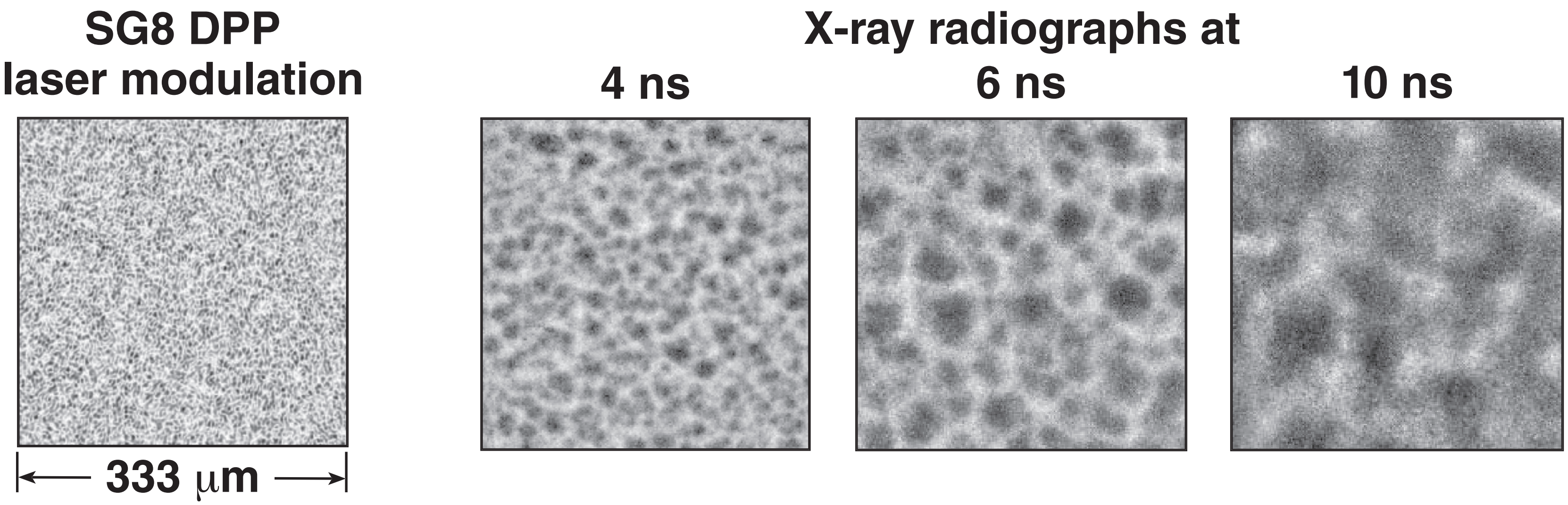
Measurements of Nonlinear Rayleigh–Taylor Growth on OMEGA



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Contributors

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Summary

The growth of 3-D broadband modulations has been measured in the nonlinear stage of the Rayleigh–Taylor instability

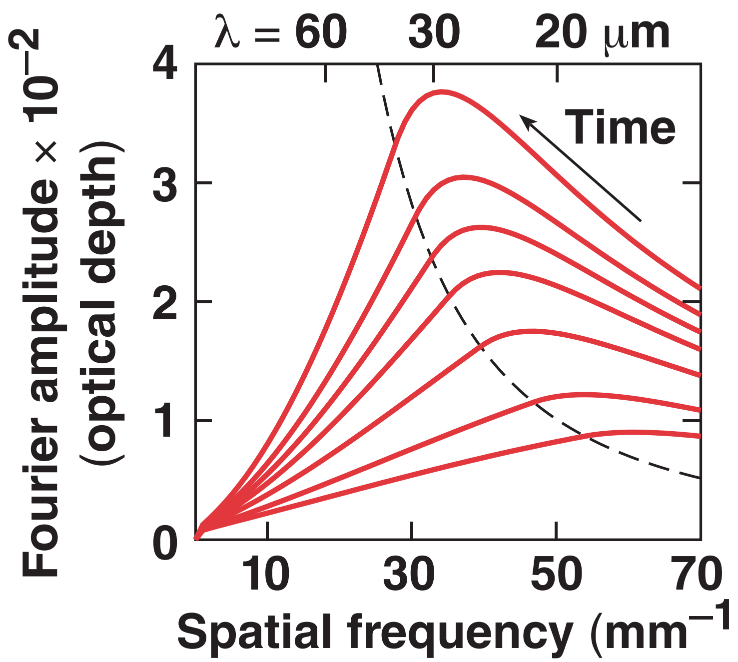
UR LLE

- In experiments the 20- and 50-μm-thick CH foils are driven by 12-ns pulses at 5×10^{13} W/cm^2.
- Nonlinear velocities are consistent with Haan model* predictions.
- Enhanced nonlinear coupling is consistent with J. Sanz *et al.*** predictions
- Nonlinear growth is insensitive to initial conditions.
- In real space, the bubble merger is quantified by the evolution of distributions of the bubble size and amplitude.

*S. Haan, Phys. Rev. A 39, 5812 (1989).
**J. Sanz *et al.*, Phys. Rev. Lett. 89, 195002 (2002).

In the Haan saturation model,* the Fourier amplitudes of broadband modulations saturate at $S_k = \frac{2}{Lk^2}$

- Fourier amplitudes grow exponentially up to the saturation levels $S_k = \frac{2}{Lk^2}$
- Subsequent growth is linear in time with velocities $V_s = S_k \times \gamma(k)$ ($\gamma(k)$ is the linear growth rate).
- The shape of the modulation spectrum is relatively insensitive to the initial modulation spectrum and to growth history (growth rates).



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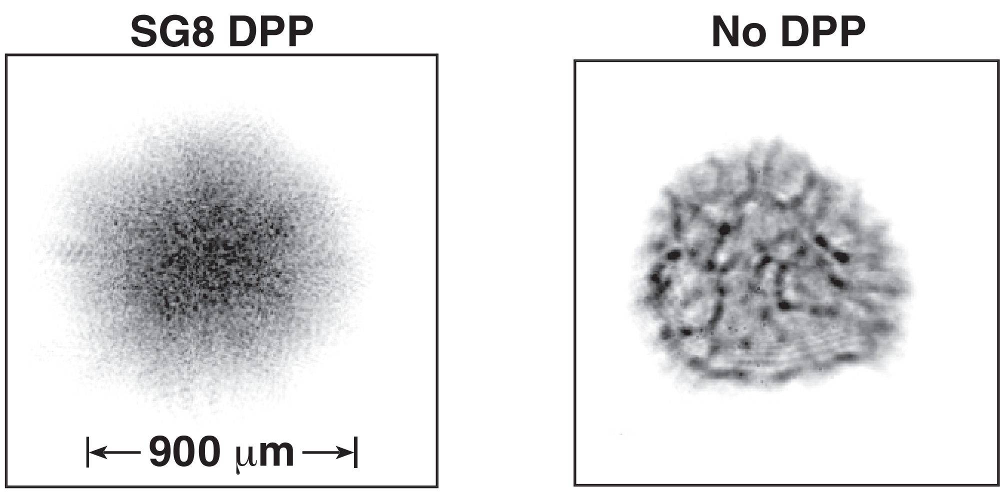
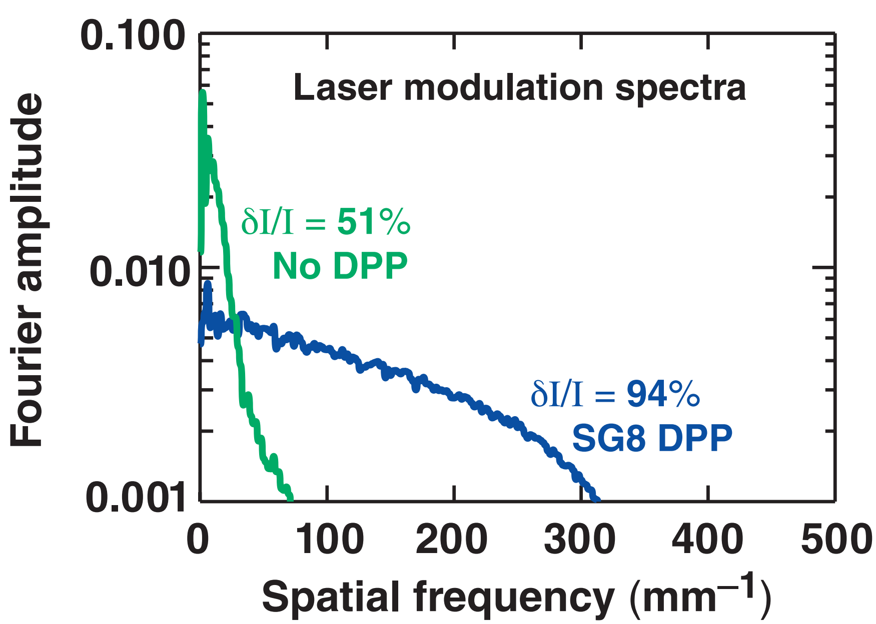
*S. Haan, Phys. Rev. A 39, 5812 (1989).

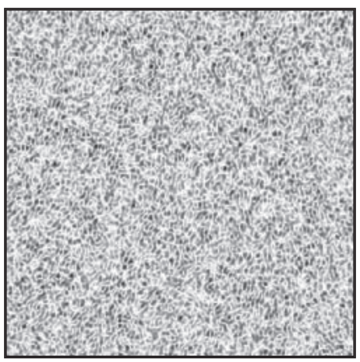
Initial seeds for the Rayleigh–Taylor instability were produced by laser imprinting





Broadband modulations become larger as they grow in a nonlinear regime of Rayleigh–Taylor instability

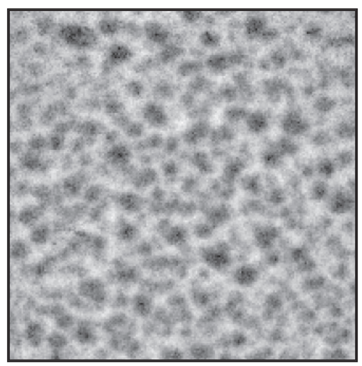
SG8 DPP laser modulation



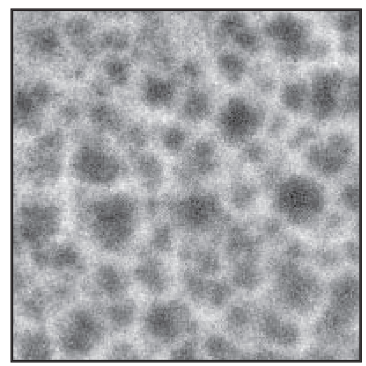
333 μm

X-ray radiographs at

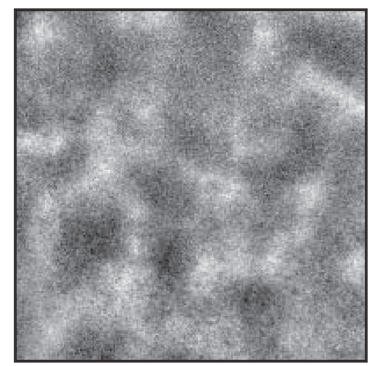
4 ns



6 ns



10 ns



- 50-μm-thick CH foils were driven with 12-ns-square laser pulses at 5×10^{13} W/cm^2

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Modulation spectra shift to longer wavelengths as they grow, similar to Haan model predictions

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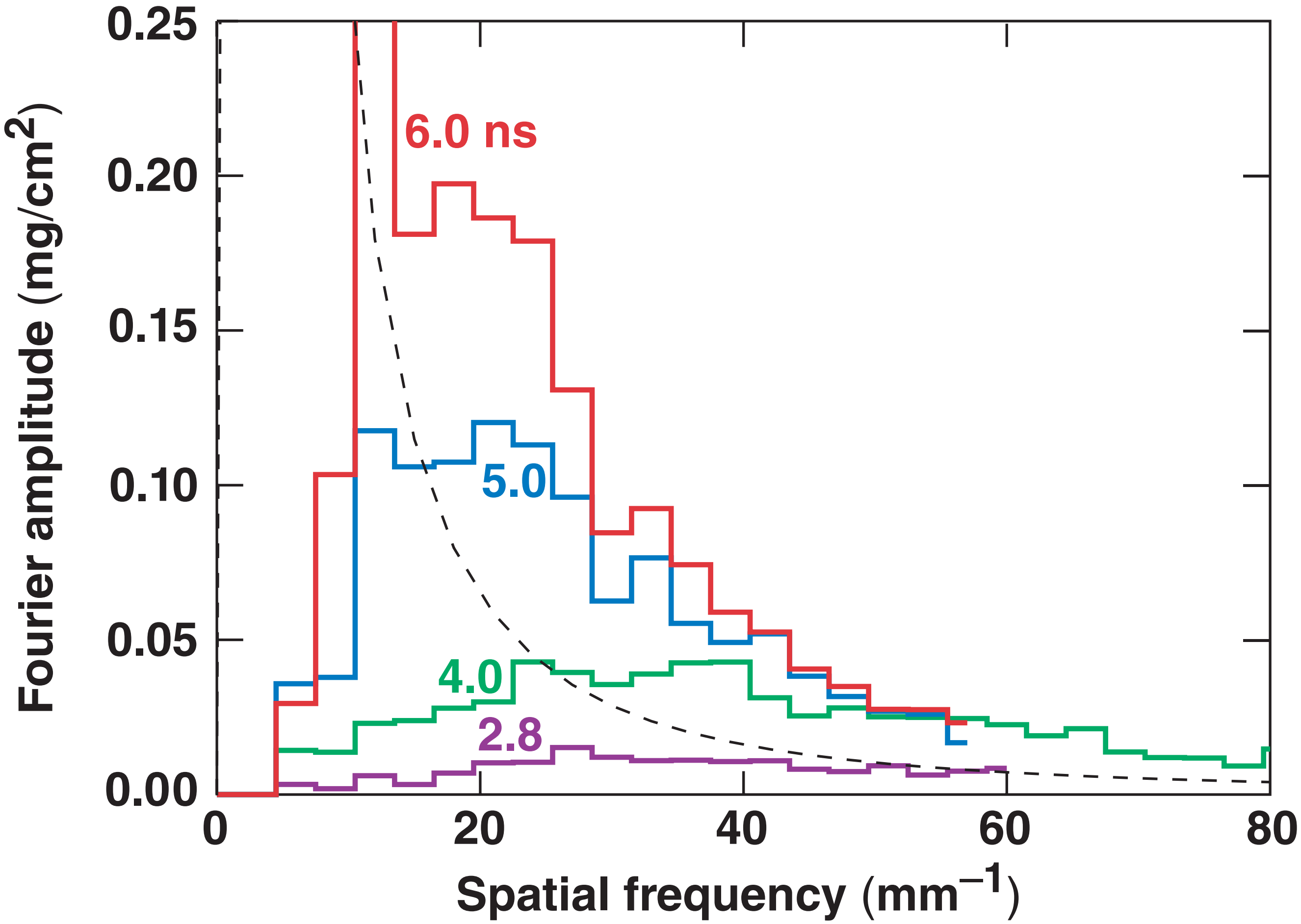

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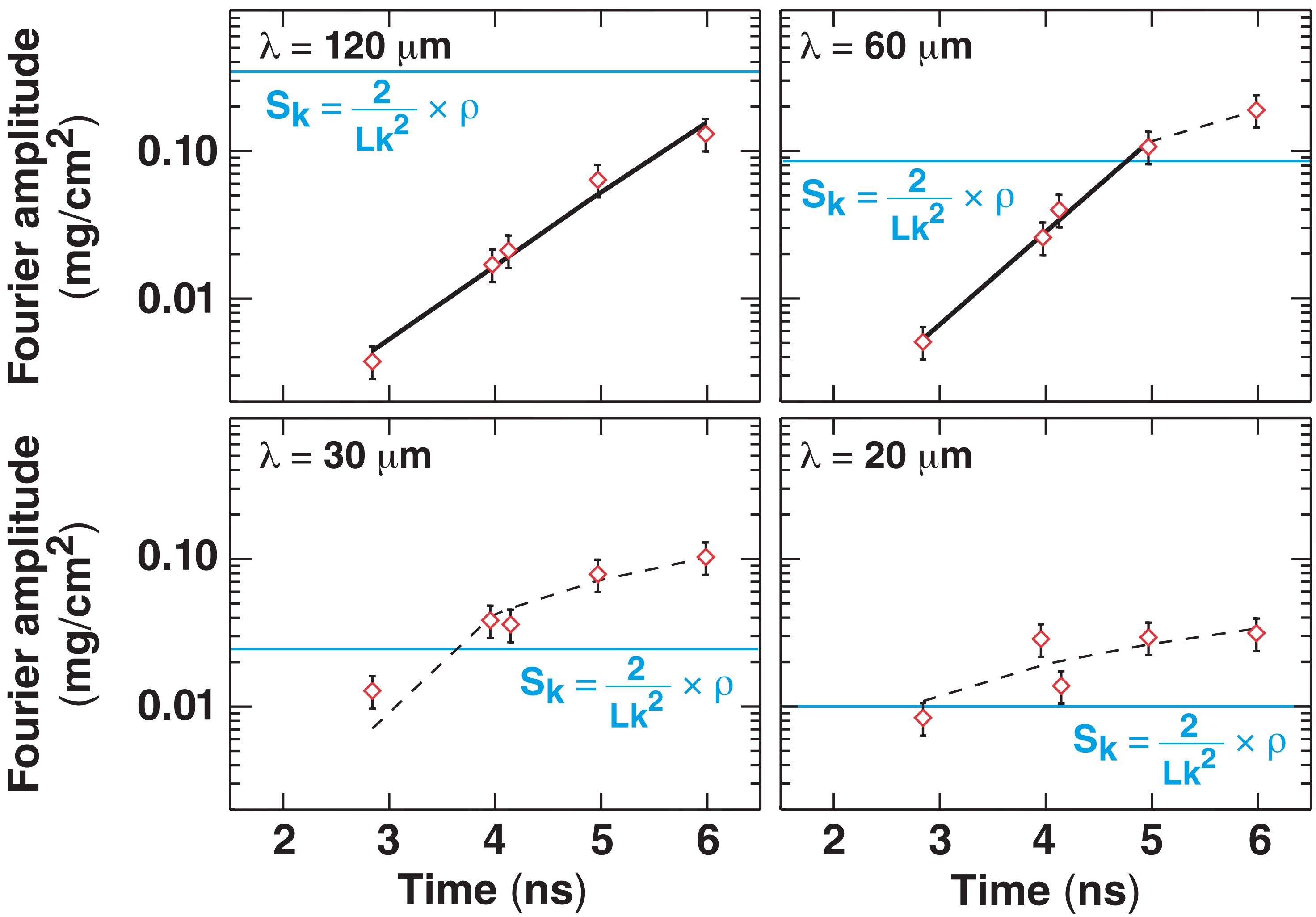
Nonlinear velocities and growth rates were determined by fitting the experimental data at various wavelengths



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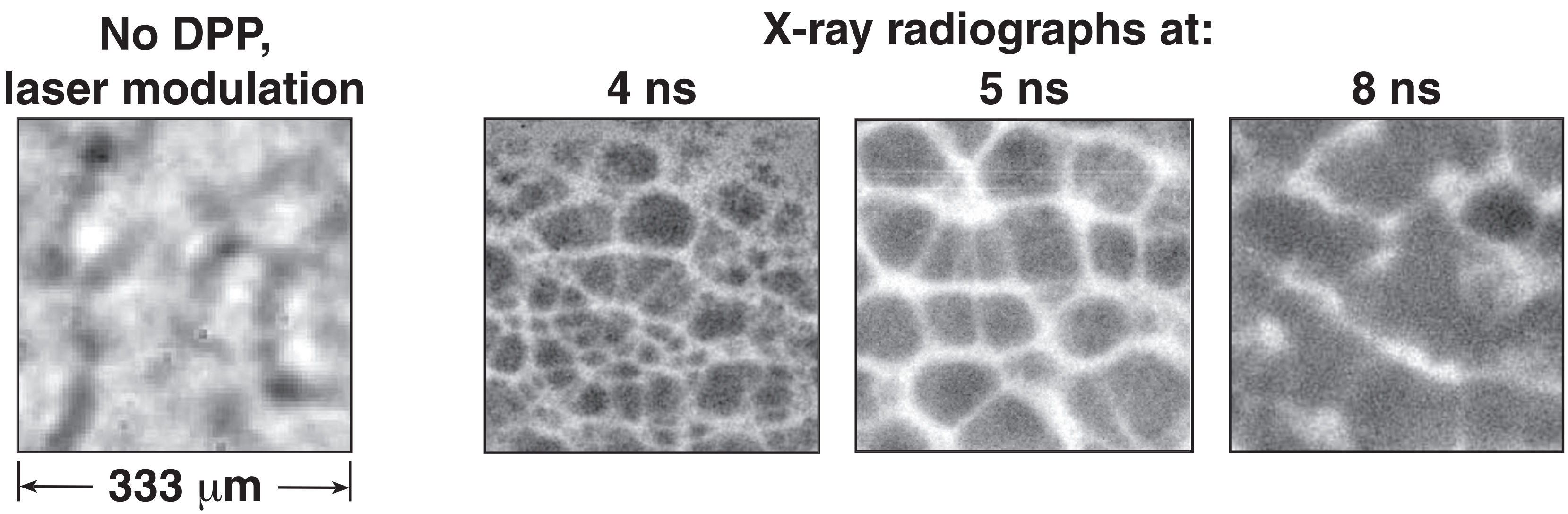
- Initial modulations were imprinted using a beam with SG8 DPP.

Wormlike structures of the laser beam without DPP evolve into bubble–spike modulations in nonlinear Rayleigh–Taylor instability



- 50-μm thick CH foils were driven with 12-ns-square laser pulses at 5×10^{13} W/cm^2

Measured nonlinear velocities are in good agreement with Haan model predictions

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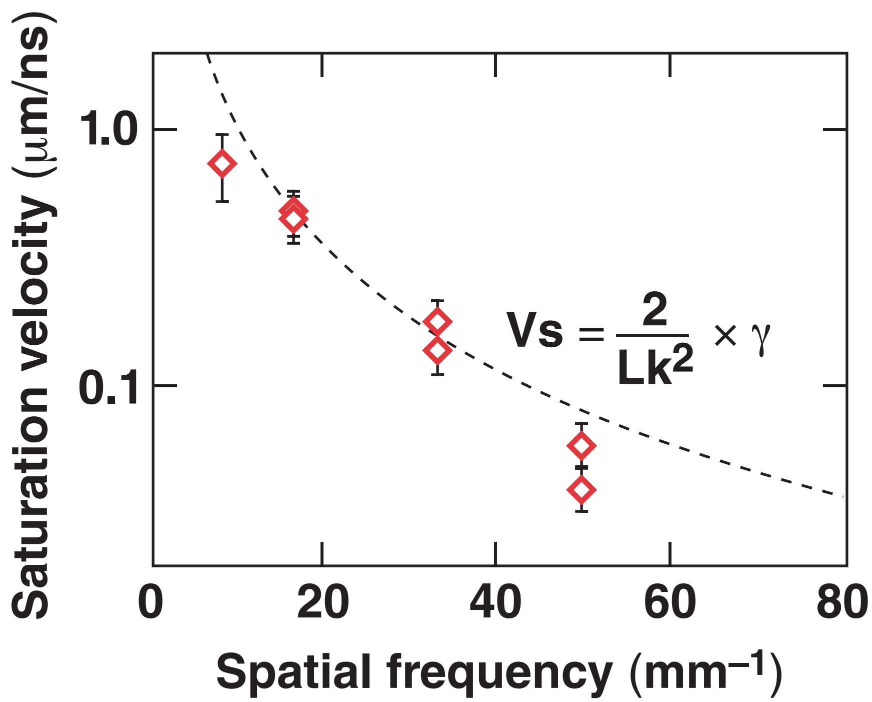

- Growth rate $\gamma = 0.94\sqrt{\frac{kg}{1 + kL_m}} - 1.5\,V_a\,k$, $g = 10$ μm/ns, $V_a = 0.65$ μm/ns, $L_m = 0.1$ μm, $\rho = 1.7$ g/cm^3
- 3-D broadband nonlinear velocity $Vs = 2/Lk^2 \times \gamma$

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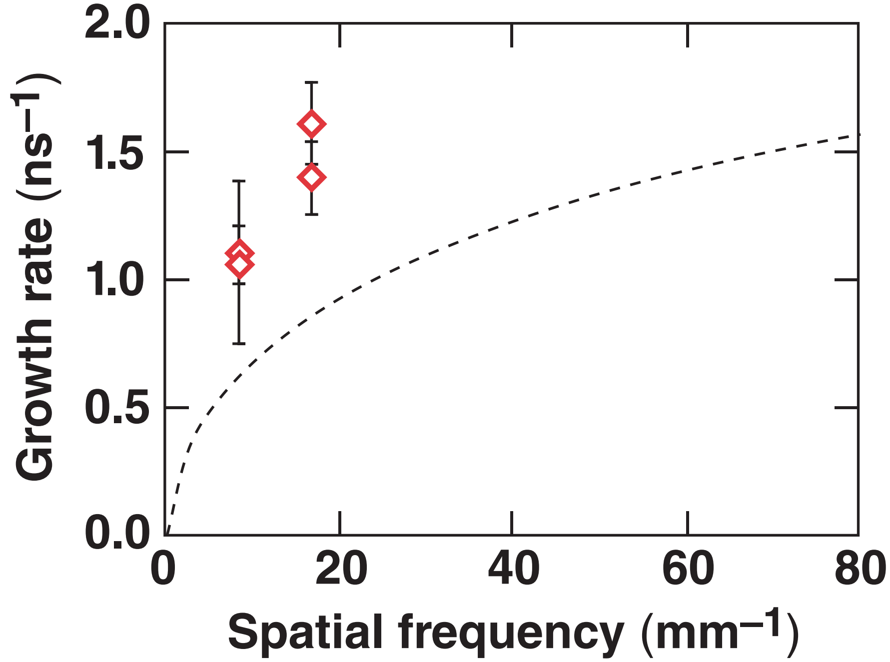
Measured growth rates of longer modes are consistent with enhanced nonlinear mode coupling



- Growth rate $\gamma = 0.94 \sqrt{\frac{kg}{1 + kL_m}} - 1.5\, V_a\, k$
- S. W. Haan* and D. Ofer *et al.*** predict no significant mode coupling in the ablative case.
- J. Sanz *et al.*† predict enhanced mode coupling in the ablative case compared to the classical case.

*S. W. Haan, Phys. Fluids B 3, 2349 (1991). **D. Ofer *et al.*, Phys. Plasmas 3, 3073 (1996).
†J. Sanz *et al.*, Phys. Rev. Lett. 89, 195002 (2002).

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In the self-similar regimes, both the average bubble size and rms amplitude grow linearly with the distance traveled

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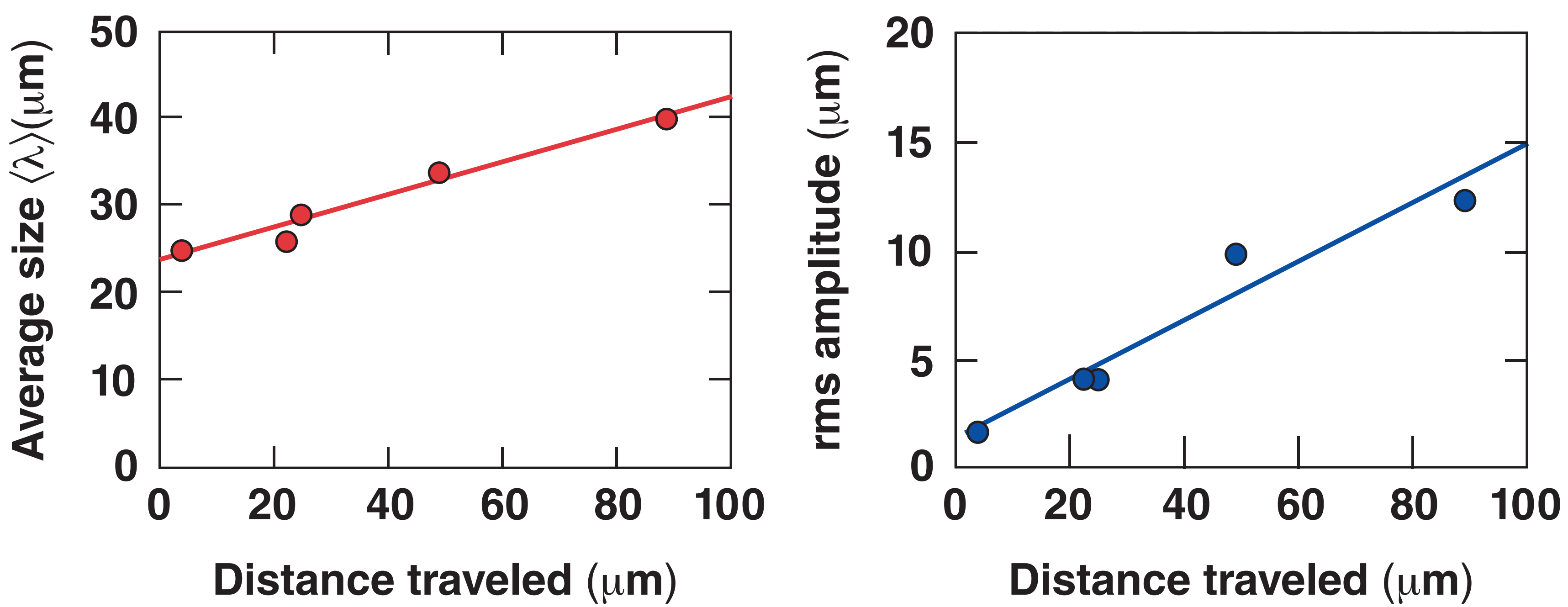
Real Space Analysis



- Linear growth was predicted in self-similar regimes.

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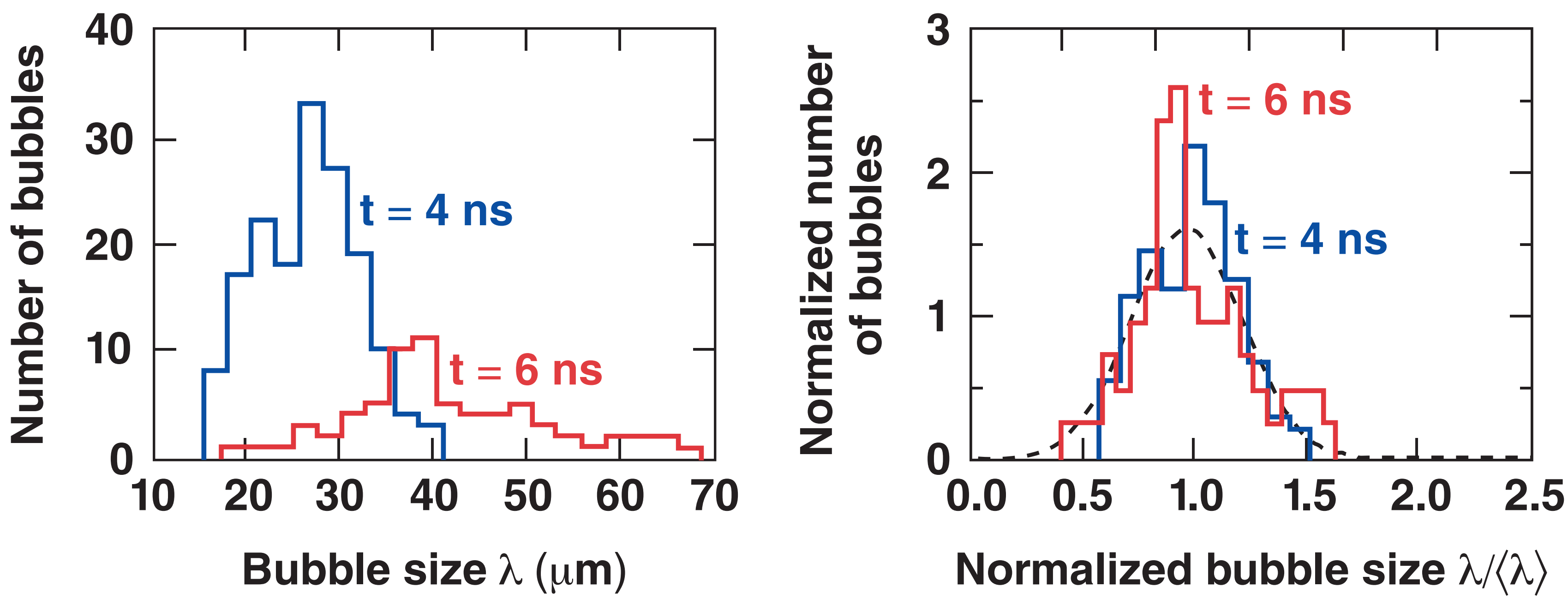
The normalized bubble size distribution does not change when bubbles grow in a self-similar regime



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The normalized bubble amplitude distribution does not change in a self-similar regime

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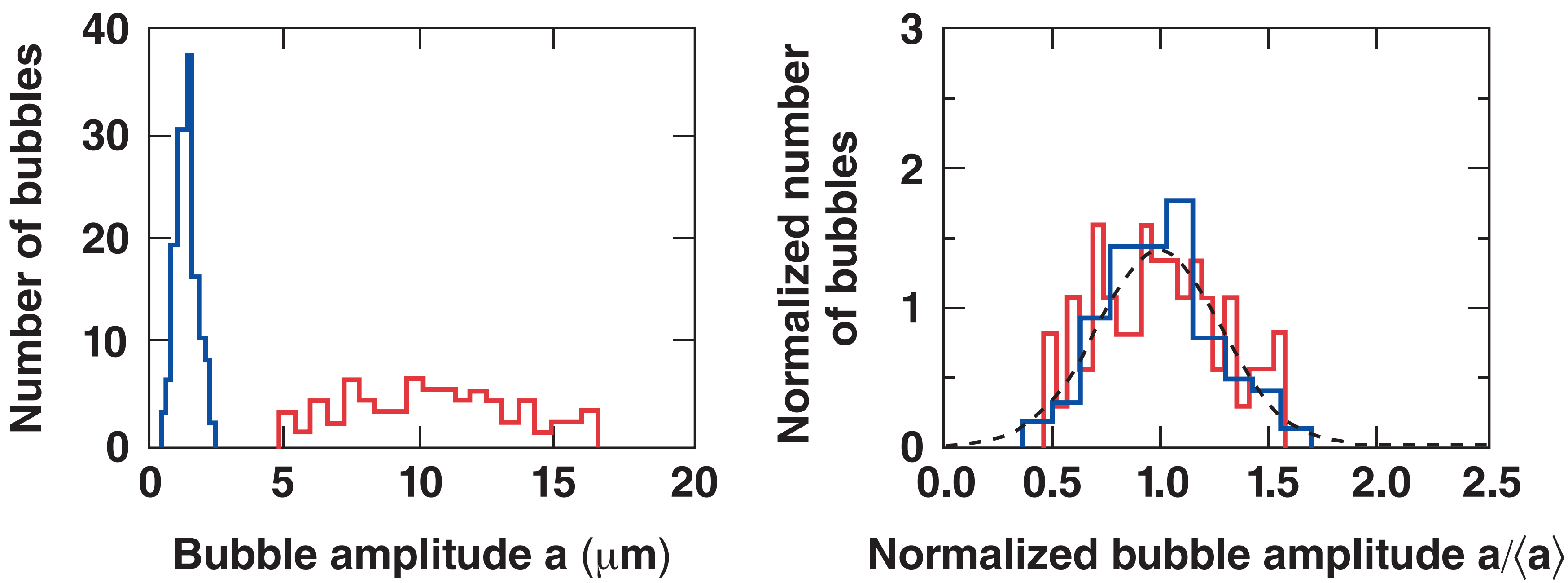

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Summary/Conclusions

The growth of 3-D broadband modulations has been measured in the nonlinear stage of the Rayleigh–Taylor instability

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