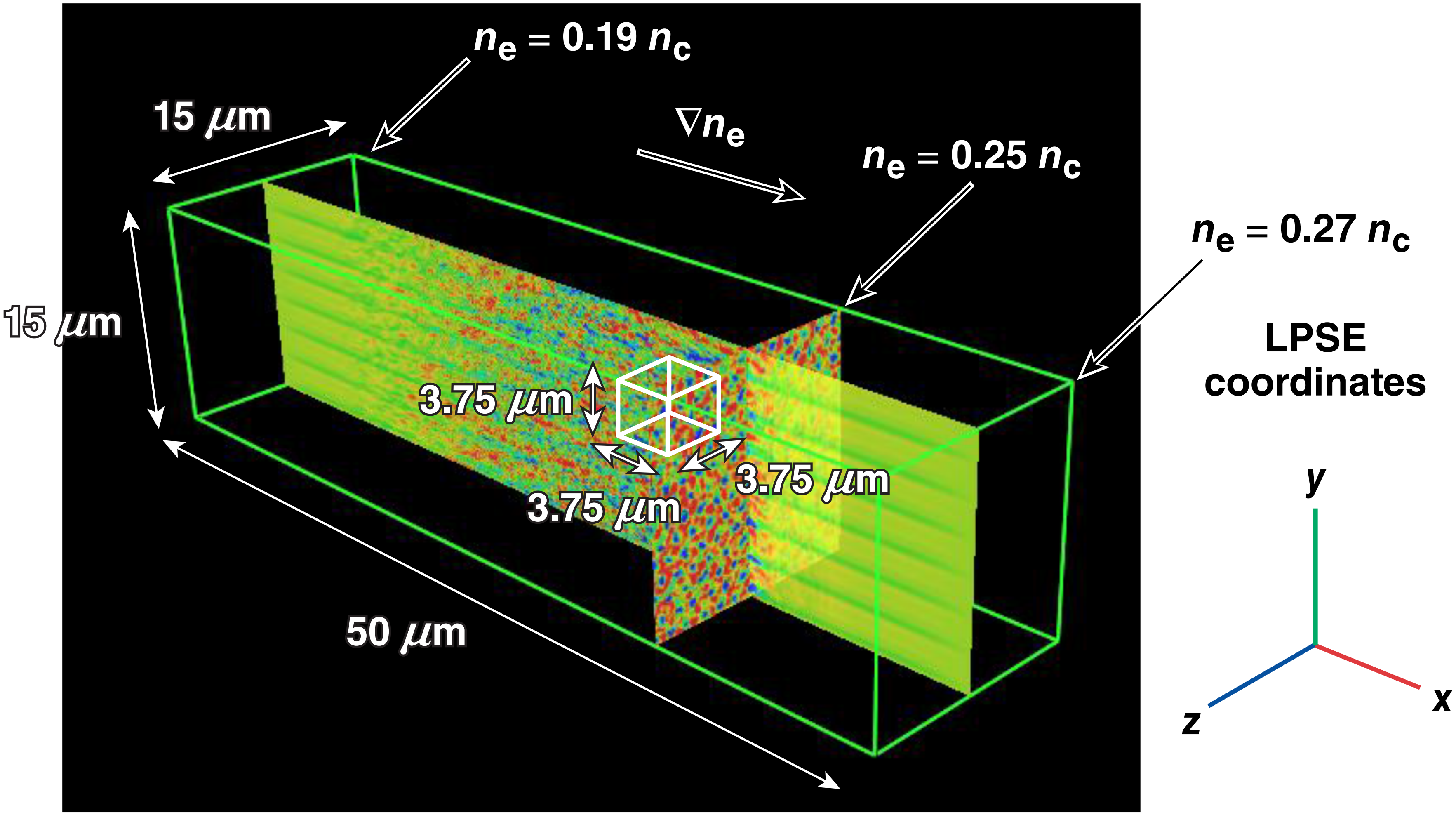
Room-temperature CH target (870-μm diam), SG4, SSD on
2.5-ns triple-picket pulse, 126.4 kJ, I_{14} (nominal) ~ 9.5 $I_{14,\text{ single beam}}$ ~1.3



TC11255

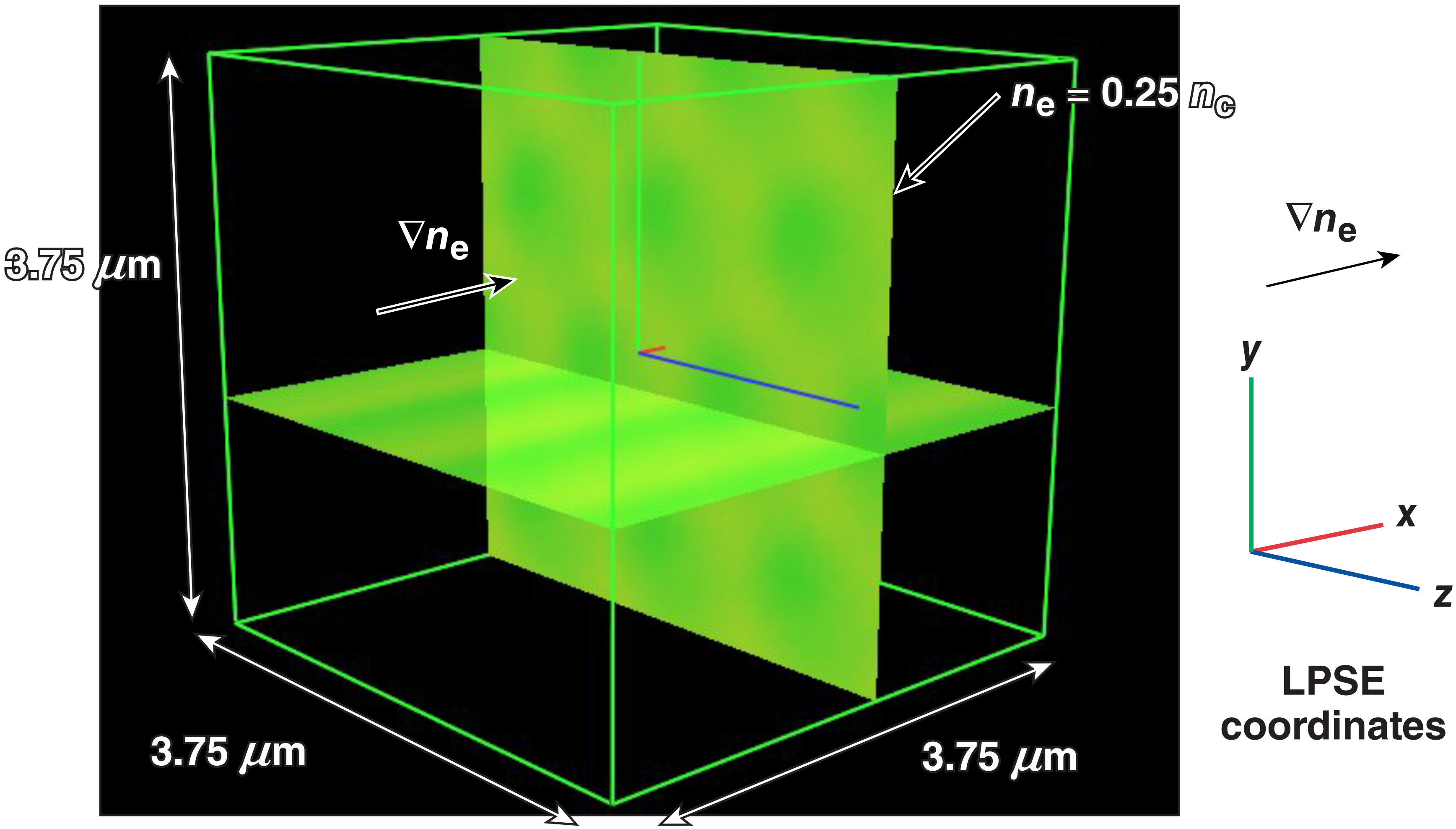
*W. Seka *et al*., Phys. Rev. Lett. 112, 145001 (2014).

There is too much detail to absorb; we can look at subvolumes* of the calculation (e.g., 1/256th)



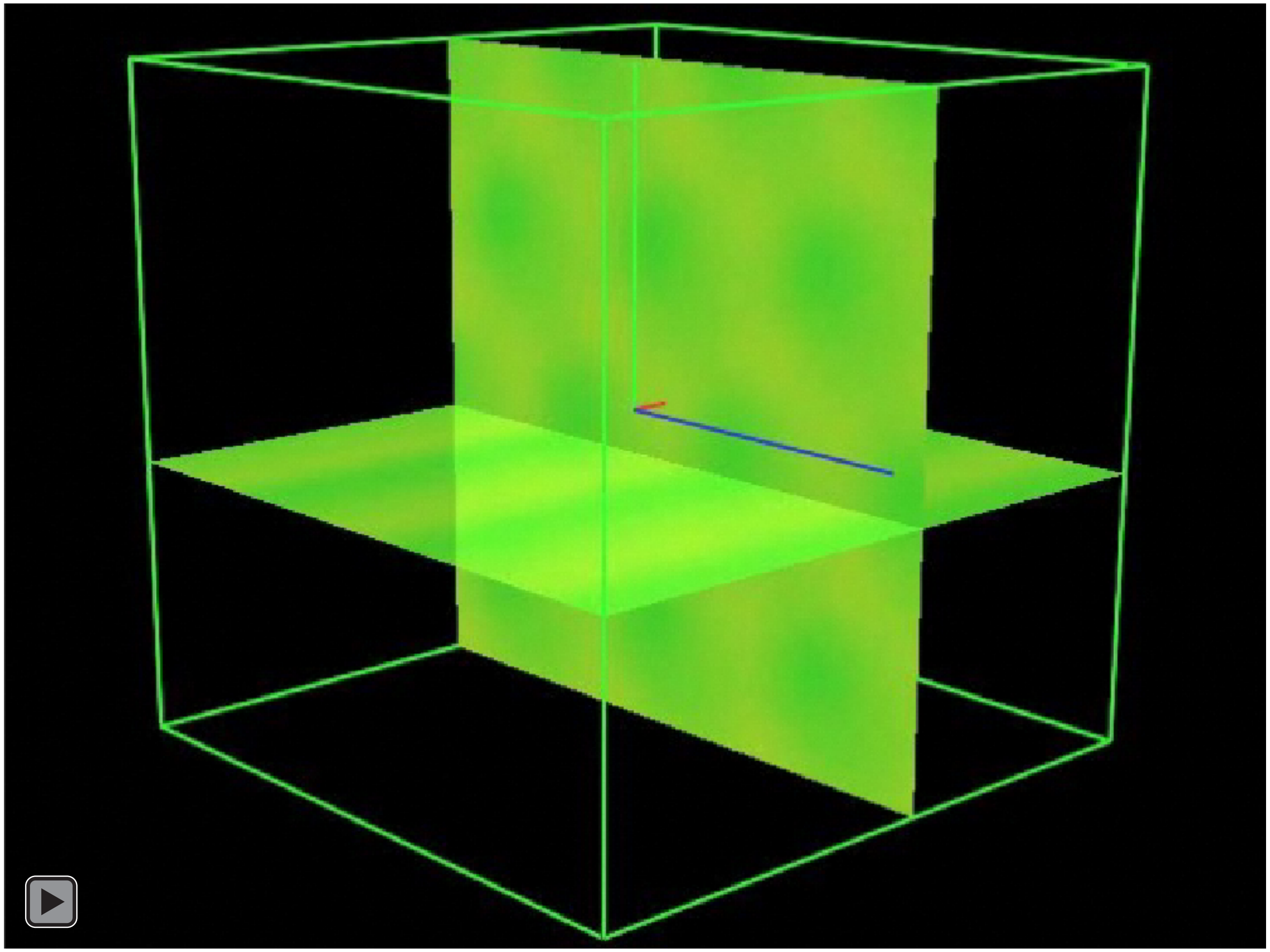
*Various utility programs manipulate the ~100-GB files (per field component)

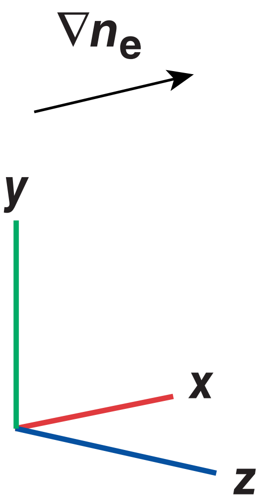
Interesting ion-acoustic wave dynamics can be seen in the small subvolume straddling the $n_c/4$ surface



TC11302

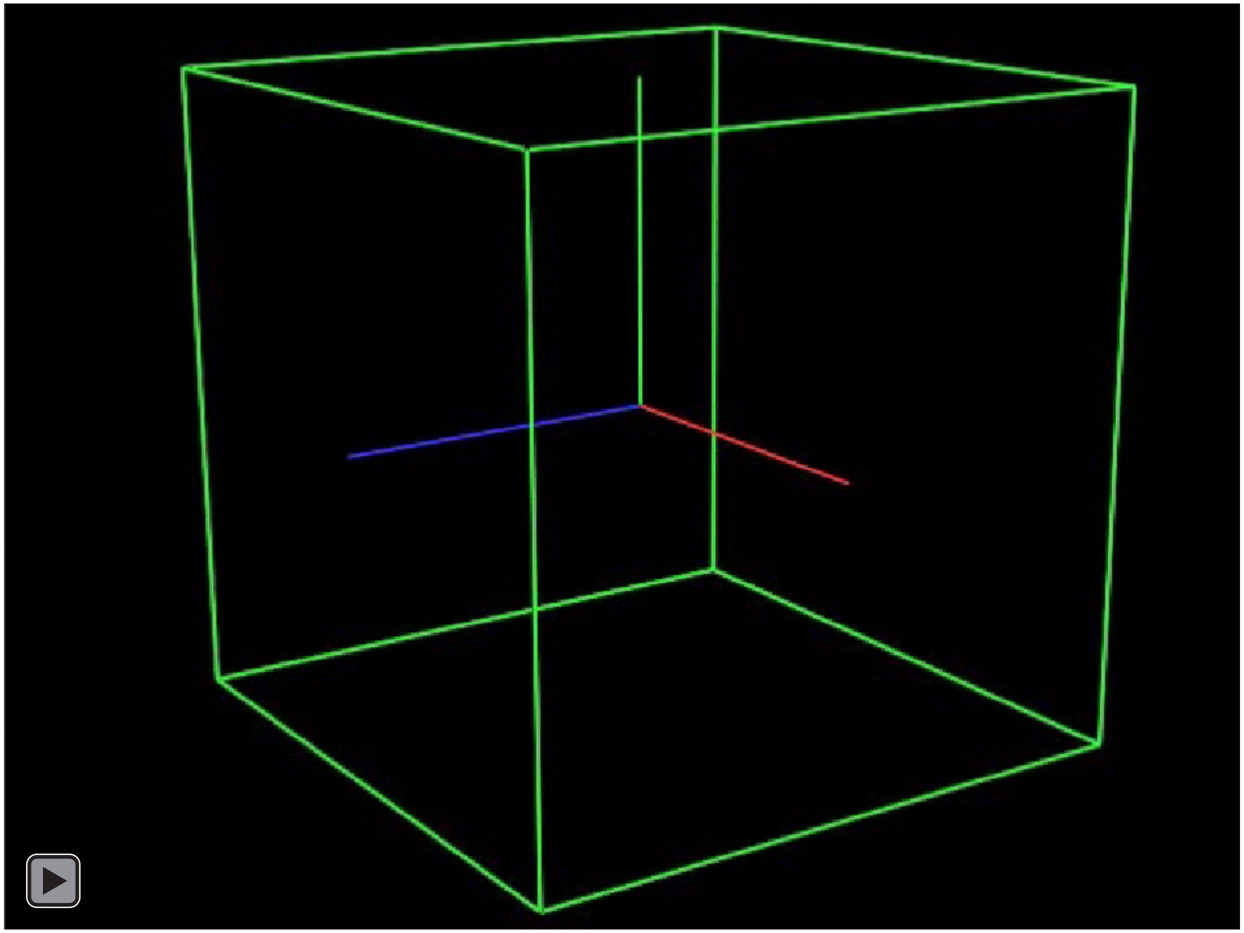
Interesting ion-acoustic wave dynamics can be seen in the small subvolume straddling the $n_c/4$ surface

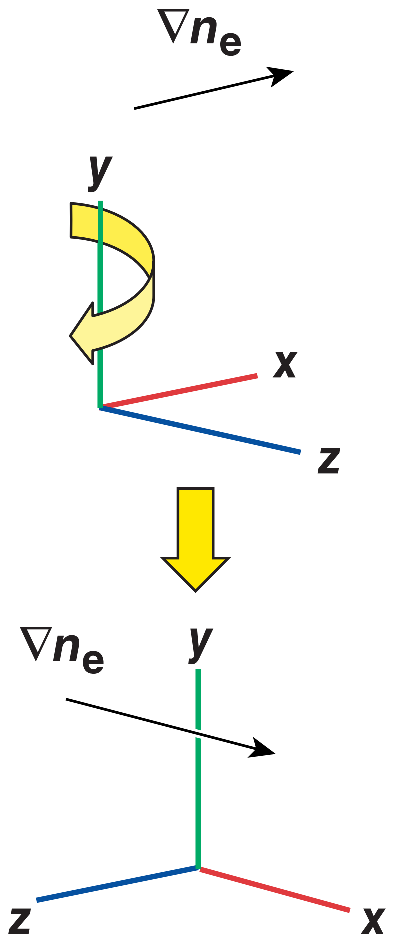




LPSE coordinates

Isosurfaces of Langmuir wave intensity show cavitation and collapse near $n_c/4$



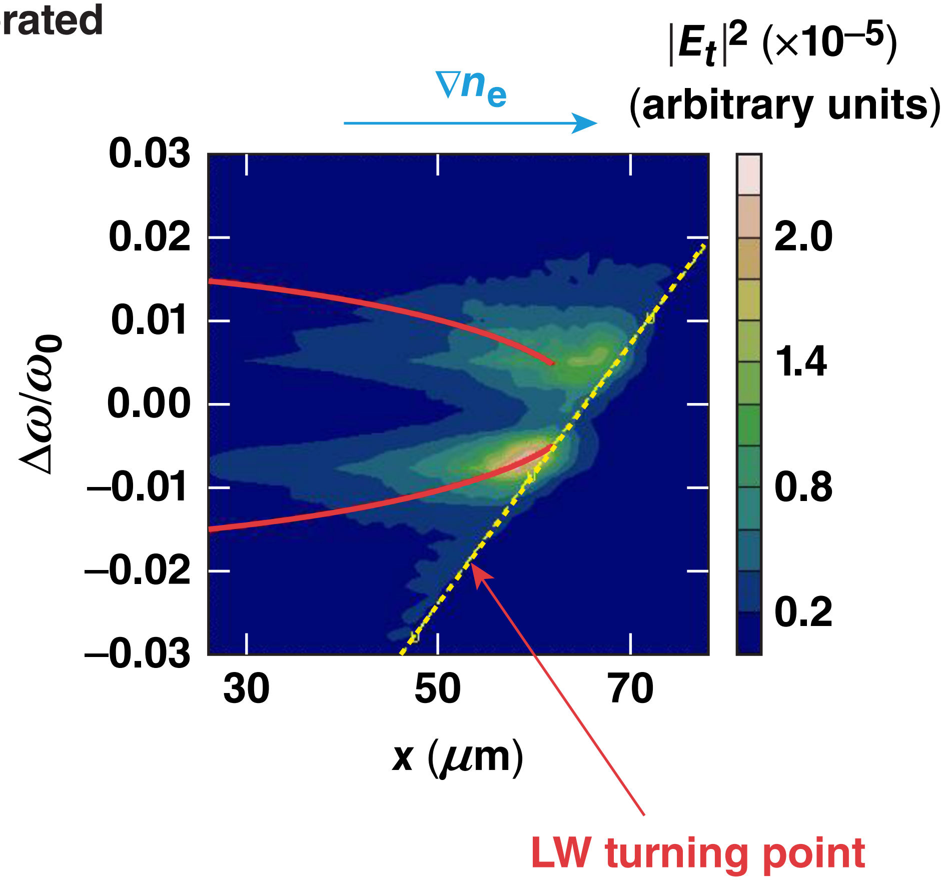


LPSE coordinates

TC11302b

A variant of LPSE is being tested in 2-D that directly computes half-harmonic emission*

- Half-harmonic emission can be generated in various ways
  - linear conversion
  - nonlinear conversion
  - Thomson scattering
- A transverse wave envelope is required
- Linear and nonlinear conversion are competitive
- The algorithm can be implemented in 3-D LPSE



*J. Zhang, Ph.D. student, Mechanical Engineering Department, University of Rochester, Rochester, NY.

Summary/Conclusions

Three-dimensional calculations demonstrate the spatial localization of two-plasmon decay (TPD) in spherical implosions

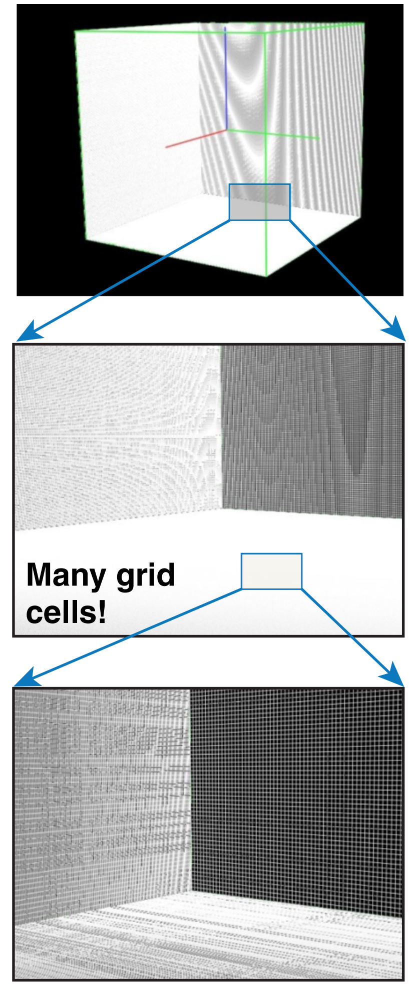
- Multibeam laser–plasma instabilities (LPI's) have to be studied in three dimensions
- The laser–plasma simulation environment (LPSE) code describes TPD in 3-D
  - fast, makes efficient use of memory, and extensible
  - includes 3-D visualization tools
  - three-dimensional calculations can be performed in ~1 h
- LPSE calculations show TPD localization in spherical targets that is consistent with experimental observations

The computational resources required for 3-D LPI simulations are quite significant

UR LLE

- Code
  - C++ (~ten classes + ten utilities + Yorick scripts)
  - uses MPI, FFTW, and MKL libraries
  - visualization software uses Qt + GL libraries
  - well documented*
- Algorithm
  - 14 fast Fourier transforms (FFT's) per iteration
  - metrics and virtual instrumentation
  - O (10^8 to 10^9) nodes, nine degrees of freedom/node
- CPU time: O (1 to 10) hours using 100 cores
- I/O: two or three large files, O (10 to 100) GB

$1024 \times 256 \times 256$



TC11258

*http://florence.lle.rochester.edu