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Numerical Simulation of Mode Coupling in Laser-Driven Rayleigh-Taylor Instability Experiments

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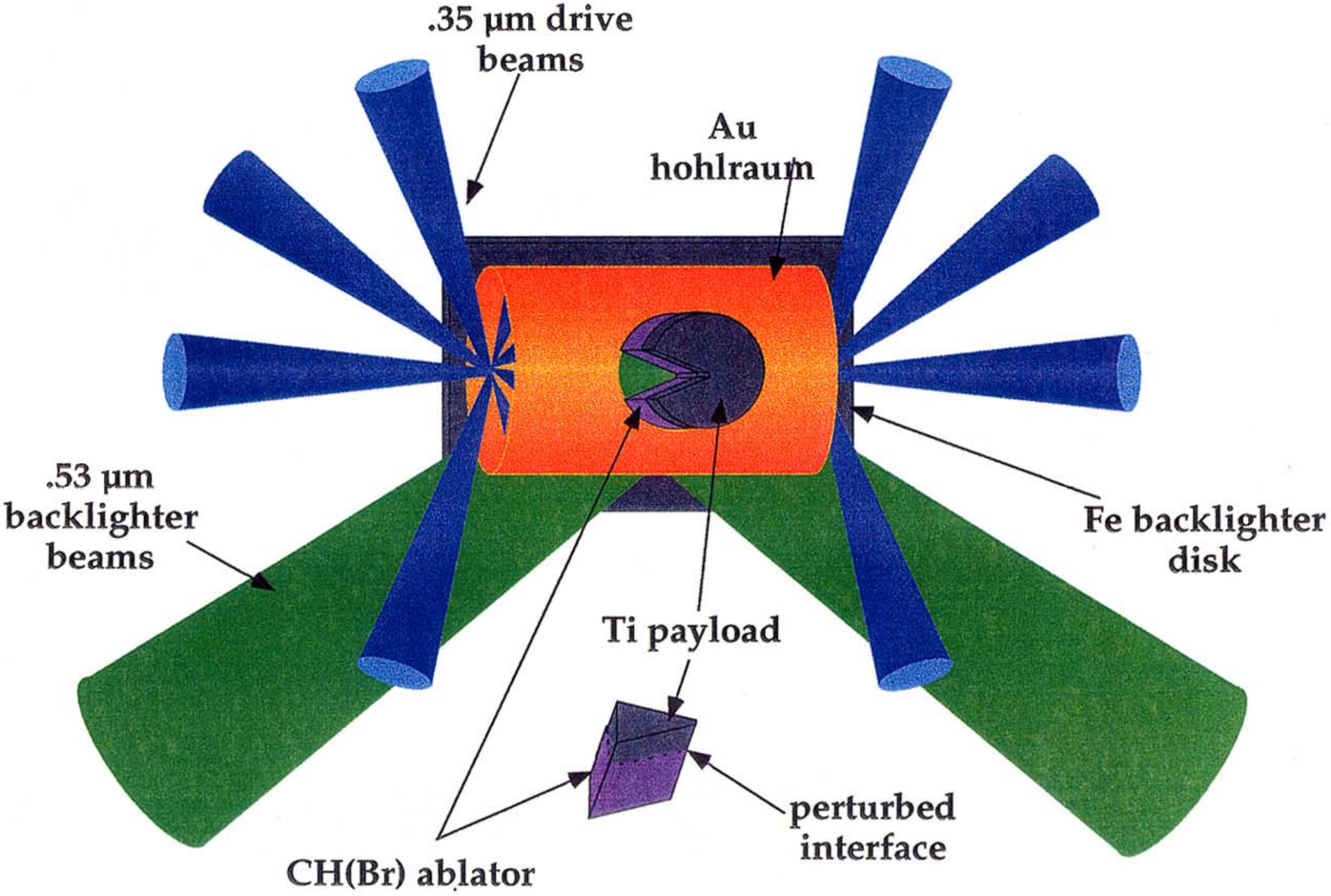
Experimental configuration for the Nova classical Rayleigh-Taylor instability measurements

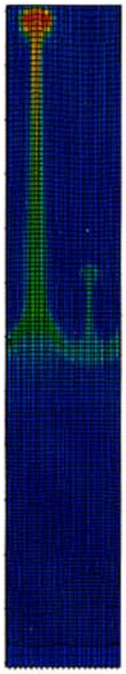


Numerical methods

- 2 dimensional
- Domain reduced from 700 *um* to 200 *um*, horizontal zone size 0.4 *um*
- ALE mesh motion allowed zones to concentrate vertically in areas of greatest interest.

Initial Mesh

target moves 200 *um*



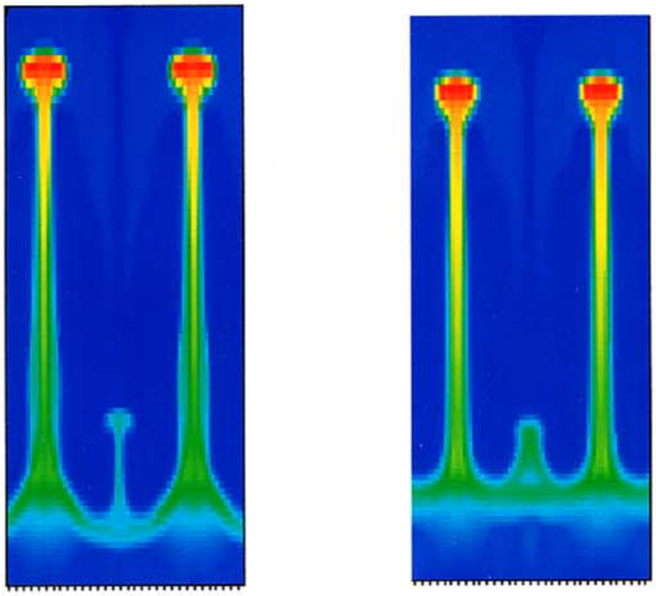
Final Mesh
time 5.5 ns

Physical Models

- Material temperature + Plankian radiation

- Initially the Titanium was modeled as a solid with the Steinberg-Guinan strength model. As the material melted, it converted to an inviscid fluid. The presence of the strength model led to better defined bubble and spike structures, and a very slight increase in instability growth.

Material density, 20 + 4 micron perturbation



solid to fluid

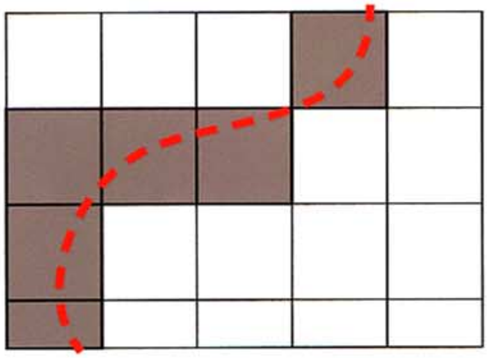
fluid only

melt occurs as the shock progresses through the Ti layer, ending as the shock breaks out of the rear surface.

- No material interface was applied between the CHBr and Ti layers. Material species were differentiated to allow for measurement of material mixing as shown:

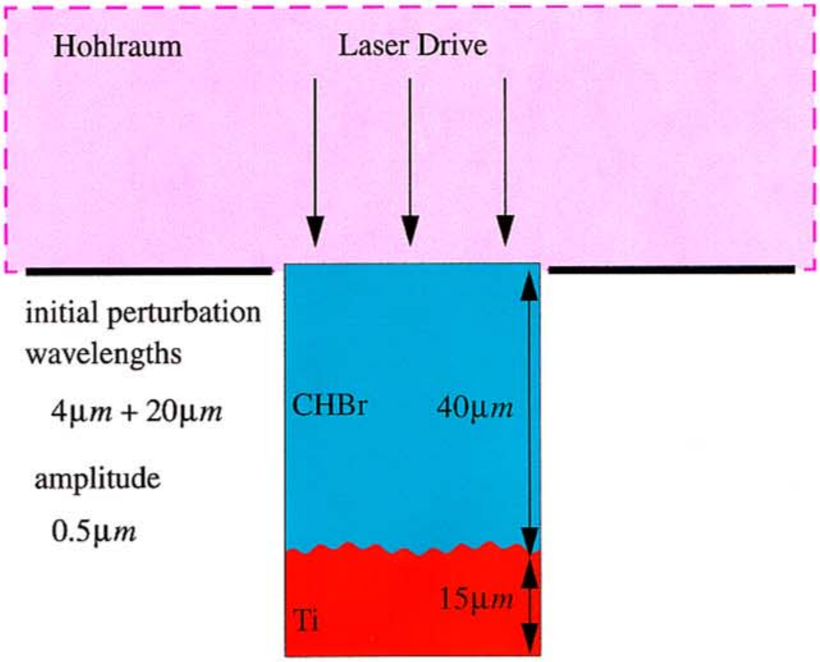
Zones that have between 1% and 99% of both materials (shaded zones) are considered mixed.

Material mass is summed in these zones to gauge the amount of mixing at the interface.

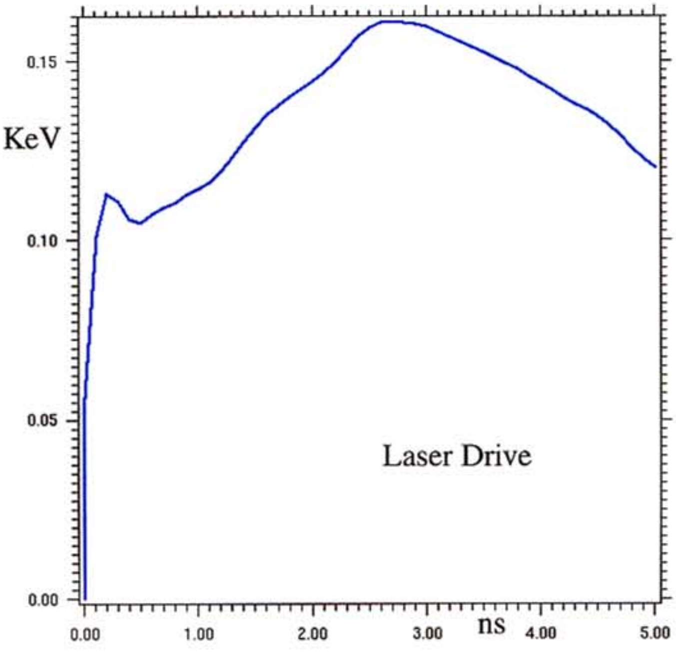


Superposition of a small and large mode

1. initial condition

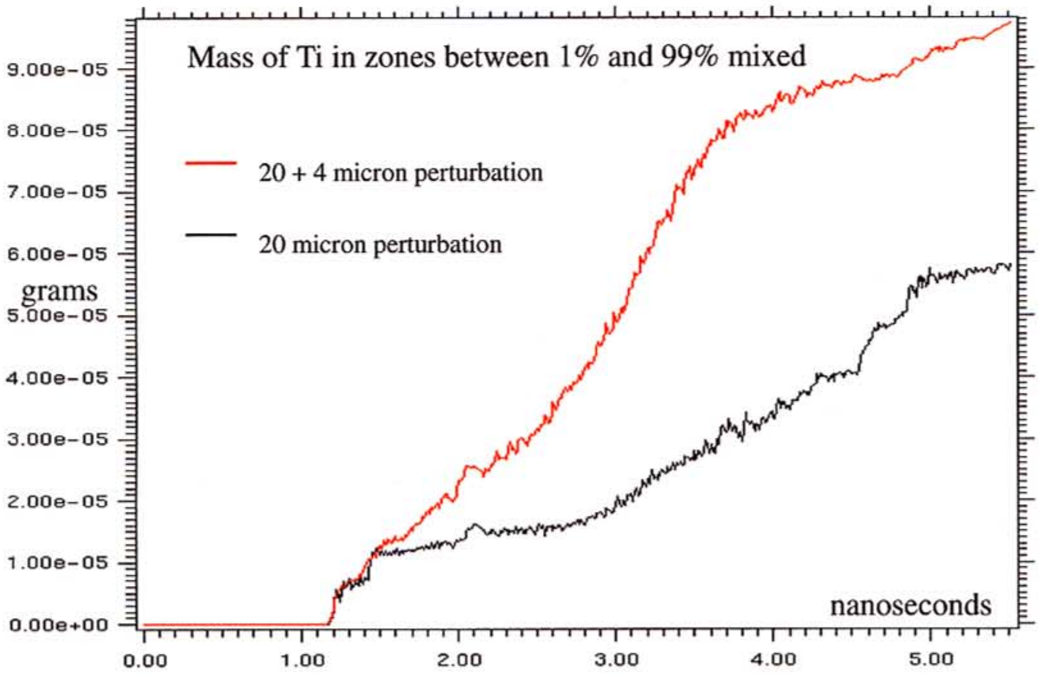


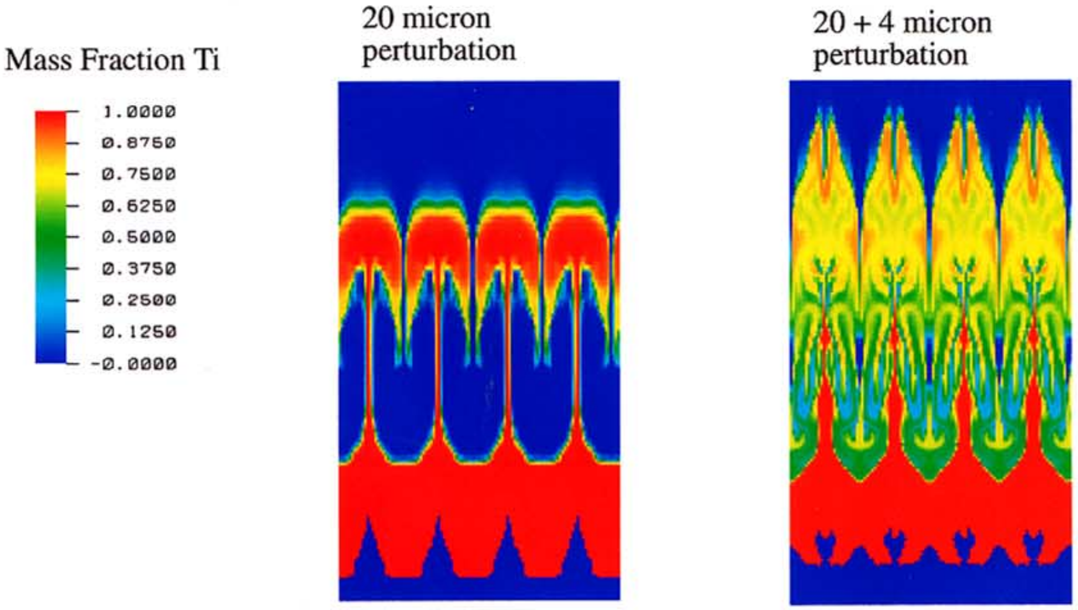
Initial Atwood number 0.5625



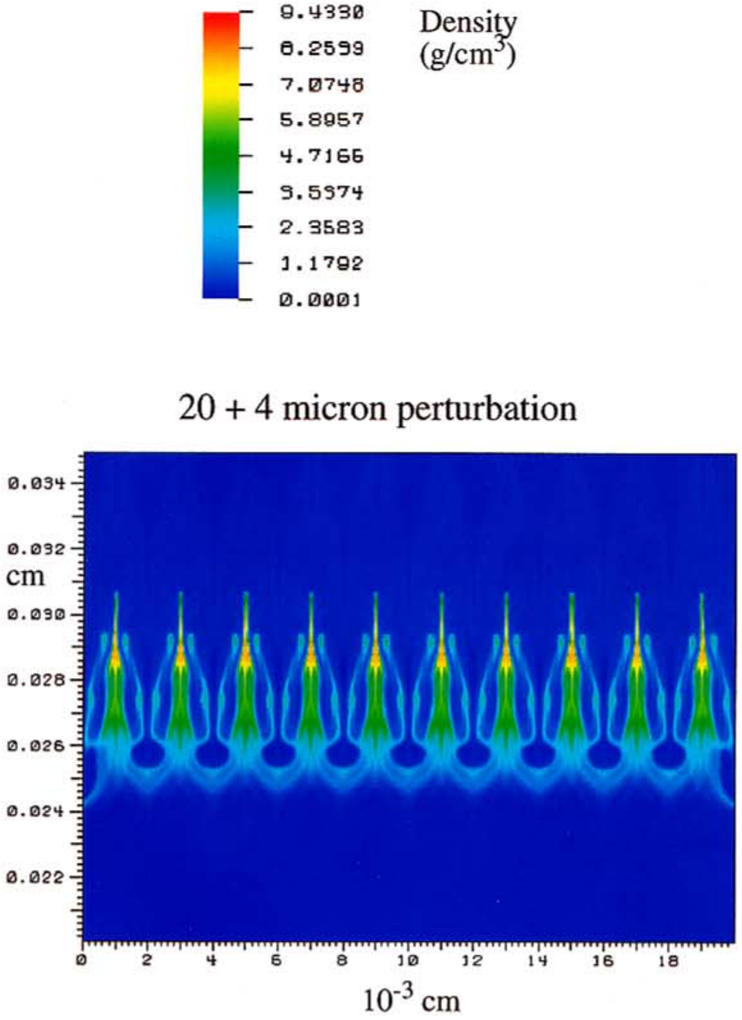
Material Mixing

The presence of the 4 μ*m* mode greatly increases material mixing:
By 5.5 ns, 43% of Ti is mixed for the 20 μ*m* mode alone, while 72% of Ti is mixed for both modes.



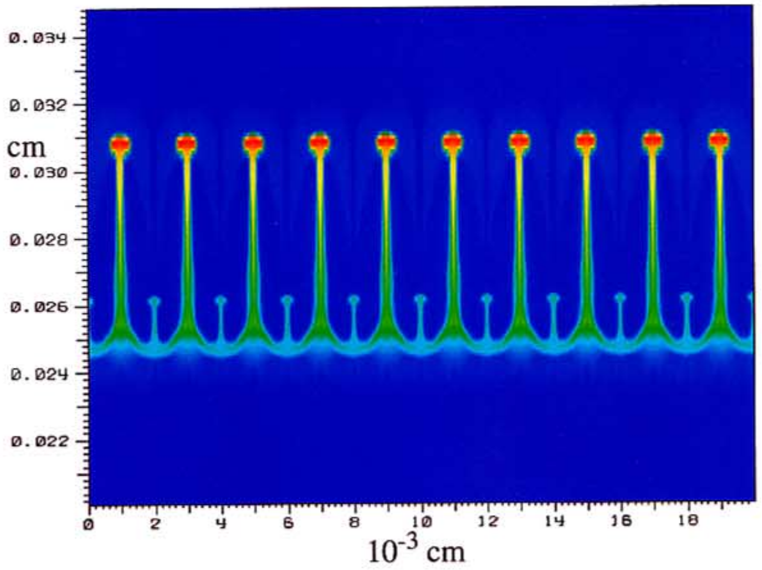


Material Density

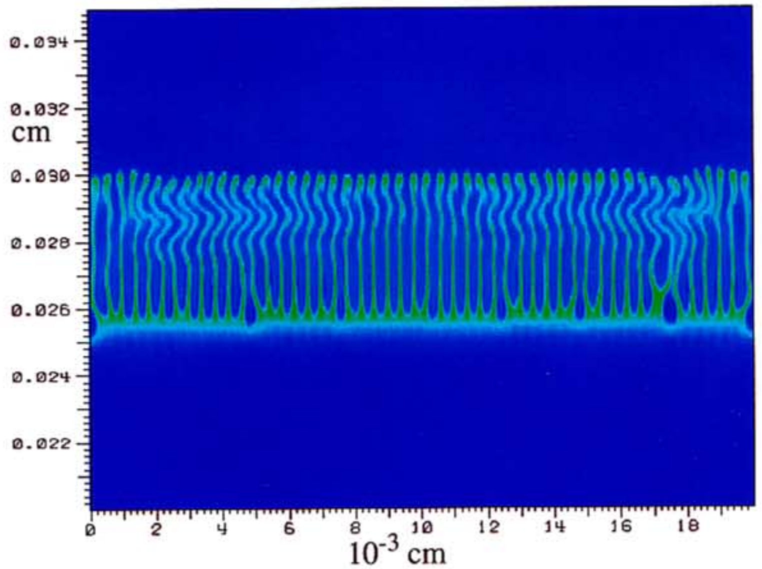


note: boundary effects are removed in analysis.

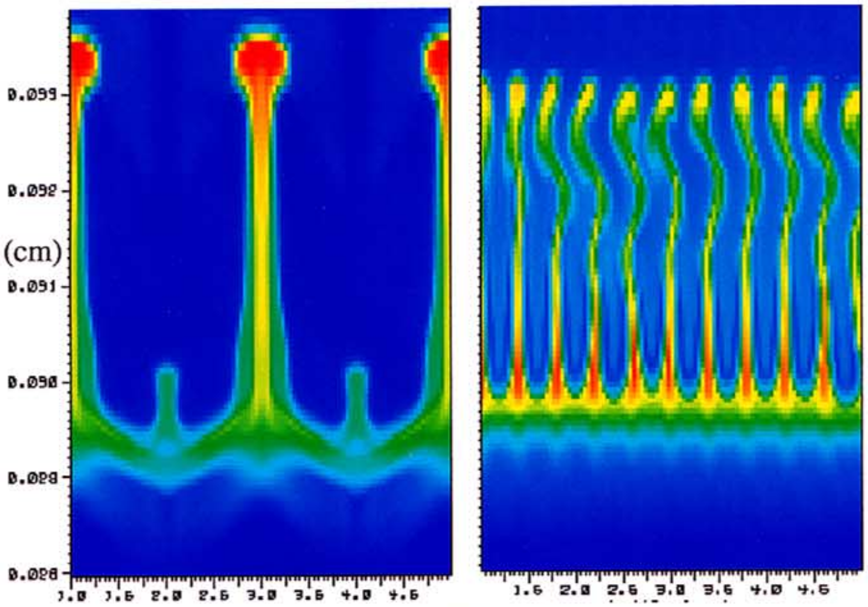
20 micron perturbation



4 micron perturbation



The 4 micron mode curls up which reduces growth

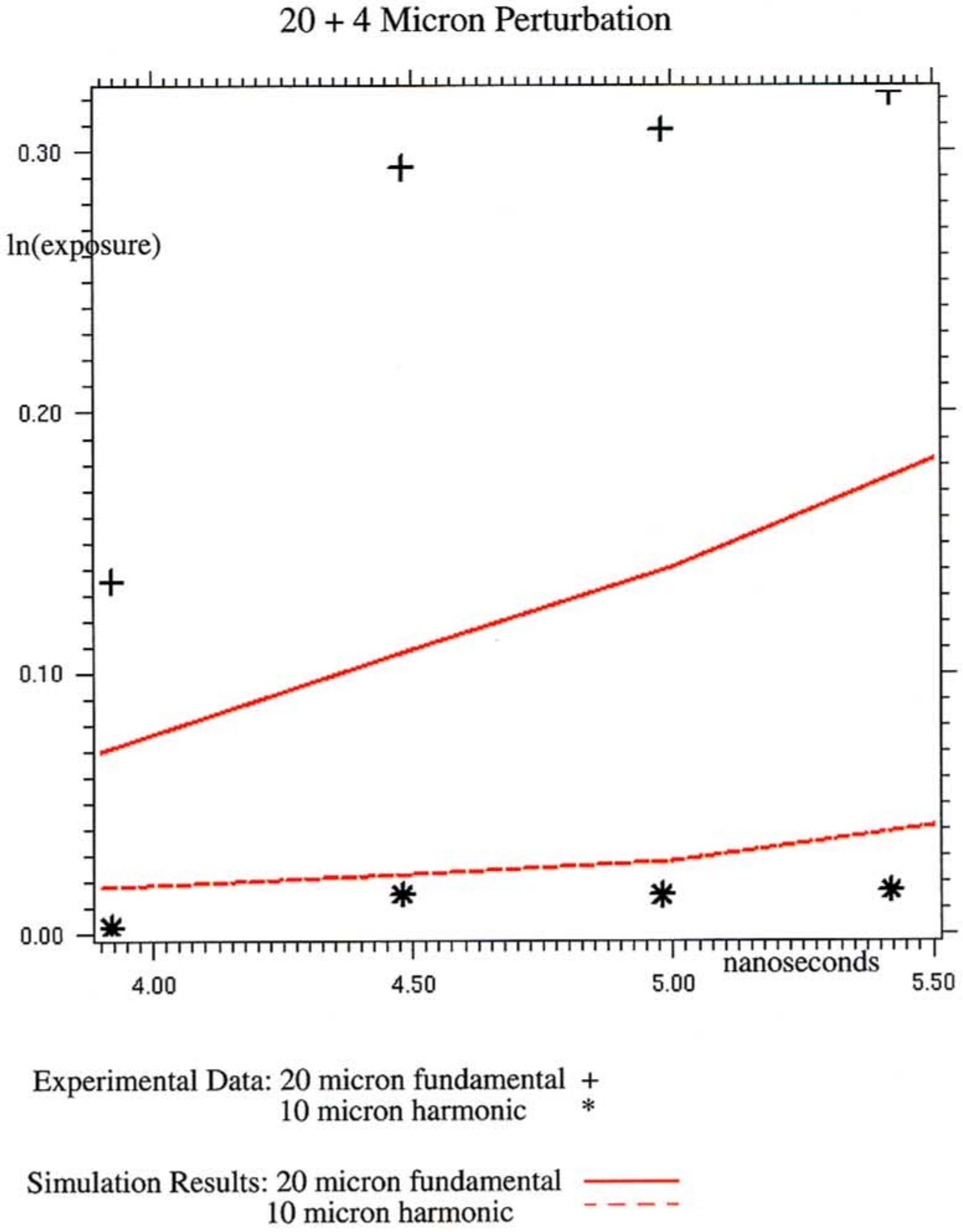


time = 5 ns

20 micron only

4 micron only

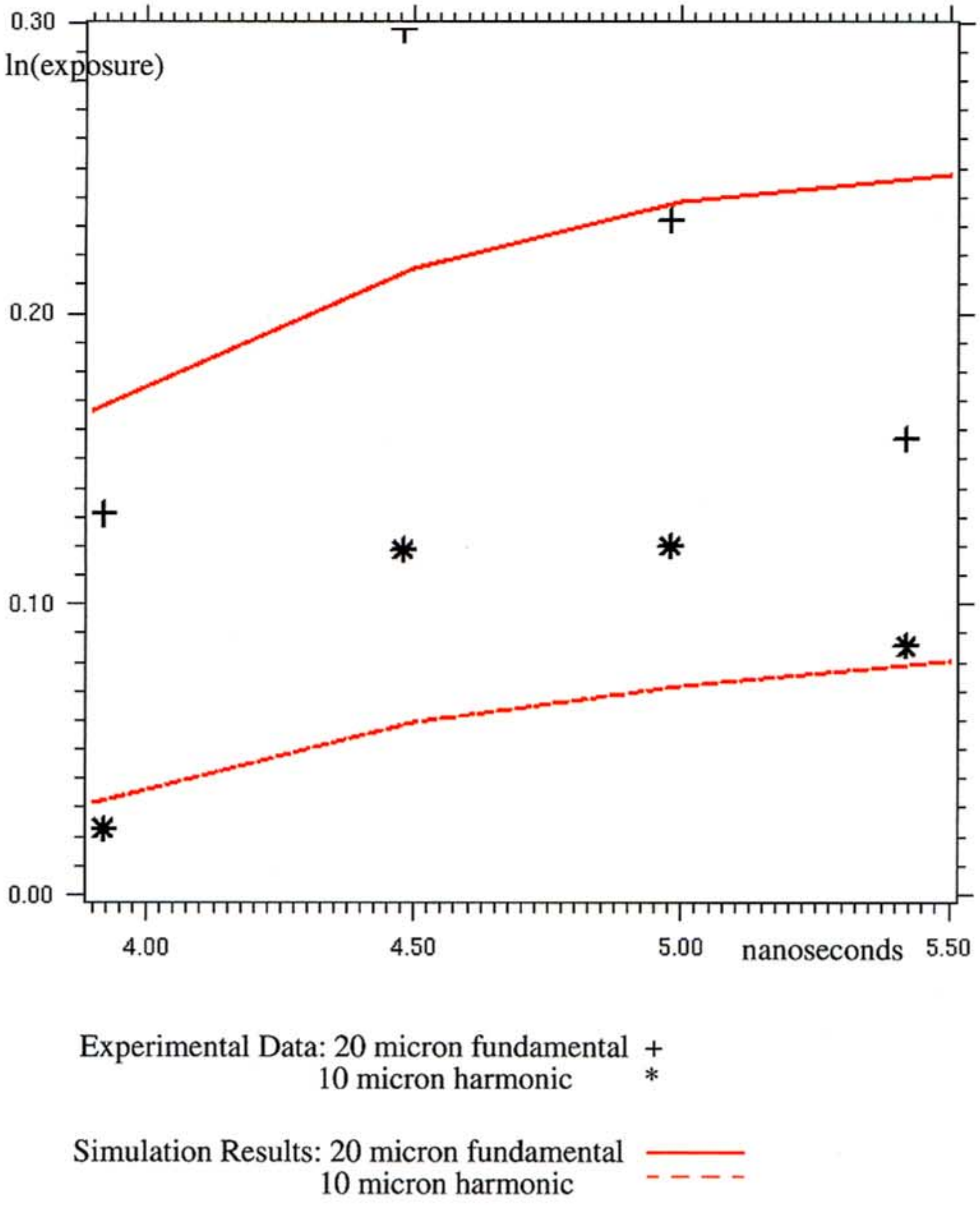
Comparison with Experimental Data



A simulated radiograph was calculated, to evaluate ln(exposure) = $\int \rho\, dy$ across the domain. This was Fourier analyzed, and limited detector response at small wavelengths was accounted for.

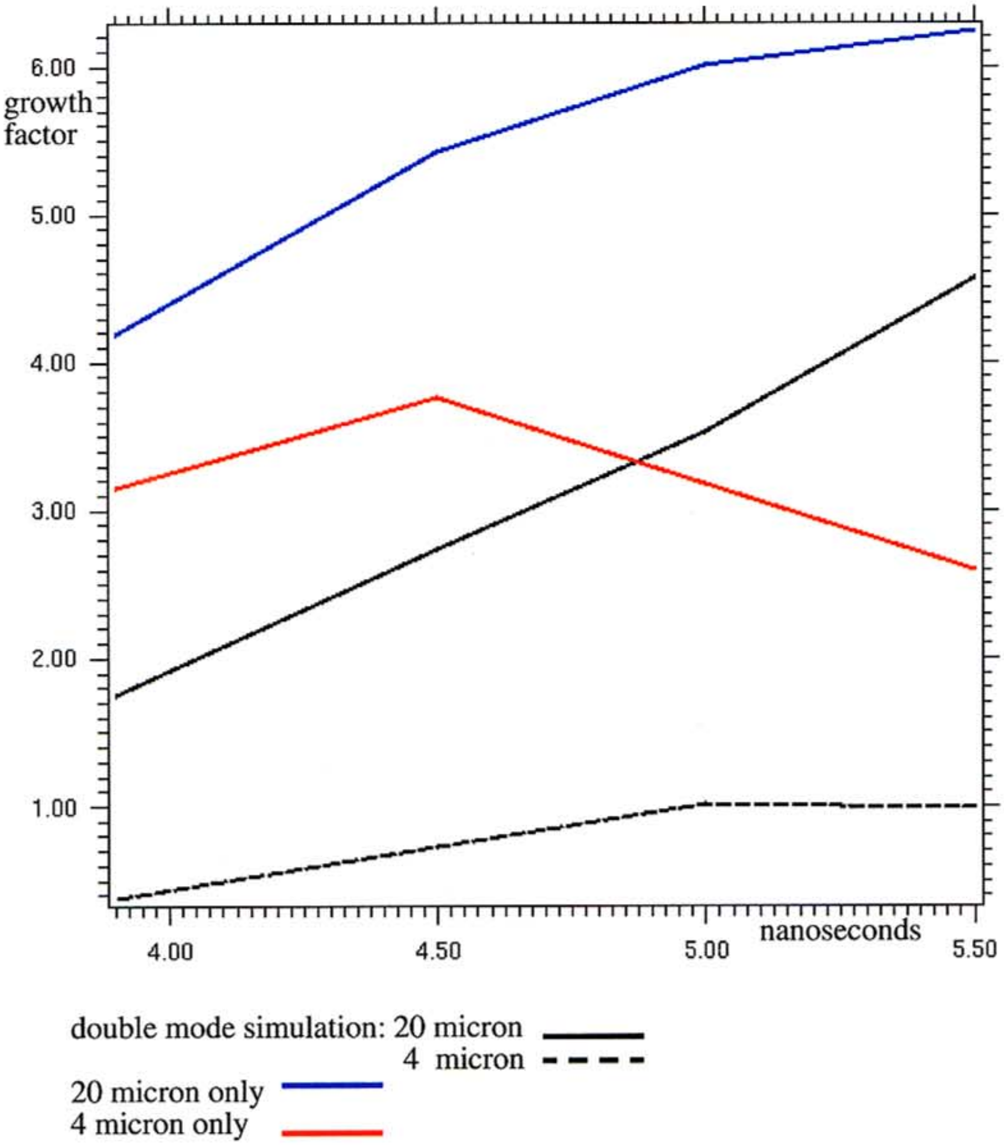
Comparison with Experimental Data

20 micron perturbation only



Mode Suppression

Both modes appear suppressed in the double mode simulation, but especially the 4 μm mode.

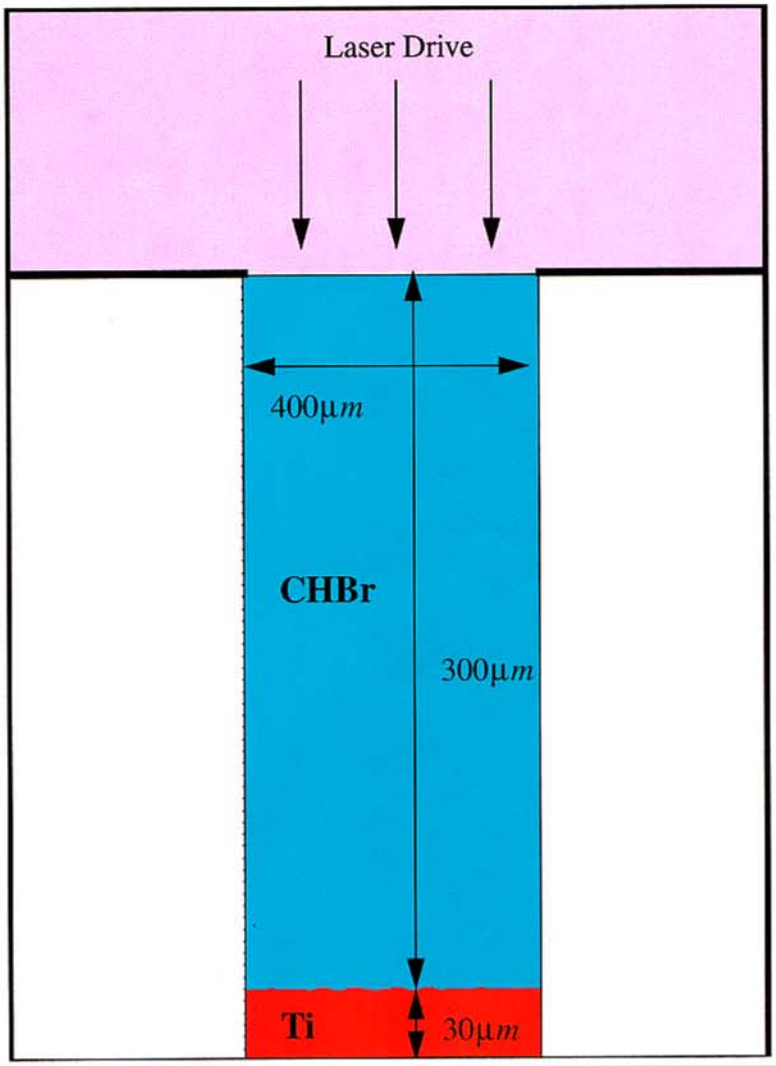


ln(exposure) values are divided by their initial values to provide growth factor.

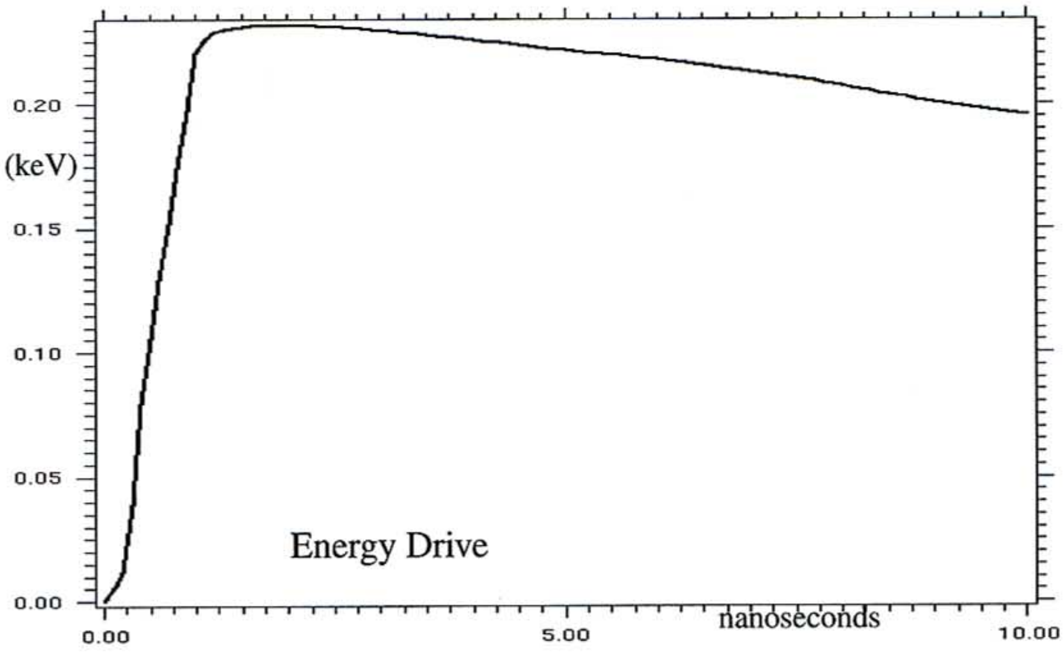
Multi-mode Perturbation

A simulation of a hypothetical experiment was designed to look at the continued growth of a multi-mode perturbation over an extended time.

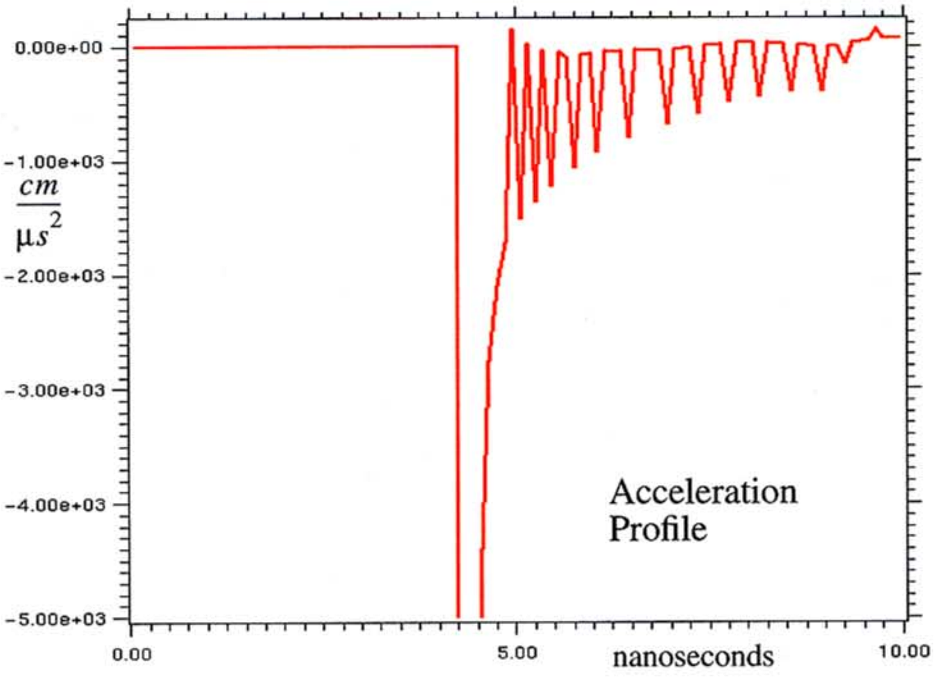
initial perturbation = $\sum_i a_i \cos(m_i x)$ **wavelengths 10-20** μm

i	a_i	m_i	Target
1	0.030618	0.314159	
2	0.0966043	0.345575	
3	0.127964	0.376991	
4	0.182545	0.408407	
5	0.0368705	0.439823	
6	0.18216	0.471239	
7	0.0704385	0.502655	
8	0.139533	0.534071	
9	0.126353	0.565487	
10	0.119258	0.596903	

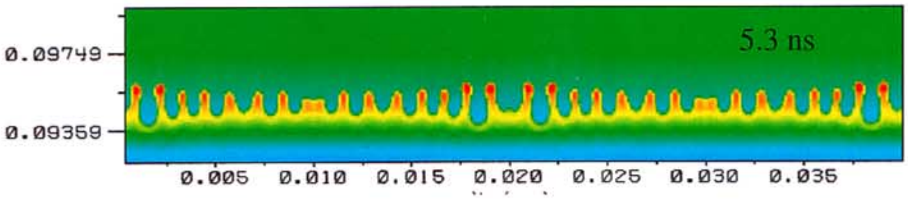
Laser Drive

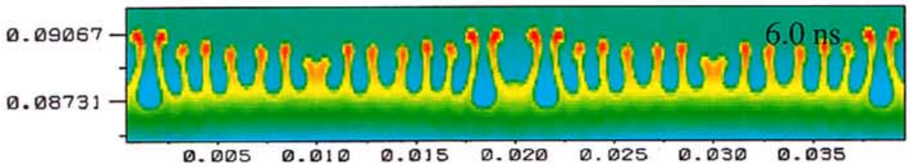


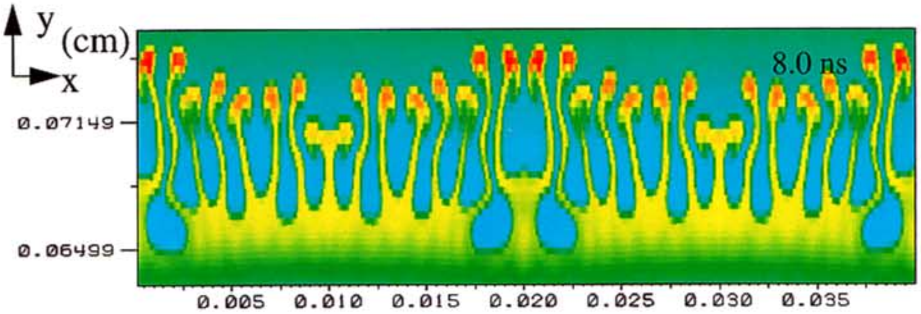
Target was driven approx 600 μm. Rayleigh-Taylor instability layer grew to about 150 μm.

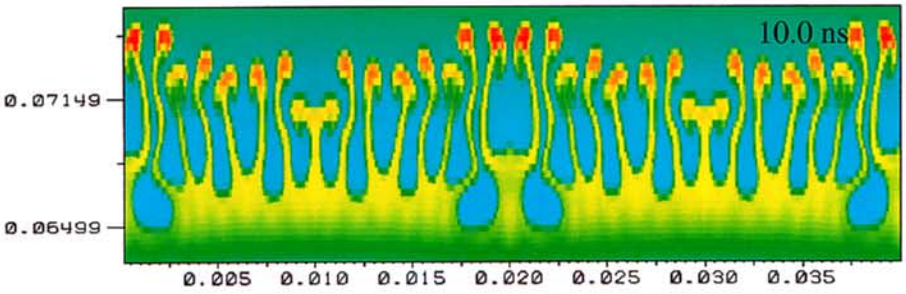



Initial Condition

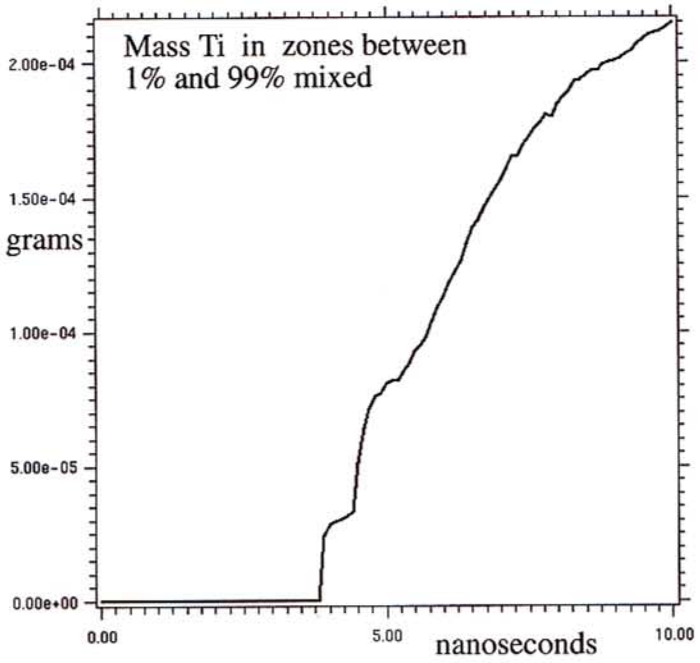

5.3 ns
0.09749
0.09359
0.005
0.010
0.015
0.020
0.025
0.030
0.035


6.0 ns
0.09067
0.08731
0.005
0.010
0.015
0.020
0.025
0.030
0.035


y
(cm)
x
8.0 ns
0.07149
0.06499
0.005
0.010
0.015
0.020
0.025
0.030
0.035

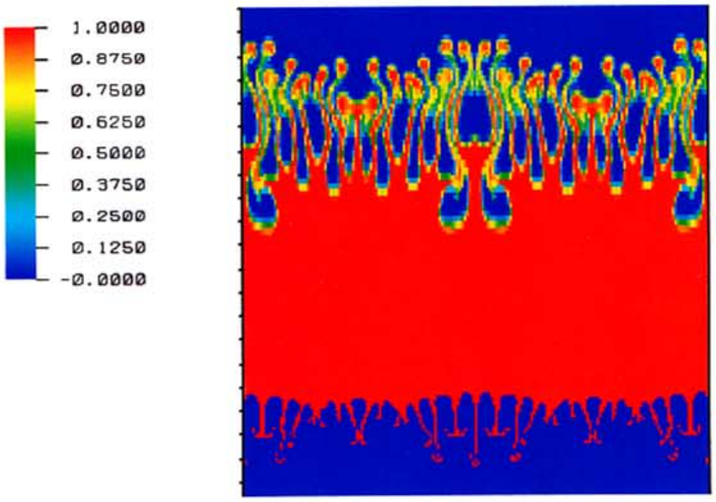

10.0 ns
0.07149
0.06499
0.005
0.010
0.015
0.020
0.025
0.030
0.035

Material Mixing



At time 10 ns, 40% of Ti was mixed.

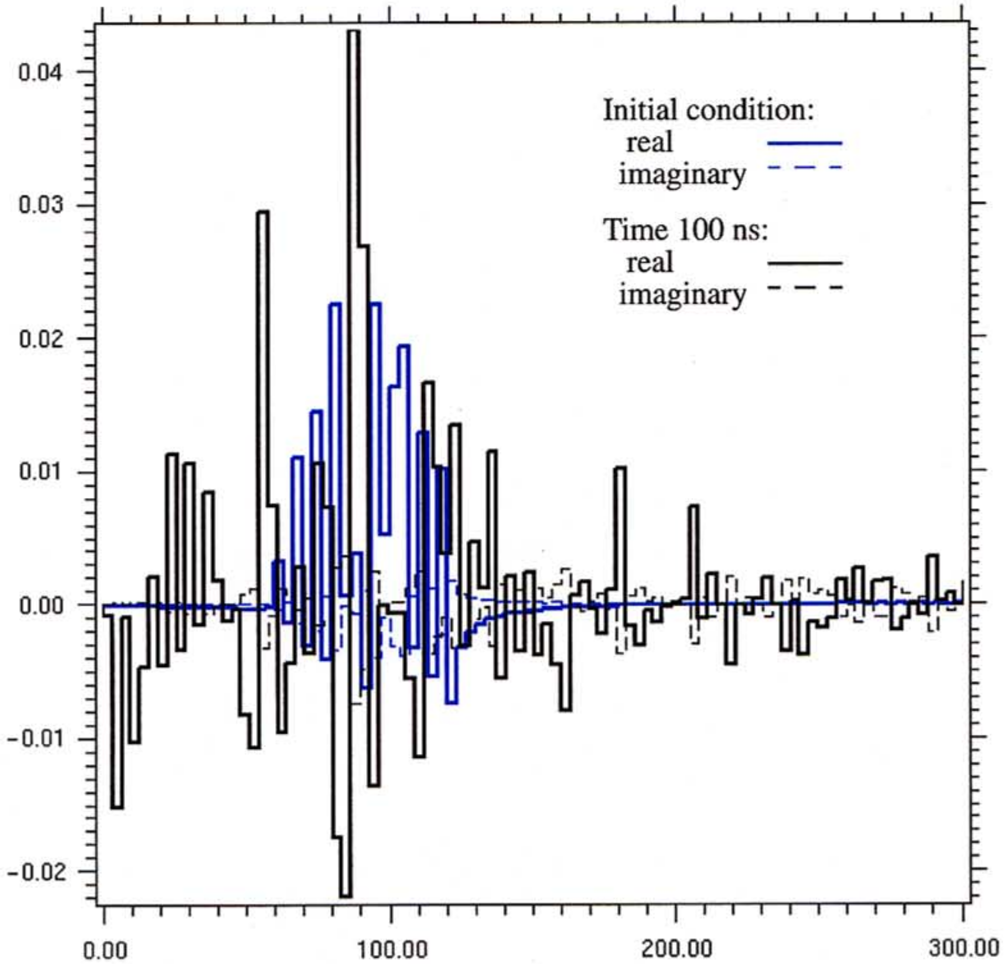
Mass Fraction Ti



maximum density of 2.9 g/cm^3

Longer Wavelengths Dominate Instability Growth

Mode coupling appears to favor the growth of longer wavelengths. Smaller wavelengths are seen up to about 2.5 μm. Grid resolution is 1 μm horizontally.



1/wavelength, 8x magnification