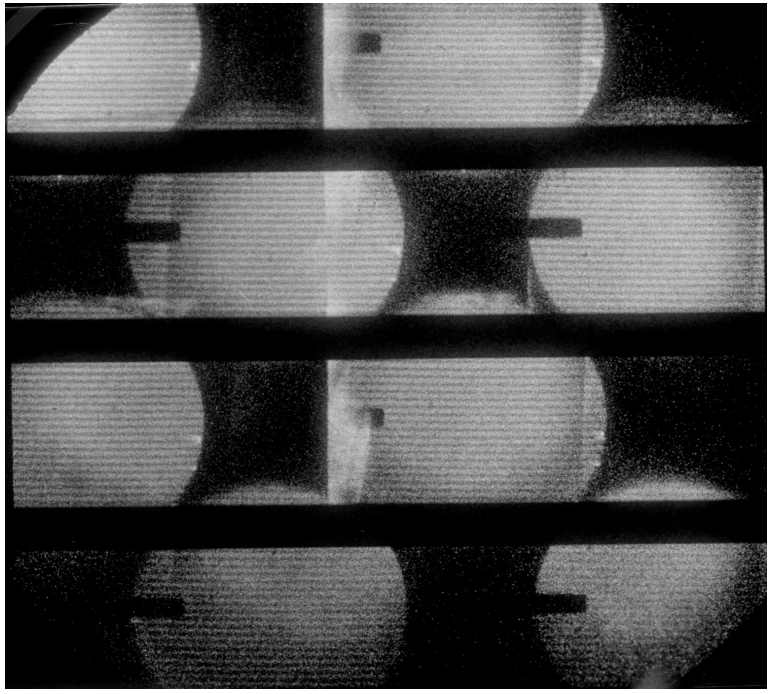
Experiments on Dynamic Overpressure Stabilization of Ablative Richtmyer–Meshkov Growth in ICF Targets on OMEGA



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Summary

An experiment to measure the ablation-front oscillations due to dynamic overpressure of the blowoff plasma has been conducted

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- The areal-density modulations show good agreement with theory and simulations.
- Almost a full oscillation period was observed.
- Analysis of the data shows phase inversion of the ripples in accordance with predictions.
- Late-time nonlinear growth exposes the need for high-spatial-resolution diagnostics.
- Experiments with a high-resolution streaked imager are being conducted to gain insight into this nonlinear behavior.

Outline

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- Dynamic overpressure effect
- Experimental requirements for direct observation
- Setup of an experiment and analysis of the data
- Conclusions

Motivations

Experimental verification is of great importance to implosion stability studies in direct drive ICF

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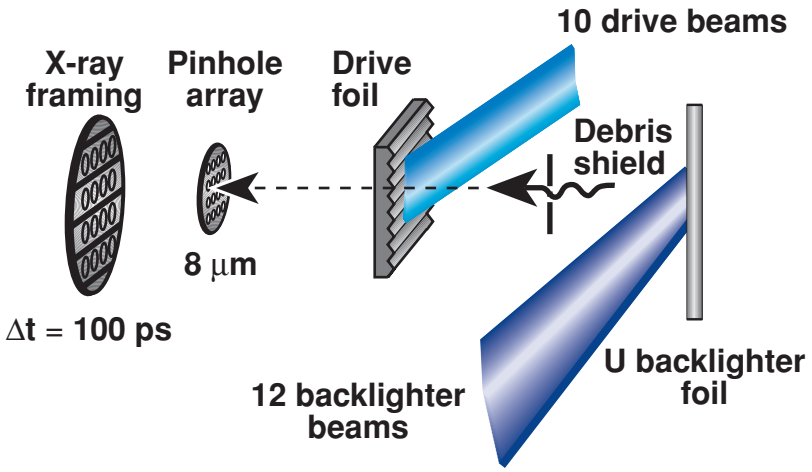
- To show that the Richtmyer–Meshkov (RM) perturbation growth turns into oscillations in ablating targets.[1]
- To estimate the magnitude of dynamic overpressure stabilization during the Rayleigh-Taylor phase.
- To verify the cutoff wavelength for RT growth in cryogenic targets:

$$\gamma = \sqrt{kg - k^2 V_a V_{bl}} - 2kV_a$$

- To check the validity of numerical codes used to simulate ICF hydrodynamics.

[1] Confirmed by Y. Aglitskiy *et al.*, Phys. Plamas 9, 2264 (2002).

Through-foil x-ray backlighting is used to measure the evolution of the target ρR perturbations



- 20- to 60-μm-thick CH targets with 20- or 30-μm modulations
- Initial amplitudes of 1.65 and 2.75 μm correspondingly
- $I_{laser} \approx 4 \times 10^{14}$ W/cm^2
- $t_{FWHM} = 1.5$ ns
- SSD with 1-THz bandwidth

Data is recovered from the raw images using Wiener filter and calculated MTF:

$$RS(f) = \frac{MS(f)}{MTF(f)} \frac{|S(f)|^2}{|S(f)|^2 + |N(f)|^2}$$

$$|S(f)|^2 = |MS(f)|^2 - |N(f)|^2 \text{ for } |MS(f)|^2 > 2|N(f)|^2$$

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Experimental data agree reasonably well with model and simulation (20-μm wavelength) at early times

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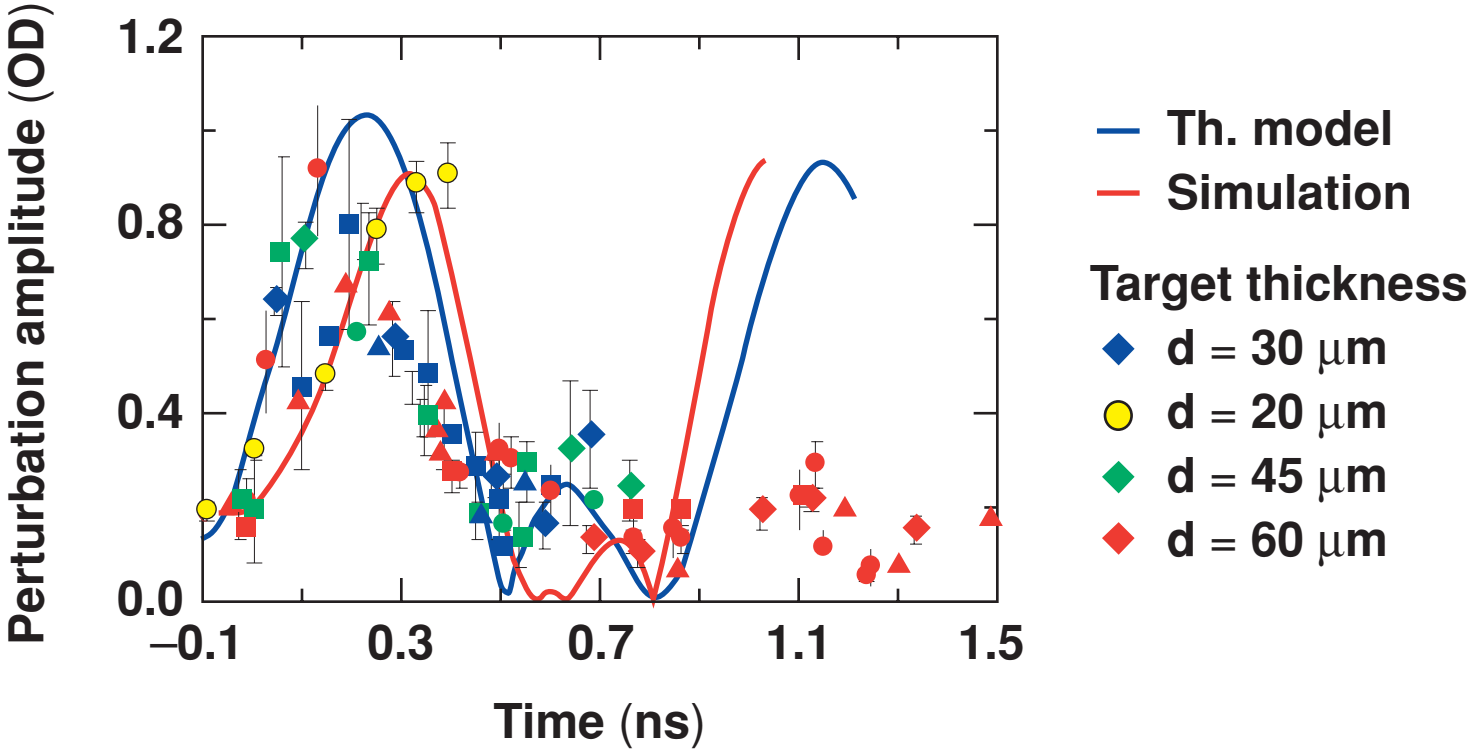
Evolution of single-mode perturbations, 20-μm wavelength



The initially sinusoidal ripple grows nonlinearly into a tall sharp spike that cannot be resolved by the diagnostic.

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Evolution of 30-μm modulations follows the model prediction

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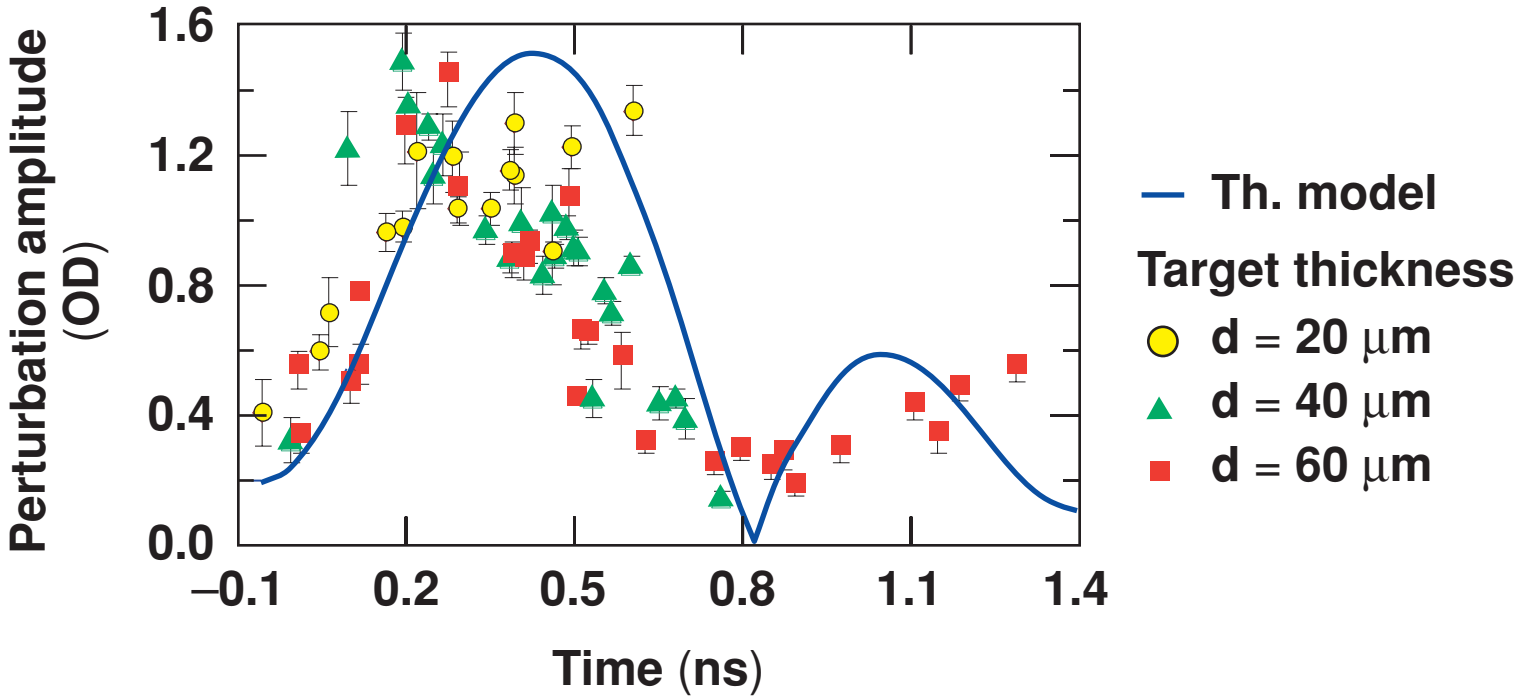
Evolution of single-mode perturbations, 30-μm wavelength



As predicted, 30-μm modulations oscillate more slowly.

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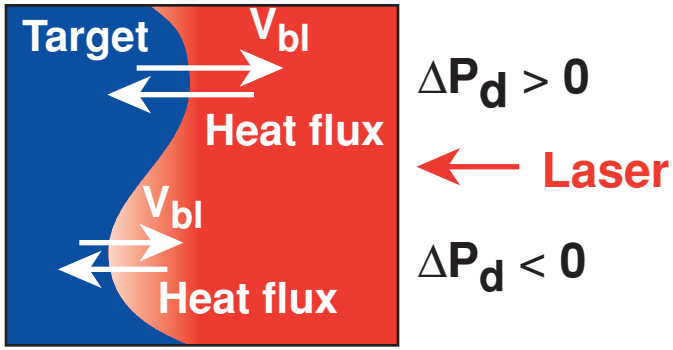
Dynamic overpressure is the main physical mechanism stabilizing ablative Richtmyer-Meshkov (RM) growth

$\delta(\nabla T) \rightarrow \delta V_a \rightarrow \delta V_{bl} \rightarrow \delta P_d$



Ablation front

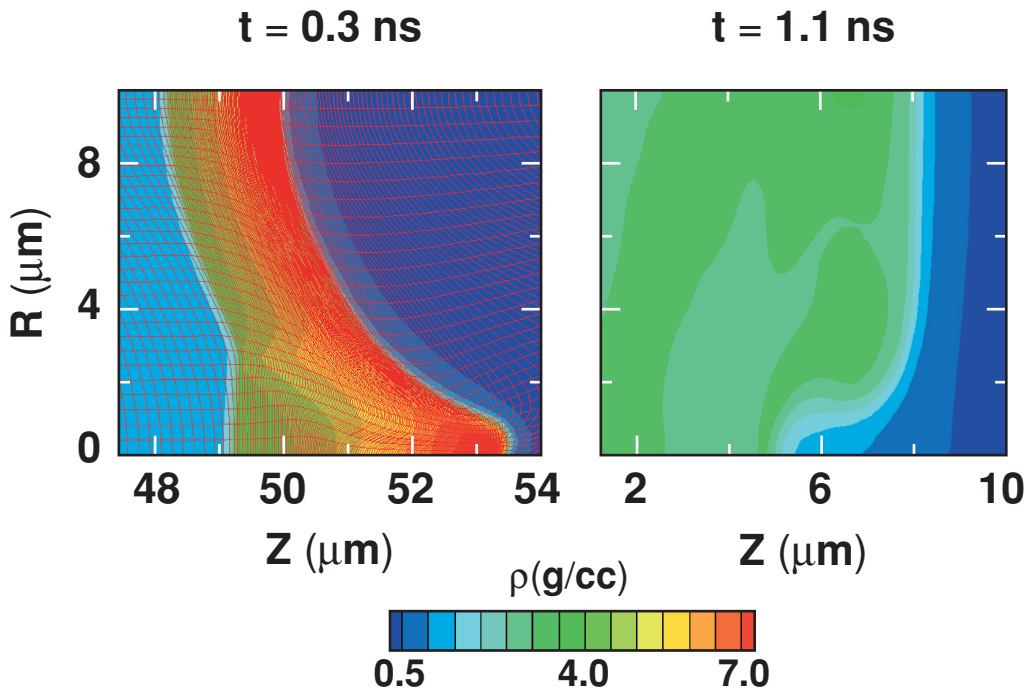
- Classical RM growth: $\eta \sim k c_s \eta_0 t$
- With ablation[1] $V_a \sim \nabla T \sim I^{1/3}$:

  $\eta \sim \eta_0 \cos(\omega t),\ \omega = k\sqrt{V_{bl} V_a}$

- Oscillations are observable only before rarefaction breakout.
- Thick targets ($d > 30\ \mu m$) are needed in order to observe more than half a period.
- Laser pulse must be longer than t_{rb}.

[1] V. N. Goncharov, Phys. Rev. Lett. 82, 2091 (1999).

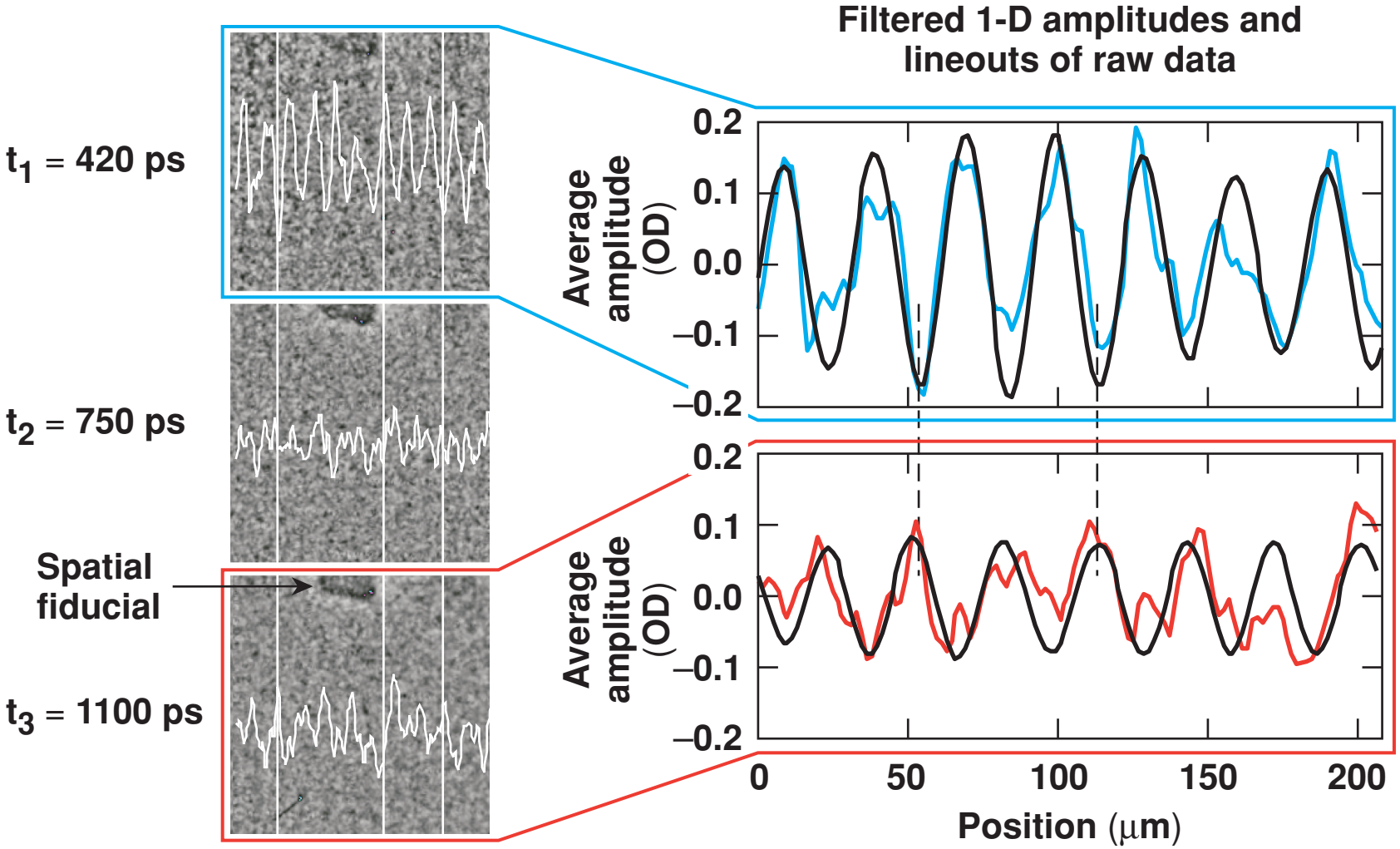
The observation of short-wavelength modes is an experimental challenge demanding high resolution



ORCHID simulations based on actual pulse shapes show nonlinear evolution of the perturbations even for $a_0 < 0.1\ \lambda$.

- Spatial features with less than 10-μm size must be resolved.
- Surface ripples with low initial amplitude $a_0 << \lambda$ must be used.
- High-dynamic-range diagnostic is needed to observe small modulations on thick targets.

Phase inversion in the ablation-front oscillations was seen for several shots



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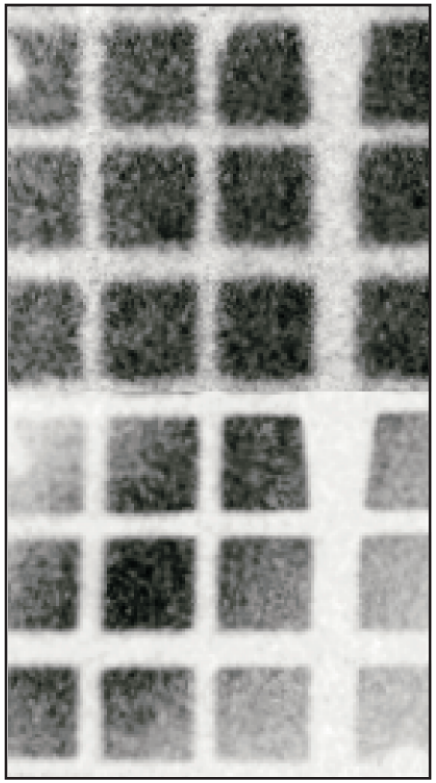
An improved experiment is underway to resolve the late-time nonlinear spikes



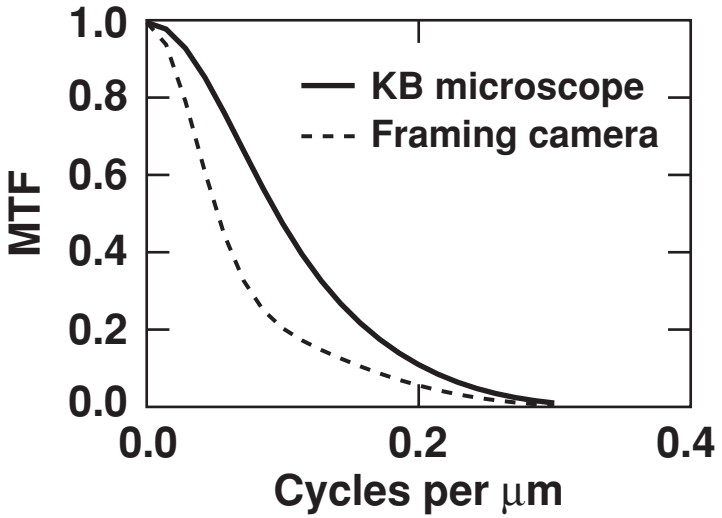
Framing camera

KB microscope

Images of 400-lines/inch mesh taken with the two instruments.

- The new streaked imager (KBPJX) provides two orders of magnitude higher throughput.
- It has a resolution of 3 μm on axis and less than 6 μm over a field of view of 150 μm.
- It provides a continuous record in time, allowing observation of the oscillations in a single shot.

Modulations transfer functions for KB and XRFC



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Conclusions

Observed mass oscillations at the ablation front confirm the predictions of theory and simulations

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- The areal-density modulations follow theoretically predicted behavior within the observed period of oscillation.
- Analysis of the data shows phase inversion of the ripples in accordance with predictions.
- Late-time nonlinear growth exposes the importance of high-spatial-resolution diagnostics.
- Experiments with a high-resolution streaked imager are being conducted to gain insight into this nonlinear behavior.