First Rayleigh–Taylor and Richtmyer–Meshkov Instability Measurements in Laser-Driven Planar Targets on the OMEGA EP Laser

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Introduction to the Rayleigh–Taylor instability

- Rayleigh–Taylor instability (RTI)
  - instability at the interface of fluids with different densities when a lighter fluid supports a heavier fluid
  - in ICF, RTI occurs during the acceleration and deceleration phases of the implosion
  - modulations grow exponentially early in time, then grow linearly after reaching the saturation level ($Z_k = \lambda/10$) with the growth rate given by*

$$\gamma_{RT} = \alpha\sqrt{\frac{k \times g}{1 + k \times L_m}} - \beta \times k \times V_a{}^{\dagger}$$

Variable	Description
α	Constant
β	Constant
k	Modulation wave number
g	Interface acceleration
V_a	Ablation velocity
L_m	Density scale length

*S. W. Haan, Phys. Rev. A 39, 5812 (1989).
†R. Betti, Phys. Plasmas 5, 1446 (1998).

E17794

Introduction to the Richtmyer–Meshkov instability

- Richtmyer–Meshkov instability (RMI)
  - instability at the modulated interface of two fluids when a shock wave crosses the interface
  - in ICF, the RMI seeds modulations for the faster growing RTI as well as contributing to turbulent mixing between the capsule's fuel and shell
  - modulation evolution in the linear and nonlinear regime can be characterized by the expression*

$$U(t) = U_0 \frac{1 + B \times t}{1 + D \times t + E \times t^2}$$

$$B = U_0 \times k \qquad D_{b/s} = (1 \pm A)\, U_0 \times k$$

$$E_{b/s} = \left[(1 \pm A)/(1 + A)\right] \times \left(\frac{1}{2} \times \pi \times C\right) U_0^2 k^2$$

Variable	Description
U	Modulation velocity
k	Modulation wave number
A	Constant (Atwood number)
C	Constant
U_0	Richtmyer initial velocity
b/s	+ is for *b*ubble, – is for *s*pike

*O. Sadat, Phys. Rev. Lett. 80, 1654 (1998).

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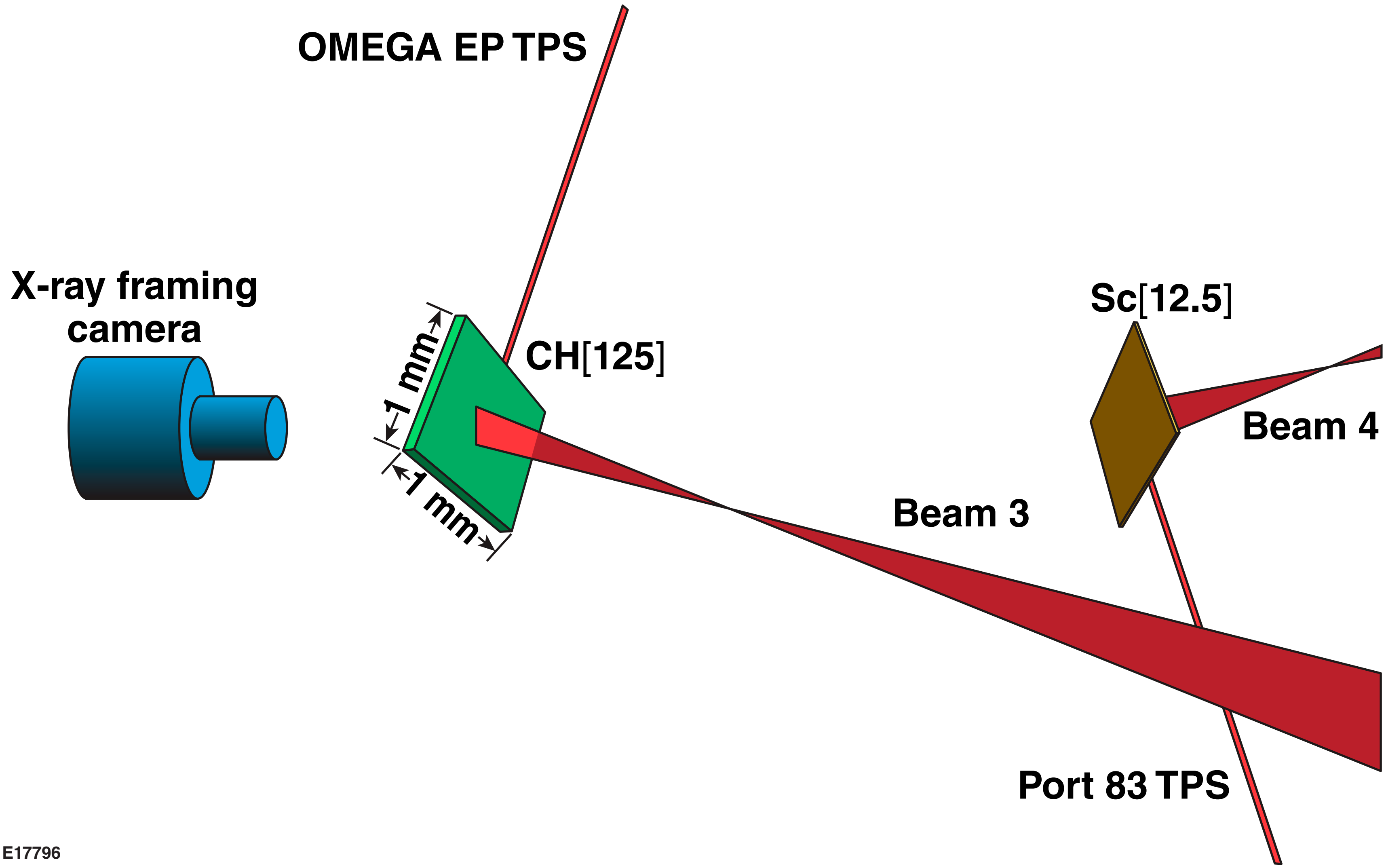
On OMEGA EP, an unmodulated CH[125] foil was driven at an intensity of 2 × 10^{14} W/cm^2 for 2.5 ns and backlit by an Sc[12.5] foil



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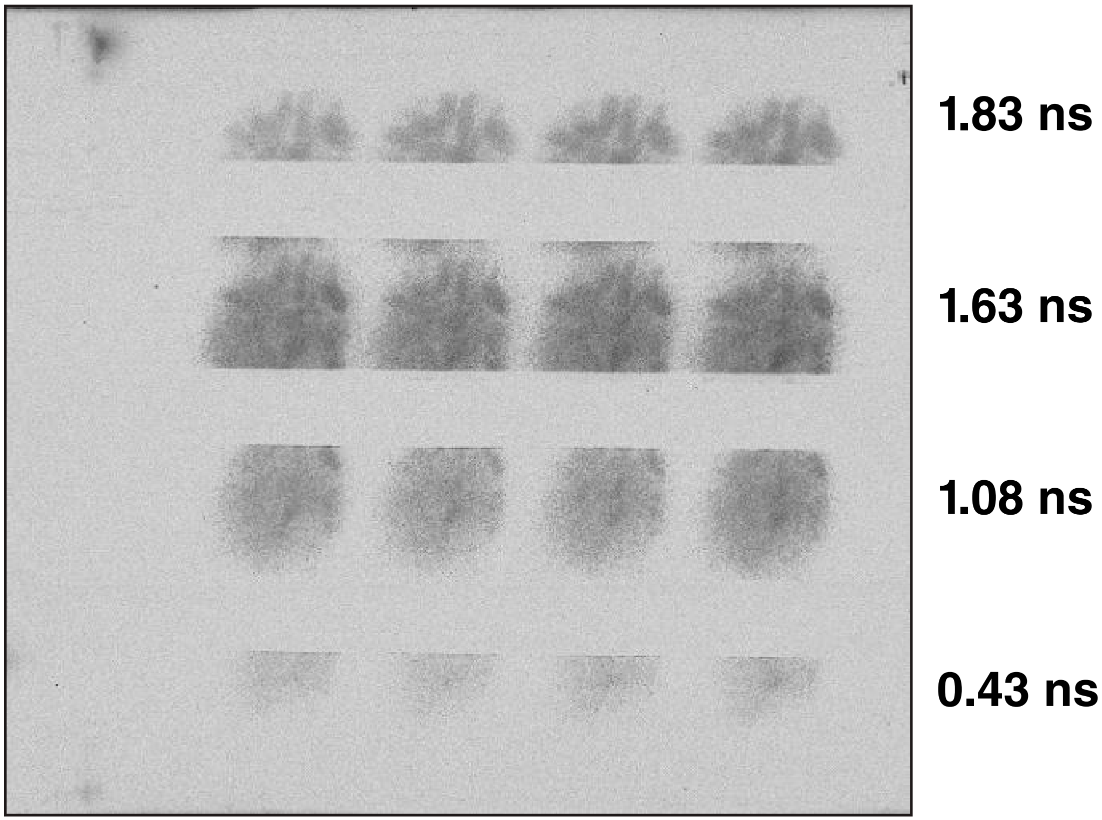
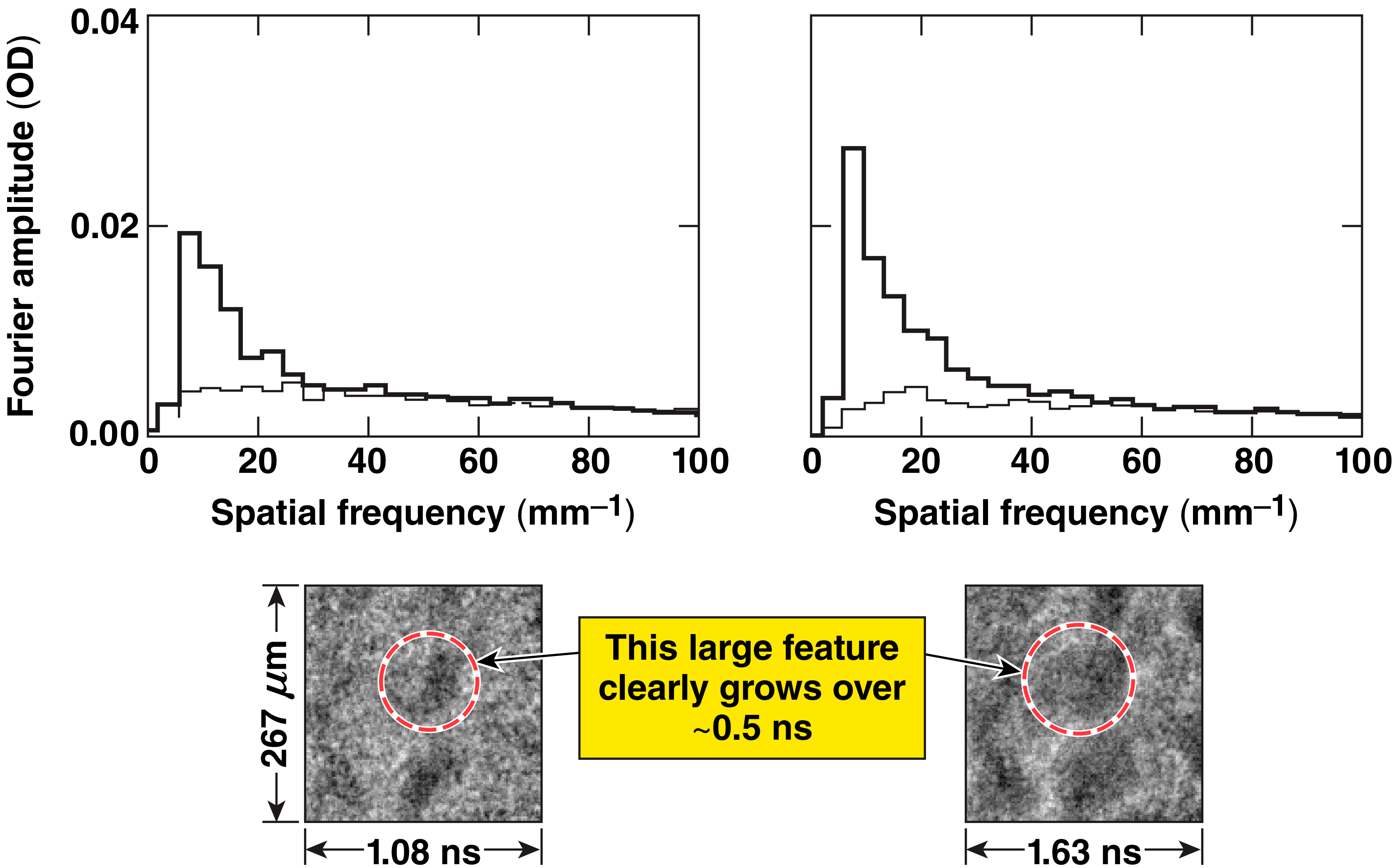
Face-on x-ray radiography of a CH[125] target backlit by an Sc[12.5] foil showed significant modulation growth in the backlighter



Features imprinted by the drive beam grow much faster than anticipated for a drive target of this thickness. A future shot was planned using only the backlighter to explore whether the growth was occurring in the target, backlighter, or both.

Modulation growth was dominated by the Sc[12.5] backlighter foil, instead of the CH[125] drive target



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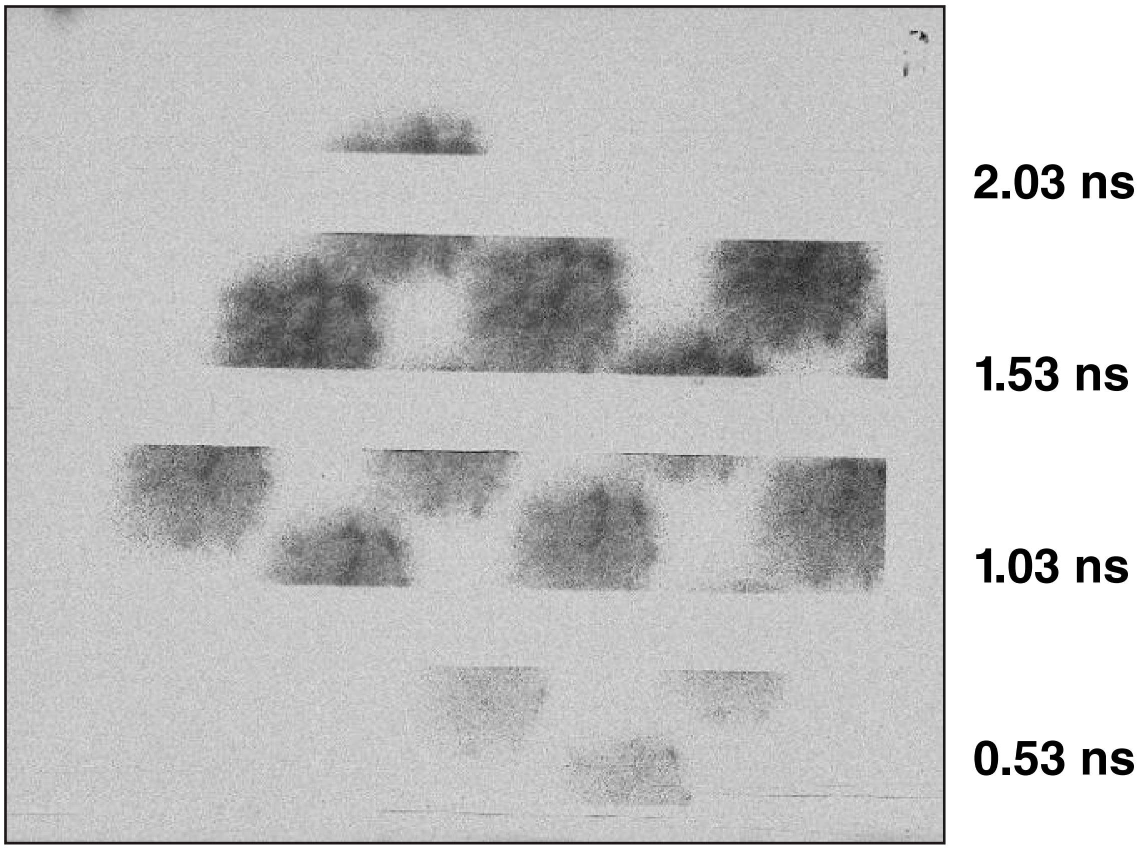
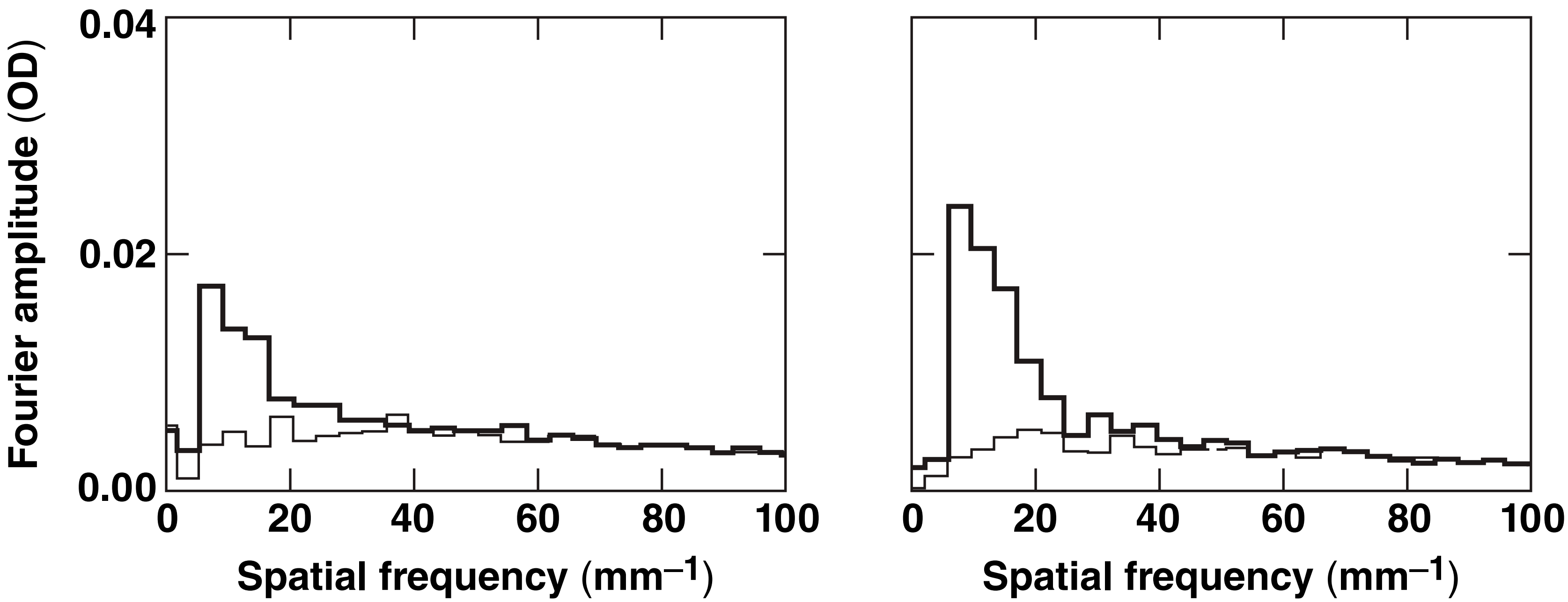
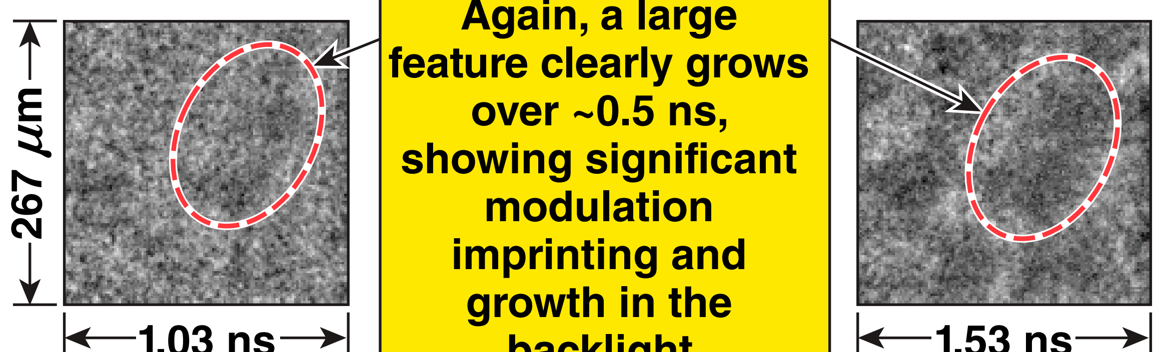
A misaligned pinhole array hindered this Sc[12.5] "backlighter-only" shot, but useful data was recovered



This "backlighter-only" shot shows similar results to the previous shot that used both the CH[125] target and Sc[12.5] backlighter. Unfortunately, the pinholes were not properly installed, but the data indicates that the majority of the growth is occurring in the backlighter.

Large-scale features are also observed in the Sc[12.5] backlighter-foil-only experiment





Again, a large feature clearly grows over ~0.5 ns, showing significant modulation imprinting and growth in the backlight.

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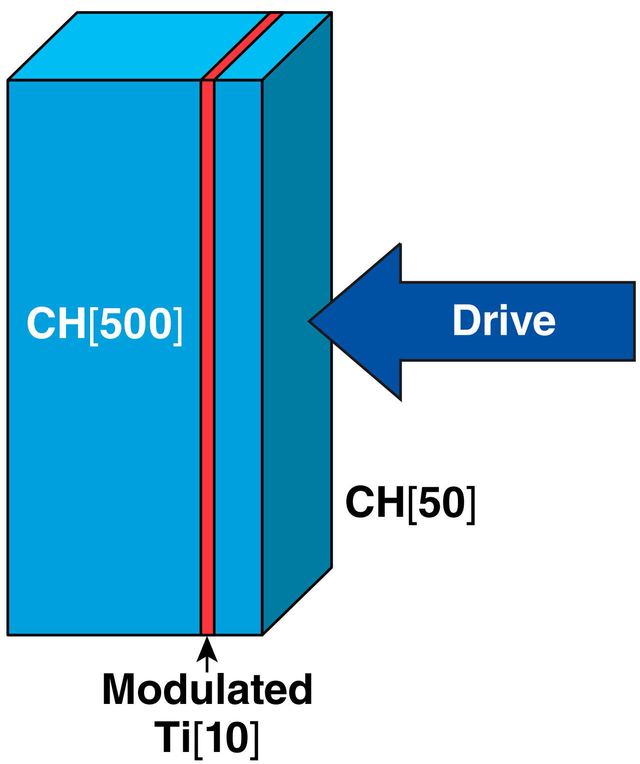
Overall, the shot day was very challenging, but useful data was obtained

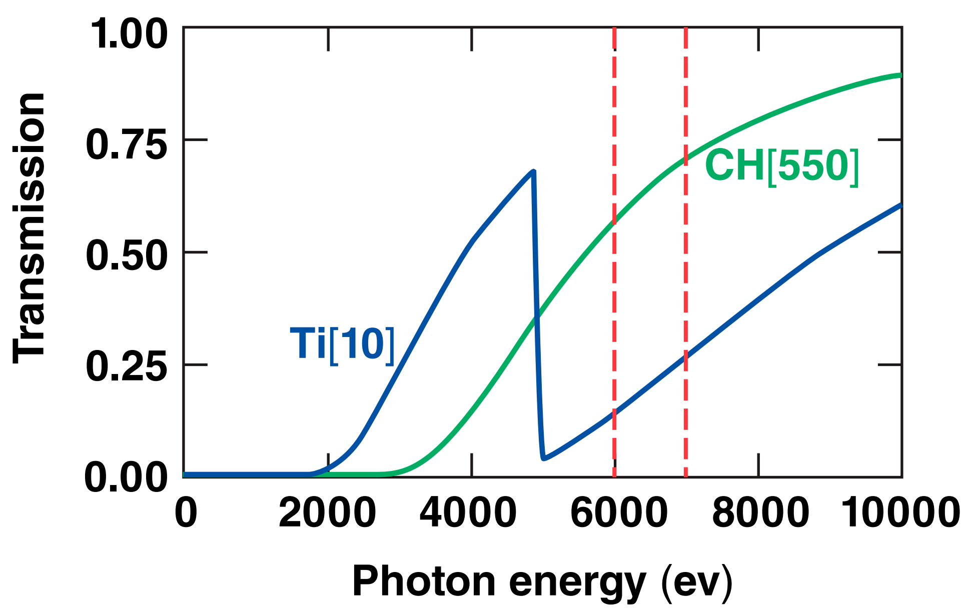
- The OMEGA EP pulse length was inconsistent, compromising some of the data
- Problems with the x-ray framing camera also compromised some of the data
  - timing was inconsistent—compromised data when combined with the reduced pulse length of the OMEGA EP laser
  - the framing camera film package was damaged while under vacuum and exposed during the recovery process for one shot
  - the pinhole array was improperly installed for one shot, compromising data on two of the four framing camera strips
- Three target shots were taken, with useful data obtained on two of the three shots

Future RTI and RMI experiments on OMEGA EP will require beam smoothing, longer pulse lengths (10 ns), and higher energies (5 kJ)

Proposed RMI target design



X-ray transmission for CH[50]Ti[10]CH[500]



- 10-ns drive with an intensity of ~3×10^{14} W/cm^2
- 6- to 7-keV x rays will radiograph the modulated Ti[10] layer

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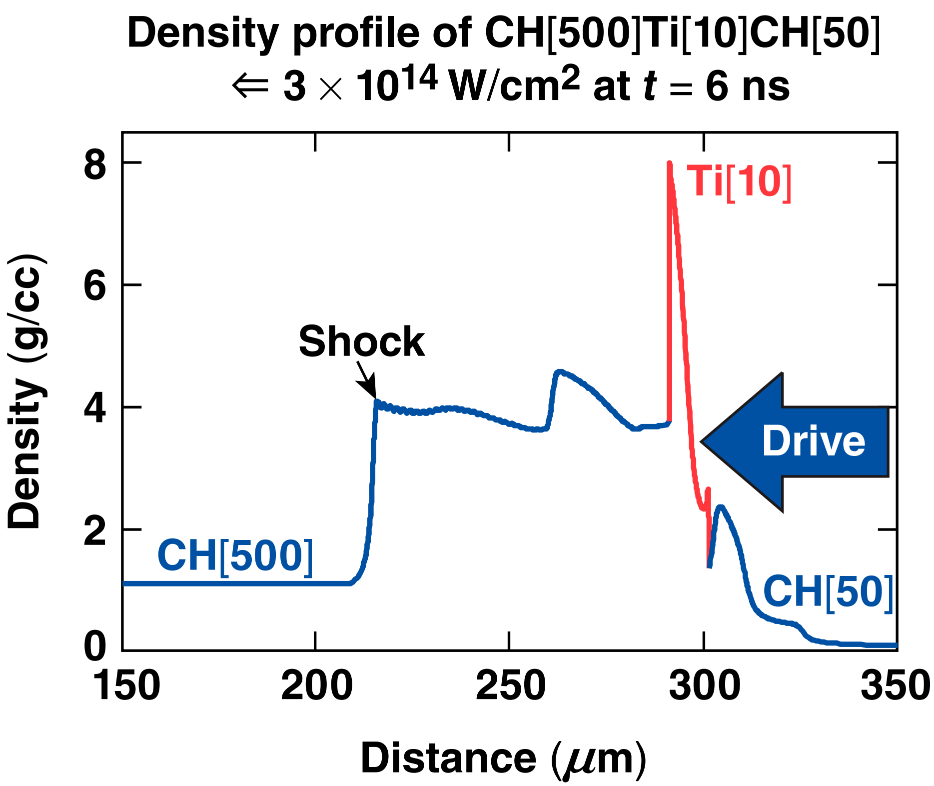
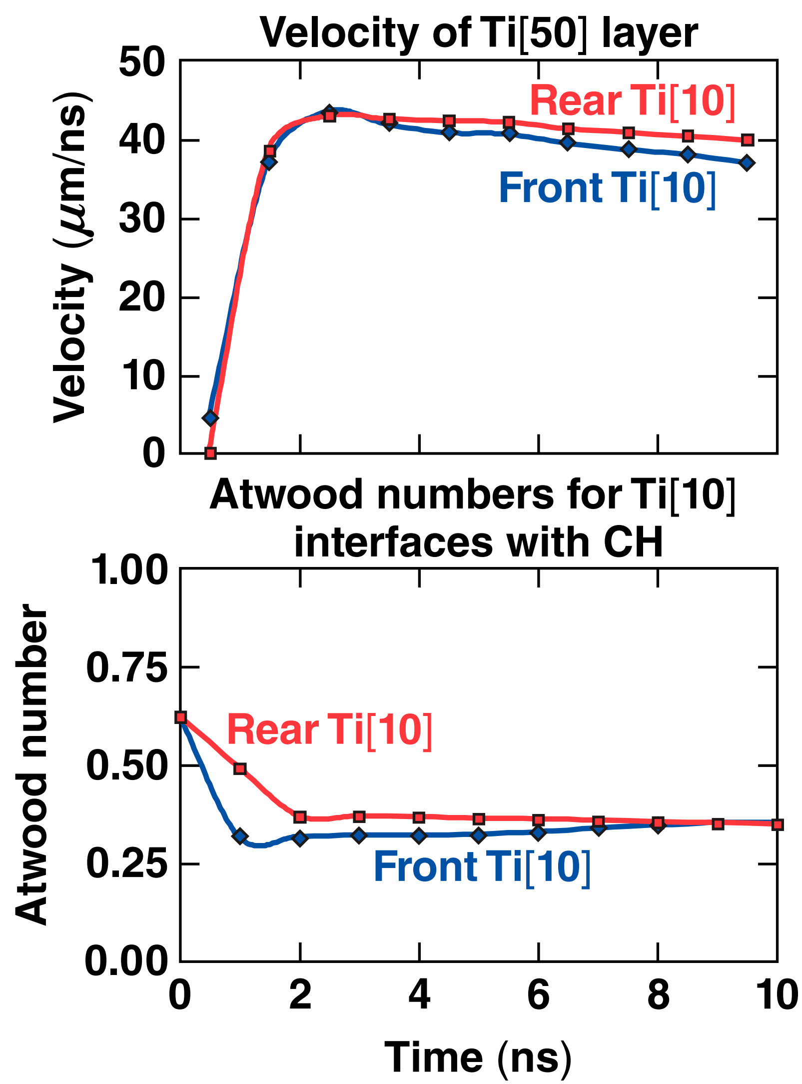
LILAC simulation results show the Ti[10] layer travels at a nearly constant velocity after the initial shock





These conditions are ideal for experimentally measuring modulation growth caused by the RMI independent from the RTI that typically dominates ICF instability experiments.

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Low target acceleration minimizes the effect of RT growth, allowing the RMI to dominate

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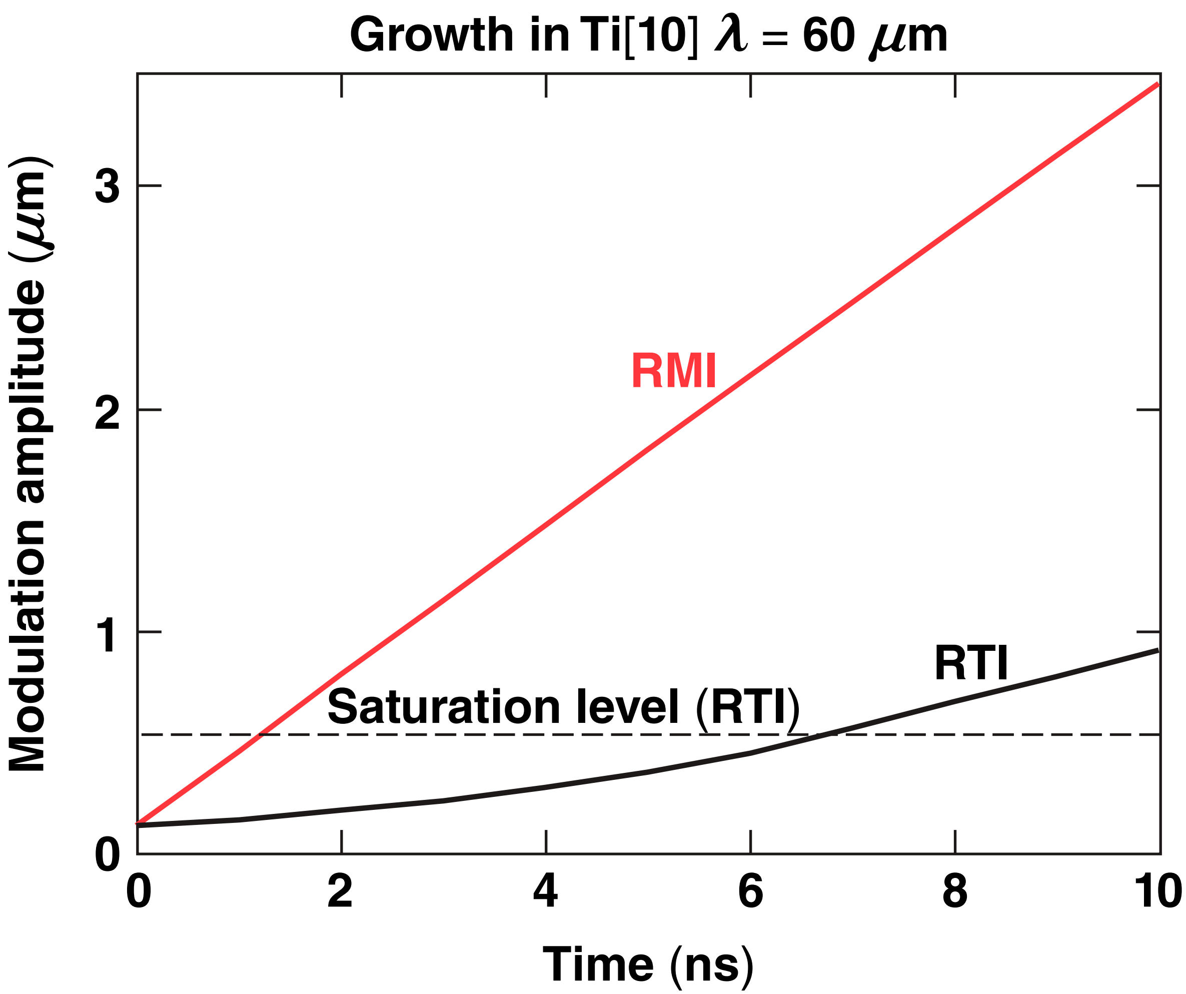

Conditions from *LILAC* simulation	
Variable	Value
a_0	0.125 μm
λ	60 μm
g	3.6 μm/ns^2
A	0.35
ΔU	36.9 μs/ns

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Summary/Conclusions

The first RTI and RMI planar experiments on OMEGA EP were useful tools in planning for future OMEGA EP experiments

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- An unmodulated CH[125] foil was driven with a single OMEGA EP beam at an intensity of 2×10^{14} W/cm^2 for 2.5 ns and backlit with an Sc[12.5] foil.
- System and diagnostic issues hindered the experiment, but useful results were still obtained.
- Modulations imprinted by the OMEGA EP beams grew significantly in the Sc[12.5] backlighter.
- Future experiments on OMEGA EP will require beam smoothing, longer pulse lengths, and higher beam energies.