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SAND2013-4971C

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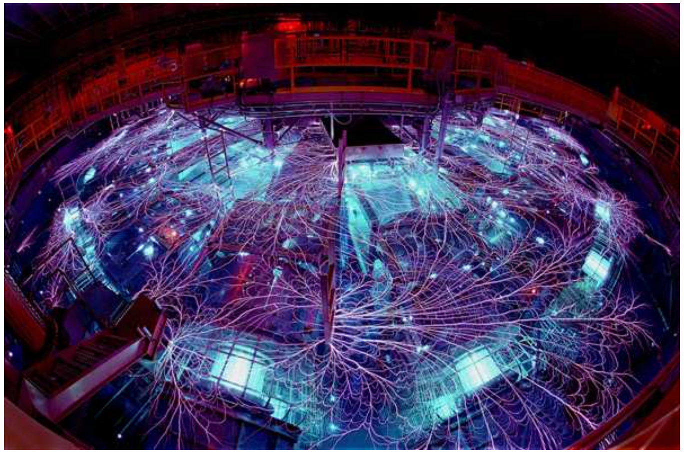
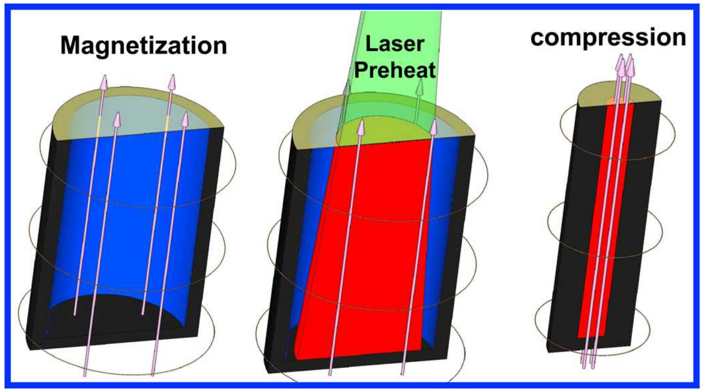


The effect of surface roughness and structure on subsequent magneto-Rayleigh-Taylor instability growth in beryllium liner implosions on Z



Daniel B. Sinars[1], C. Jennings[1], M. Herrmann[1], R.D. McBride[1], M.E. Cuneo[1], K.J. Peterson[1], S.A. Slutz[1], E.P. Yu[1], B.E. Blue[2], K. Tomlinson[2]

[1] *Sandia National Laboratories, Albuquerque, NM*

[2] *General Atomics, San Diego, CA*

PPPS 2013, San Francisco, CA June 17-21, 2013

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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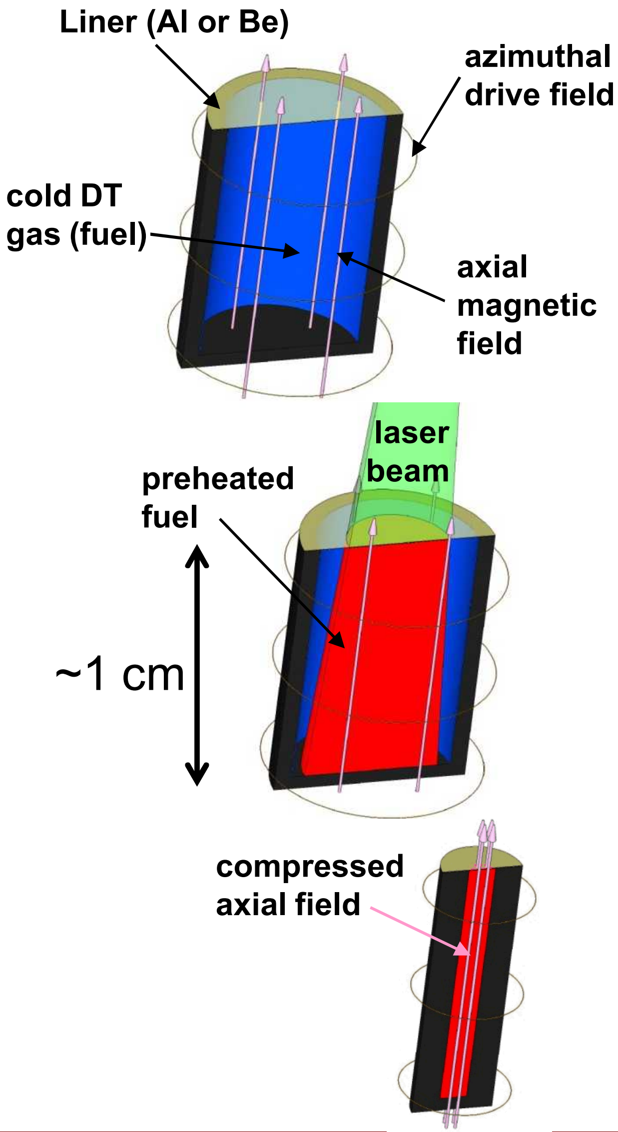
We are working toward the evaluation of a new Magnetized Liner Inertial Fusion (MagLIF)* concept



- An initial ~10 T axial magnetic field is applied
  - Inhibits thermal conduction losses
  - Enhances alpha particle energy deposition
  - May help stabilize implosion at late times
- During implosion, the fuel is heated using the Z-Beamlet laser (<10 kJ needed)
  - Preheating reduces the compression needed to obtain ignition temperatures to 20-30 on Z
  - Preheating reduces the implosion velocity needed to “only” 100 km/s (slow for ICF)
  - Stagnation pressure required is ~5 Gbar, not 300-500 Gbar
- Scientific breakeven may be possible on Z with DT fuel (fusion yield = energy into fusion fuel)

* c.f., A. Sefkow P1-9 on Monday

*S.A. Slutz *et al.*, Phys. Plasmas 17, 056303 (2010). S.A. Slutz and R.A. Vesey, Phys. Rev. Lett. (2012).

A major threat to MagLIF is instabilities—we are very concerned about the validity of our predictions for liner stability

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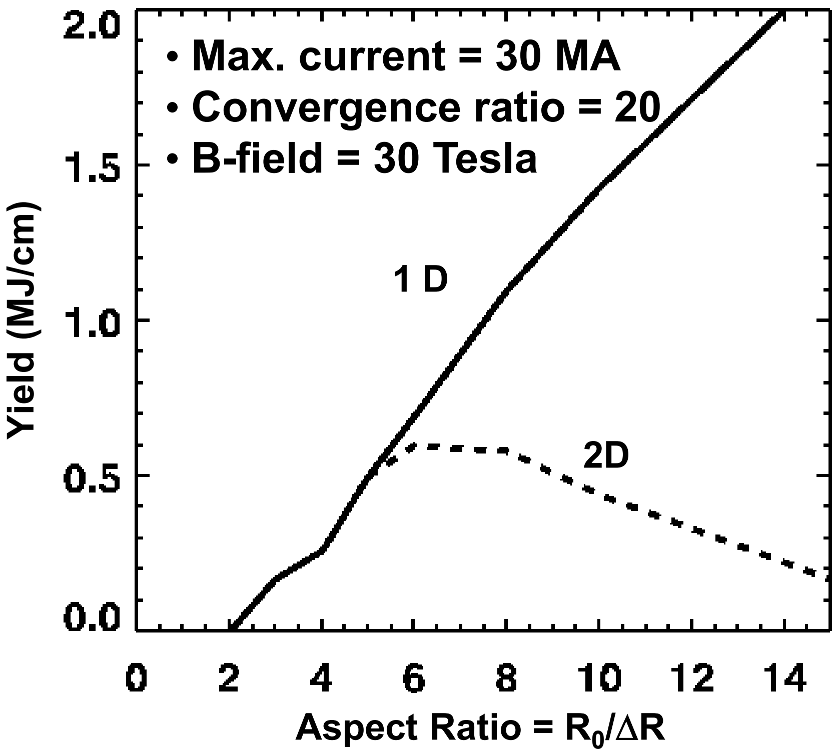

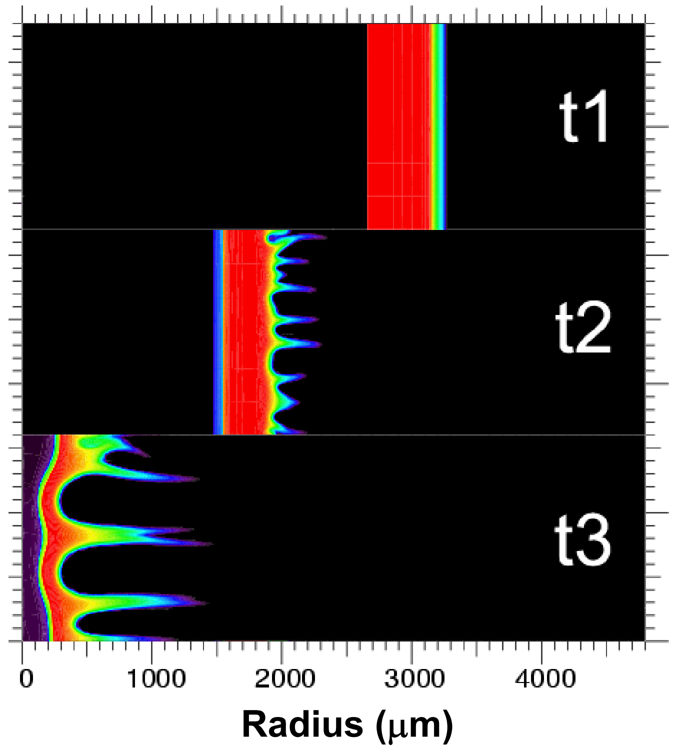

- The Magneto-Rayleigh-Taylor instability degrades the yield as the aspect ratio is increased (due to decreased liner ρr)

- Simulations of AR=6 Be liner
- Include ~60 nm surface roughness and resolve waves down to ~80 μm
- Simulations suggest wavelengths of 200-400 μm dominate near stagnation

S.A. Slutz *et al.*, Phys. Plasmas 17, 056303 (2010).

Our initial experiments served as the first critical test of our understanding of the Magneto-Rayleigh Taylor instability

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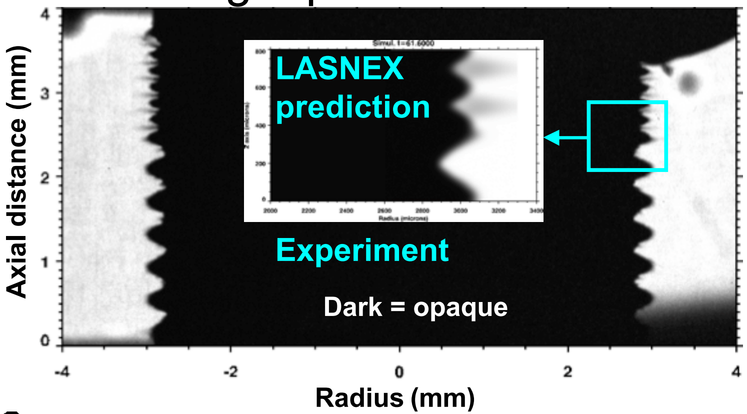
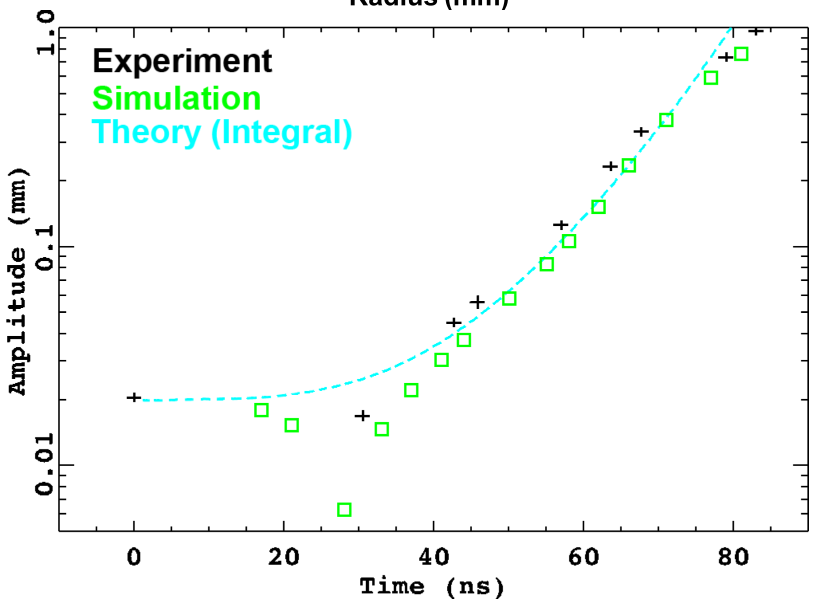
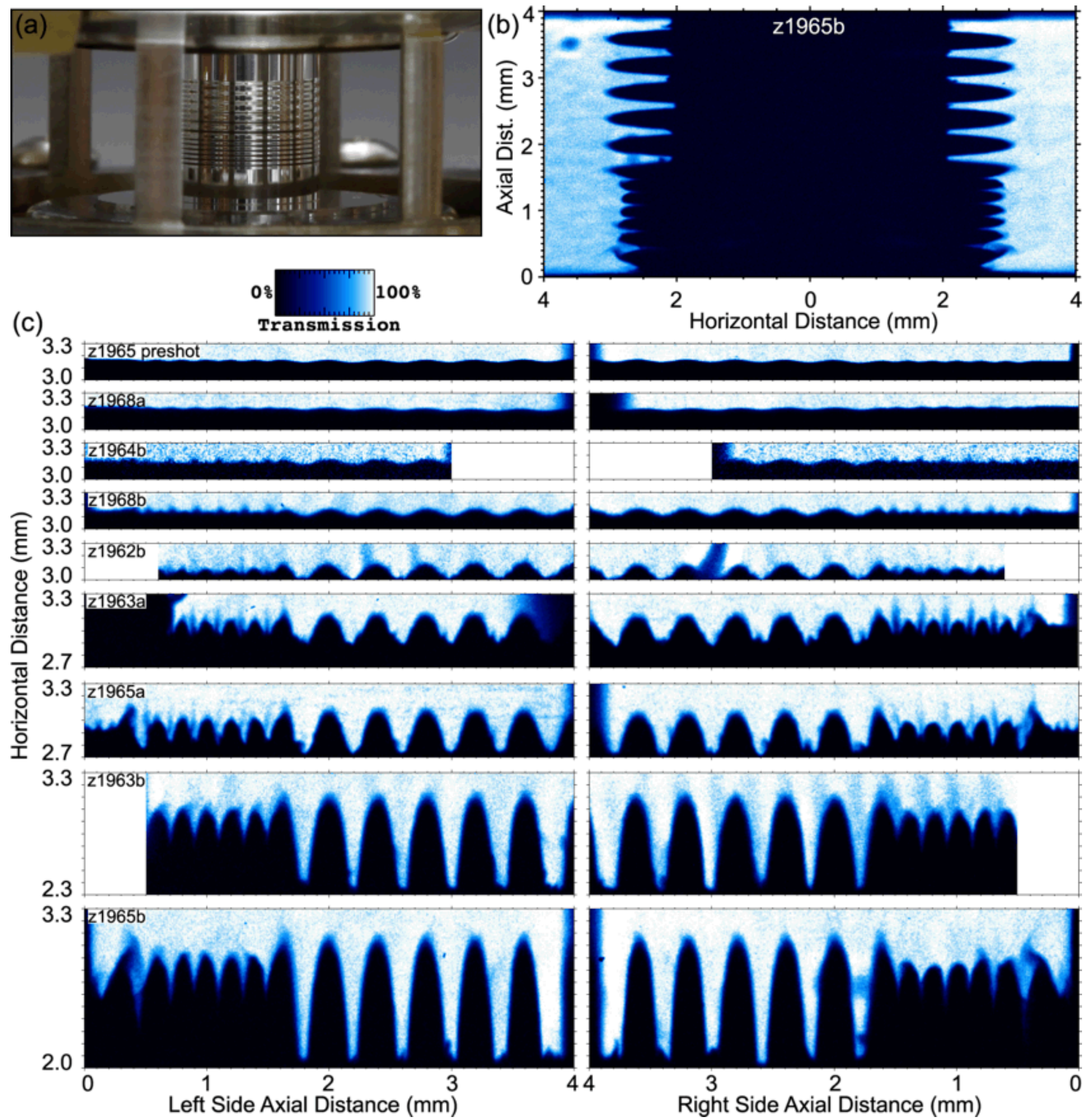
Radiographs captured growth of intentionally-seeded 200, 400-μm wavelength perturbations

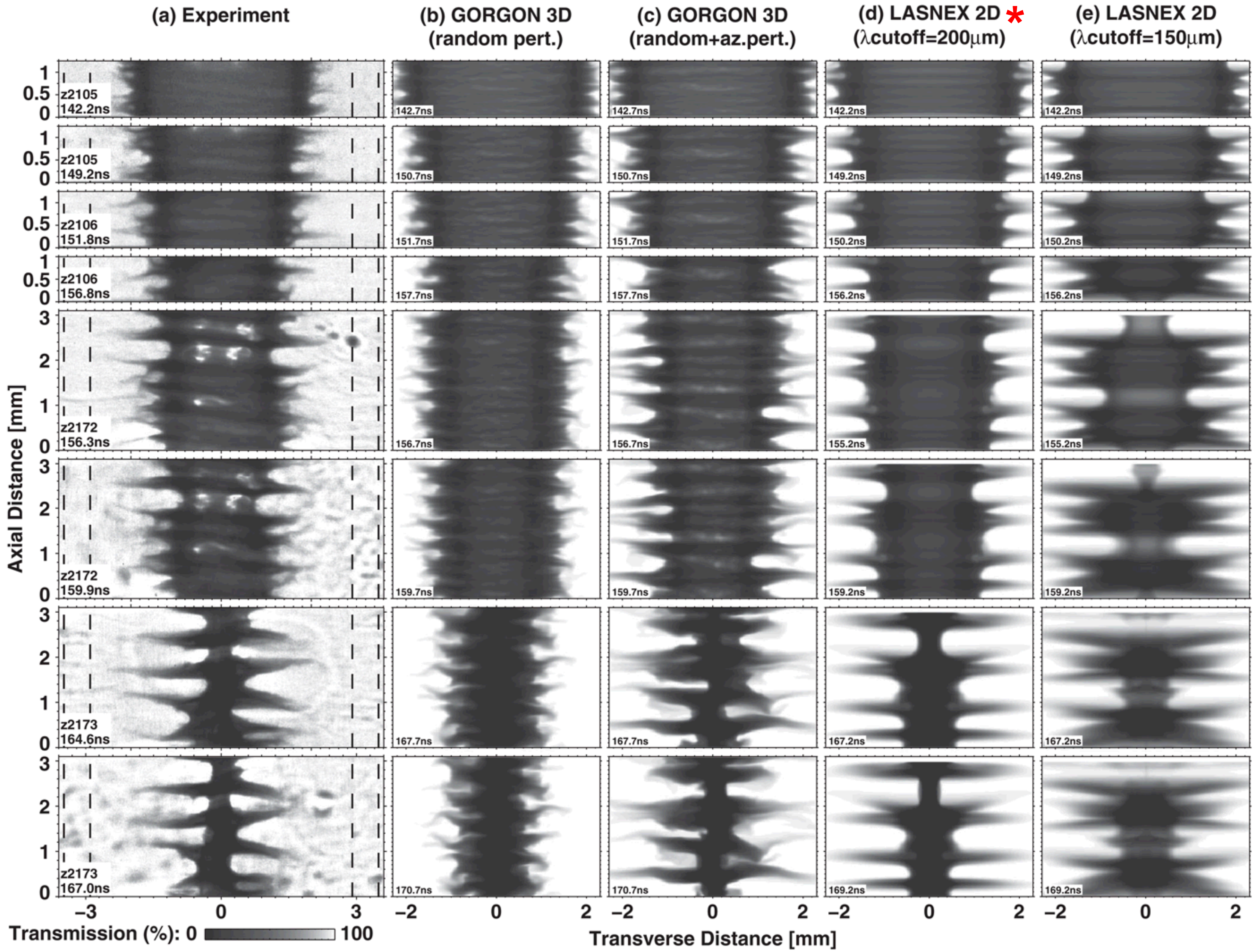






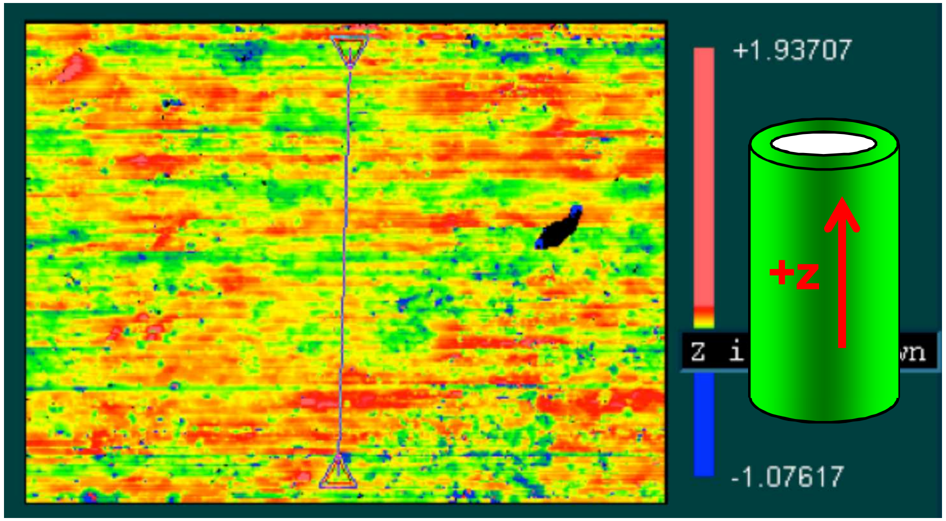
D.B. Sinars *et al.*, Phys. Rev. Lett. (2010); D.B. Sinars *et al.*, Phys. Plasmas (2011).

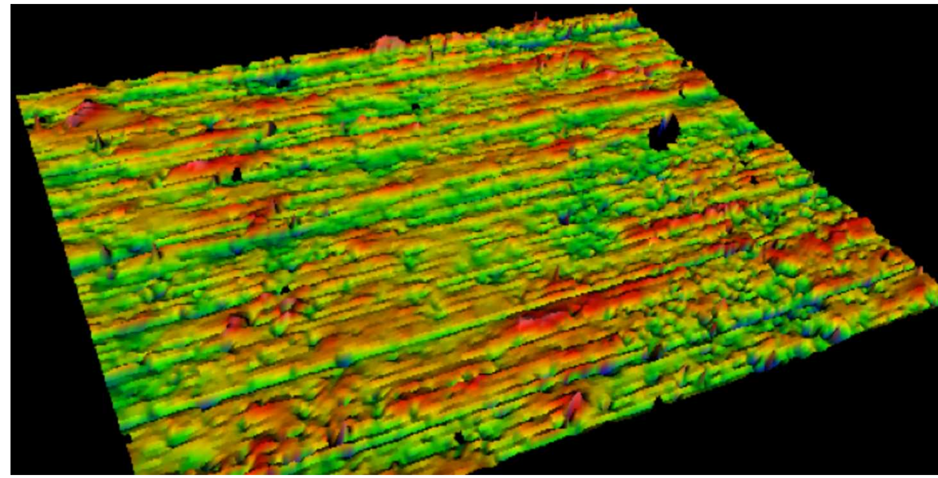
Beryllium experiments show surprisingly correlated instability growth at late times that may imply a highly-correlated initial perturbation

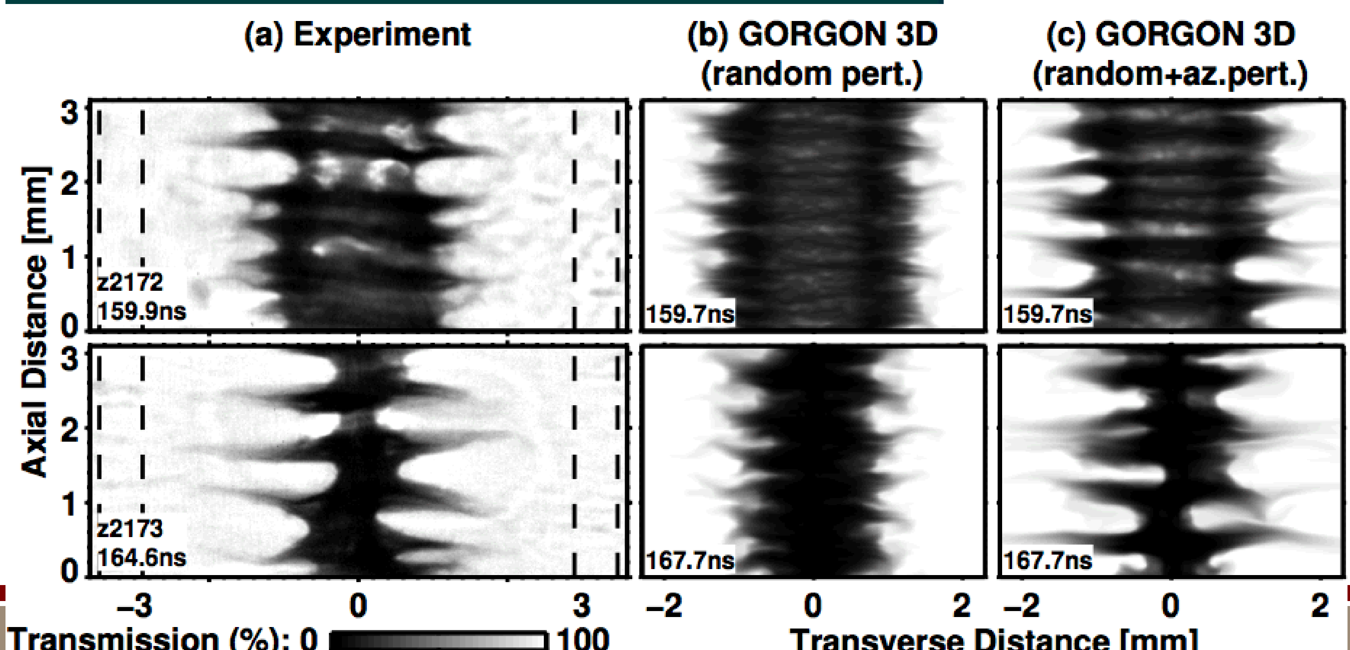


R.D. McBride *et al.*, Phys. Rev. Lett. (2012); R.D. McBride *et al.*, Phys. Plasmas 20, 056309 (2013).

Our liners are diamond-turned on a lathe to provide smooth surfaces, but this process leaves azimuthally-correlated tool marks that could seed correlated MRT instability growth

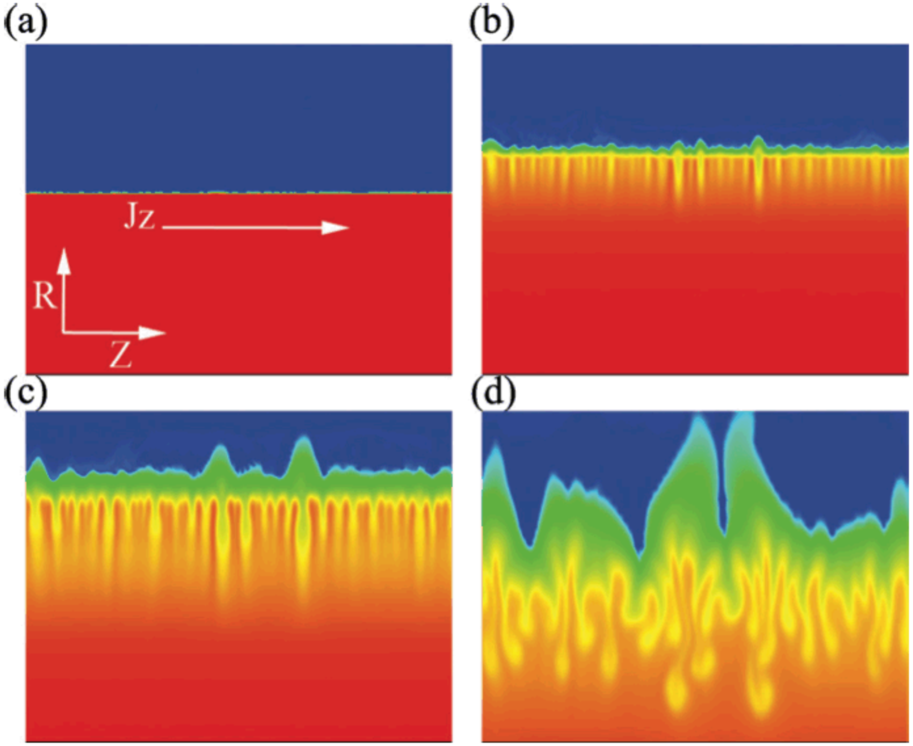


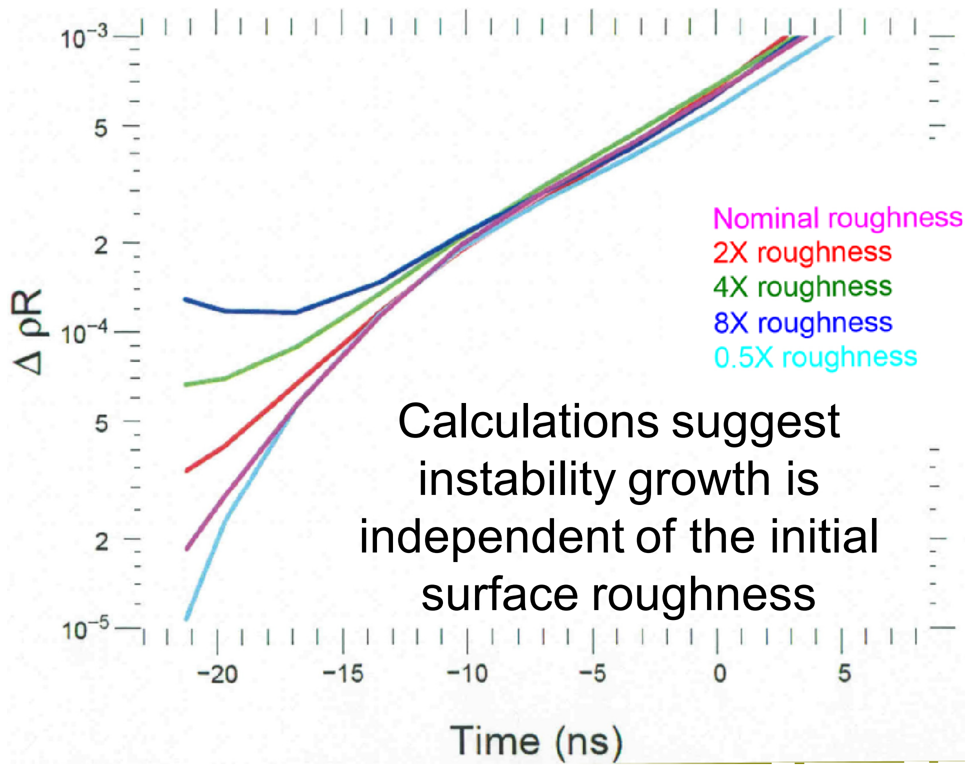




GORGON simulations with a small correlated surface perturbation can be made to look like the data, random surface perturbations look noticeably different

The electro-thermal instability is a second mechanism that could seed MRT growth*

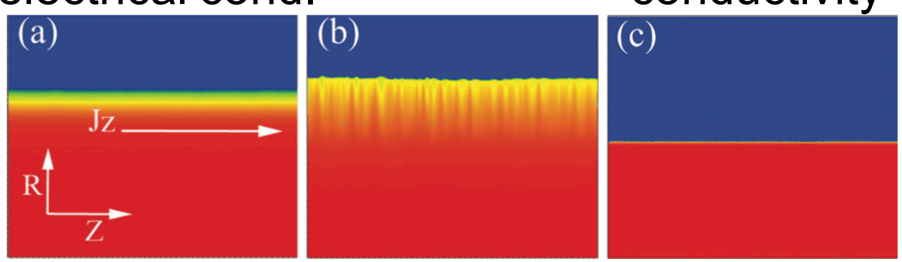




Constant electrical cond.

Nominal

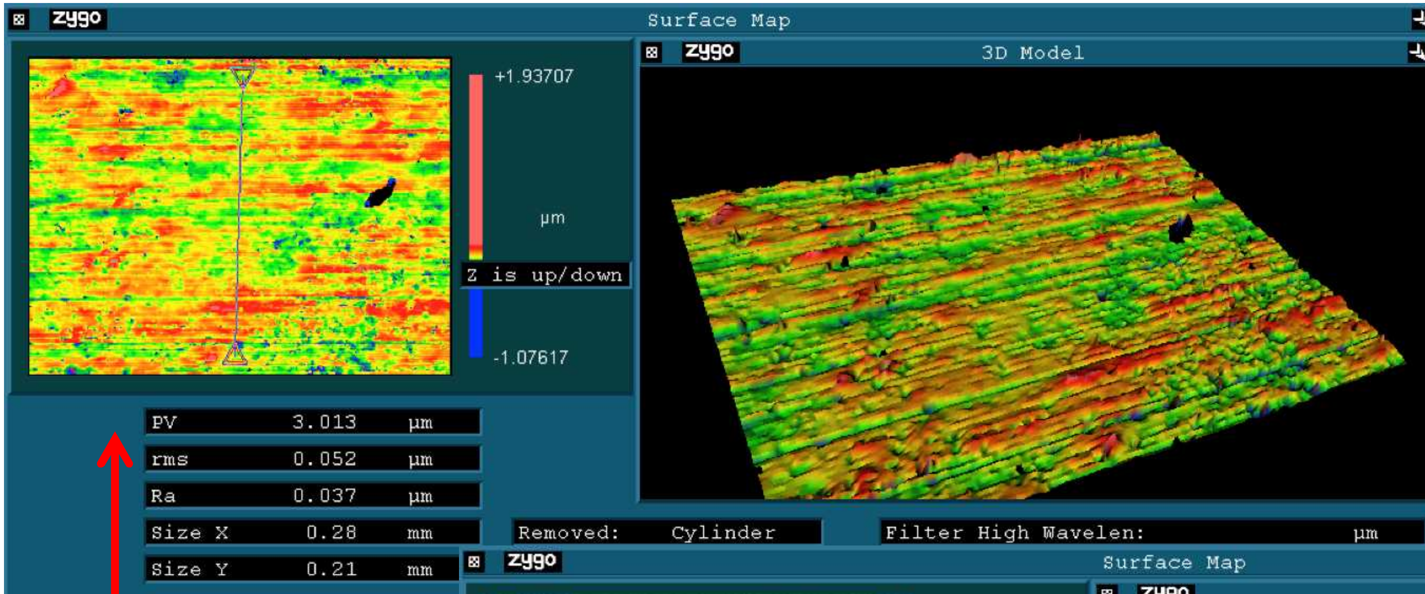
10x thermal conductivity

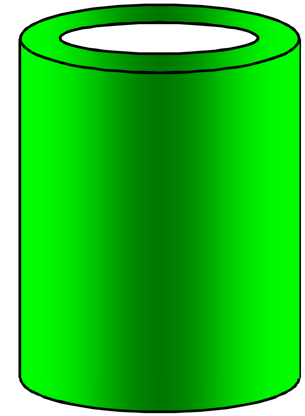


Temperature perturbations give rise to pressure variations which eventually redistribute mass

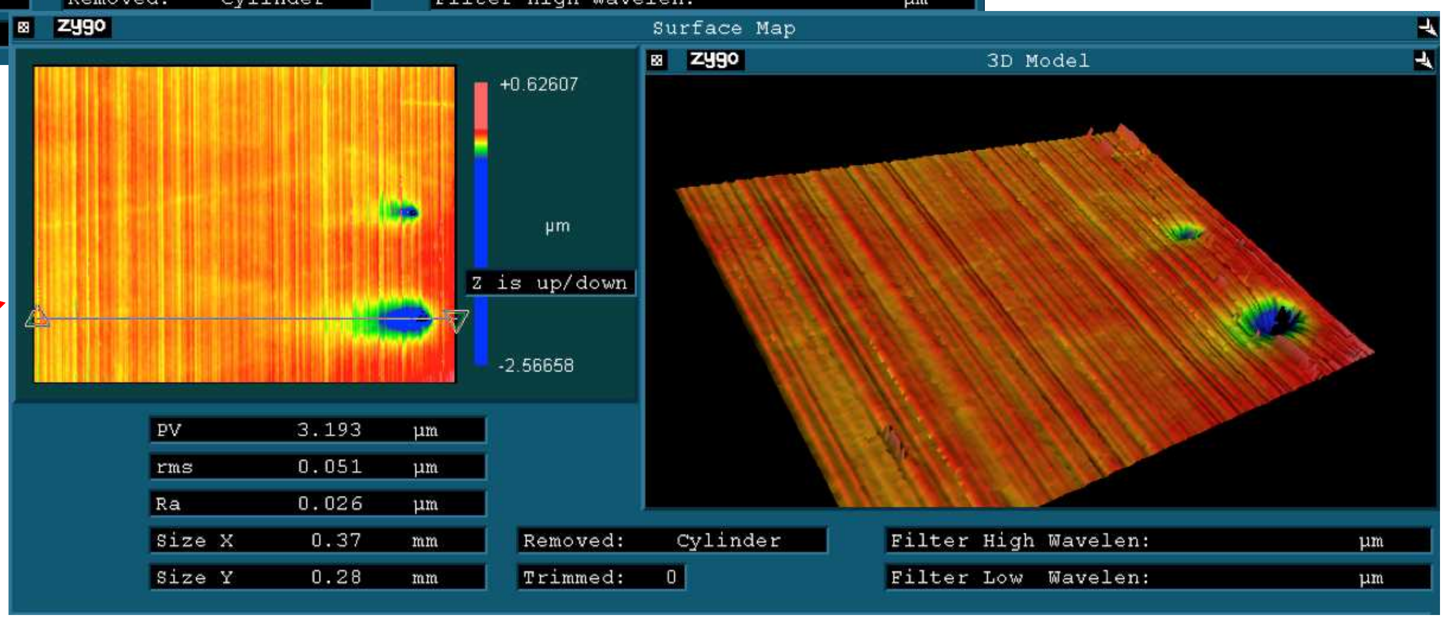
* c.f., K. Peterson P1-8 on Monday

General Atomics developed an axial polishing technique to fundamentally change the surface topology



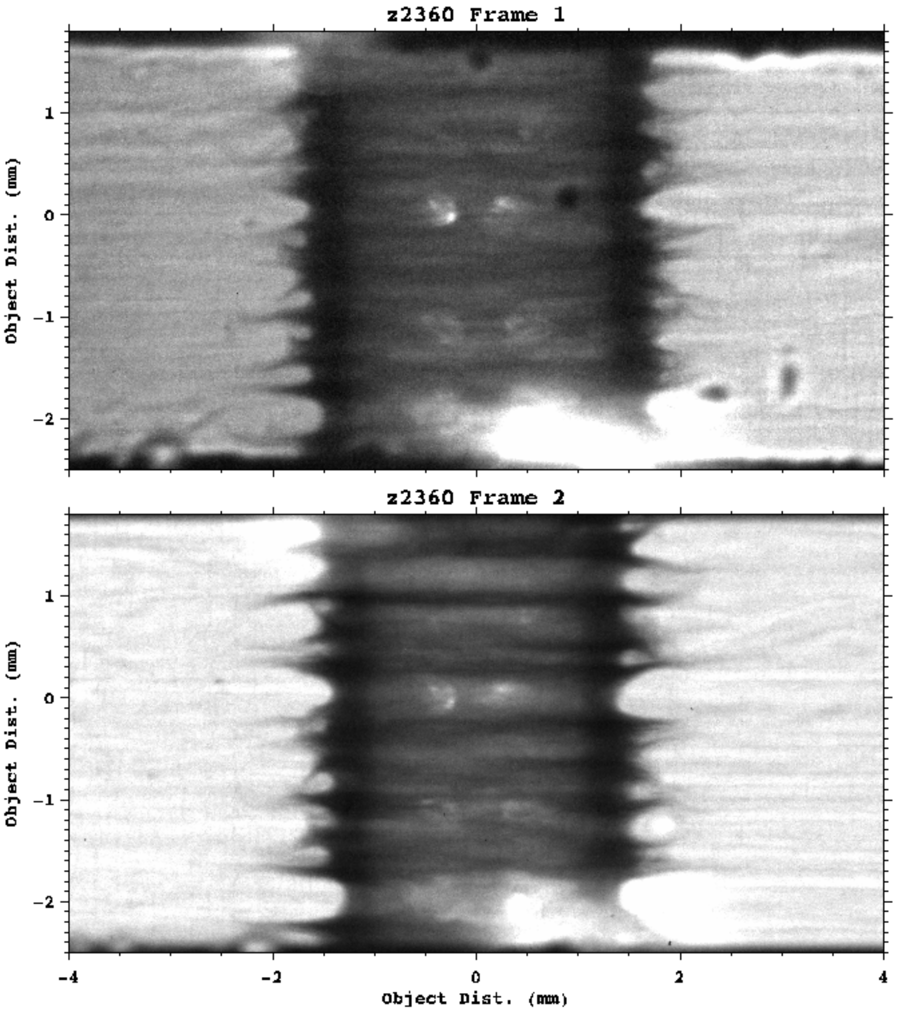


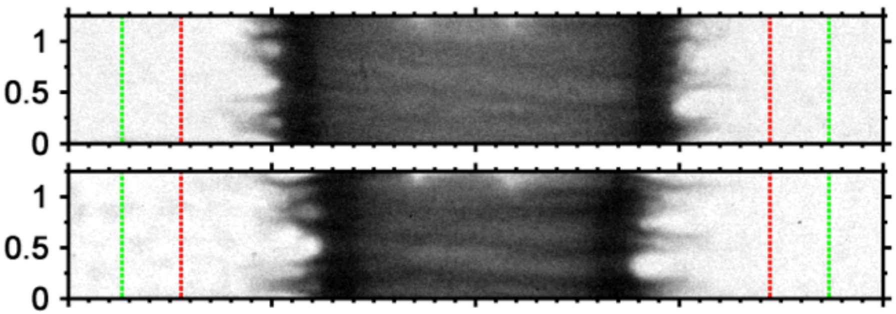
Standard process
(50 nm RMS)



After axial polishing
process applied
(50 nm RMS)

It is difficult to say whether the early time data really shows a significant difference





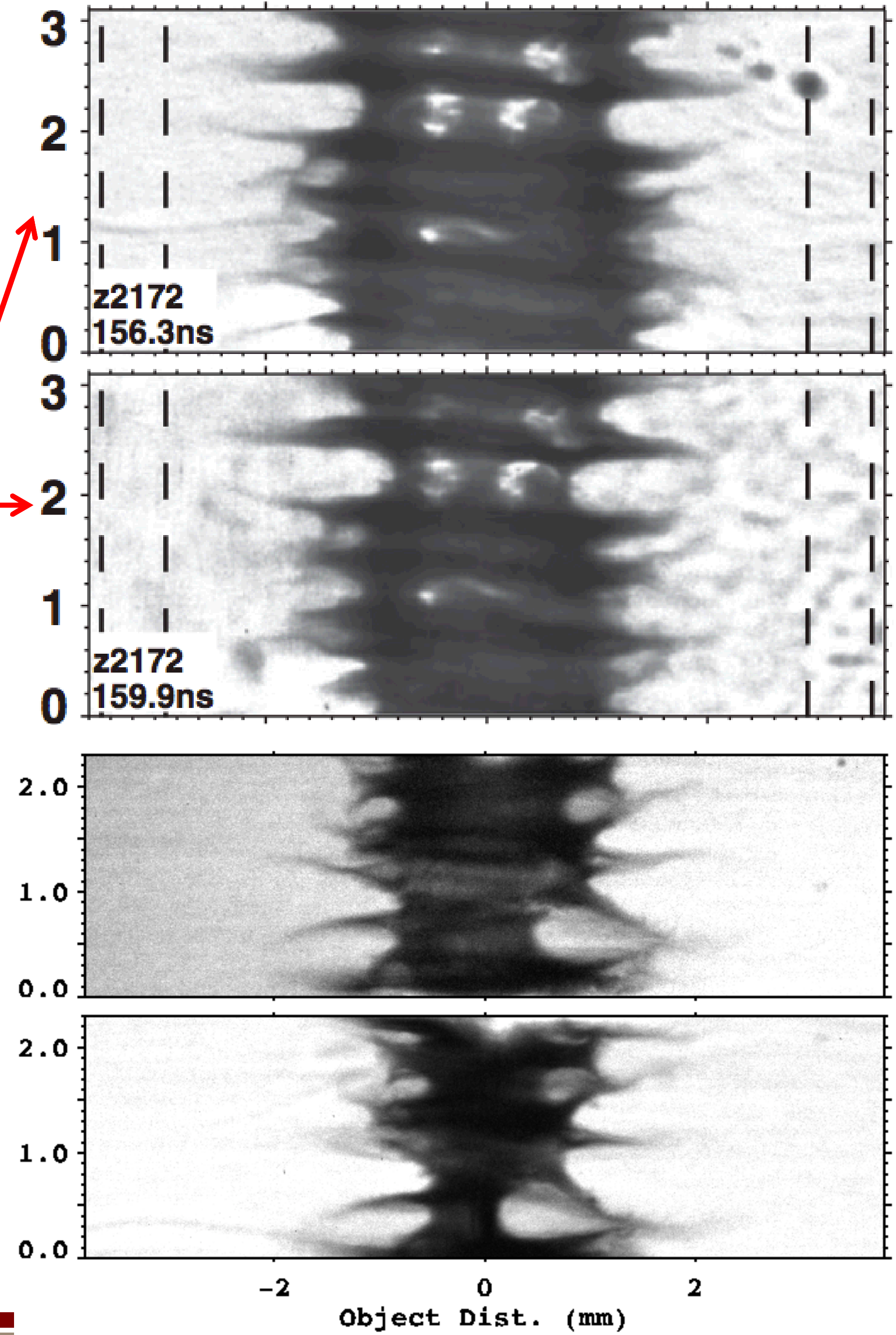
Z2360 Frame 2 at equivalent time to z2105 Frame 2

I have more detailed analysis and comparisons, but am still working on the figures and showing this more quantitatively

Late-time results from z2356 may show an effect of removing azimuthal correlation

Normal azimuthally-correlated finish from previous experiments*

Axially-polished data from Lincoln 6 experiments



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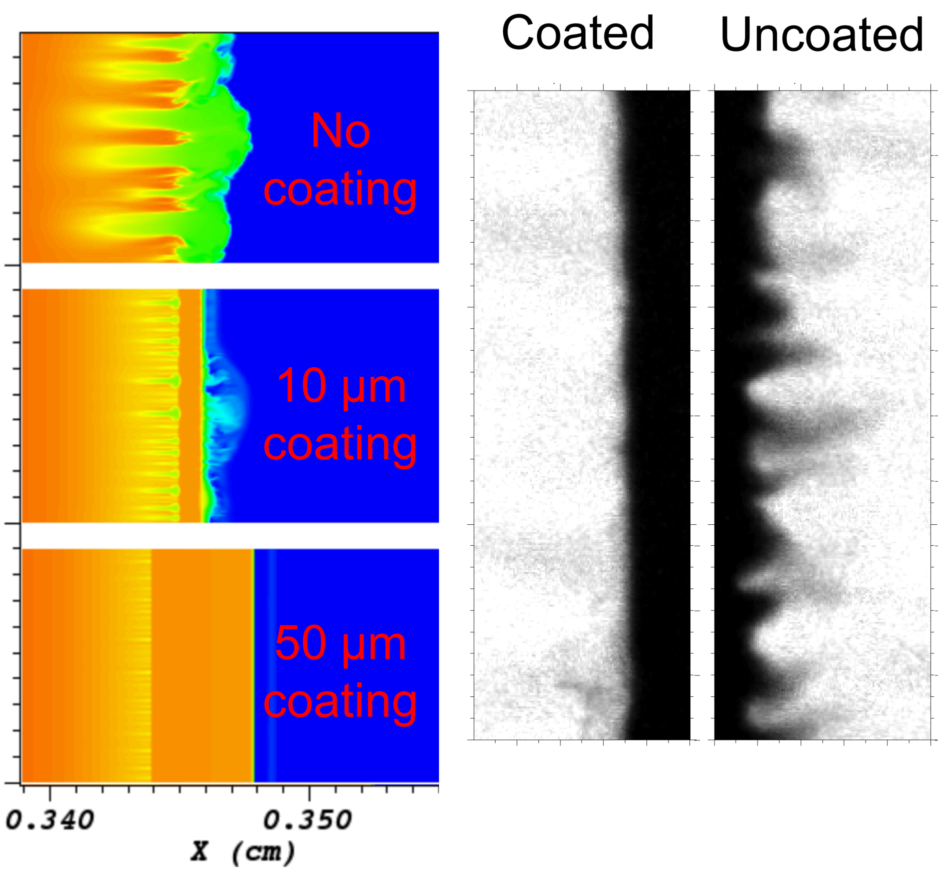
* R.D. McBride *et al.*, Phys. Rev. Lett. 109, 135004 (2012).

Note: I am still working on a more detailed analysis of the radiography data on the preceding two slides, but wanted to submit something for R&A sooner rather than later. The technical content and data will not change substantially.

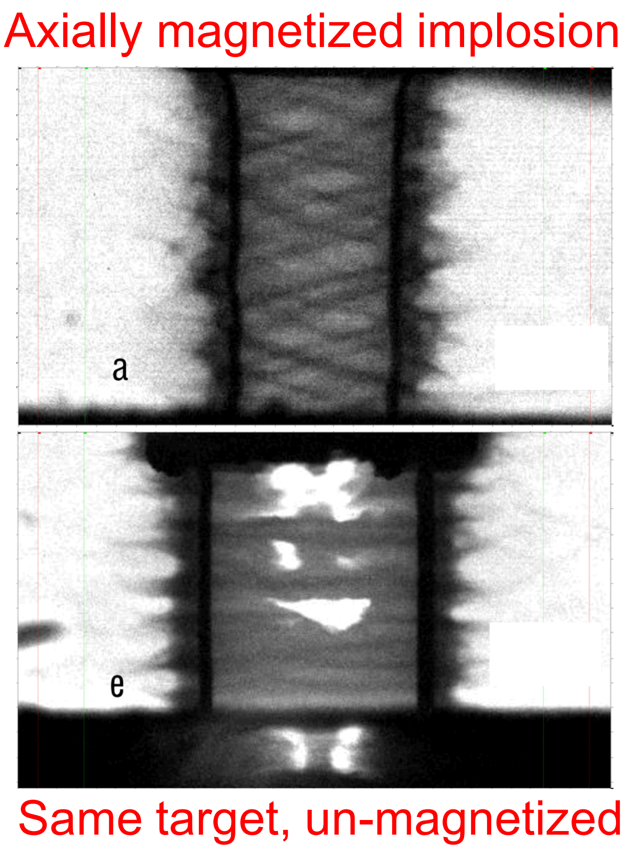
Two very recent results suggest that the surface topology may not be the dominant seed for instabilities

Dramatic reduction of instability growth is consistent with predictions of electro-thermal instability origin



K.J. Peterson *et al.*, manuscript in preparation.

Persistent helical structure in magnetized tests suggests lathe marks do not dominate structure



T.J. Awe *et al.*, manuscript in preparation.

We will continue to look at surface quality issues, as well as the physics of how the instabilities evolve

- We will conduct one additional Z shot with an axially-polished liner to determine if resulting increased asymmetry is reproducible
- Materials scientists at Sandia are currently evaluating electro-chemistry treatments for Al 1100 and Al 2099 alloys used in liner implosions*
  - Electrochemistry based on an "onion-skin" approach carefully removes nano-scale surface layers, and the process appears to help migrate and concentrate metal precipitates to the outer skin layer. Surface precipitates of Al, Fe, and SI found in Al 1100, Cu in Al 2099.
  - Al 2099 alloy was improved from 16 nm roughness to 3 nm after 3 cycles of barrier anodization and chromic acid etching. Electro-polishing may improve this still further—research is ongoing.
- We will do experiments to understand how small wavelengths couple to larger wavelengths in upcoming multi-mode experiments
  - Similar to original seeded MRT growth experiments, we will study growth of overlapping 400, 550 micron wavelength perturbations in Al liners
  - Simulations suggest mode coupling behavior similar to that seen in M.R. Douglas, C. Deeney, N.F Roderick, Phys. Plasmas 5, 4183 (1998).

* W.G. Yelton, J.R. Pillars, A.C. Sun (Sandia Org. 1728)

Extras

The addition of a 7-10 T axial magnetic field produces a dramatic change in the structure of the liner instabilities

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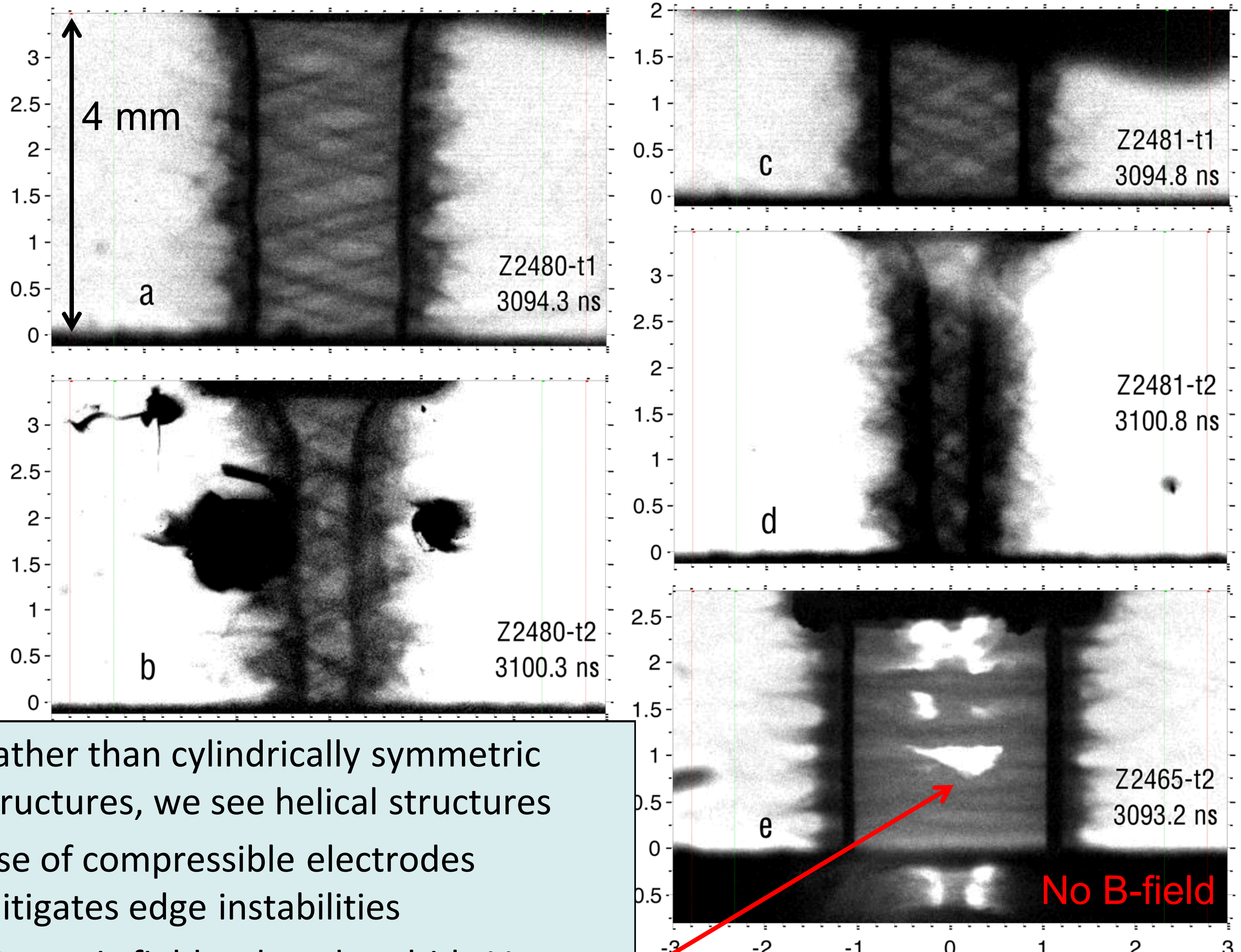
CR =2.7

CR =6.4



CR =2.9

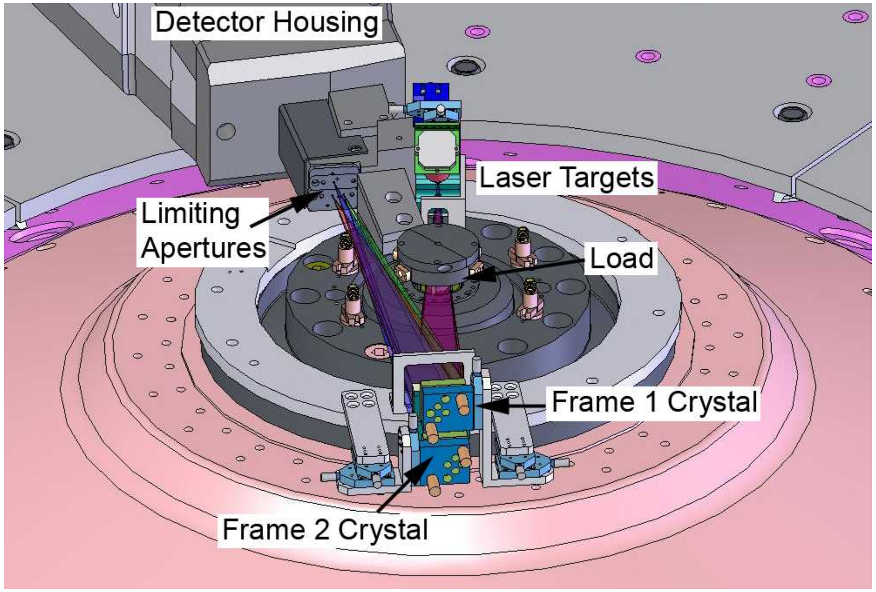
CR =6.9

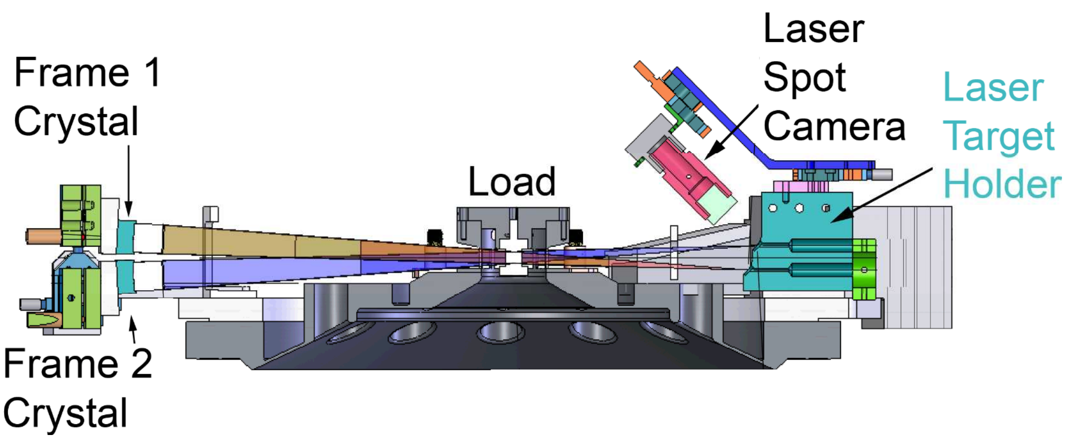
CR =2.0

- Rather than cylindrically symmetric structures, we see helical structures
- Use of compressible electrodes mitigates edge instabilities
- Magnetic field reduced multi-keV x rays associated with late-time instabilities

Add some Yelton photos

We used a 2-frame 6.151 keV monochromatic crystal backlighting diagnostic to study liner dynamics on Z





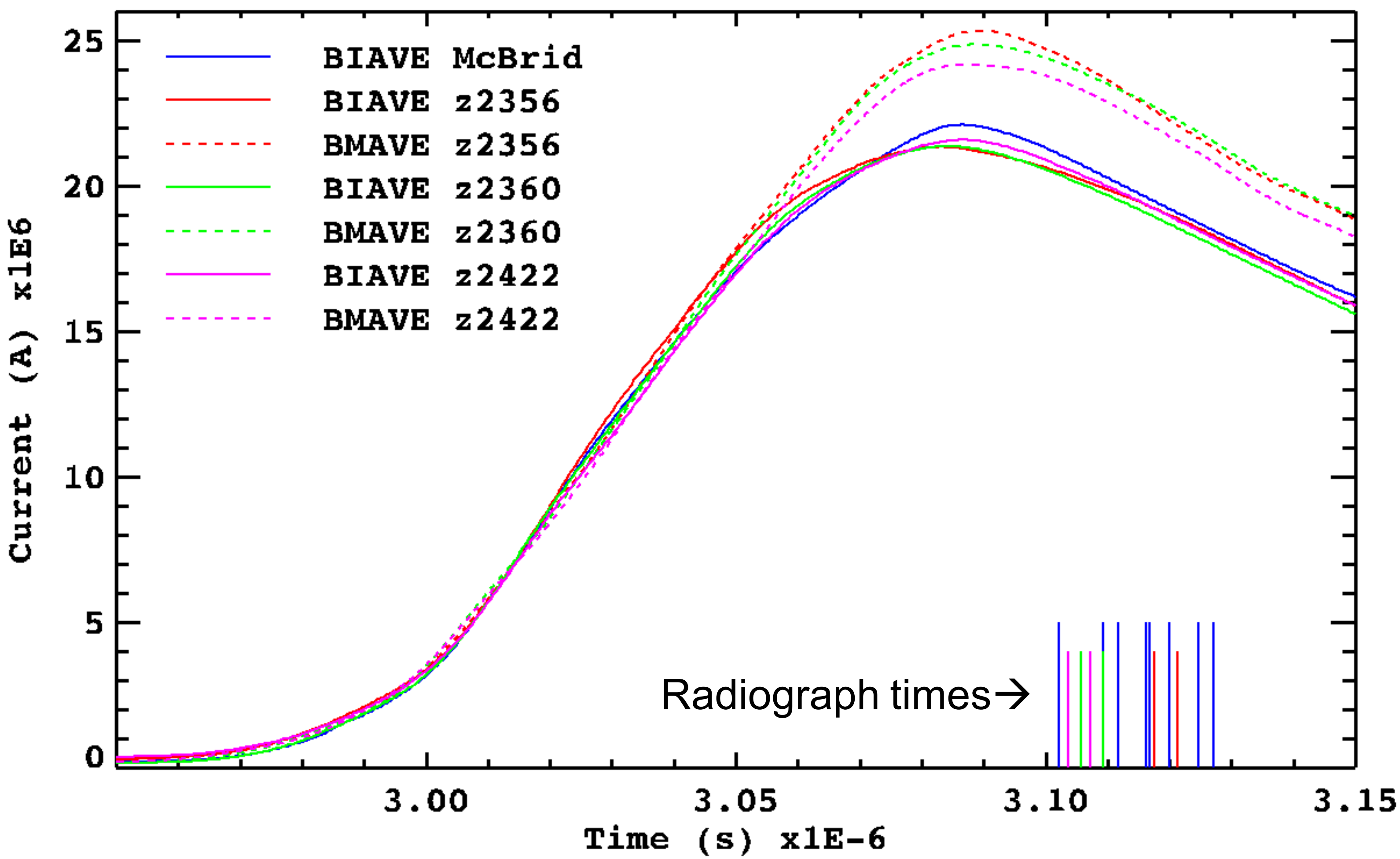
Radiograph lines of sight ±3° from horizontal

2-frame 6.151 keV Crystal Imaging

- **Monochromatic (~0.5 eV bandpass)**
- **15 micron resolution (edge-spread)**
- **Large field of view (10 mm x 4 mm)**
- **Debris mitigation**

- **Original concept**
  - S.A. Pikuz *et al.,* RSI (1997).
- **1.865 keV backlighter at NRL**
  - Y. Aglitskiy *et al*., RSI (1999).
- **Explored as NIF diagnostic option**
  - J.A. Koch *et al*., RSI (1999).
- **Single-frame 1.865 keV and 6.151 keV implemented on Z facility**
  - D.B. Sinars *et al*., RSI (2004).
- **Two-frame 6.151 keV on Z facility**
  - G.R. Bennett *et al*., RSI (2008).

We obtained similar BIAVE currents to Ryan's original series, as well as radiography data at times close to some of his radiographs



The goal of z2422 was to obtain radiography data in between the data obtained on z2356 and z2360, but the 9-10 ns shift in the current prevented us from getting this data

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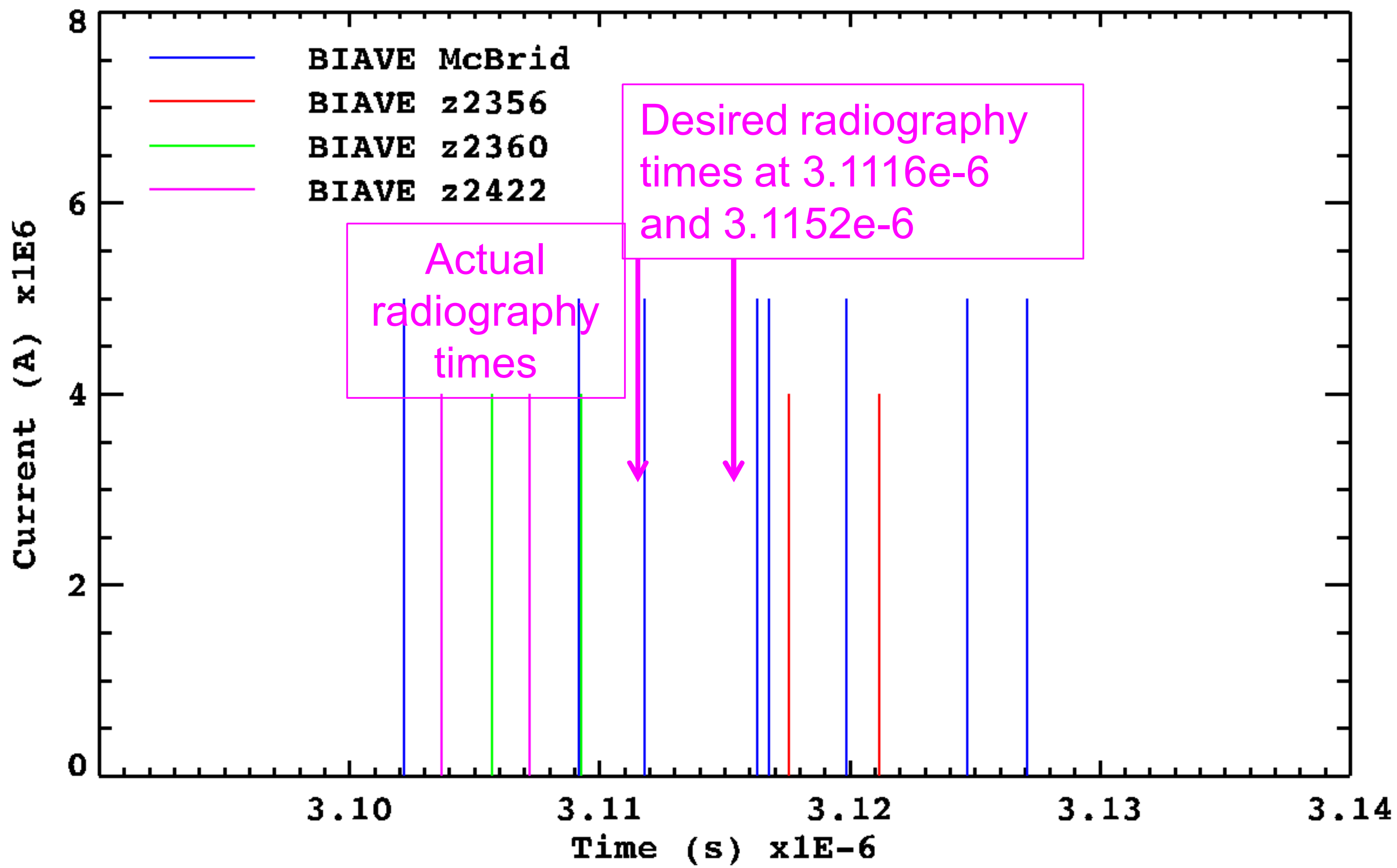
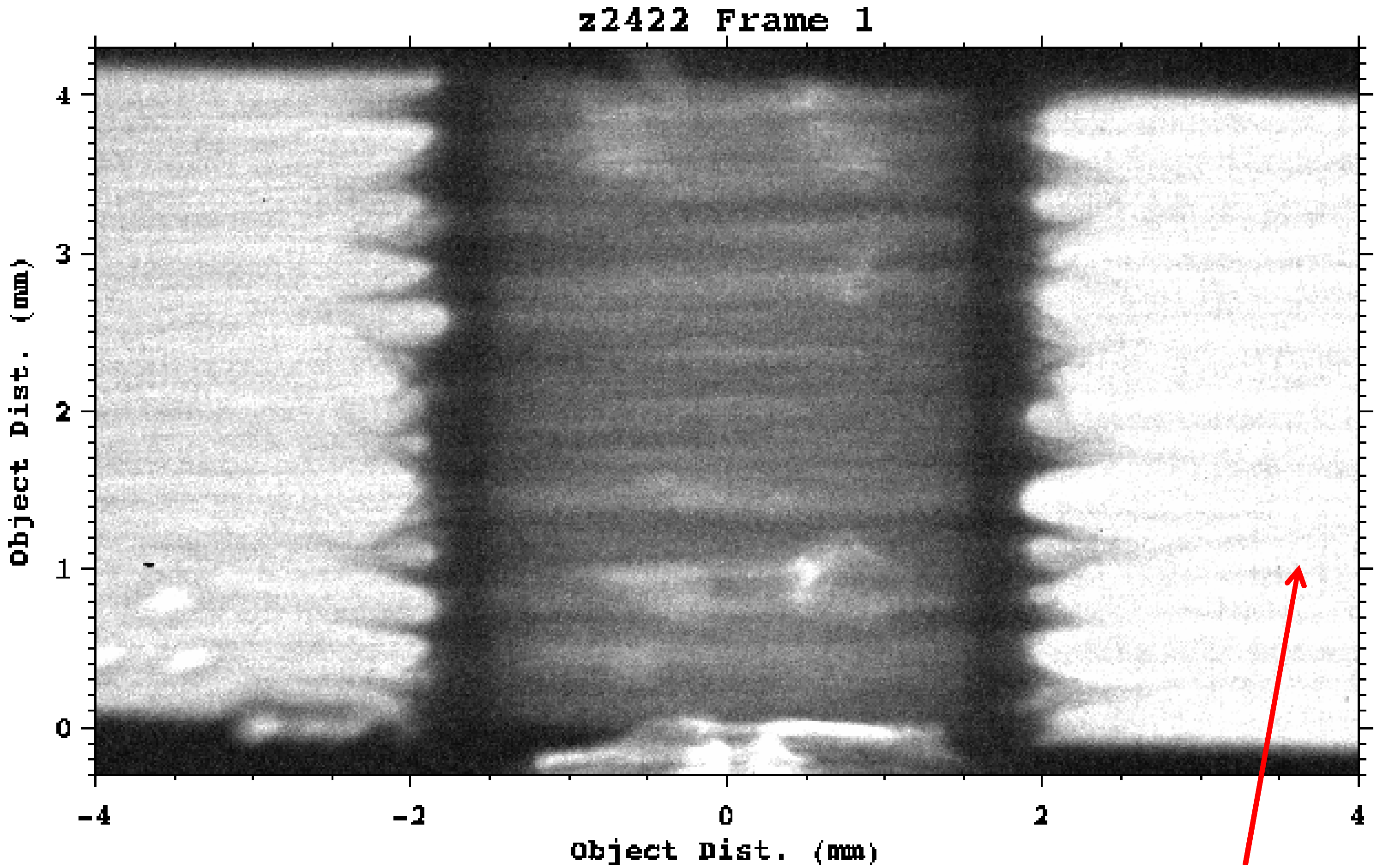
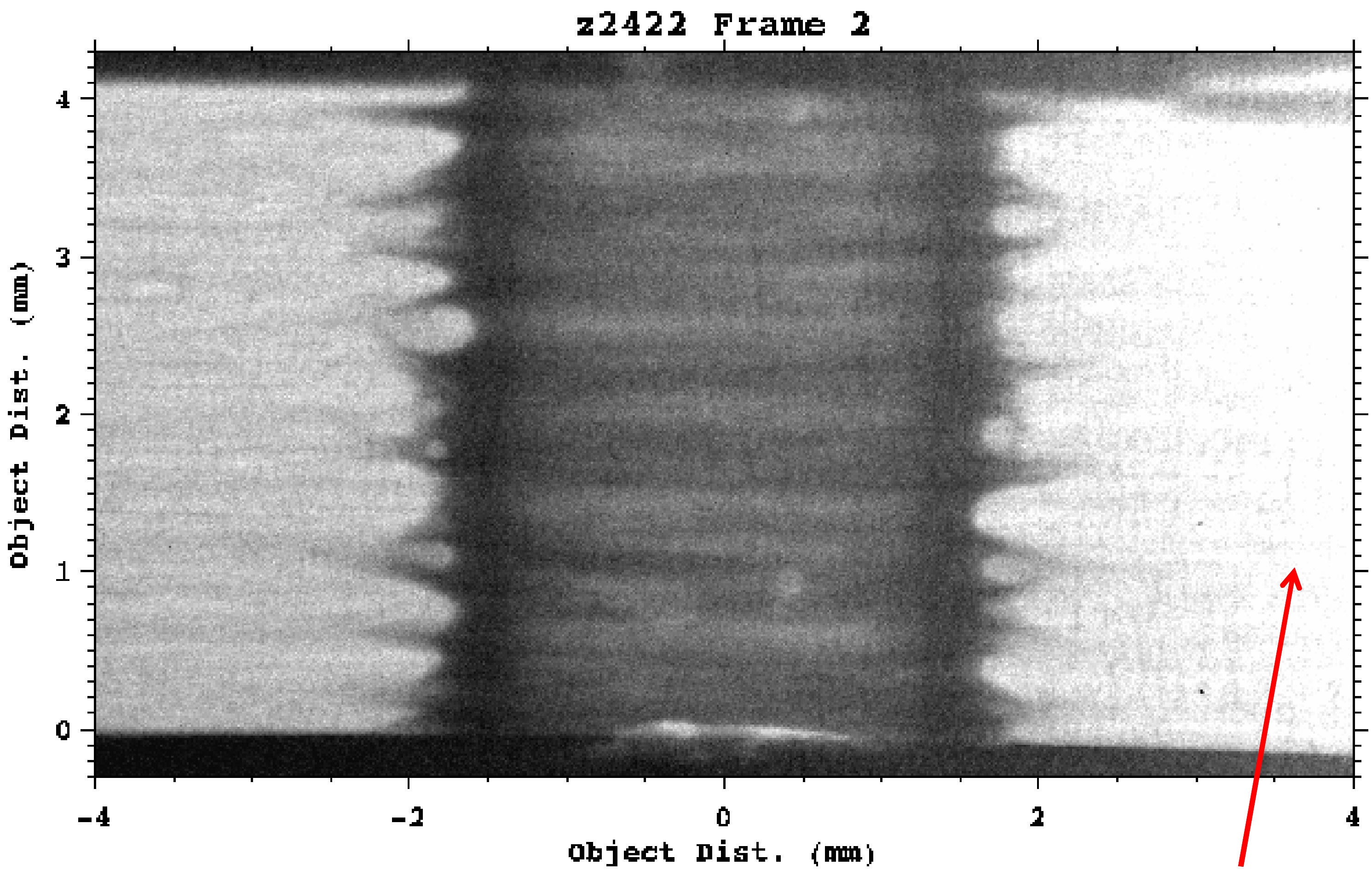




Significant background on image plate for unknown reasons



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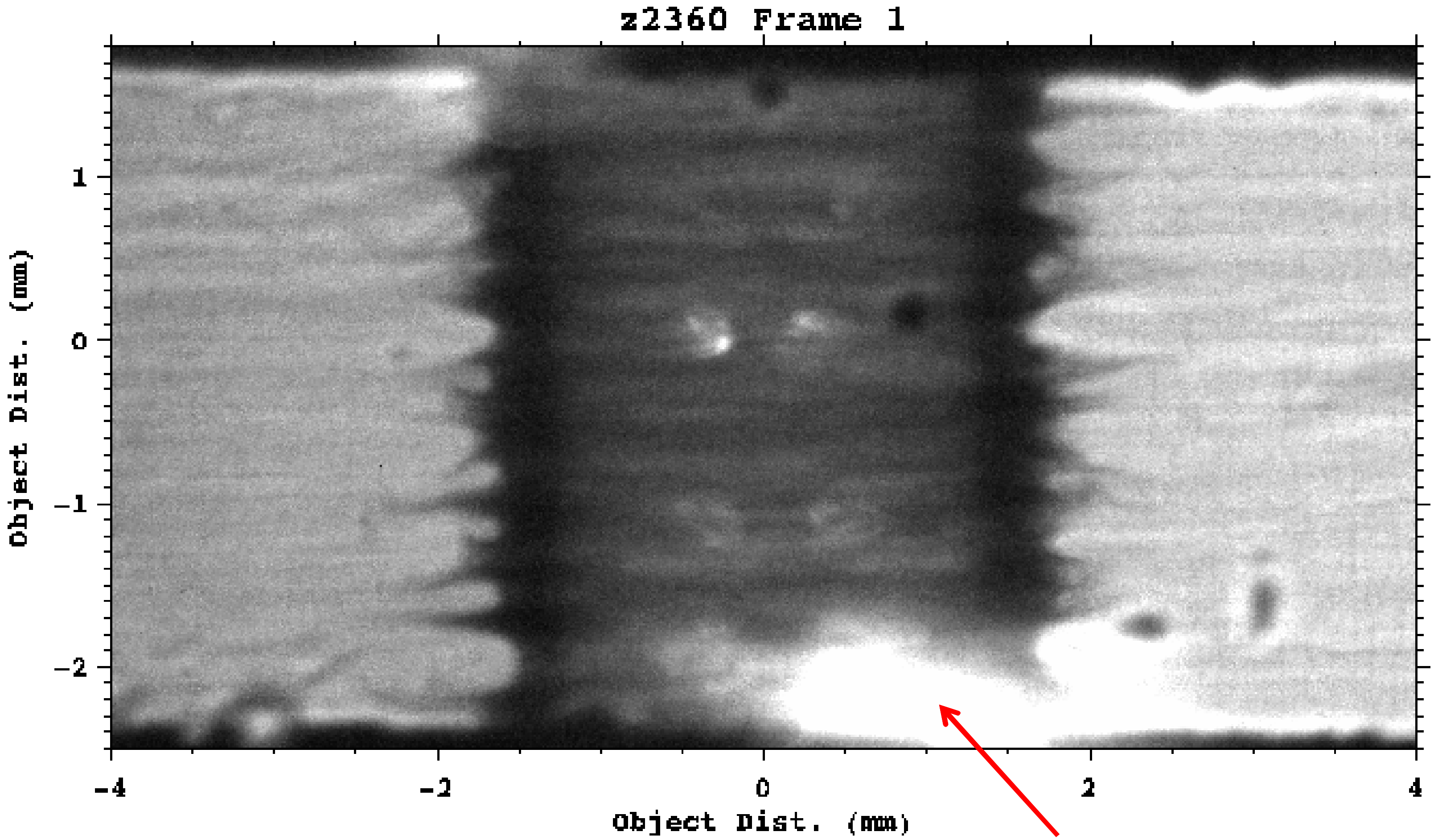
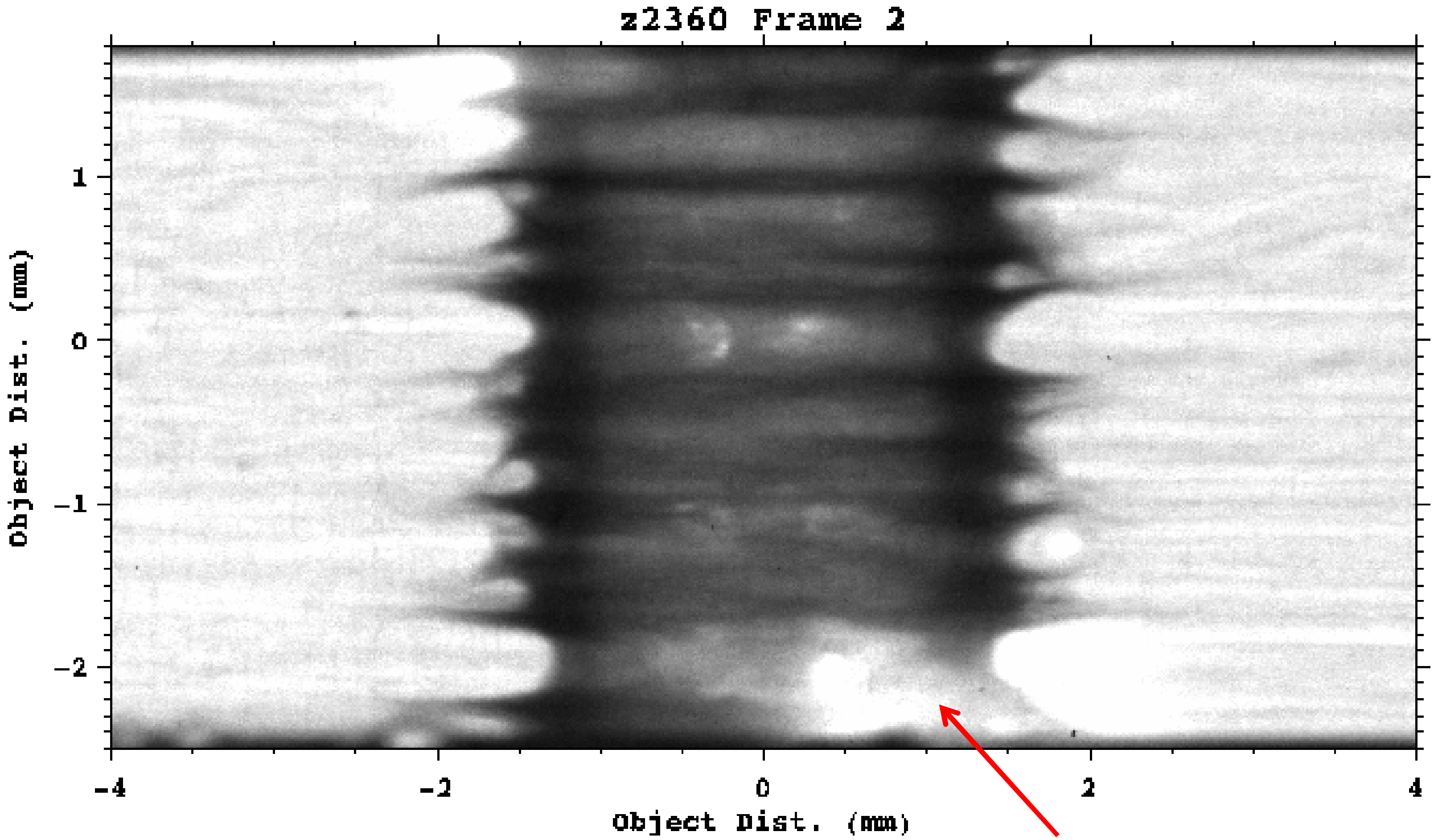


White spots are time-integrated self-emission radiation produced when the liner stagnates



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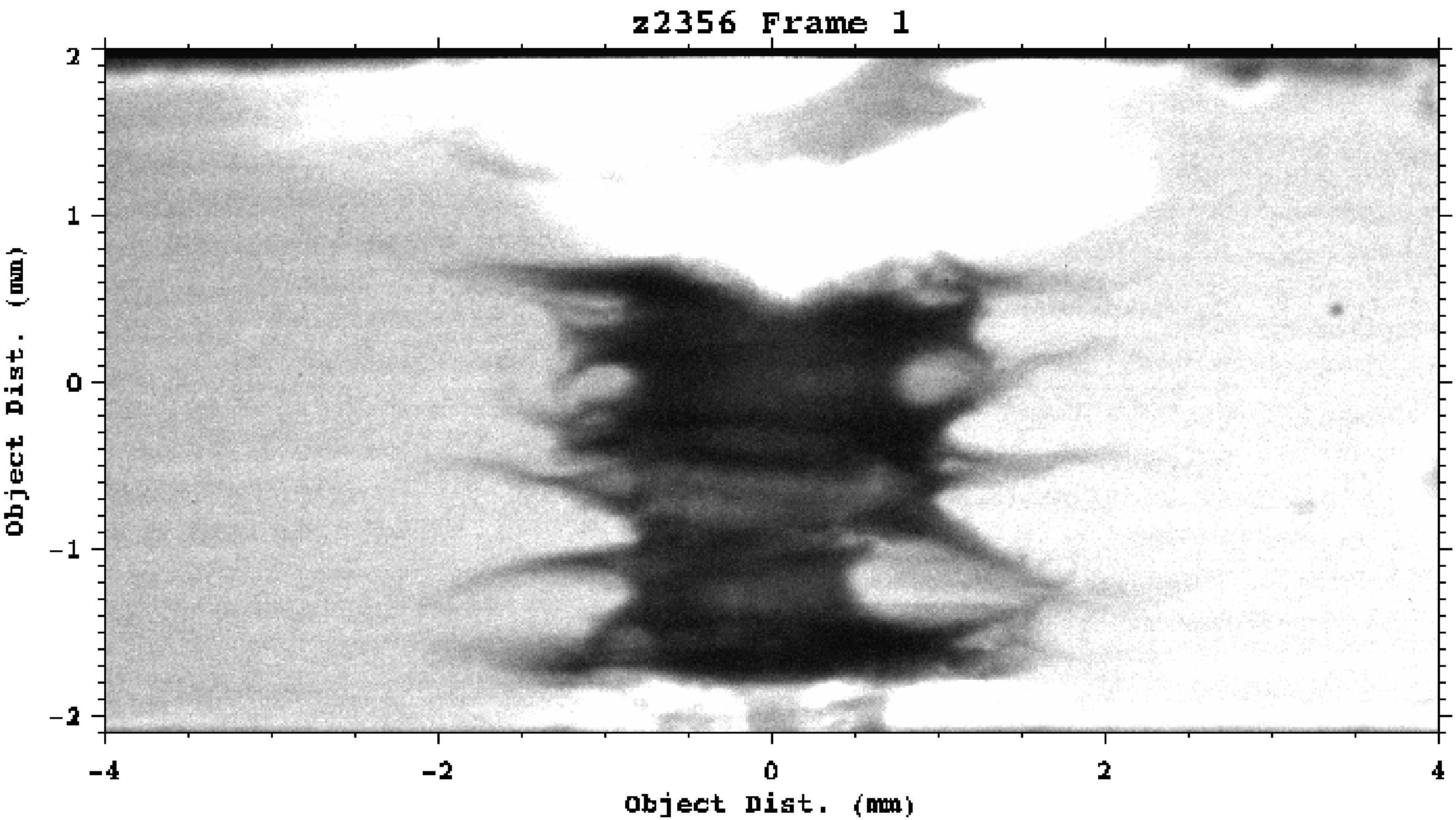
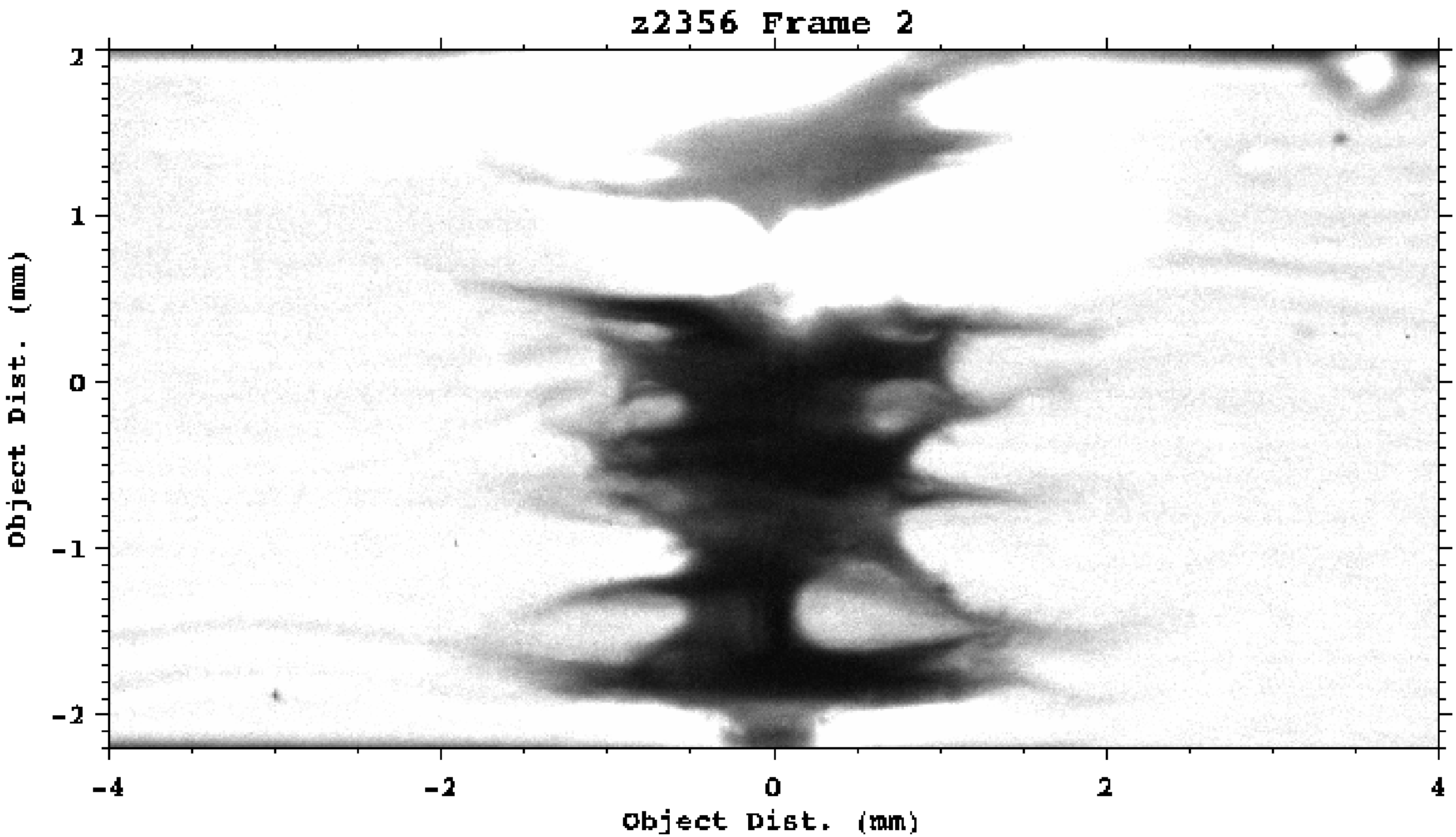

z2356 Frame 1
Object Dist. (mm)
Object Dist. (mm)
2
1
0
−1
−2
−4
−2
0
2
4


z2356 Frame 2
2
1
0
-1
-2
Object Dist. (mm)
-4
-2
0
2
4
Object Dist. (mm)