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Title:

CALCULATIONS OF DOUBLE CYLINDER IMPLOSIONS AT OMEGA

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Los Alamos
NATIONAL LABORATORY

Calculations of Double Cylinder Implosions at OMEGA

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Foam-filled double cylinder targets have been imploded by the OMEGA laser at the University of Rochester. A marker layer of heavier material is placed between the foam and the outside ablator. The marker layer is hydrodynamically unstable when a strong shock passes through both these interfaces and the marker layer material mixes into the foam and the ablator. These experiments thus measure mix in the compressible, convergent, miscible, strong-shock regime.

With double cylinder targets, the initial shock converges on the central cylinder and then rebounds and expands. The shock is predicted to create even more mixing of the marker layer as it traverses the previously mixed region. The strength of the reflected shock can be varied by changing the materials in the inner cylinder. Calculations of these implosions using the AMR code, RAGE, are presented for the several target designs. The 2-d calculations give the hydrodynamic evolution of the implosion, shock timings, and the growth of the mix width. The calculations include the effects of surface roughness in the marker layer. Simulated radiographs of the cylindrical implosions are also shown.

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Calculations of Double Cylinder Implosions at Omega

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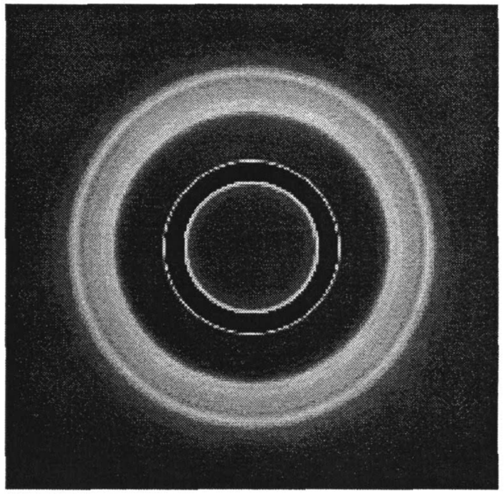
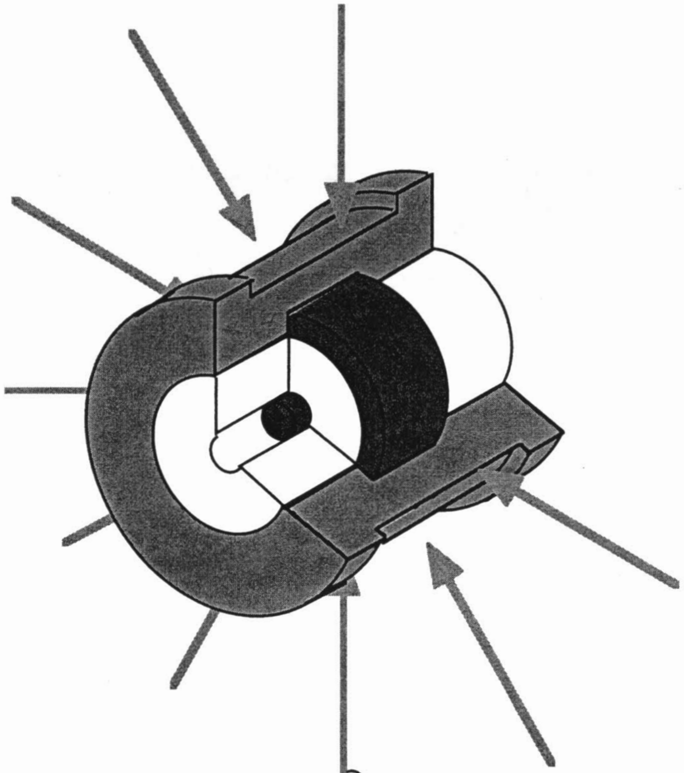
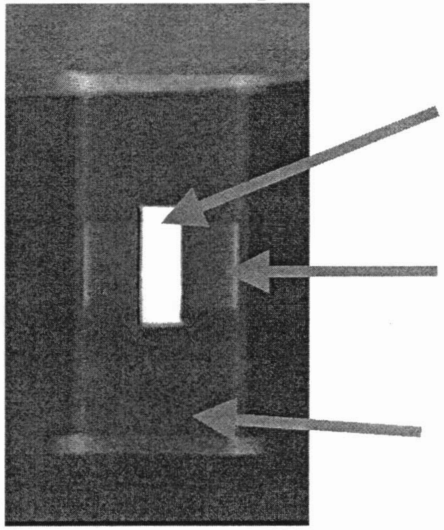


Presented at APS-Division of Plasma Physics Annual Meeting,
Orlando, FL, November 11, 2002

Double cylinder experiments will test mixing due to reshock

- Main shock rebounds off an inner cylinder and shocks already mixed region





Center Shell

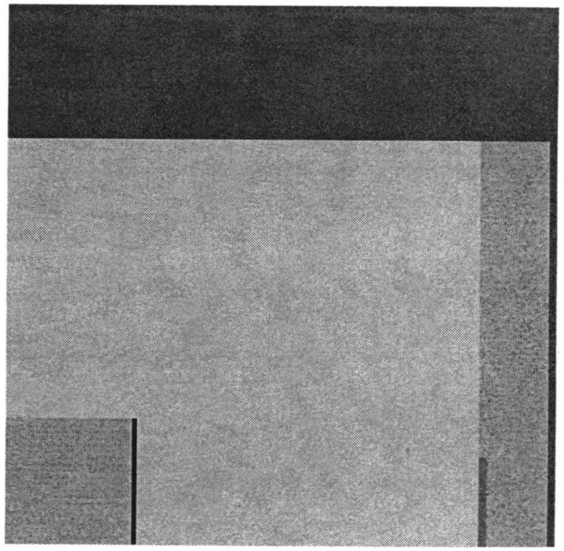
Marker Layer

CH and Foam

- Center is polystyrene or epoxy coated with 5 μm Cu
- 700 μm long
- Al marker is 500 μm long
- Outer surface of marker can be roughened

RAGE is being used for 2-D modeling of double cylinder implosions at OMEGA

- RAGE* is a multi-dimensional multi-material Eulerian radiation-hydrodynamics code developed at Los Alamos and SAIC.
- RAGE features a continuous adaptive mesh refinement algorithm for following shocks and contact discontinuities with a very fine grid while using a coarse grid in smooth regions.
- RAGE hydro uses a second order accurate Godunov type scheme. Multiple materials are handled by a separate advection step for each material and diffusion is limited at the interfaces by the use of the finest cells in the AMR grid. Mixed cells are assumed to be in pressure, temperature and velocity equilibrium.
- Laser deposition is not yet fully integrated into the code. For our calculations, the laser energy deposition is calculated with LASNEX and implemented as an energy source in RAGE.
- Radiation is treated non-equilibrium in the grey approximation with flux-limited diffusion, and SESAME database is used for EOS and opacity.
- Perturbed boundary regions are allowed so an interface with given roughness spectrum can be defined as a sum of sin and cos.
- RAGE has been extensively validated against a variety of analytic test problems and detailed experiments.



Initial grid for 2-D design

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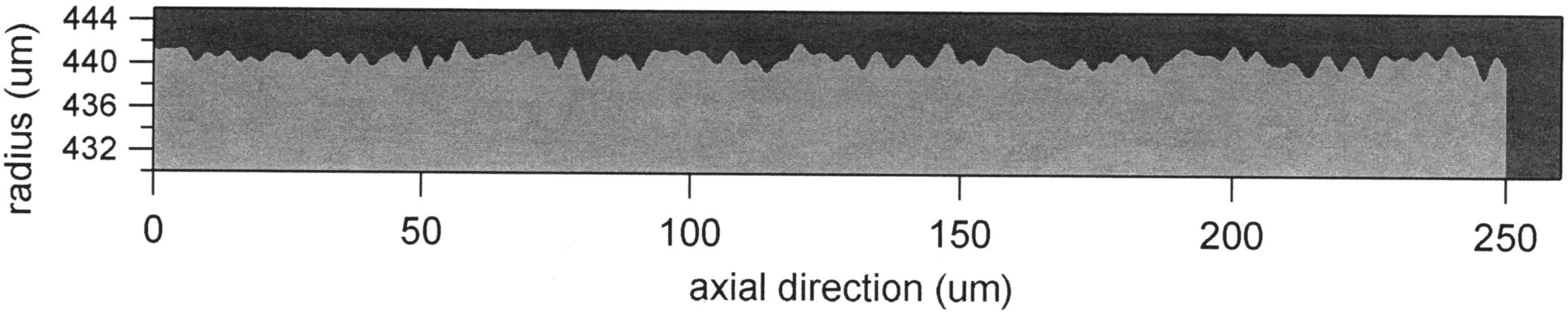
*M. Gittings in DNA Numerical Methods Symposium, 28-30 April, 1992

The as-measured surface roughness spectrum is applied to the marker layer in RAGE simulations

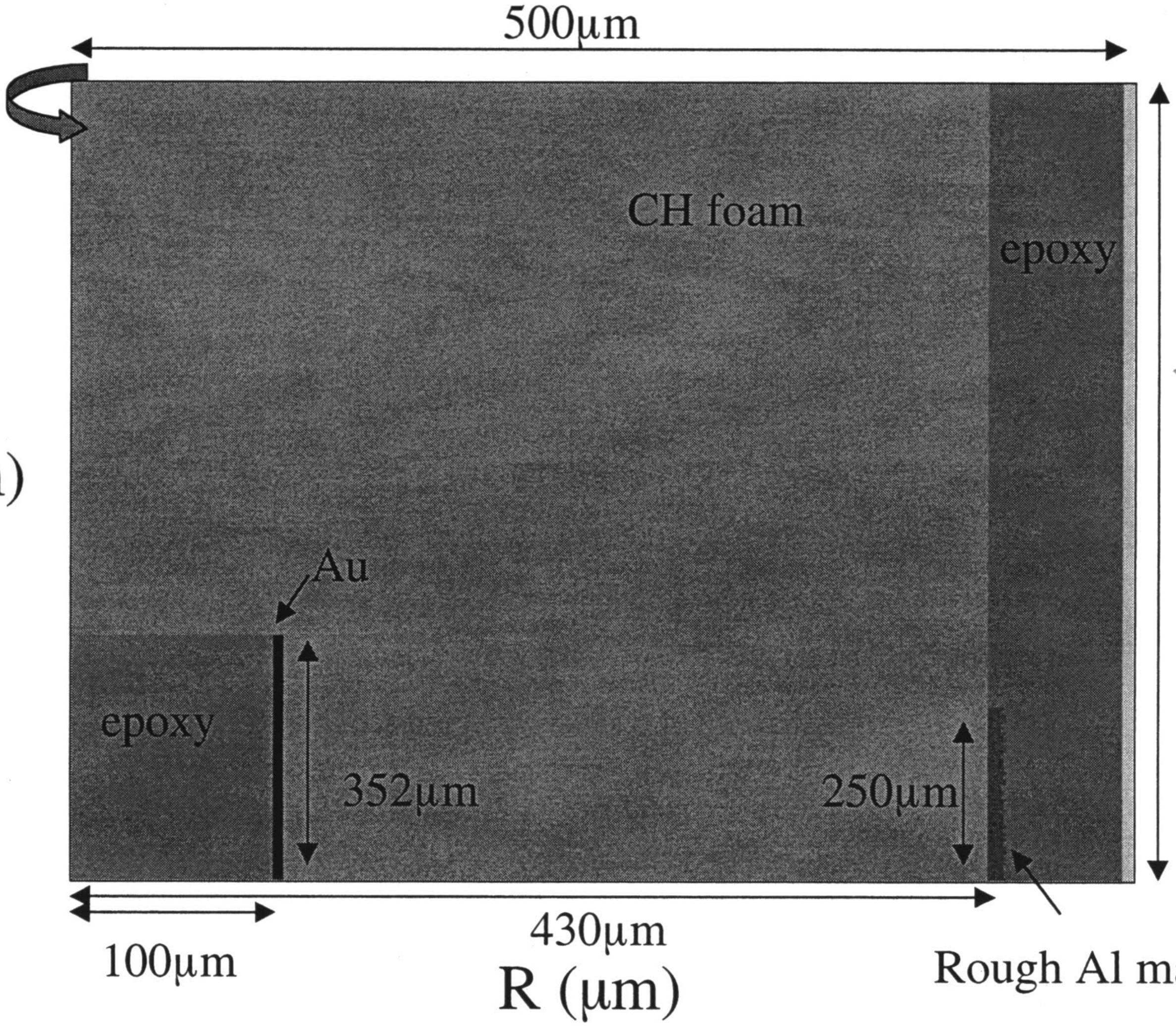
¥ Surface roughness measurements give amplitude vs. wavenumber data.

¥ Power per Δk is preserved between the measurements and the perturbations imposed in the simulation.

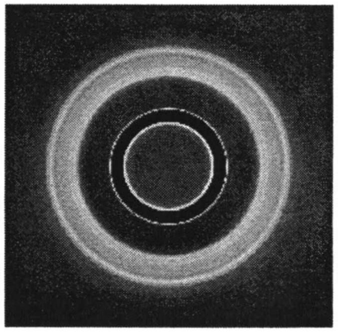
¥ Superimposed perturbations of the form $A^* \cos(Bx + C)$ are applied to the marker layer in the simulation yielding roughness spectrums with R_a values consistent with measurements.



Initial grid for problem setup

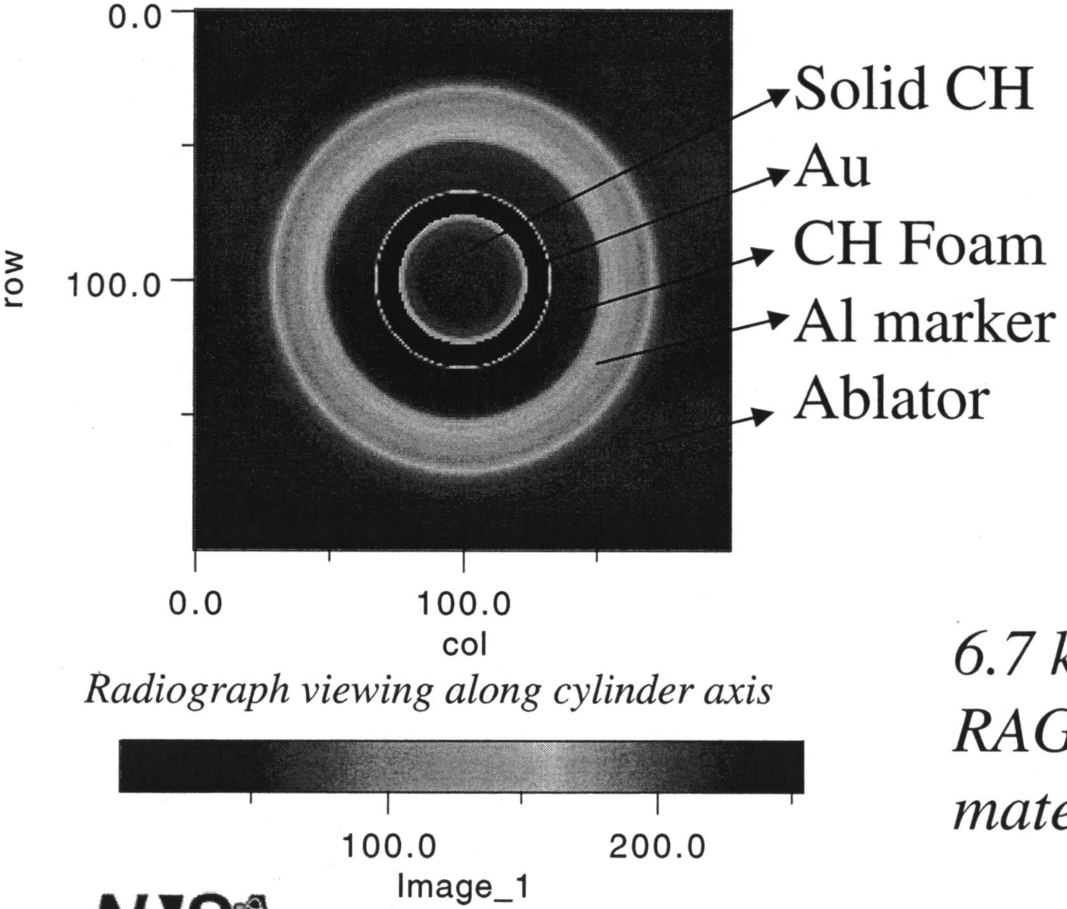


Simulation models half of the Z-extent, and the source is applied in the outer 3 µm of the ablator



Axial view

RAGE simulation includes calculation of backlit radiographic images



Solid CH

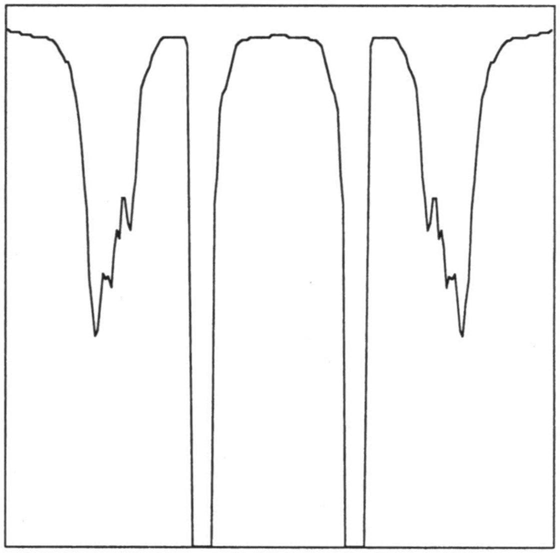
Au

CH Foam

Al marker

Ablator

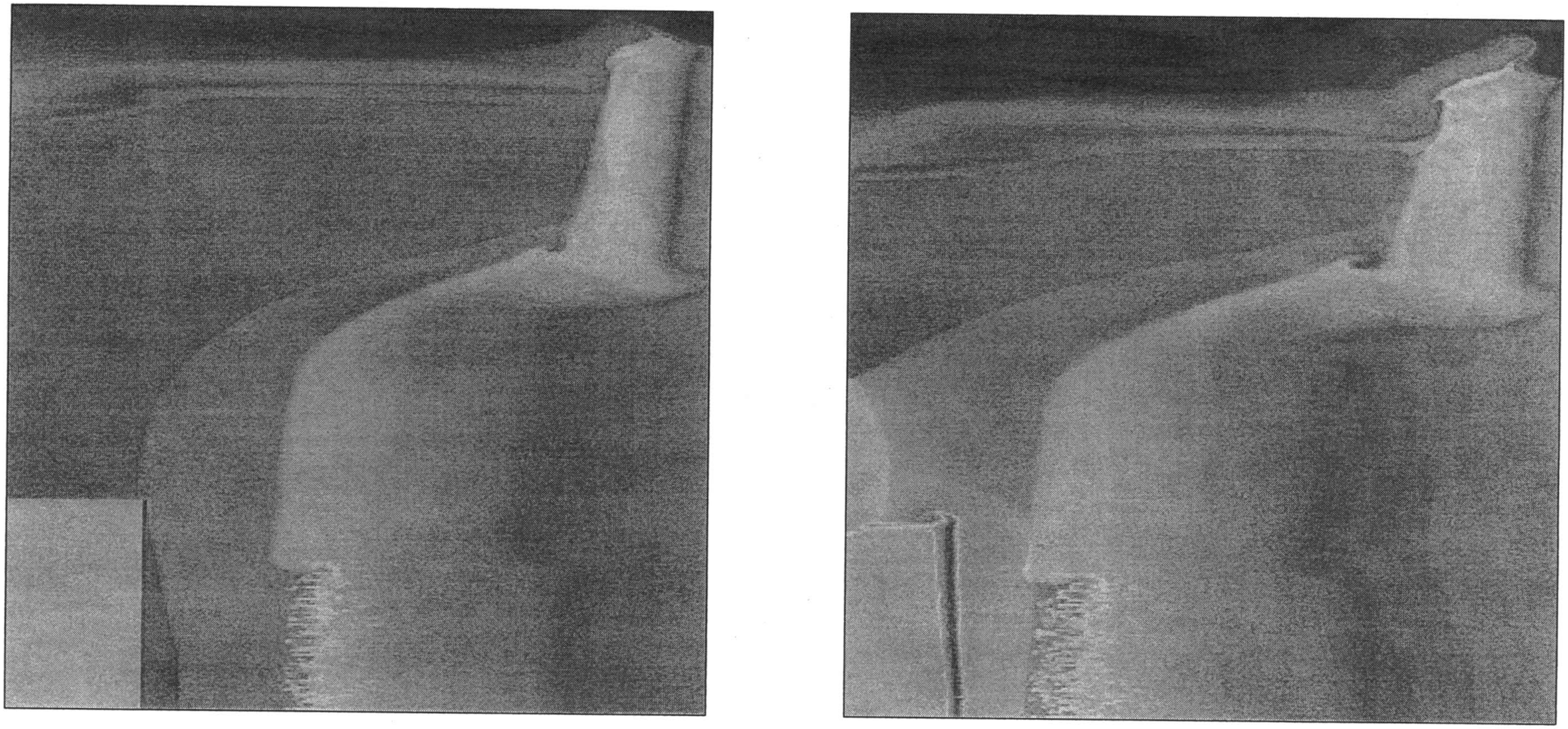
Radiograph viewing along cylinder axis



Horizontal lineout

6.7 keV Fe backlighter is used, RAGE uses cold opacities for all materials.

Density plot shows shock hitting inner cylinder at 4ns and reflected shock hits Al at 5ns in RAGE simulation with rough marker layer

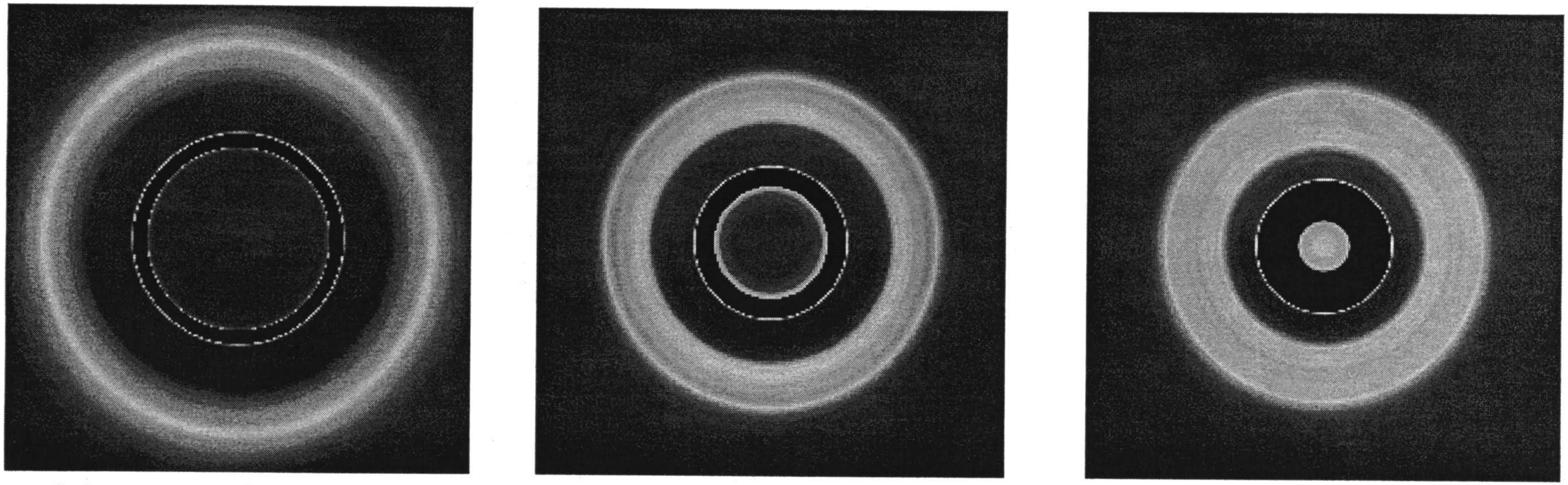


4.1ns

5.1ns

For the Al/Au double shell, RAGE predicts significant growth after rebound shock interacts with incoming rough Al marker.

Simulated backlit images using Fe backlighter



5.1ns 6.1ns 6.8ns

38 μm width 46 μm width 64 μm width

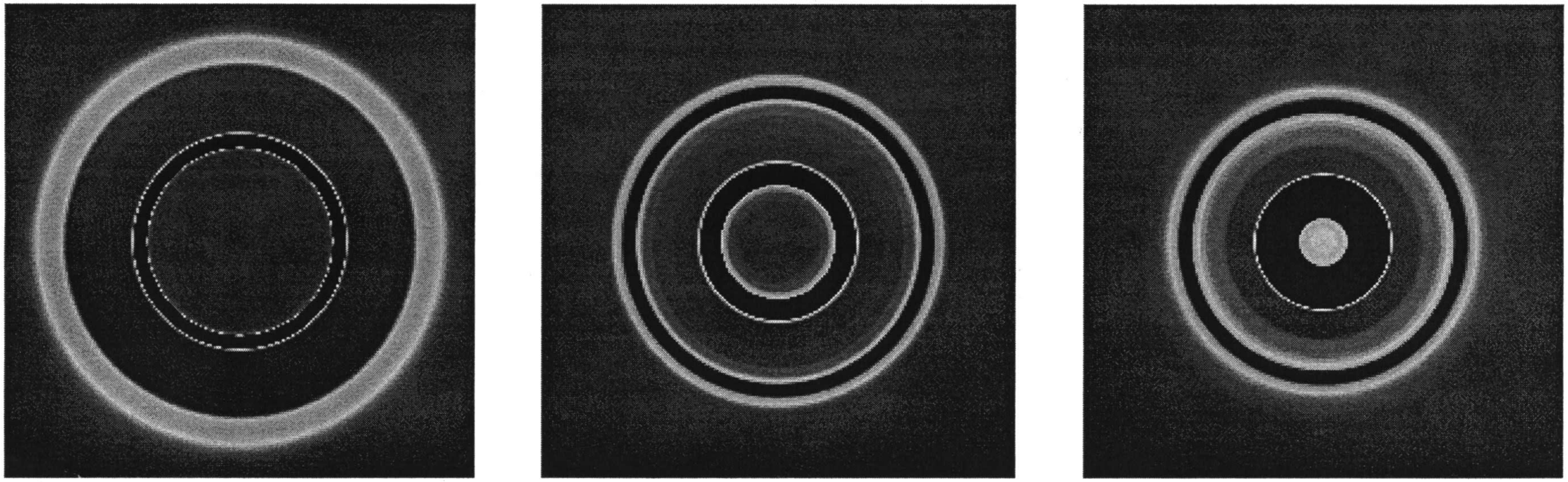
Marker widths

RAGE calculation with 0.15 μm resolution in Cl marker region,and rough surface on marker (Ra=0.5)
Backlighter calculation does not include effects of instrumental width.

For the Al/Au double shell, RAGE predicts no growth of marker width after rebound shock interacts with incoming smooth Al marker.

Simulated backlit images using Fe backlighter

5.1ns 6.1ns 6.8ns



28 μm width 26 μm width 26 μm width

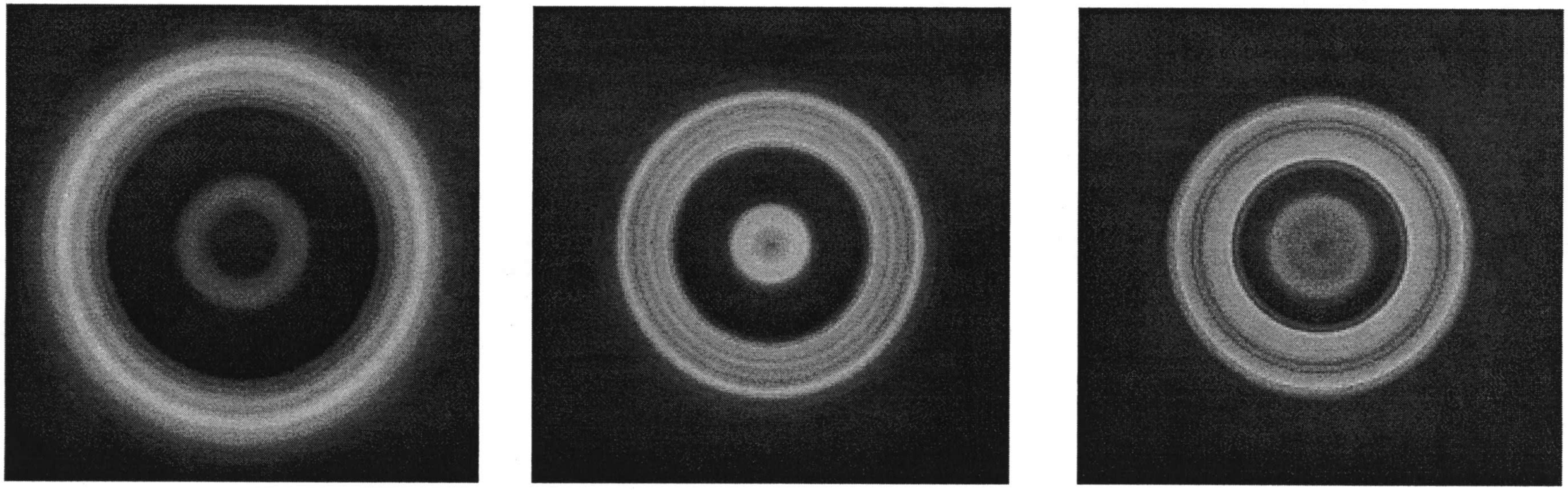
Marker widths

RAGE calculation with 0.15 μm resolution in smooth Cl marker region
Backlighter calculation does not include effects of instrumental width.

For the Al/epoxy double shell, RAGE predicts little growth after rebound shock interacts with the incoming rough Al marker

Simulated backlit images using Fe backlighter

5.4ns 6.4ns 6.9ns



~~48~~ μm width

46

48 μm width

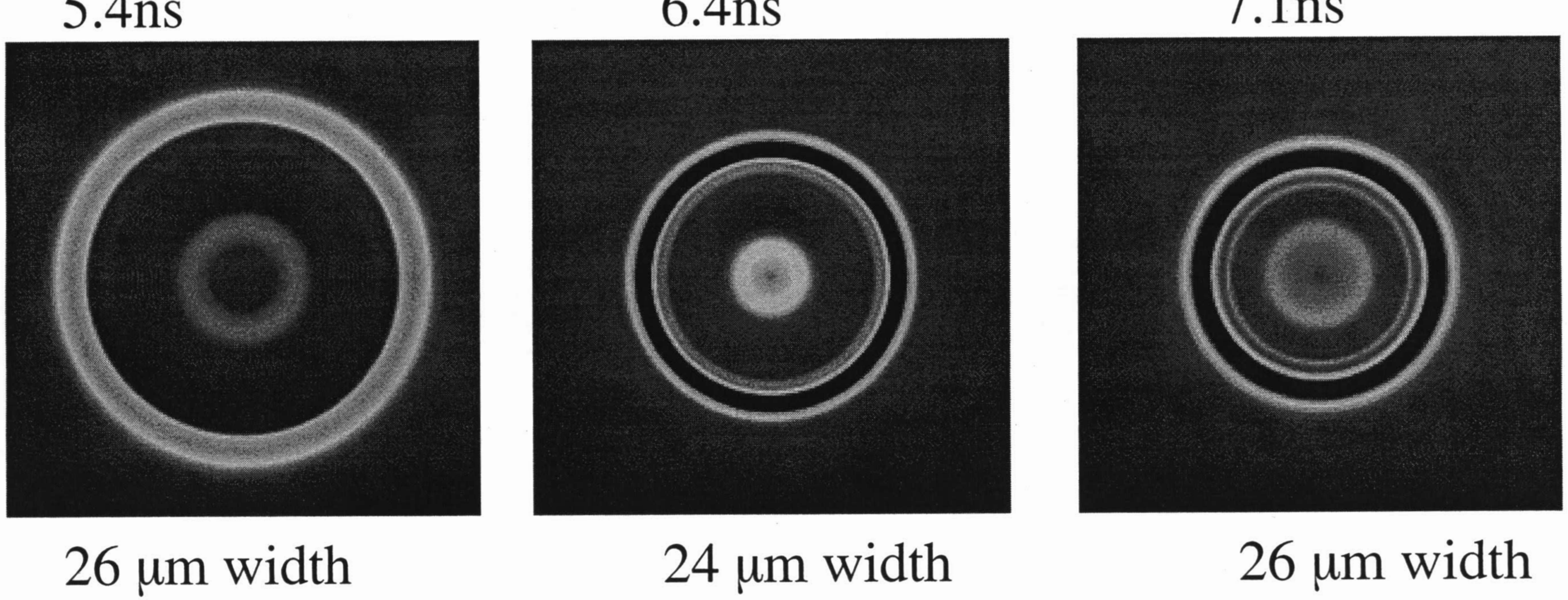
48 μm width

Marker widths

RAGE calculation with 0.13 μm resolution in Cl marker region,and rough surface on marker (Ra=0.5)
Backlighter calculation does not include effects of instrumental width.

For the Al/epoxy double shell, RAGE predicts little growth after rebound shock interacts with the incoming smooth Al marker

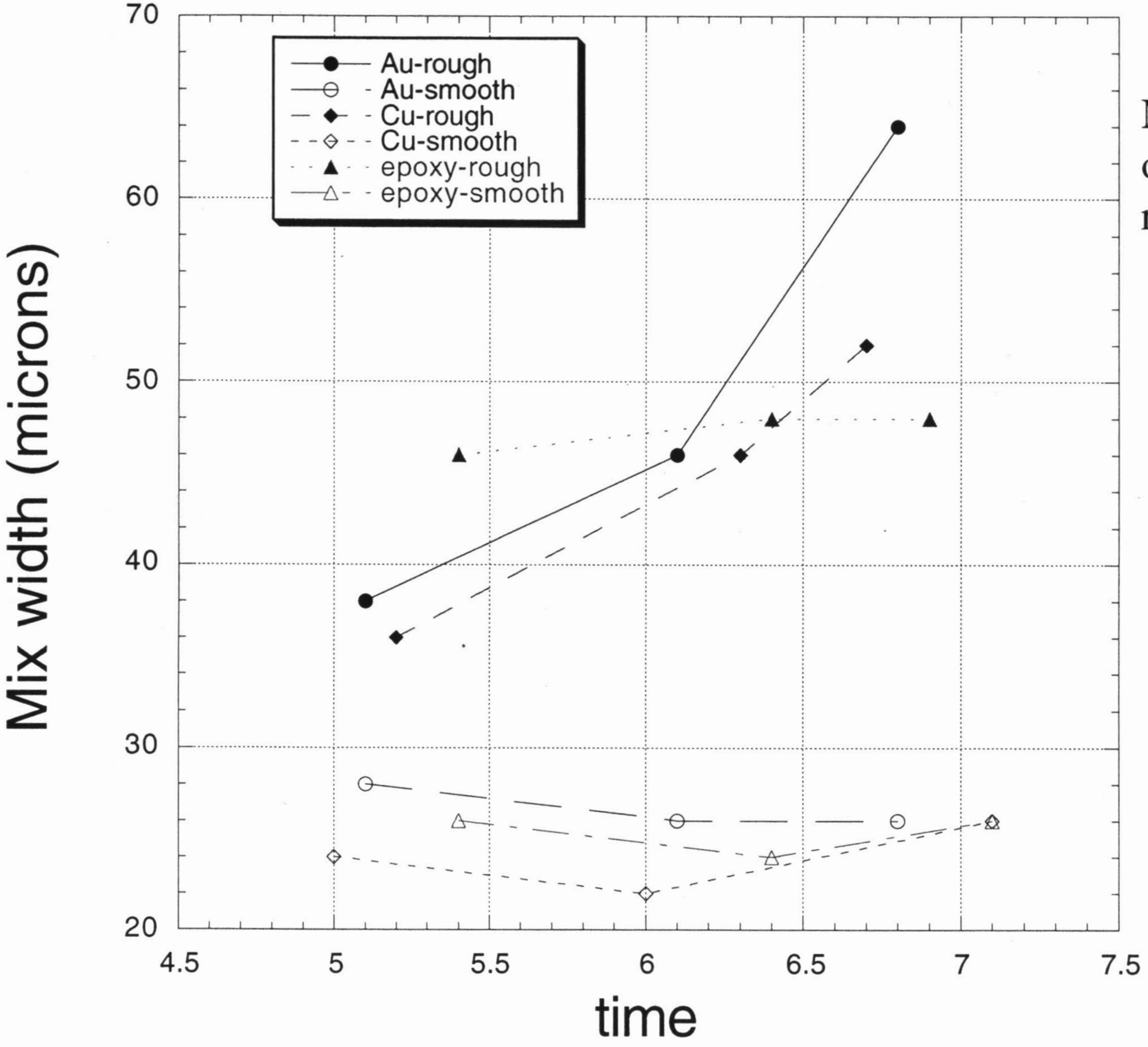
Simulated backlit images using Fe backlighter



Marker widths

RAGE calculation with 0.13 μm resolution in smooth Cl marker region,
Backlighter calculation does not include effects of instrumental width which can add 10μm.

RAGE calculated mix widths



Mix width equals FWHM of marker layer in backlit radiograph

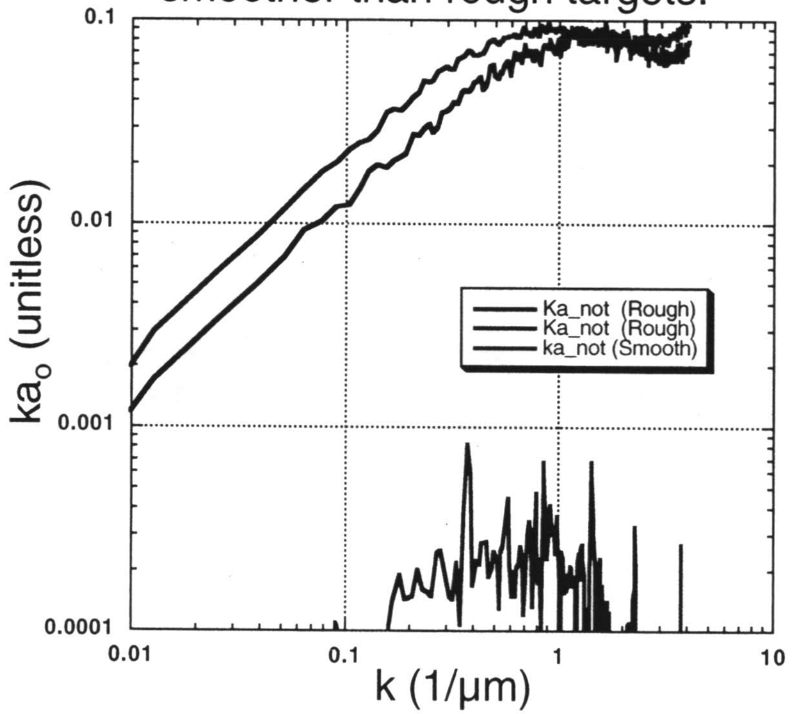
Rough targets give much greater mix widths

Widths do not include motion blur or instrument width (~10μm)

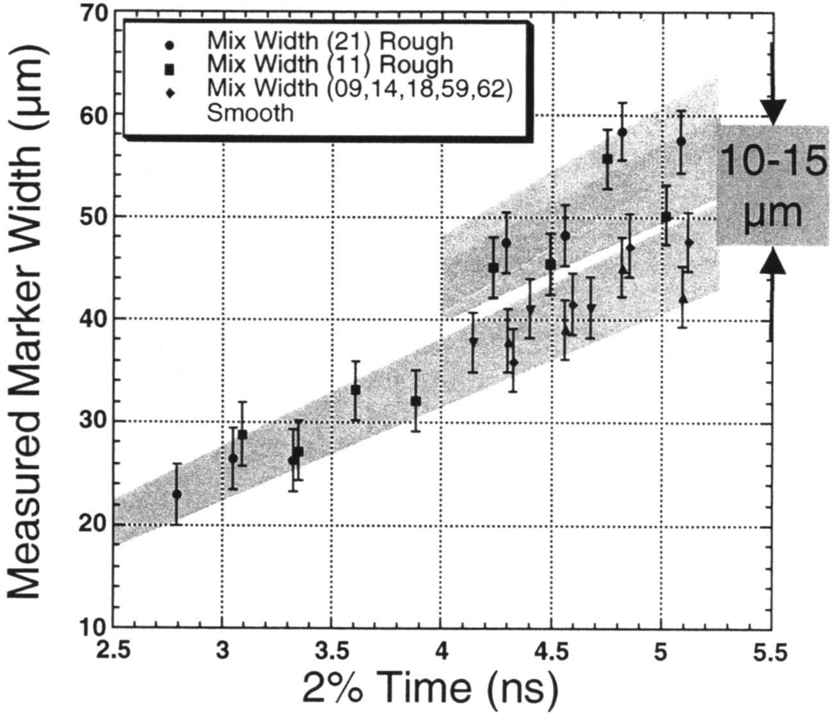
Los Alamos

Measurements Indicate that Rough Surfaces Add 10-15 µm of Additional Mix.

Smooth targets are 100 X smoother than rough targets.



Rough Targets
Show Measurable Mix.



Measured Mix Widths, (corrected for parallax, initial thickness variations, and motion blur) show rough targets give 10-15 µm more mix.

OMEGA cylindrical experiments measure mixing between two compressing cylinders

- Simulations were done with RAGE for the targets of the recent OMEGA experiments: (Al marker with Au, Cu or epoxy inner shell)
- Simulations include surface roughness spectrum in marker layer.
- Simulations agree with measured zero-order hydro data.
- RAGE simulations predict more mix growth with stronger rebounding shocks and predict mix widths from 30 to 65 μm, depending on shock strength, time and roughness.
- Data analysis is continuing, but preliminary analysis shows rough agreement with the simulations.

Future Directions for double cylinders

- Design double cylinder defect experiment which examines the interaction of the defect region with the inner cylinder.
- Possible redesign of the double cylinder to produce more unstable growth (of the Al marker after rebound) than is seen with current designs.
- Examine the effects of perturbations on the outside of the inner cylinder with a smooth outer cylinder and marker.
- Examine the effects of perturbations on both outside of inner cylinder and outside/inside of marker layer in outer cylinder.