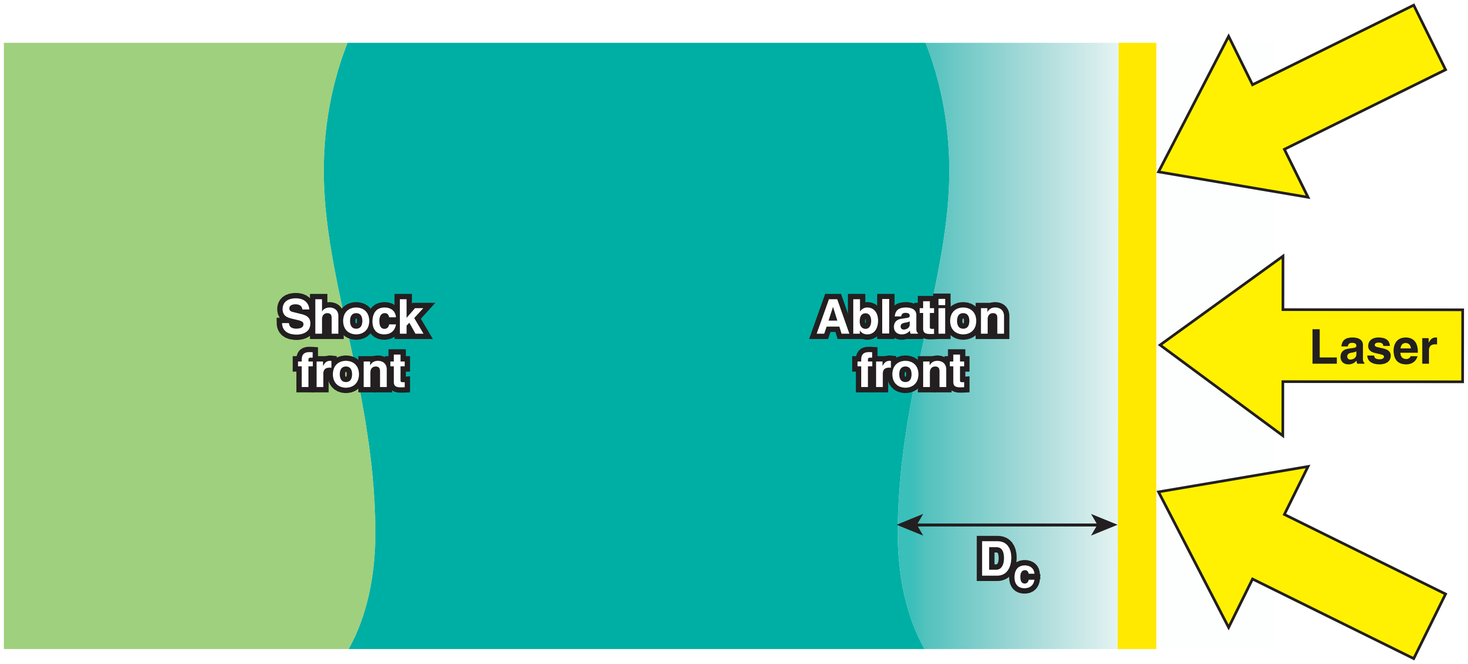
Ablative Richtmyer–Meshkov Instability as a Test of Thermal Conduction Models Used in Hydrosimulations of ICF Experiments



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Absorption Conference
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Summary

Ablative Ritchmyer–Meshkov (RM) evolution is sensitive to coronal conditions

- In the presence of mass ablation, the RM evolution depends on the size of conduction zone D_c
  - $kD_c \ll 1$, ablation front is unstable (Landau-Darrieus instability)
  - $kD_c > 1$, ablation front is stable, perturbations oscillate* with $\omega = k\sqrt{V_a V_{bl}}$
- V_{bl} and D_c depend on the thermal transport models
- Shock velocity and RM measurements are consistent with nonlocal and time-dependent flux-limiter models

RM evolution is a good test of hydrocodes

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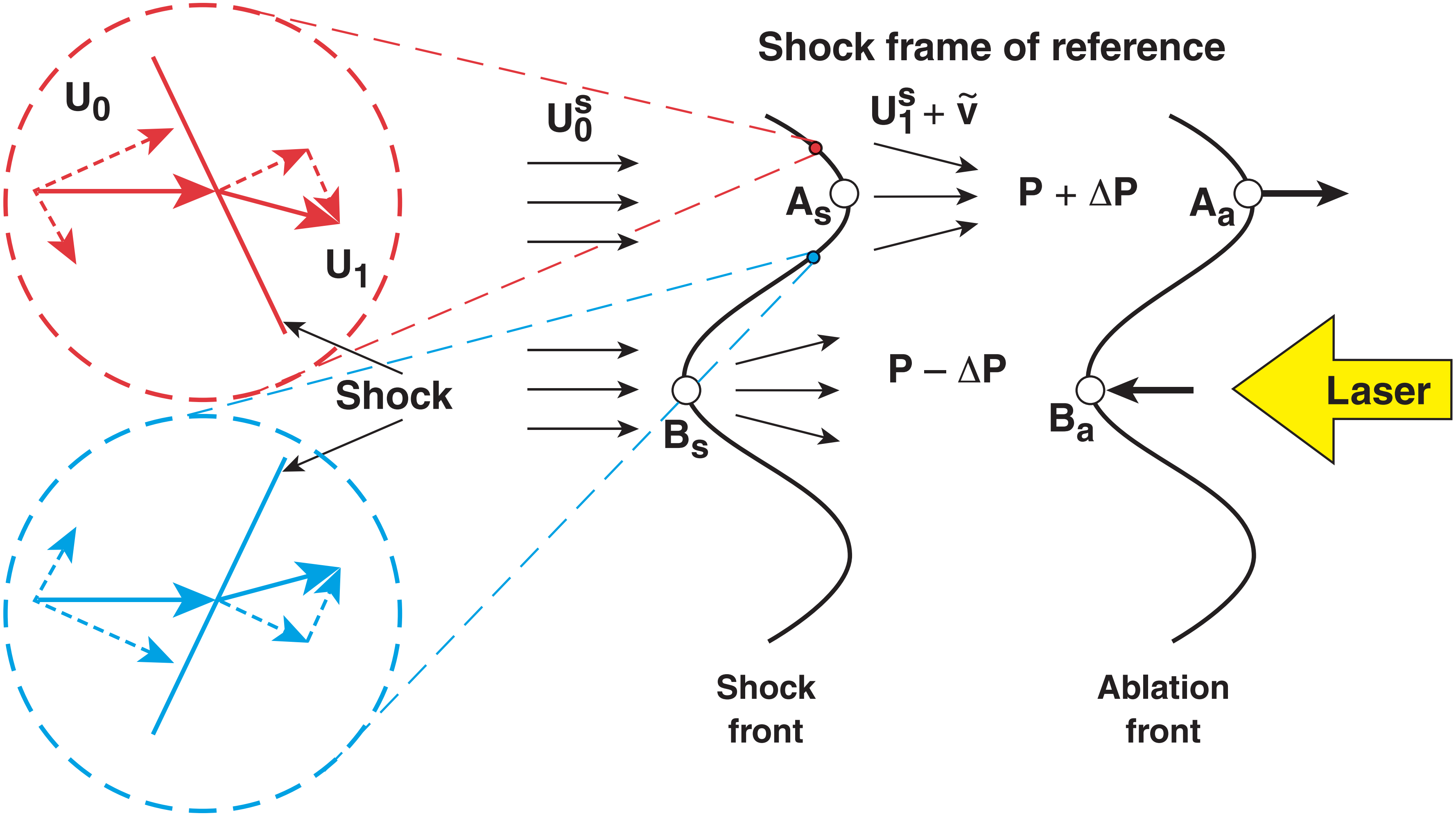
*A. L. Velikovich *et al.*, Phys. Plasmas 5, 1491 (1998); V. N. Goncharov, Phys. Rev. Lett. 82, 2091 (1999); Y. Aglitskiy *et al.*, Phys. Rev. Lett. 87, 265001 (2001).

During the shock propagation, conditions arise for Richtmyer–Meshkov-like instability



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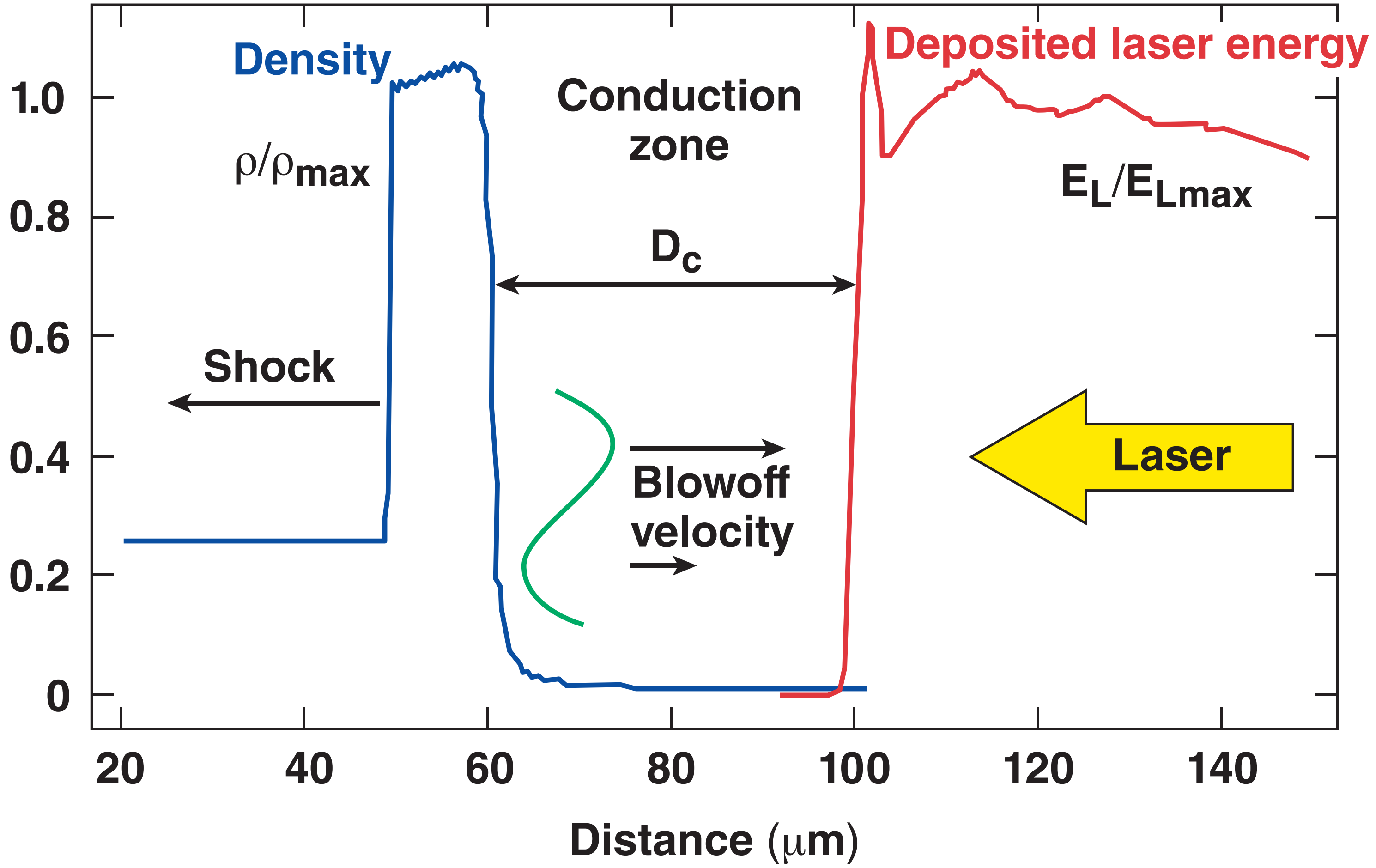
The sharp-boundary model* assumes that perturbation is localized inside the conduction zone



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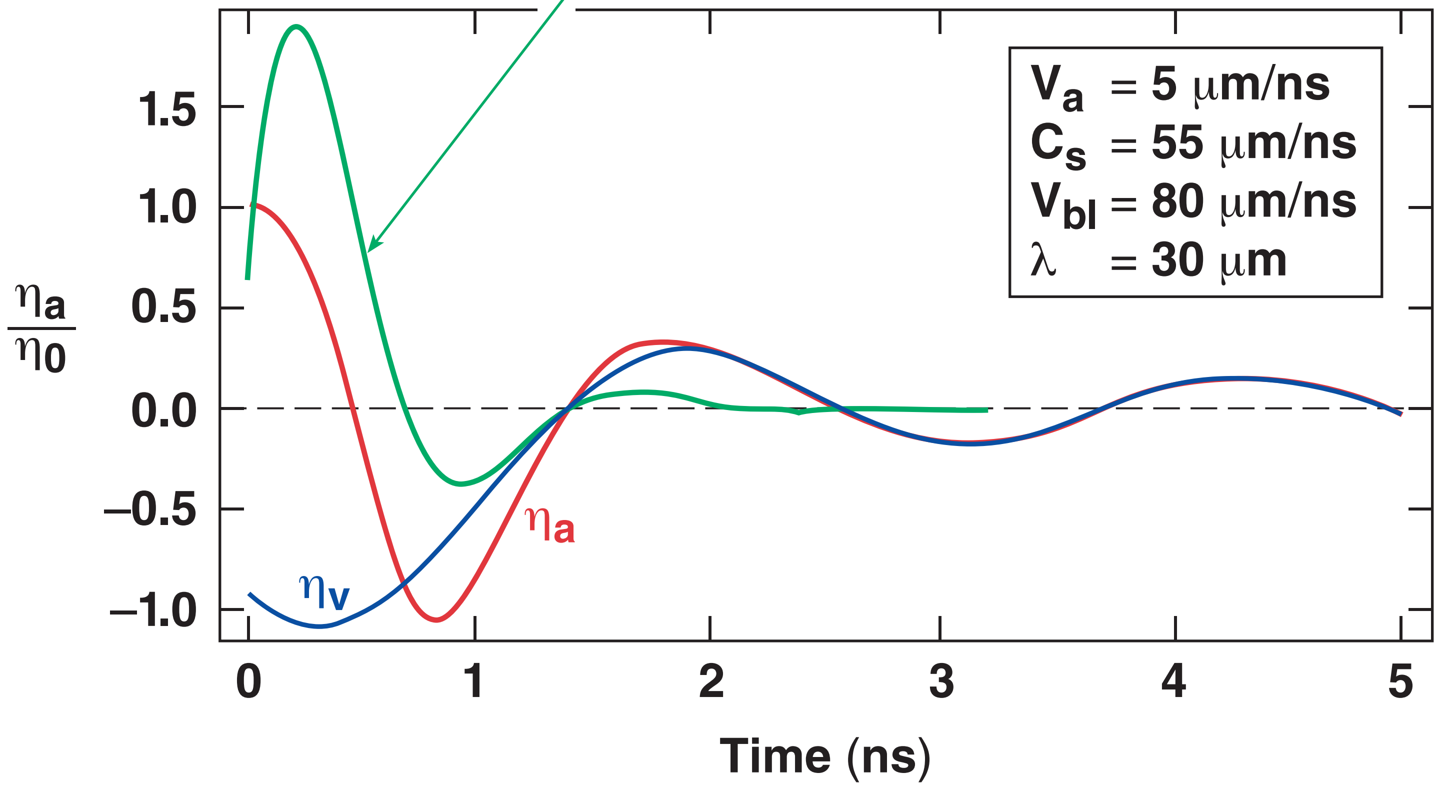
*V. N. Goncharov, Phys. Rev. Lett. 82, 2091 (1999).

Ablation-front perturbations asymptotically oscillate in time

$$\boxed{\eta_a} = \eta^{cl}(t) - \eta^{cl}_{\infty}(t) + \boxed{e^{-2kV_a t}(\alpha \cos \omega t + \beta \sin \omega t)} + \boxed{\eta_v(t)}$$

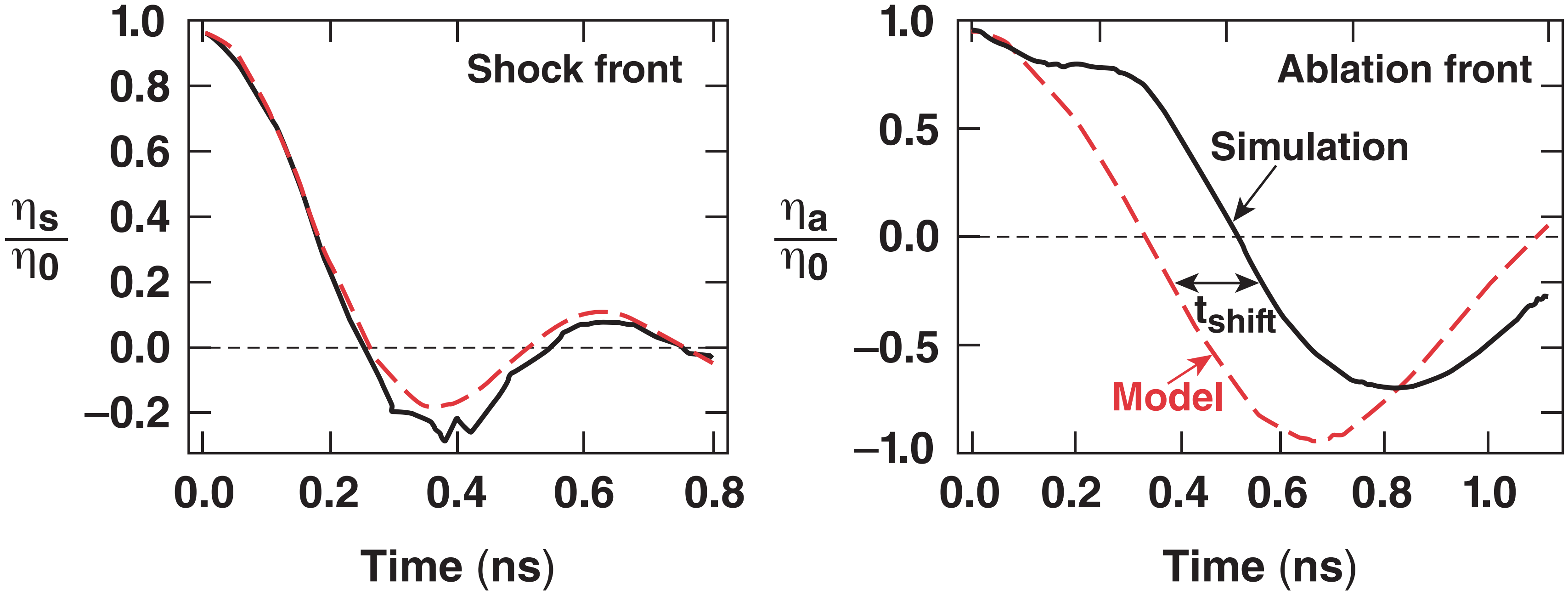
Vorticity set by shock



$$\boxed{\omega = k\sqrt{V_a V_{bl}}, \; V_{bl} \propto V(1/k)}$$

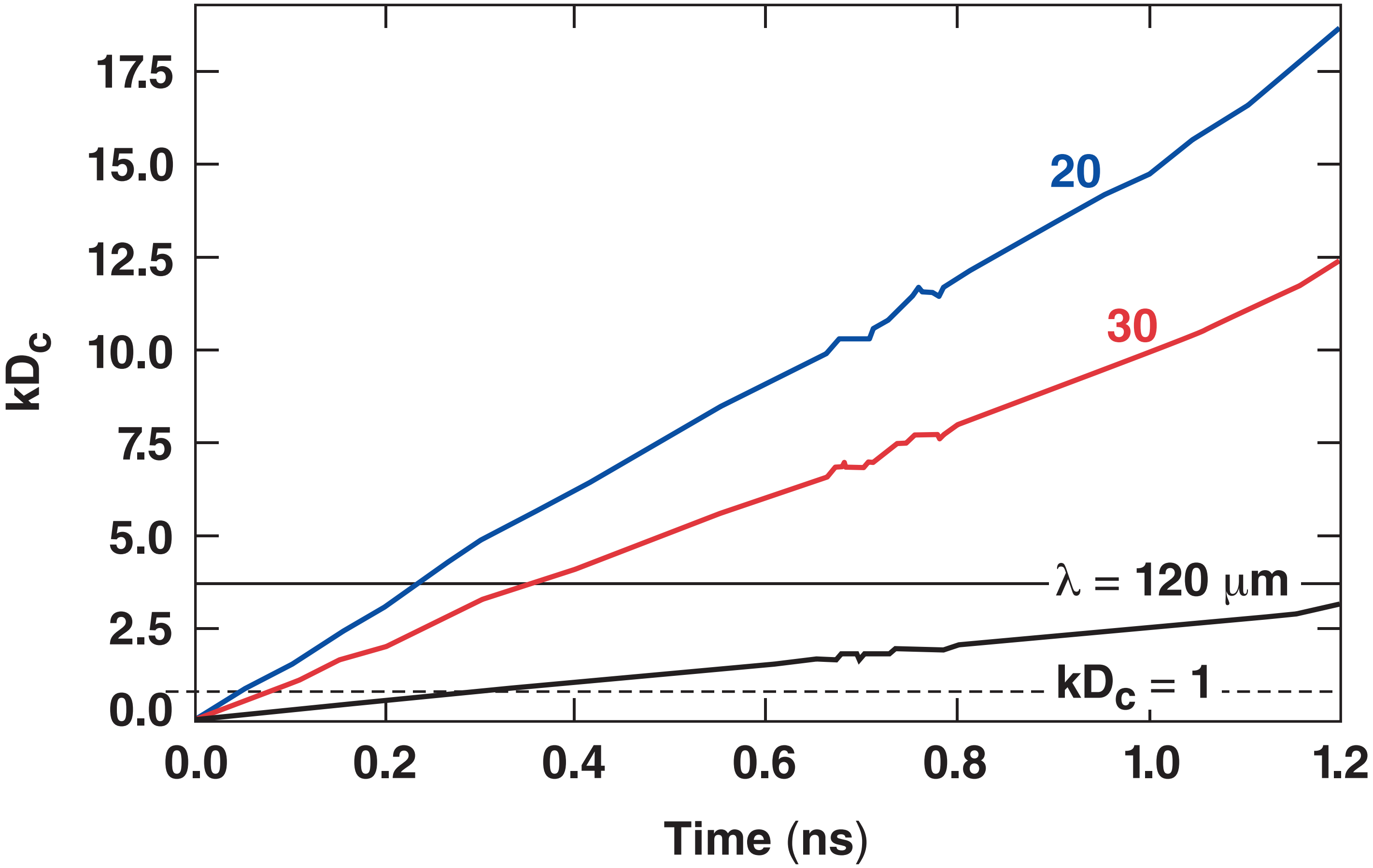
A detailed comparison between the model and simulation results shows a discrepancy at the beginning of the pulse

- DD foil, $I = 4 \times 10^{14}$ W/cm^2, $\lambda = 30$ μm



The discrepancy between model and simulation is due to a small conduction zone at the beginning of the pulse

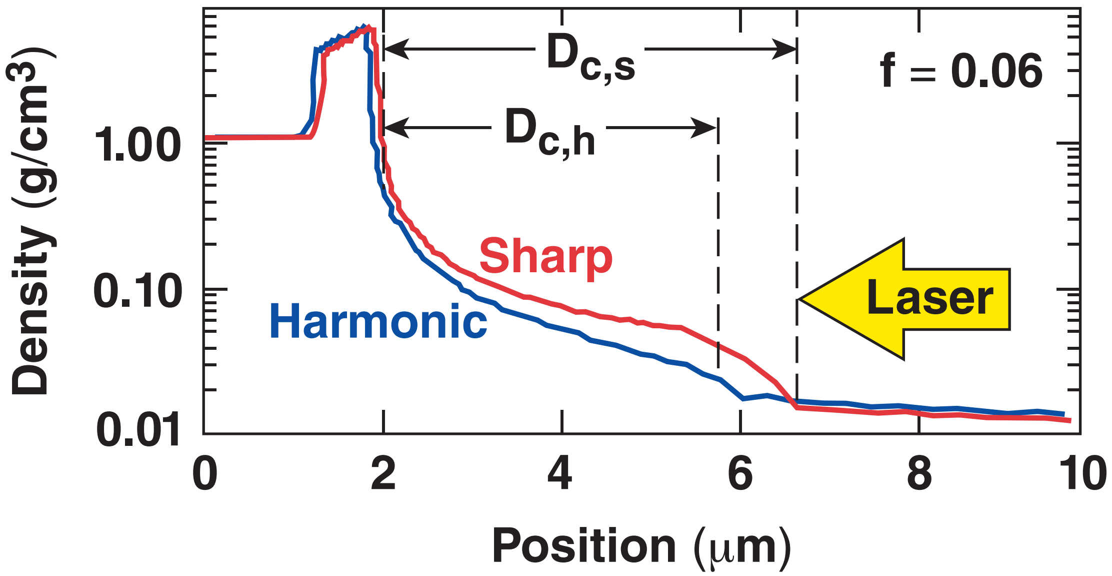
- DD foil, I = 4 × 10^{14} W/cm^2



The location of the phase reverse depends on the size of the conduction zone.

The size of the conduction zone depends on the thermal transport model

- Flux-limited thermal transport* has traditionally been used in hydrocodes
- $q_{SH} = -\kappa \nabla T \qquad q_{FS} = nTV_T$
- Sharp cutoff $\qquad q_{eff} = \min(q_{SH},\ fq_{FS})\ 0.04 < f < 0.1$
- Harmonic $\qquad q_{eff} = \dfrac{q_{SH}\, fq_{FS}}{q_{SH} + fq_{FS}}$



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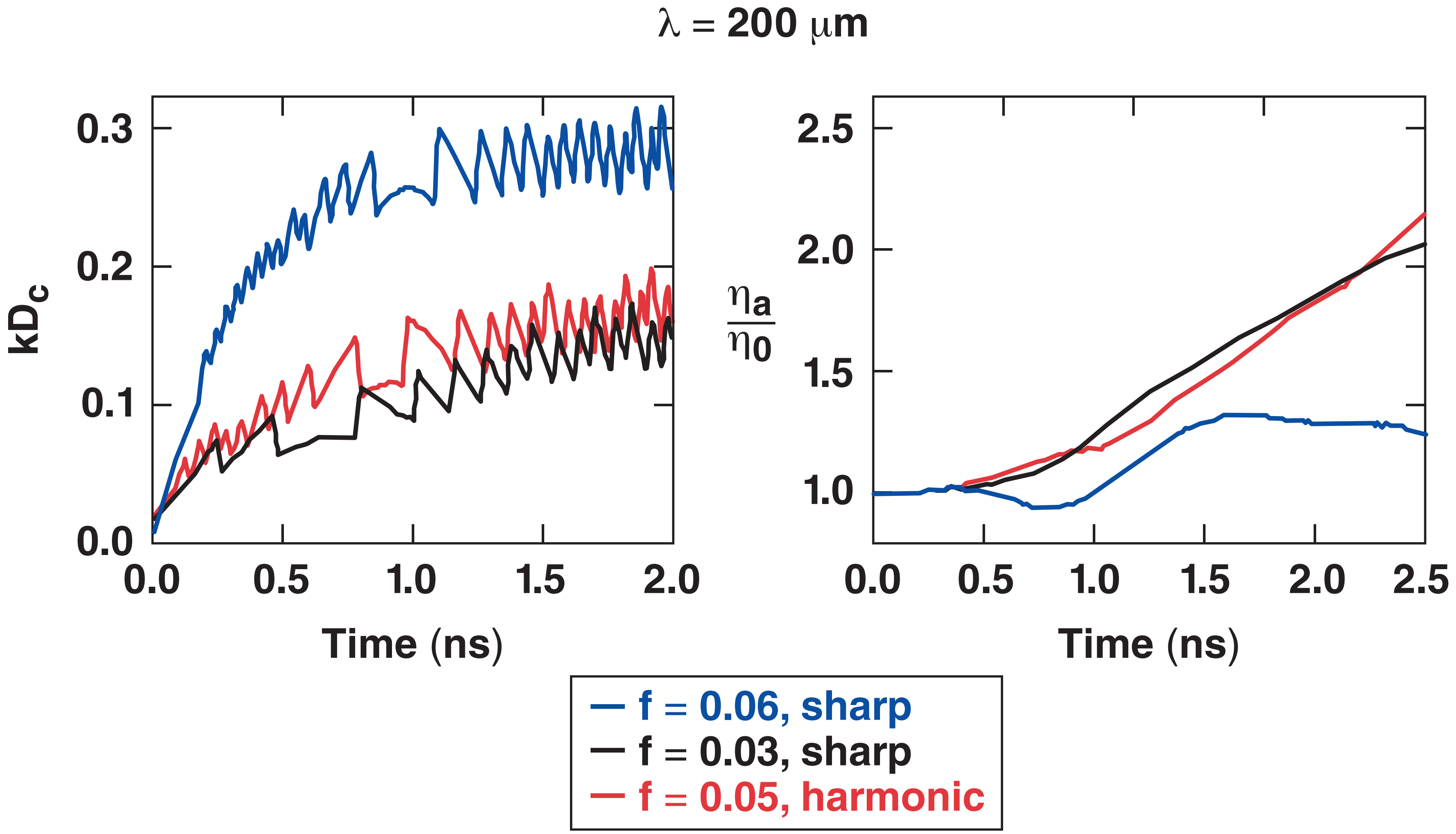
*R. C. Malone, R. L. McCrory, and R. L. Morse, Phys. Rev. Lett. 34, 721 (1975).

The ablation front is unstable in the case of a reduced conduction zone



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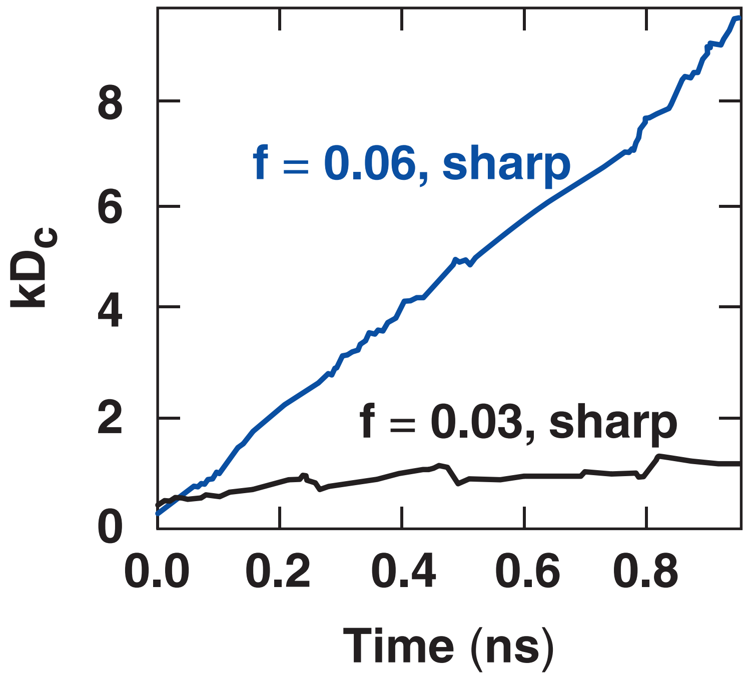
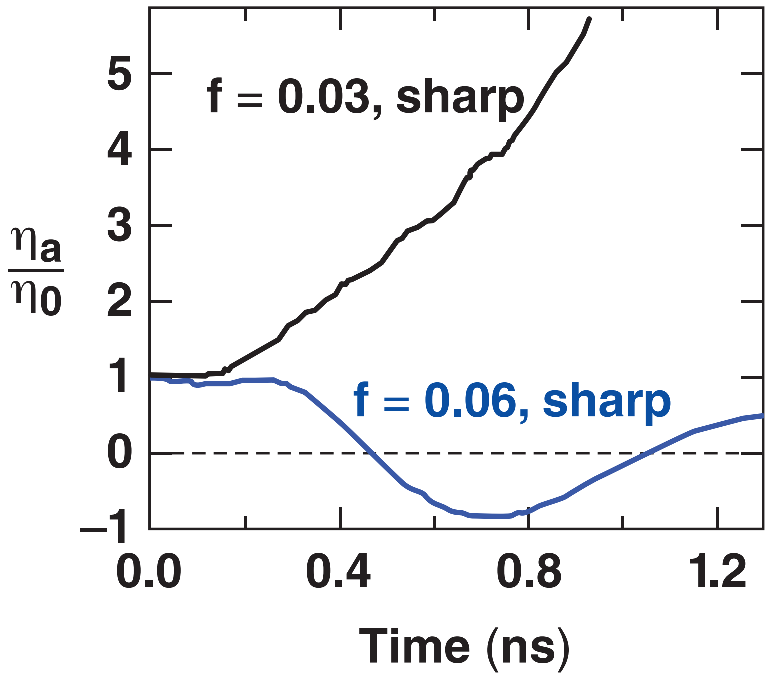
Shorter wavelengths are also sensitive to the transport model parameters

- DD foil, $I = 2 \times 10^{14}$ W/cm^2, $\lambda = 20$ μm





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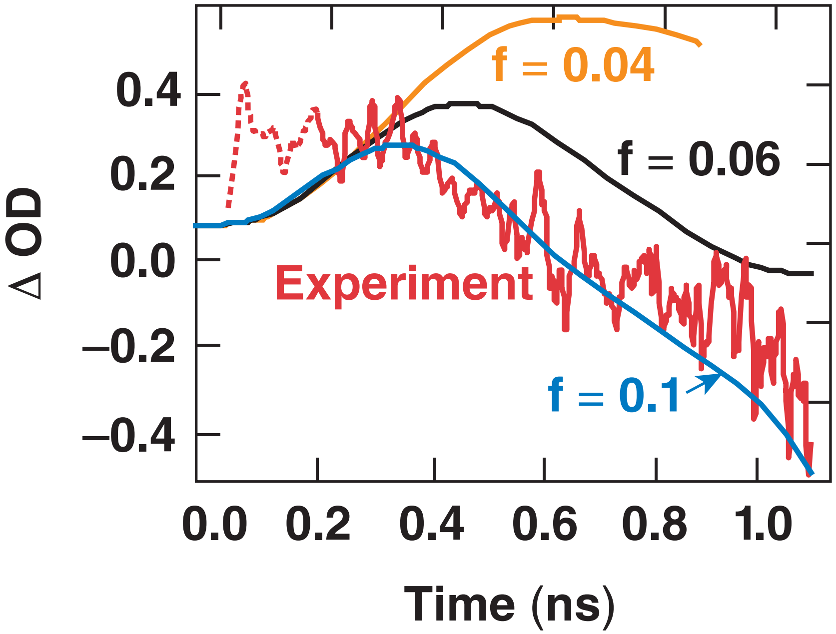
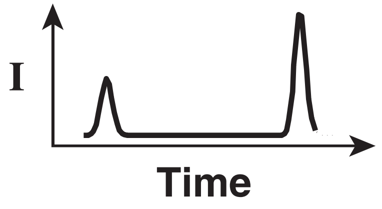
A single-valued flux limiter is not consistent with the experimental results

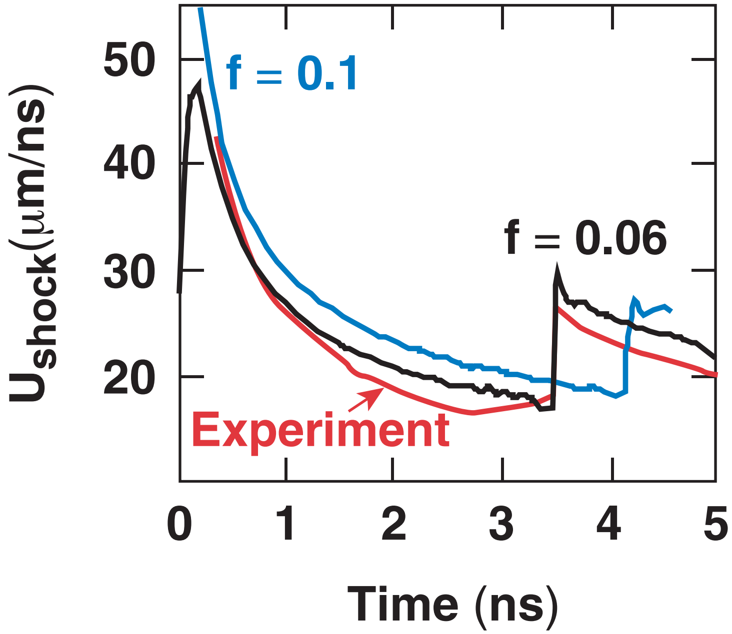
RM Experiment*

- 2-ns square pulse, $I = 4 \times 10^{14}$ W/cm^2
- CH foil d = 40 μm, λ = 20 μm



Dual Shock Timing**





* O. Gotchev, Ph.D. thesis, University of Rochester, 2004.

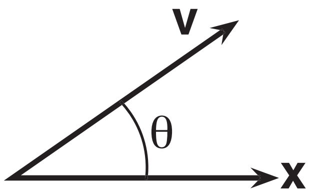
** E. Vianello *et al.*, Bull. Am. Phys. Soc 48, 205 (2003).

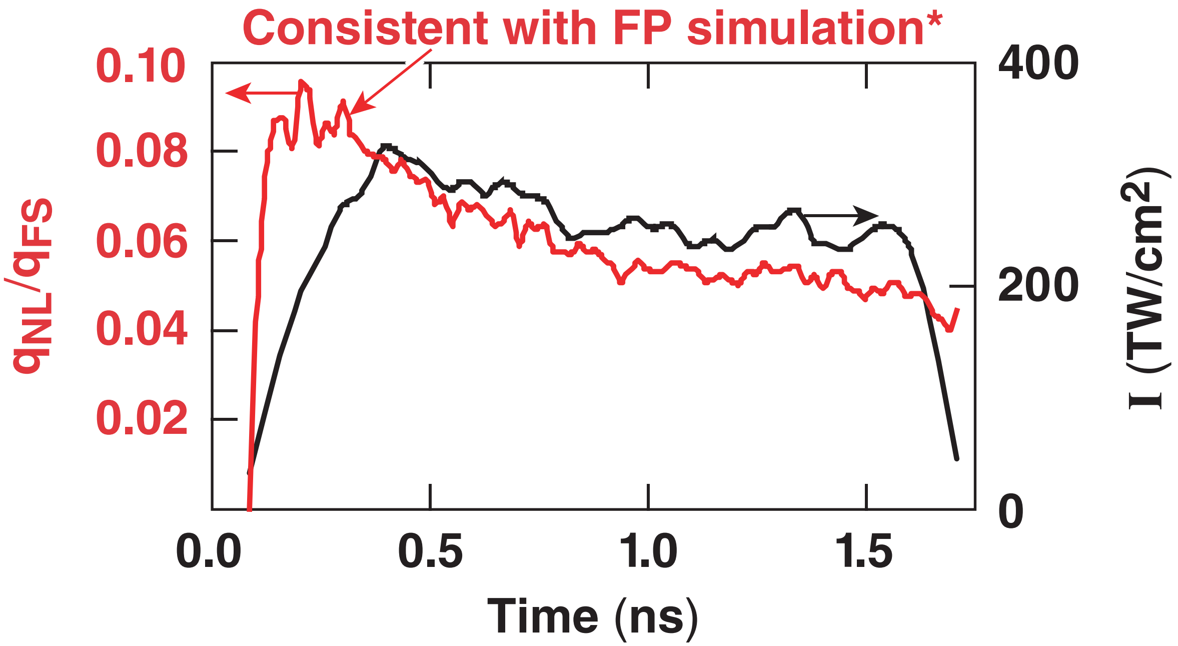
A nonlocal transport model has been developed to test the results of flux-limited approximation

- $$v\frac{\partial f}{\partial x} + \frac{e\overset{\text{Electric field}}{E}}{m}\frac{\partial f_0}{\partial v_x} = -\overset{\text{Collisional frequency}}{\nu}(f - f_0) \Rightarrow f = \int^{x}\left(f_0 - \frac{eE}{m\nu}\frac{\partial f_0}{\partial v_x}\right)e^{-\xi}\frac{dx'}{\lambda\cos\theta'},\quad \xi = \int_{x'}^{x}\frac{dx''}{\lambda\cos\theta}$$
- $$j_x = e\int d^3v v_x f,$$

  $$q_{NL} = \frac{m}{2}\int d^3v v^2 v_x f$$

  $$j_x = 0 \Rightarrow E$$




Consistent with FP simulation*

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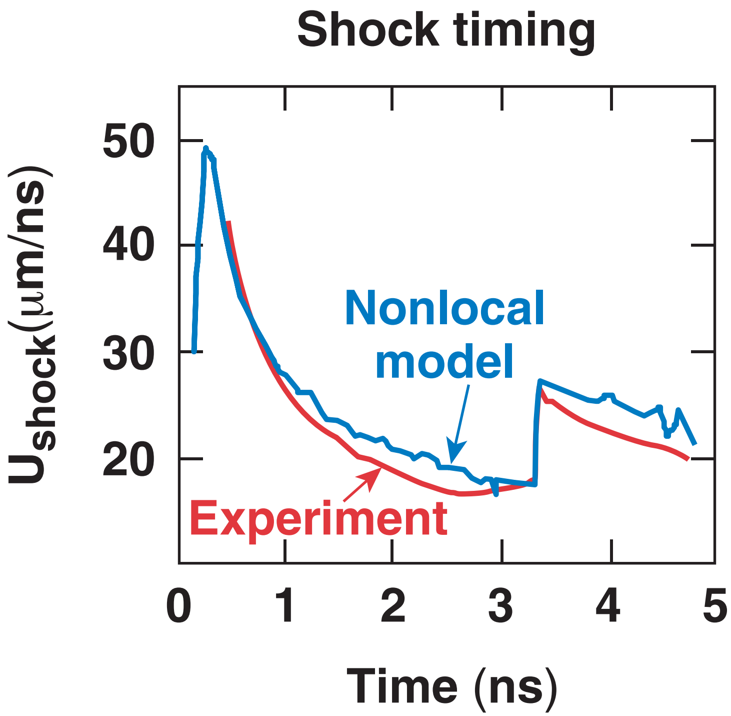
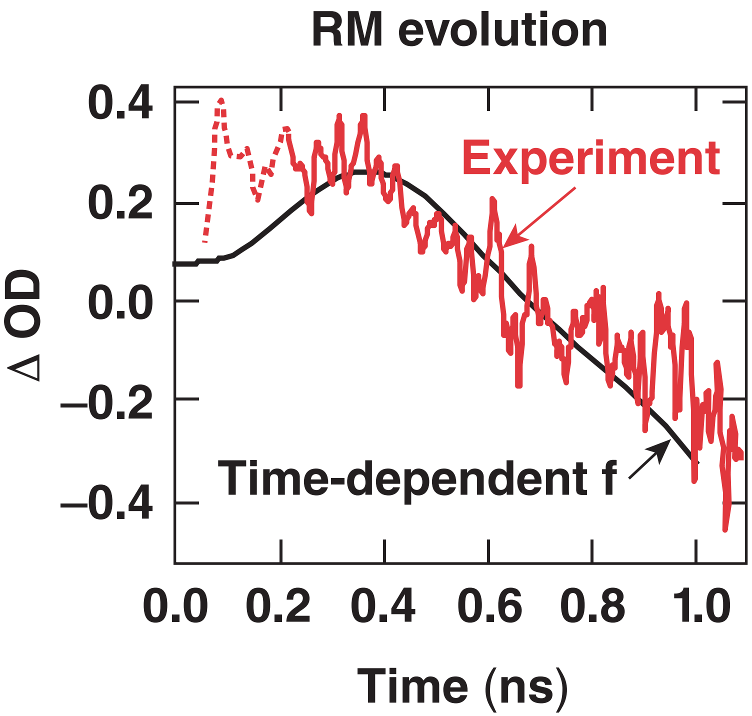
*A. Sunahara *et al.*, Phys. Rev. Lett. 91 095003 (2003).

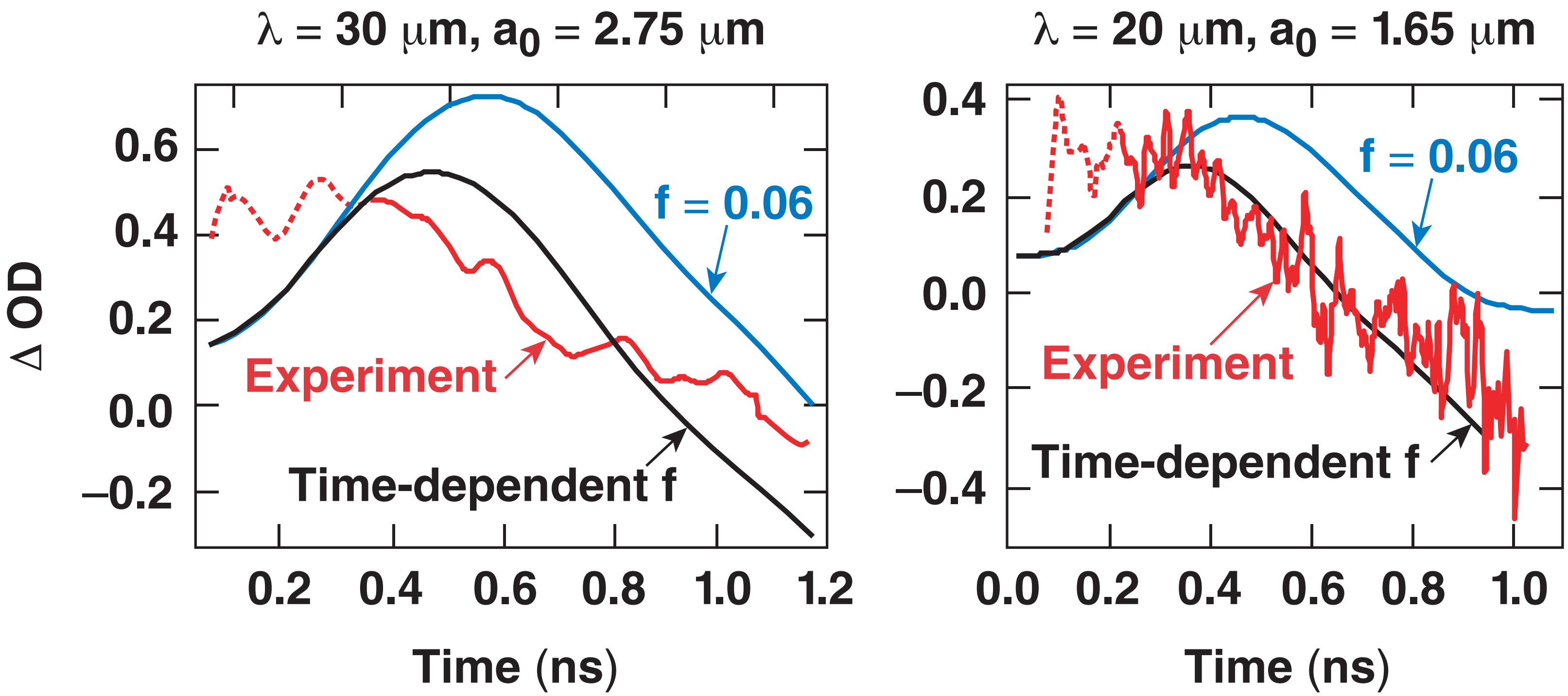
The nonlocal transport model is consistent with shock timing and RM growth measurements





Results of 2-D calculations with the time-dependent flux limiter are consistent with the RM growth measurements for different wavelengths

- 2-ns square pulse with peak intensity $I = 420\ \mathrm{TW/cm^2}$, $d_{CH} = 60 \mu m$
- Simulations use SESAME EOS and full 2-D raytracing



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Summary/Conclusions

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