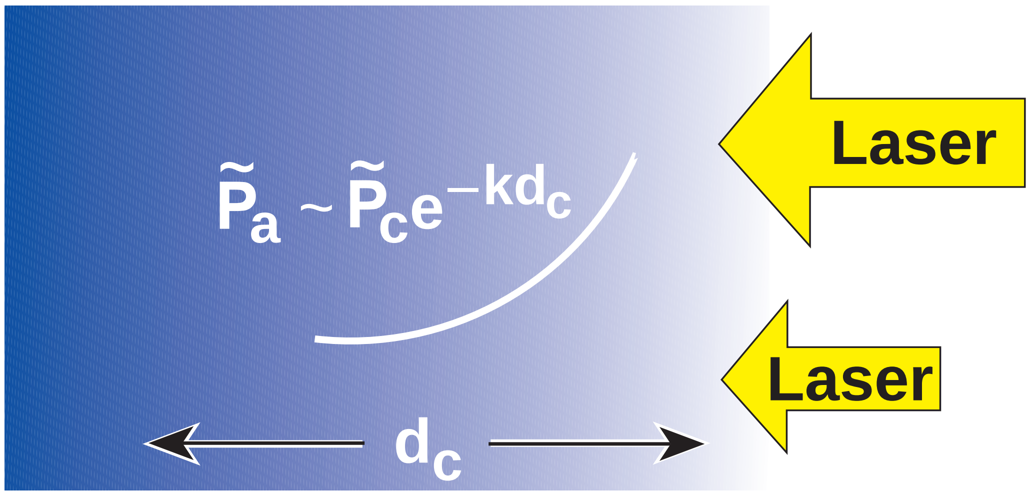
The Effect of Plasma-Formation Rate on Laser Imprinting



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Summary

Plasma-formation rate determines imprint levels and the effectiveness of beam-smoothing techniques

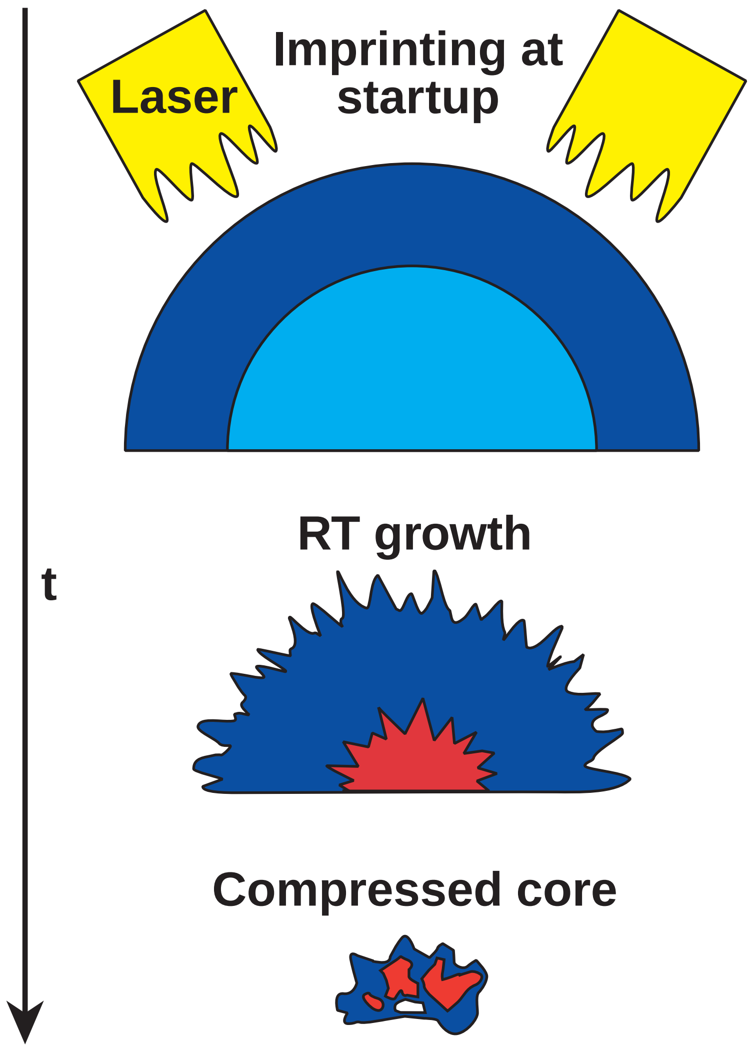
- Imprinting ends when sufficient smoothing exists to decouple laser nonuniformities and the unstable ablation surface.
- The laser pulse shape determines the rate at which this plasma is formed.
- Control perturbations are used to infer imprint levels:
  - *"equivalent surface finish"*
  - sensitive to drive nonuniformities
- Slowly rising pulses produce greater imprint than steeply rising pulses because plasma is formed more slowly.
- Results with 0.2- and 1-THz SSD confirm the effect of pulse shape on imprinting.

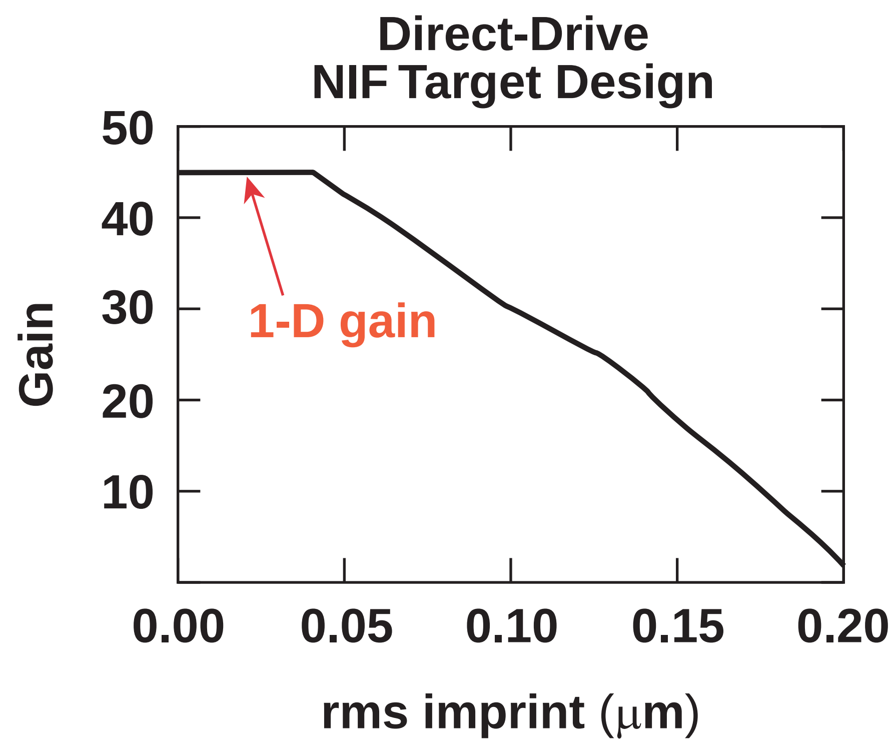
E10594

Outline

- Introduction: direct-drive ICF and imprinting
- Imprint measurements and *equivalent surface finish*
- Effect of pulse shape on imprinting
- Decoupling time
- Dynamic results (0.2- and 1-THz SSD)

Laser imprint degrades target performance





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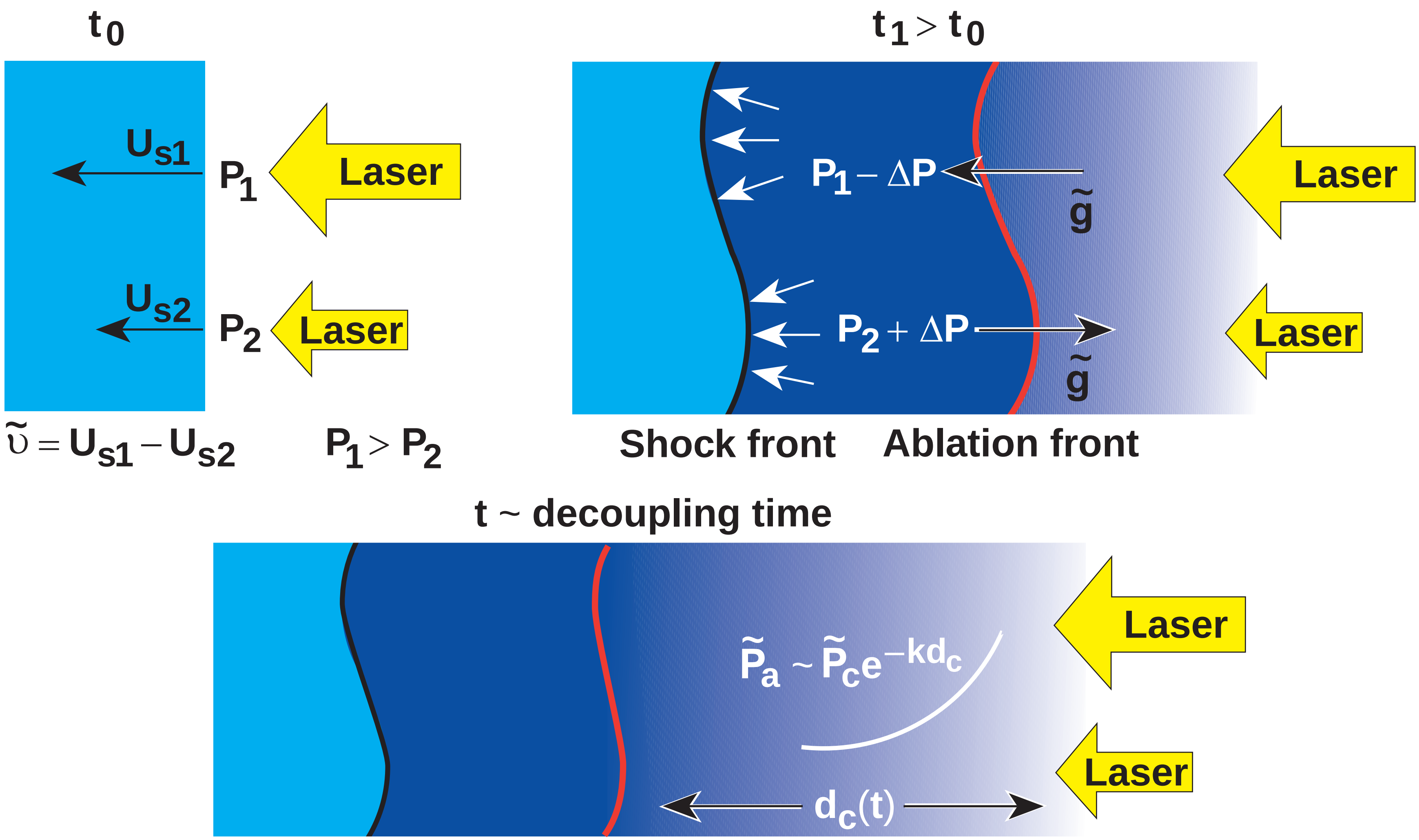
Pressure variations "imprint" the target with perturbations in velocity and acceleration



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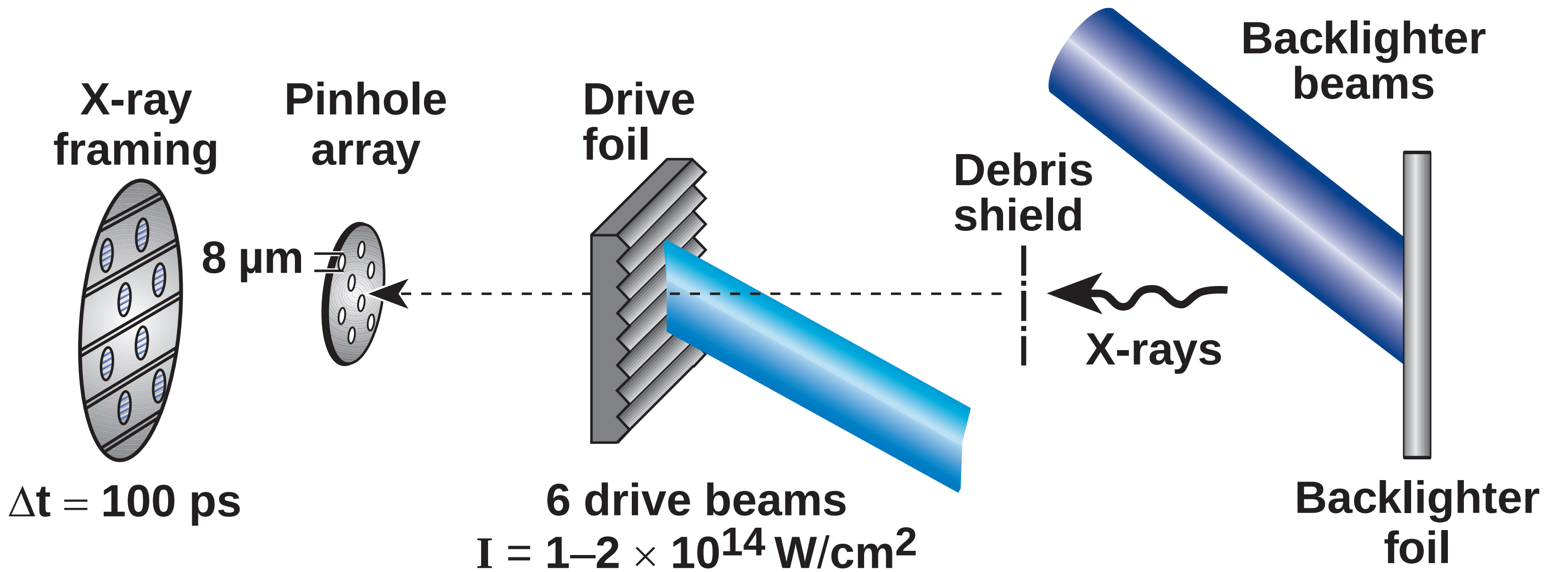
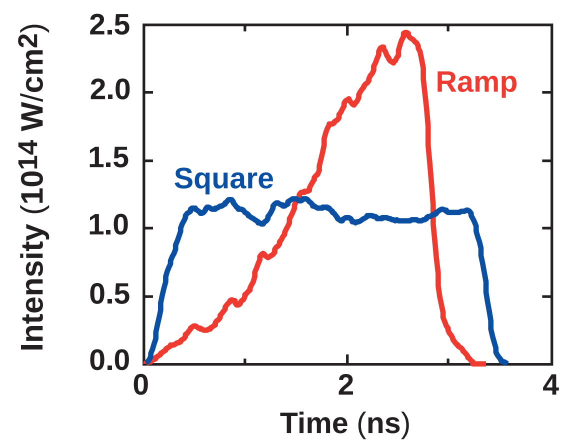
V. N. Goncharov *et al.*, "A Model of Laser Imprinting," Phys. Plasmas 7, 2062 (2000).

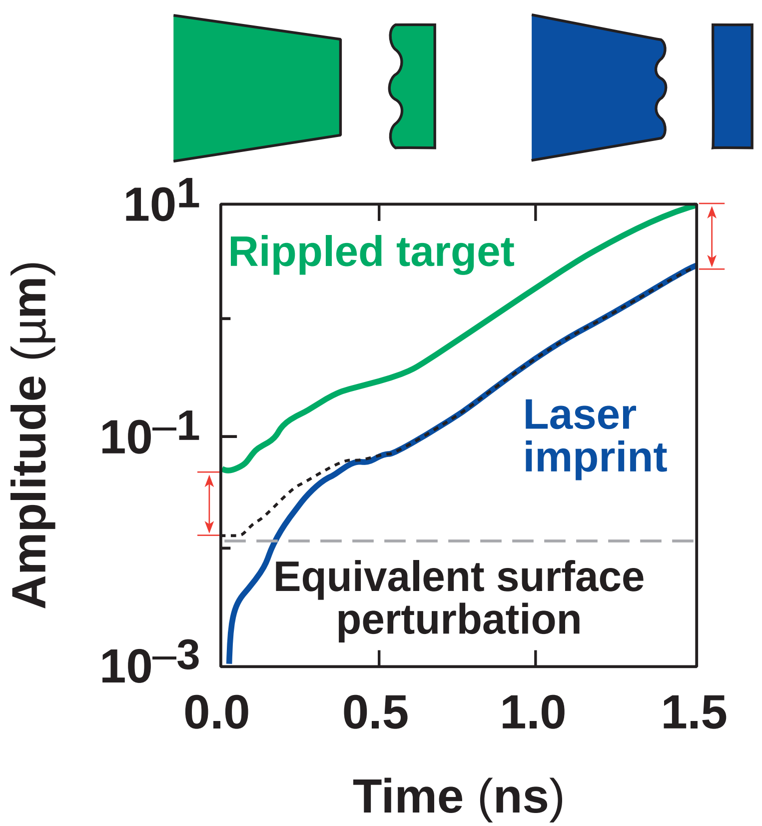
X-ray radiography is used to measure imprinted perturbations produced by two pulse shapes



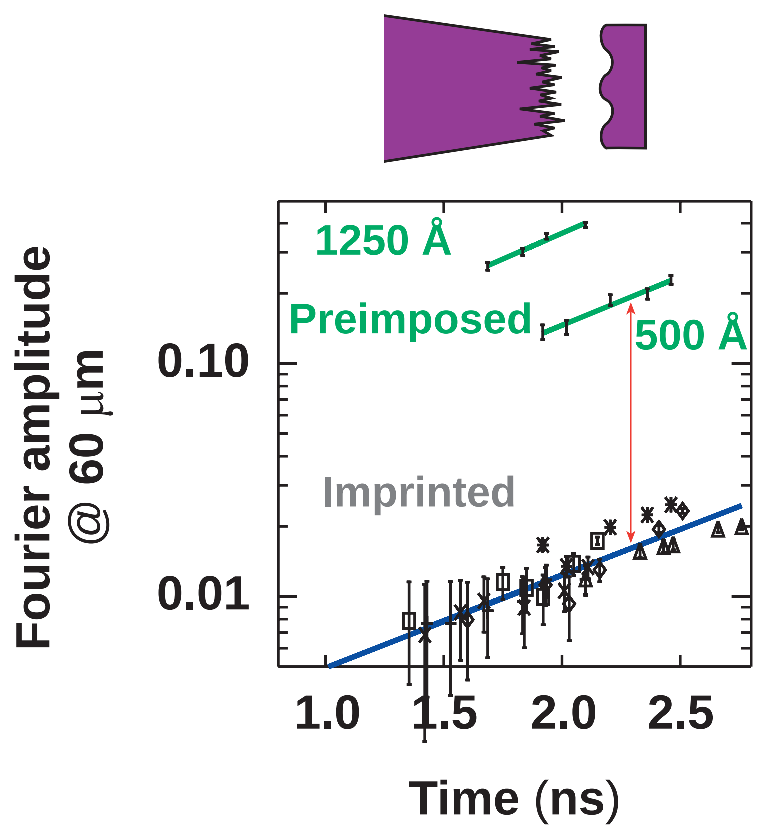


Pre-imposed target modulations are used to determine the equivalent surface perturbation of laser imprinting

Simulation of method



Experiment



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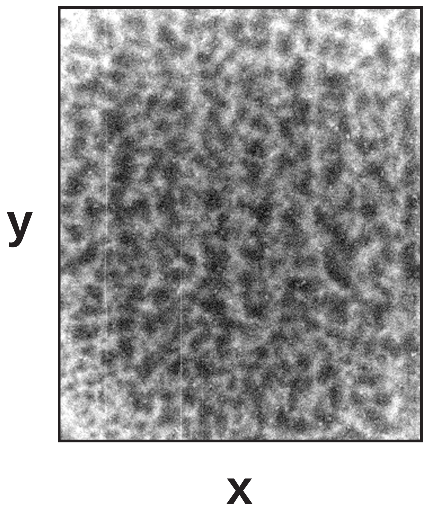
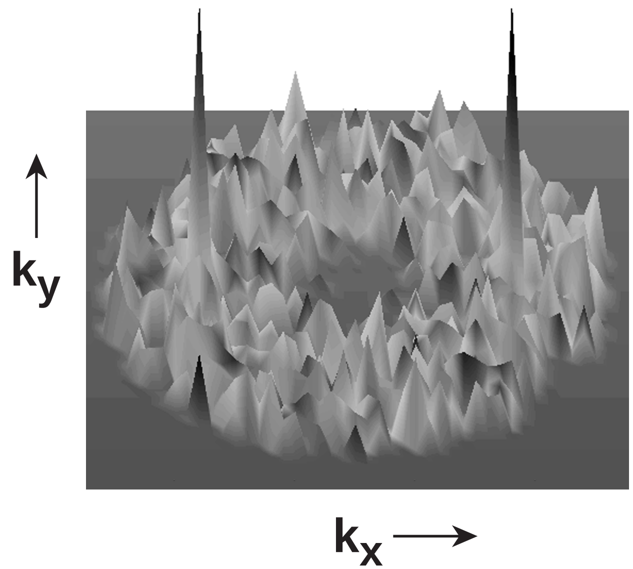
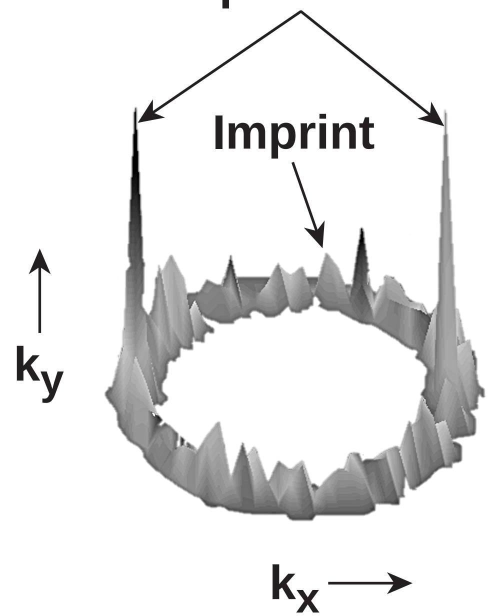
Fourier analysis is used to compare the imprinted to preimposed modulations at a single wavelength



Image



FFT and Wiener filter



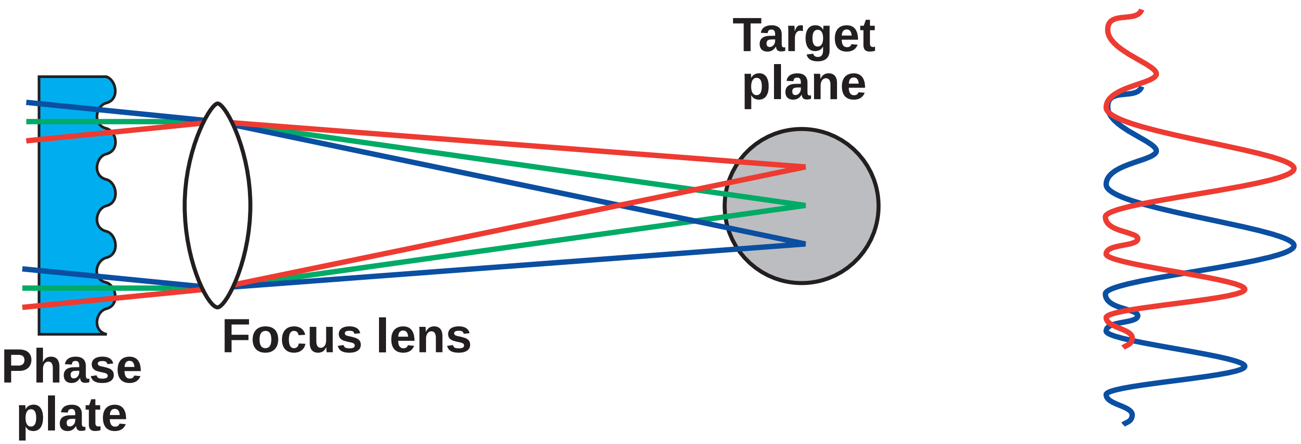
FFT (λ = 60 μm)

$$A_{eq}(k,0) = [A_{imprint}(k,t)/A_{pre}(k,t)]\ A_{pre}(k,0)$$

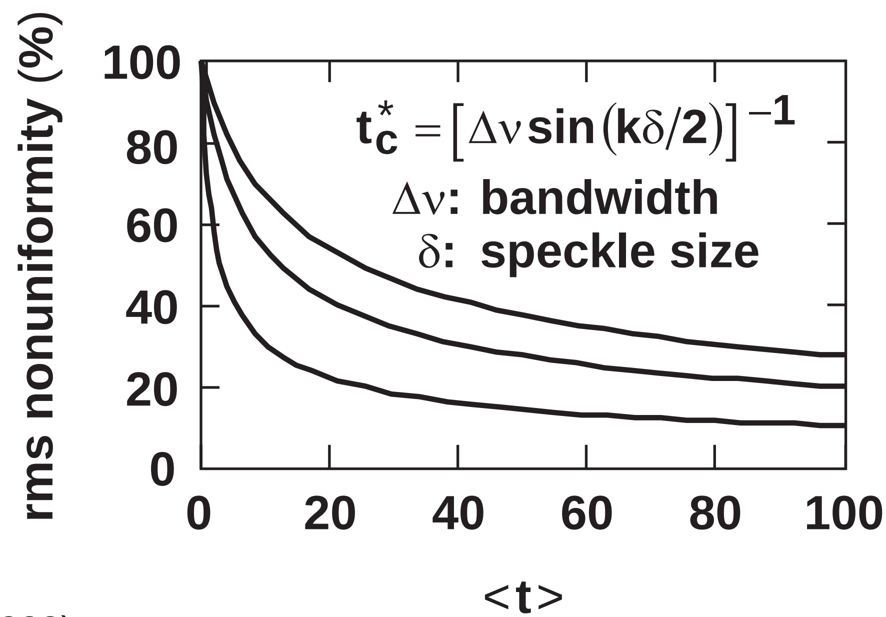
V. Smalyuk *et al.*, Phys. Plas. 6, 4022 (1999).

Laser imprint

SSD reduces time-averaged laser nonuniformity

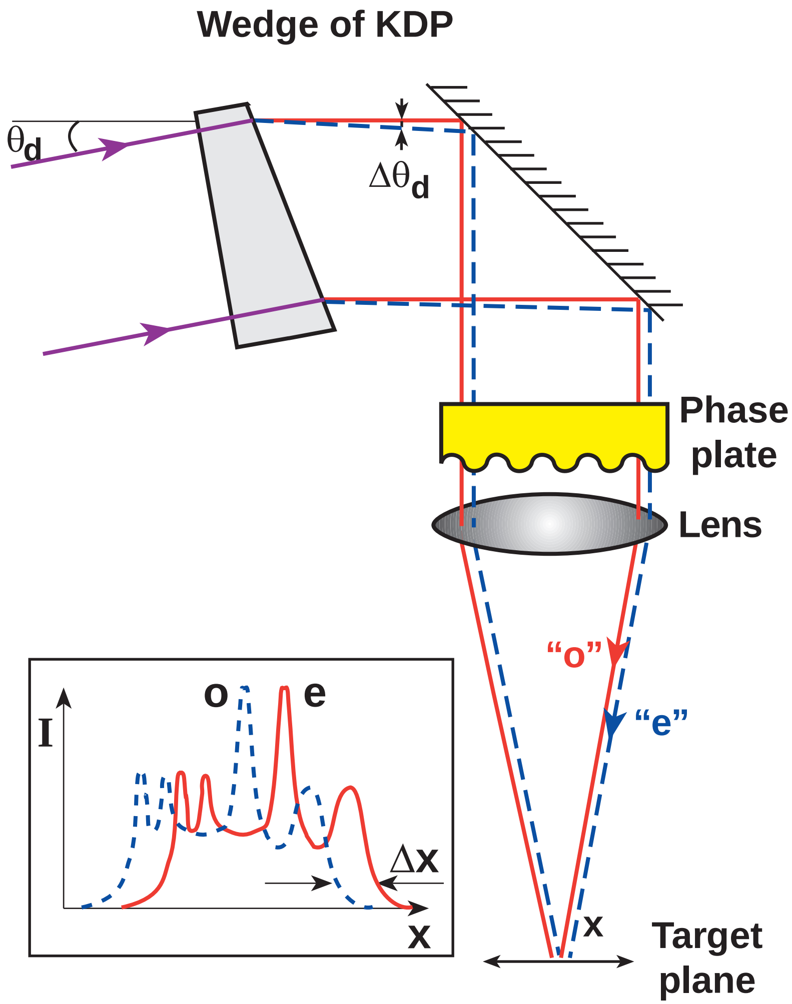


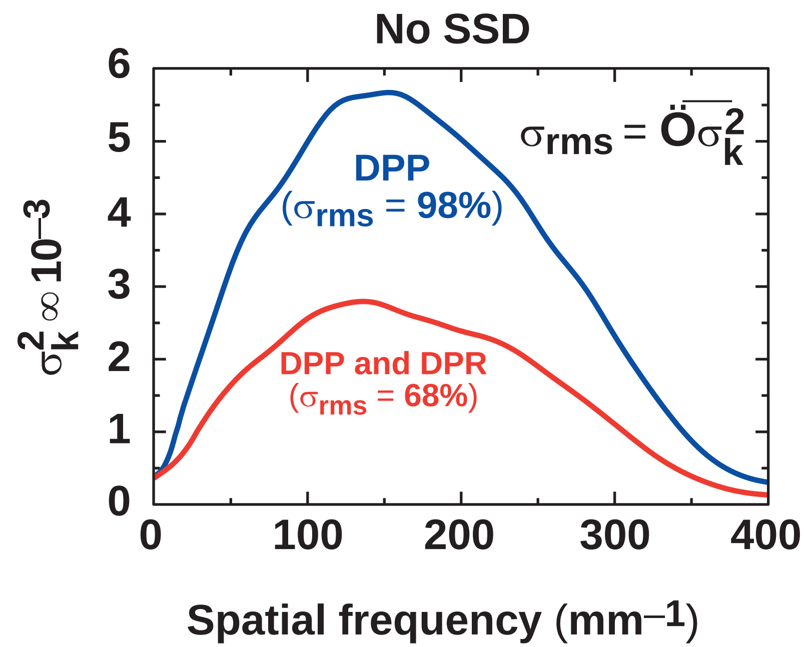
$$\langle \sigma_{rms} \rangle \sim \sqrt{t_c / \langle t \rangle}\, \langle \sigma^0_{rms} \rangle$$



TC5220a *S. Skupsky, Phys. Plasmas 6, 2157 (1999).

Polarization Smoothing[1] (PS) rotators (DPR's) provides the predicted $1/\sqrt{2}$ reduction in nonuniformity





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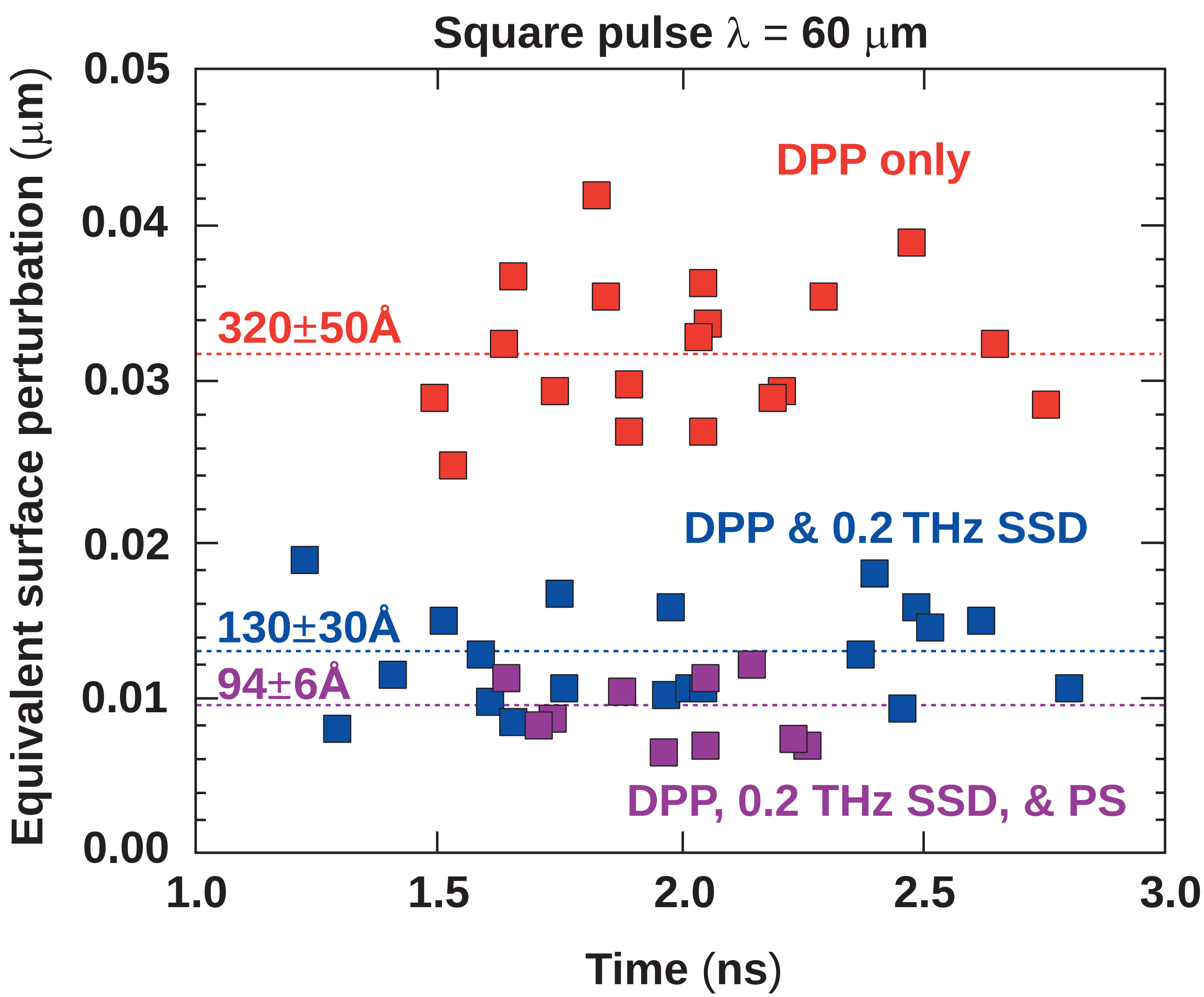
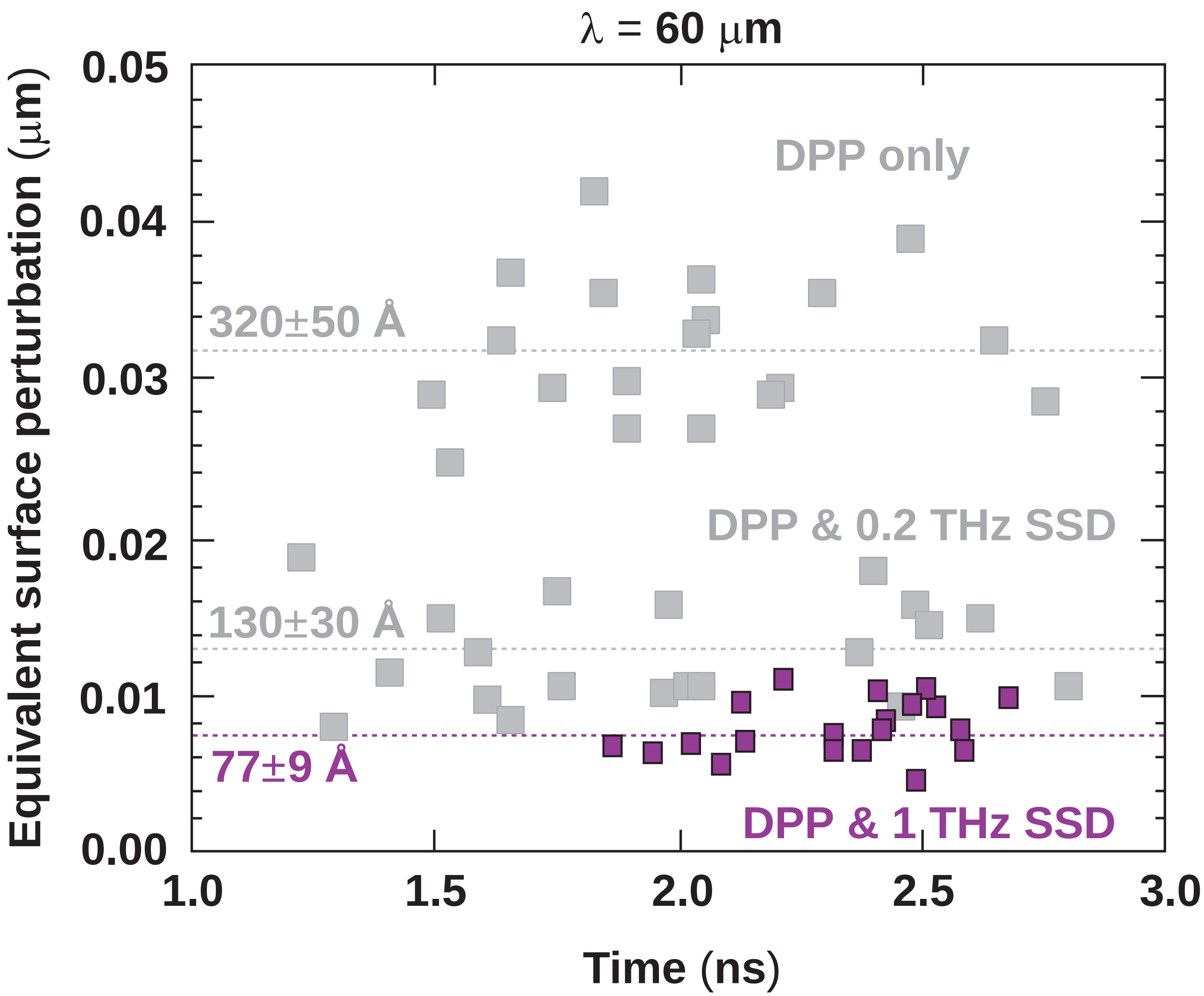
[1]Y. Kato, unpublished notes from 1984 stay at LLE.

The equivalent surface perturbation for imprinting clearly shows the effect of beam smoothing



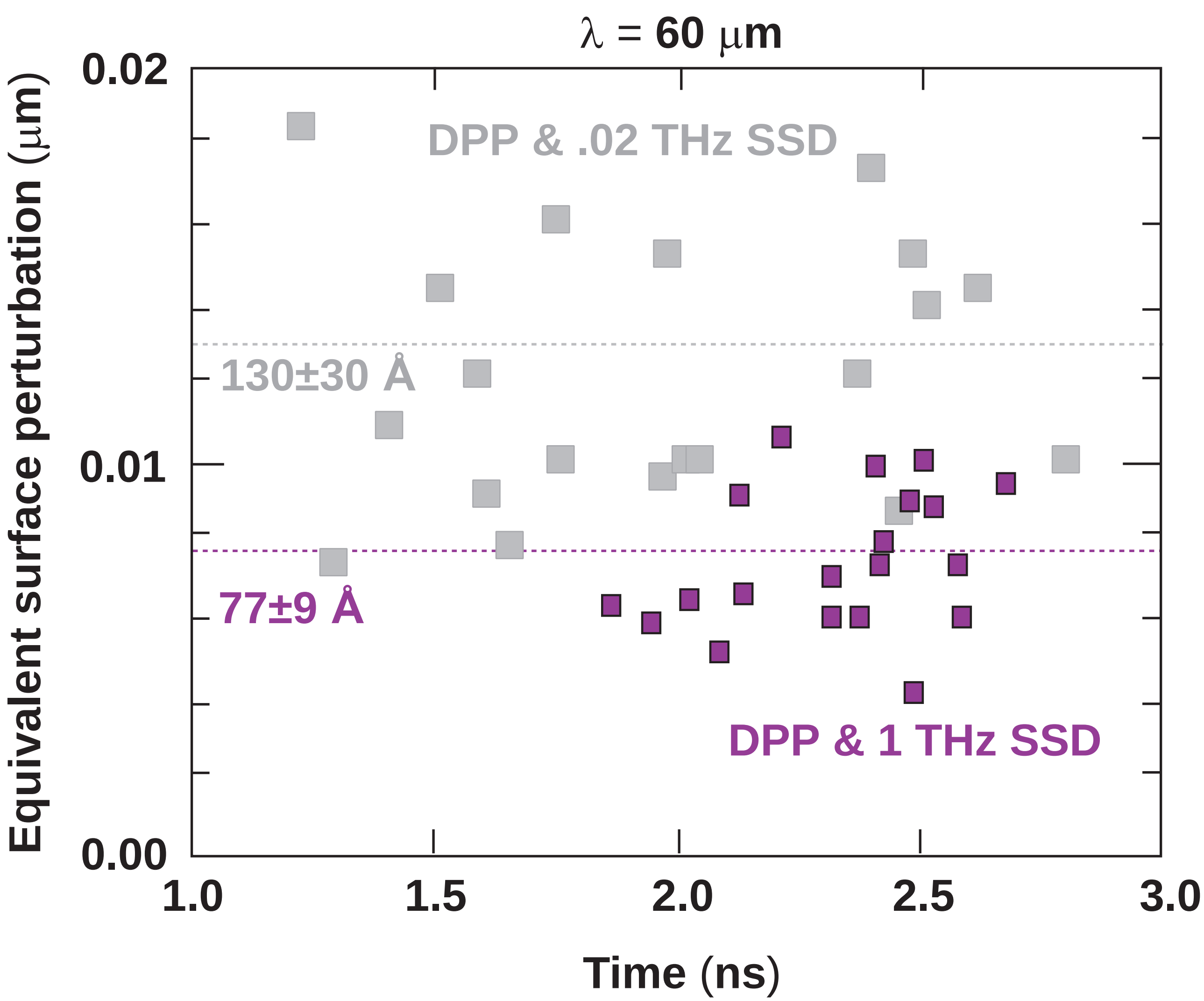
E10031

Increasing the SSD bandwidth from 0.2 to 1 THz reduces the equivalent roughness by about 60%



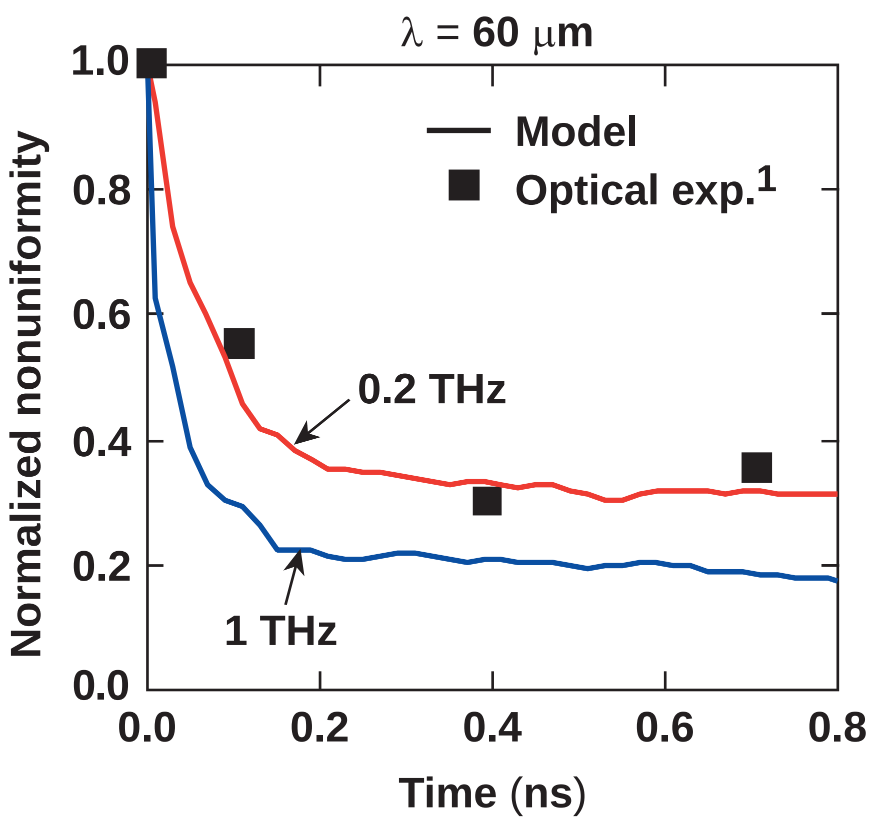
E10592

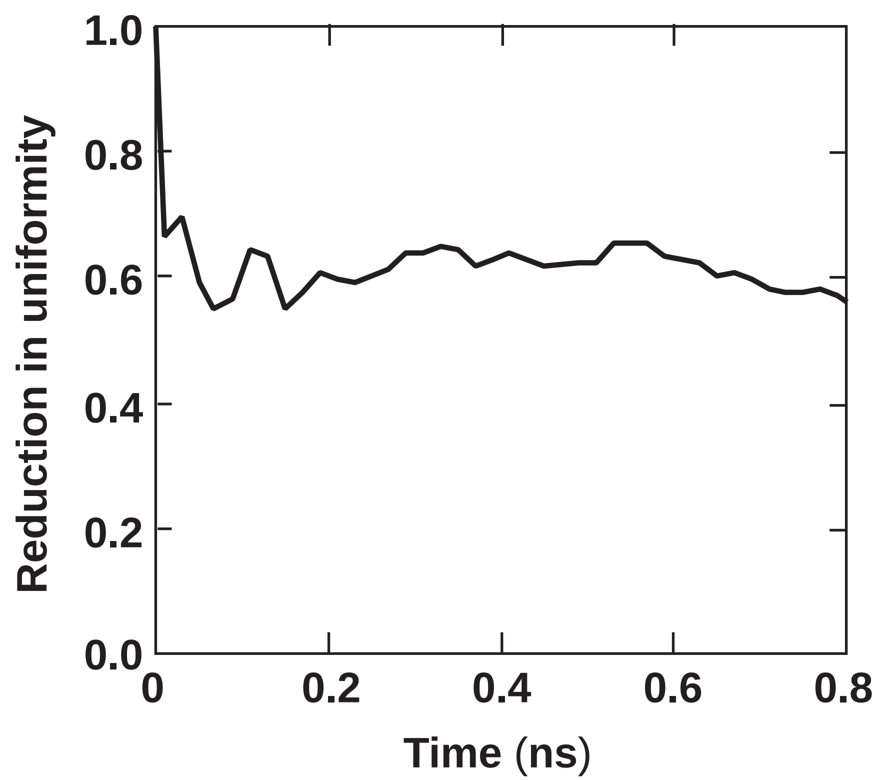
Increasing the SSD bandwidth from 0.2 to 1 THz reduces the equivalent roughness by about 60%



E10592a

Increasing SSD bandwidth from 0.2 to 1 THz reduces nonuniformities by ~60%

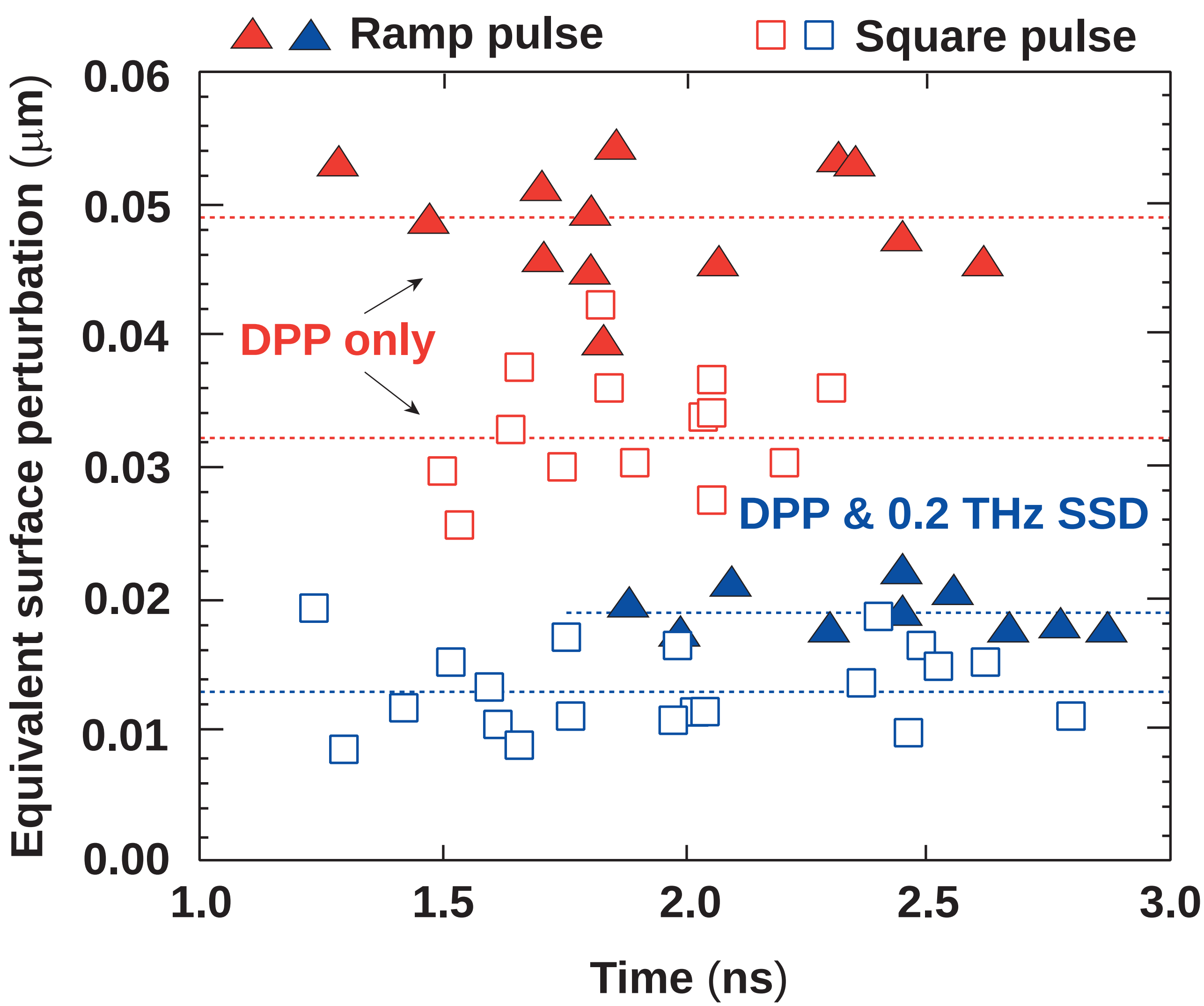




[1] S. Regan, J. Opt. Soc. Am. B <u>17</u>, 1483 (2000).

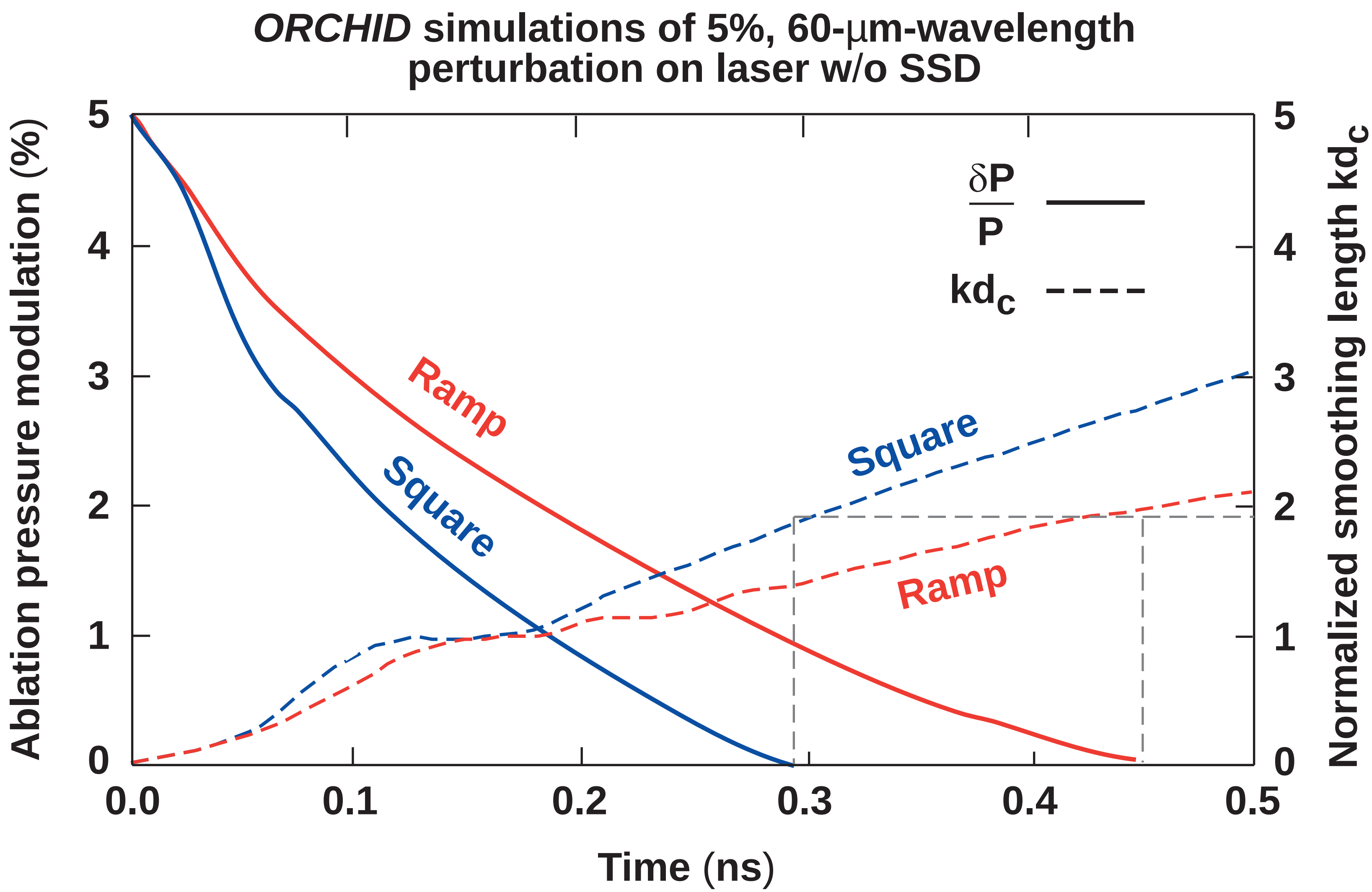
E10593

At λ = 60 μm, the level of imprinting and the effect of SSD depend on pulse shape



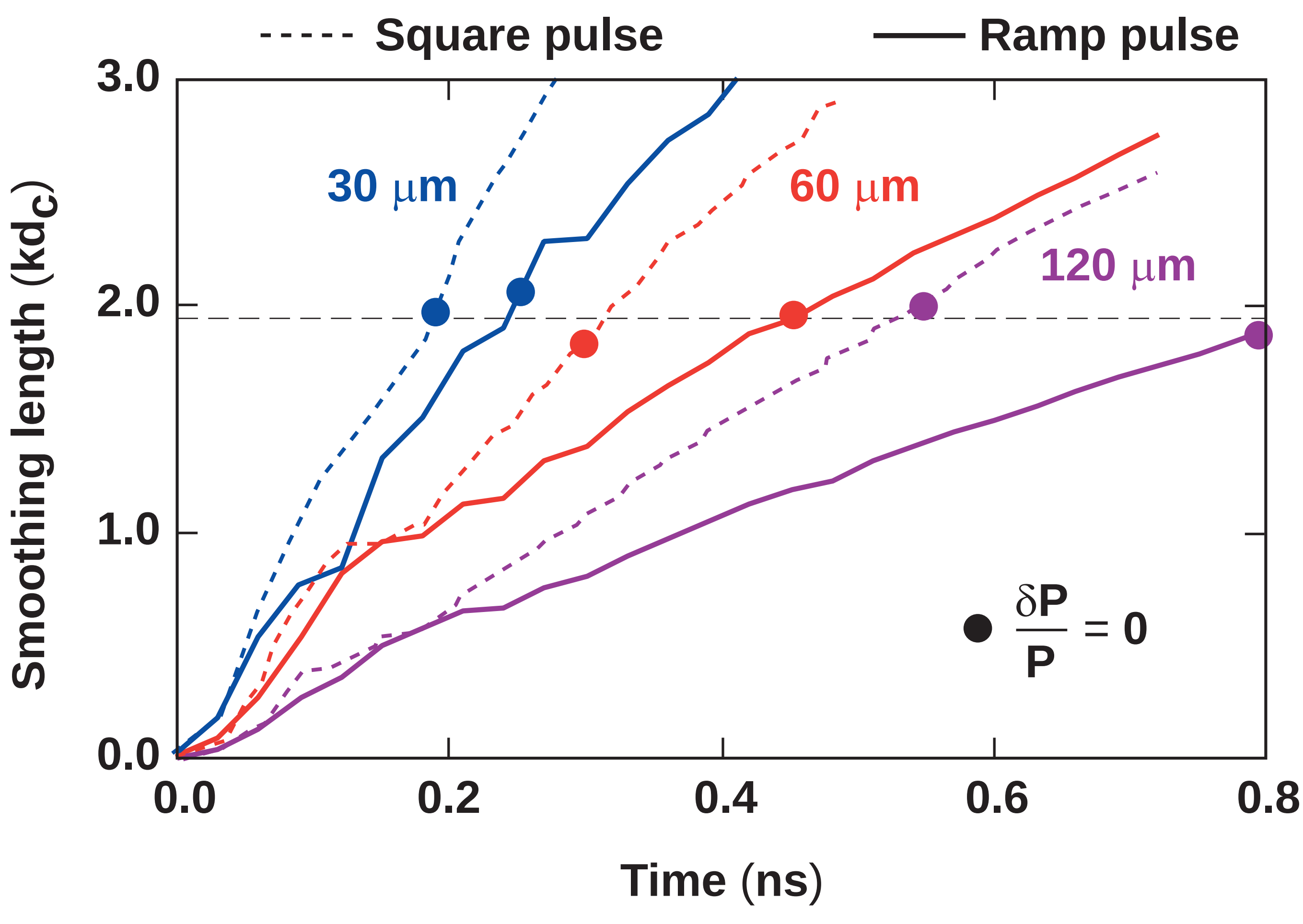
E10030

Rapid-rise pulses (square) produce smoothing plasmas faster than slow-rise pulses (ramp)



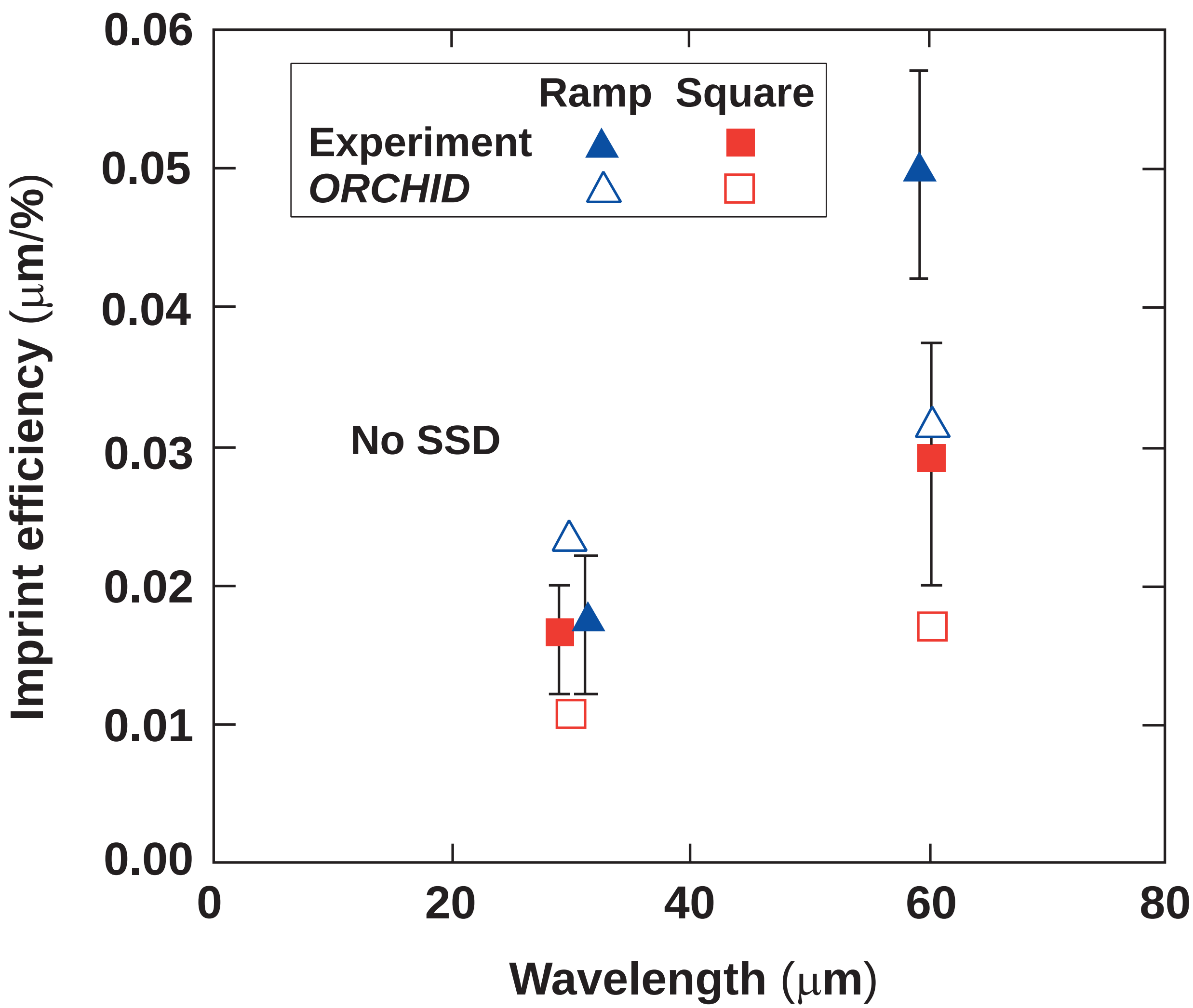
E9991

Laser nonuniformities are "decoupled" from the ablation surface when the smoothing length (kd_c) reaches ~2



E10533

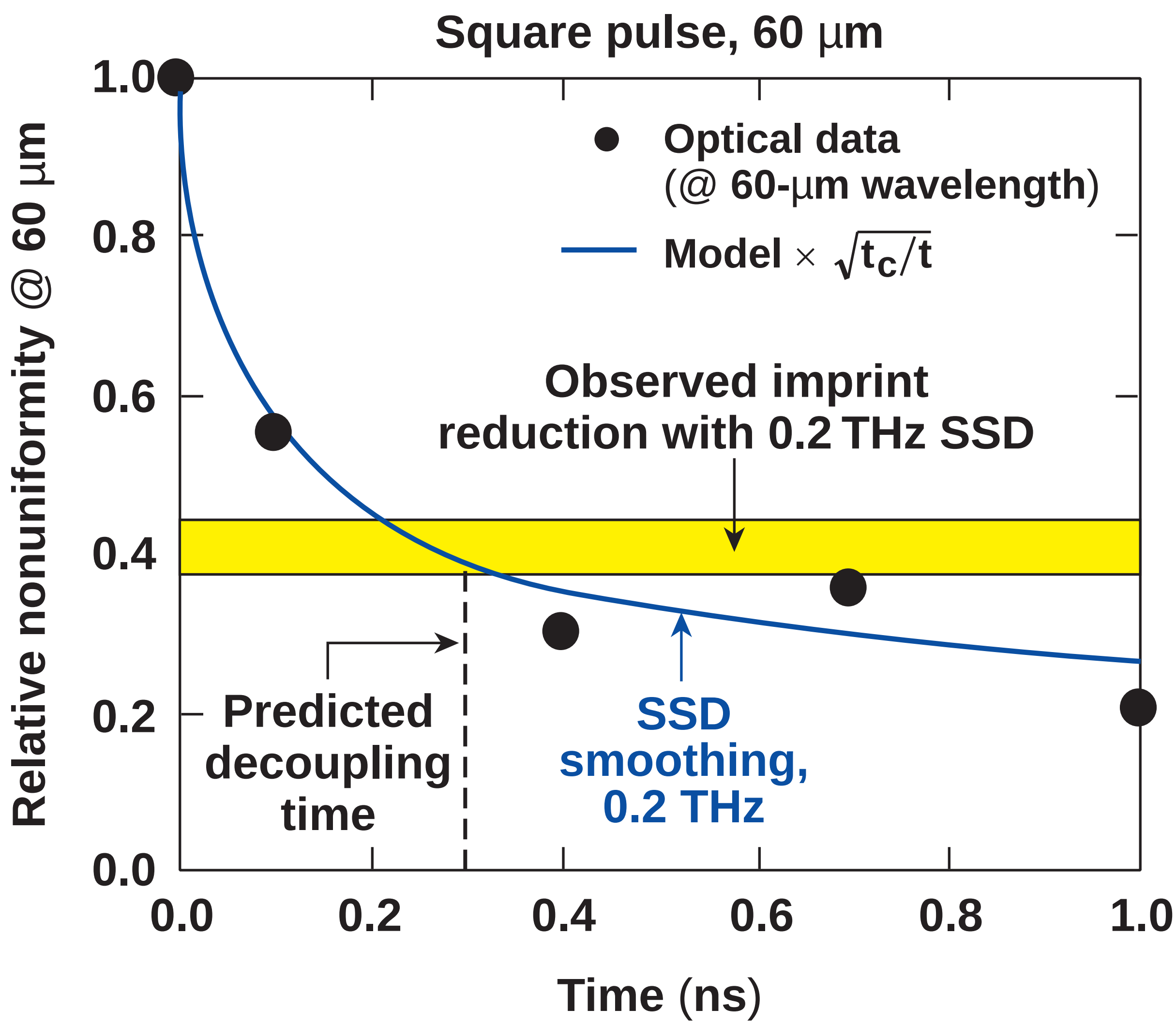
The imprint efficiency without SSD is measured at two wavelengths and compared to *ORCHID* simulations



$$\eta = \frac{\delta m/\rho}{\delta I/I}$$

E9964a

Observed imprint reduction by SSD is consistent with decoupling times and smoothing rate



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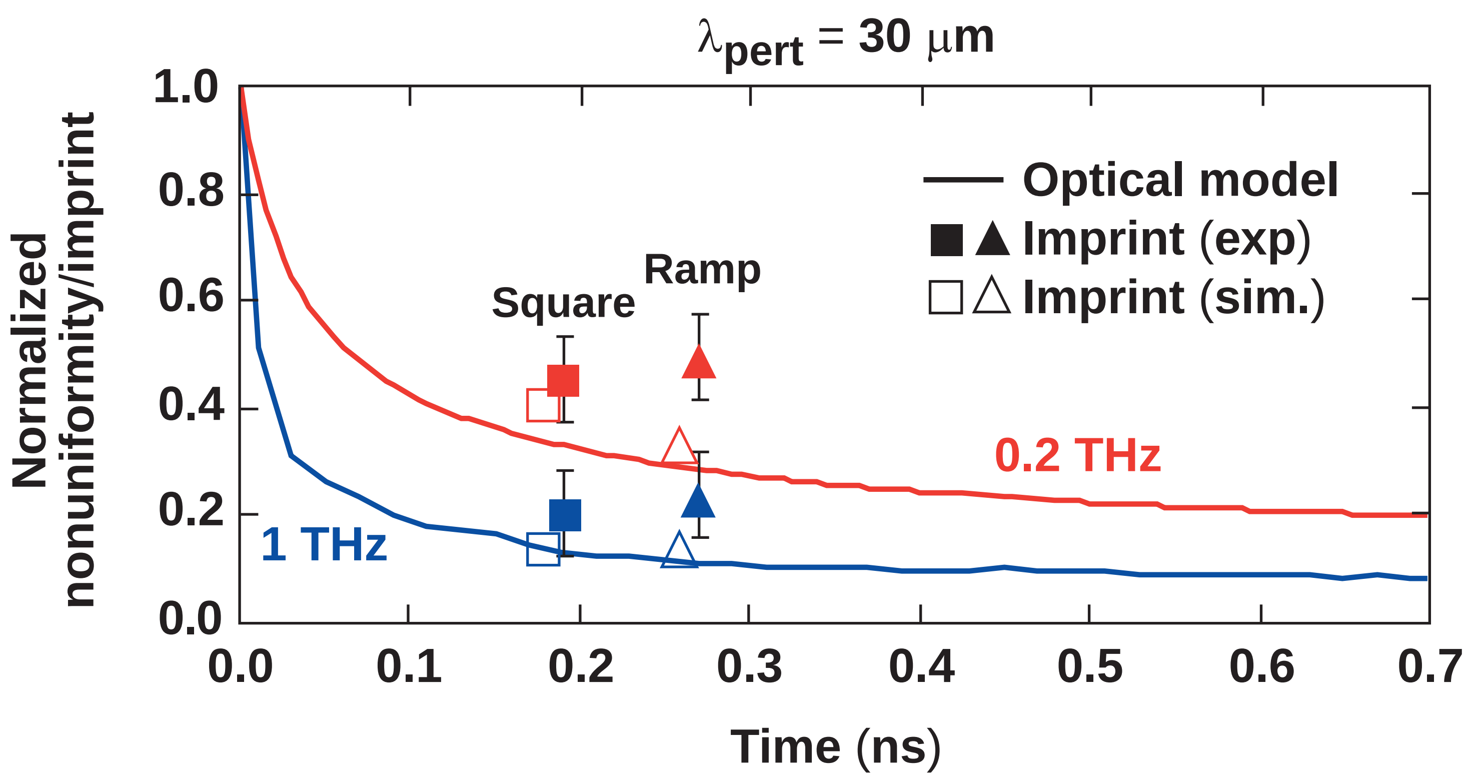
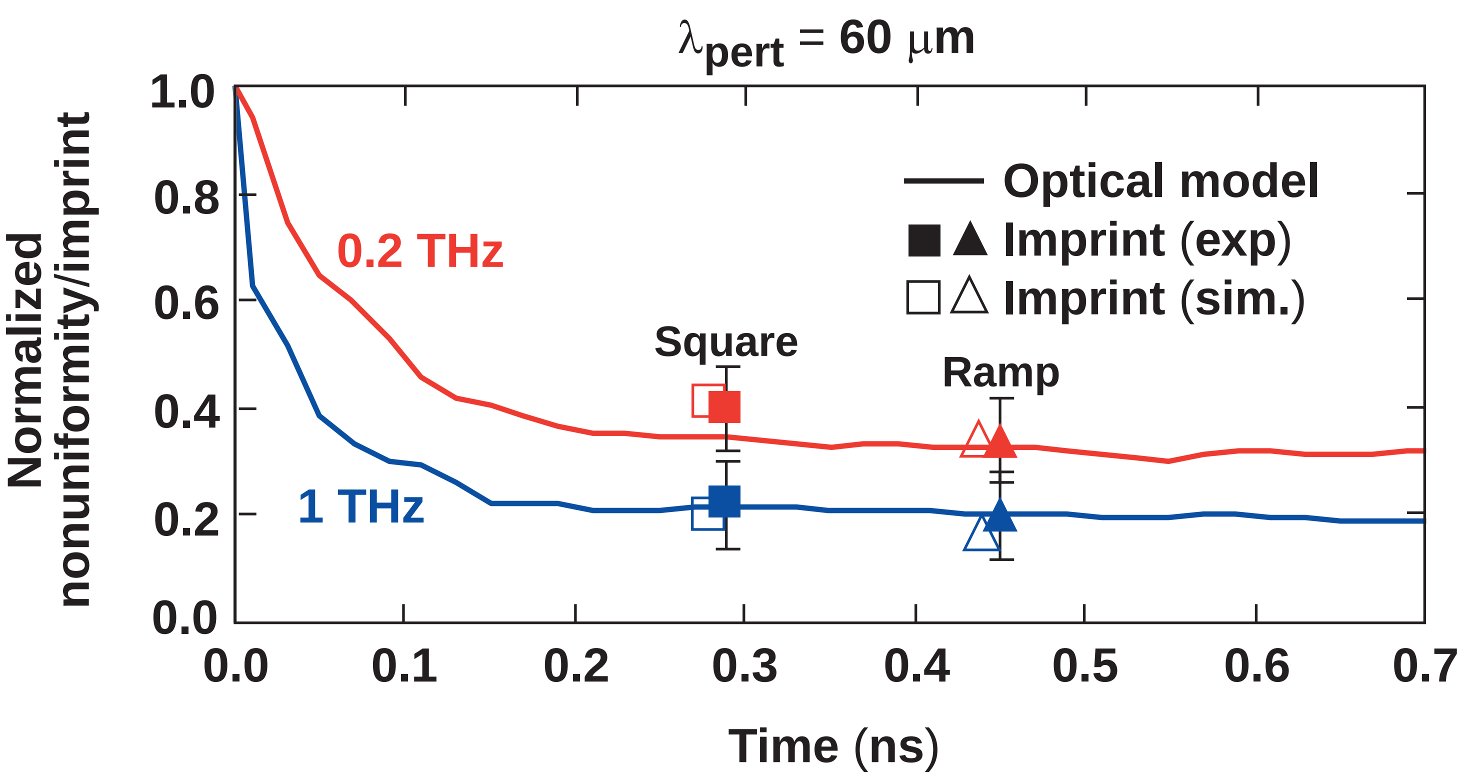
At 30 μm, the imprint reductions are less than expected for the decoupling times



E10591

Imprint reduction for 0.2- and 1-THz SSD is consistent with decoupling times for square and ramp pulses



E10590

Summary/Conclusion

Plasma-formation rate determines imprint levels and the effectiveness of beam-smoothing techniques

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- **Imprinting ends when sufficient smoothing exists to decouple laser nonuniformities and the unstable ablation surface.**
- **The laser pulse shape determines the rate at which this plasma is formed.**
- **Control perturbations are used to infer imprint levels:**
  - ***"equivalent surface finish"***
  - **sensitive to drive nonuniformities**
- **The effect of 1-THz SSD was measured.**
- **Slowly rising pulses produce greater imprint than steeply rising pulses because plasma is formed more slowly.**
- **Results with 0.2- and 1-THz SSD confirm the effect of pulse shape on imprinting.**