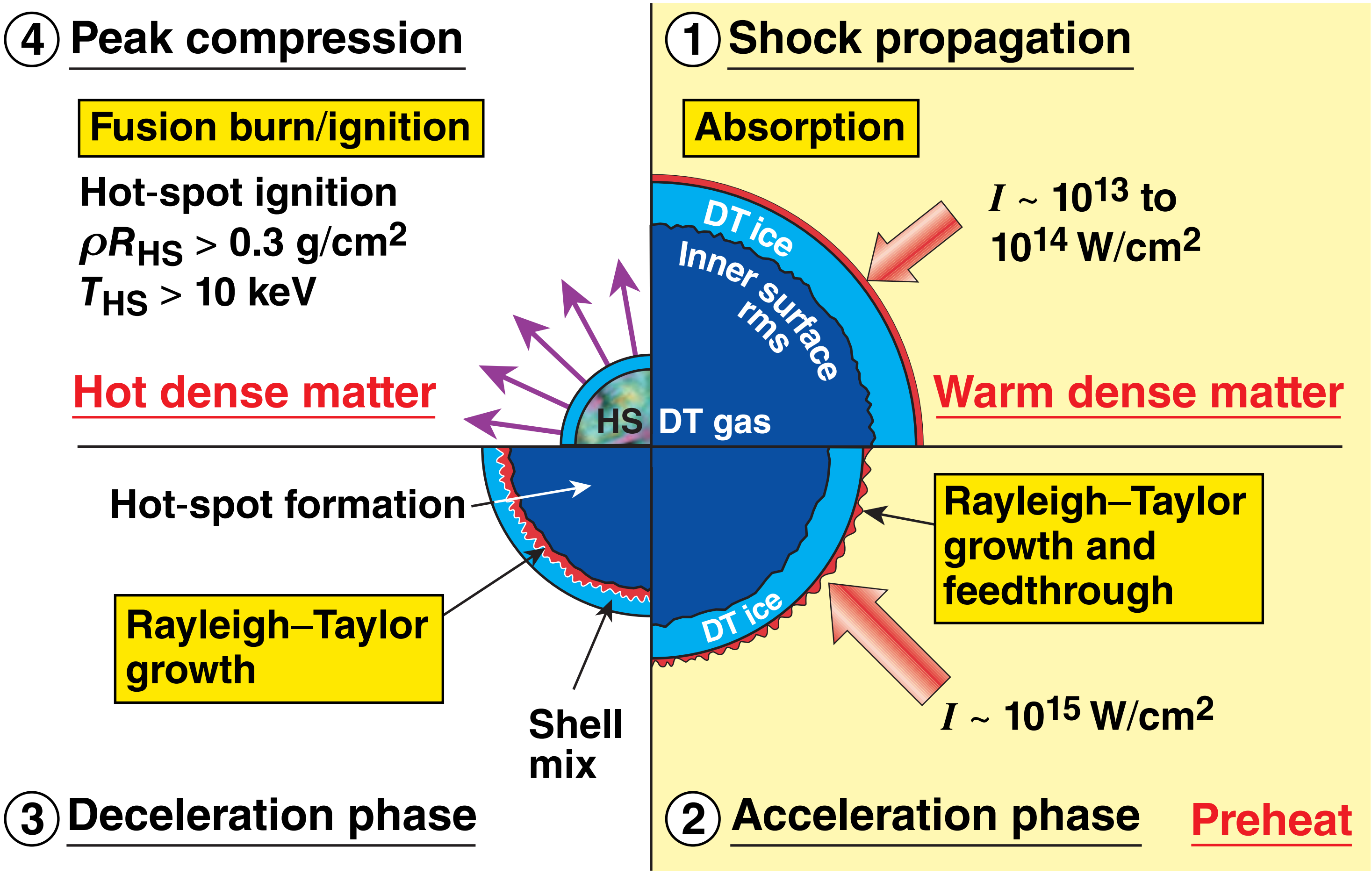
The stages of an inertial confinement fusion (ICF) implosion

Hot-spot ignition



④ Peak compression

Fusion burn/ignition

Hot-spot ignition
$\rho R_{HS} > 0.3\ \mathrm{g/cm^2}$
$T_{HS} > 10\ \mathrm{keV}$

Hot dense matter

① Shock propagation

Absorption

$I \sim 10^{13}$ to $10^{14}\ \mathrm{W/cm^2}$

Warm dense matter

Hot-spot formation

Rayleigh–Taylor growth

Shell mix

③ Deceleration phase

Rayleigh–Taylor growth and feedthrough

$I \sim 10^{15}\ \mathrm{W/cm^2}$

② Acceleration phase

Preheat

Maintaining target integrity throughout the implosion is critical to achieving thermonuclear ignition.

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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*

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

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

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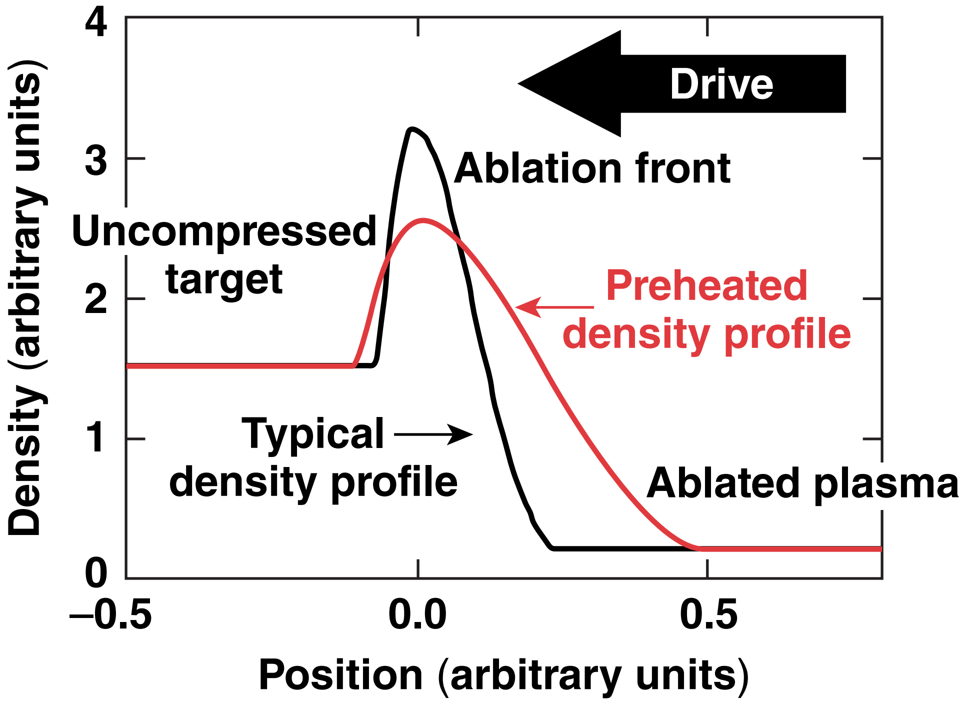
*S. W. Haan, Phys. Rev. A 39, 5812 (1989).

†R. Betti, Phys. Plasmas 5, 1446 (1998).

Previous RT experiments demonstrated decreased instability growth at peak laser intensities of 1×10^{15} W/cm^2 in CH targets caused by electron preheat*



$$\gamma_{RT} = \alpha \cdot \sqrt{\frac{k \cdot g}{1 + k \cdot \boxed{L_m}}} - \beta \cdot k \boxed{\cdot V_a}^{**}$$

Target preheat leads to increased density scale length (L_m) and ablation velocity (V_a), resulting in decreased RT modulation growth.

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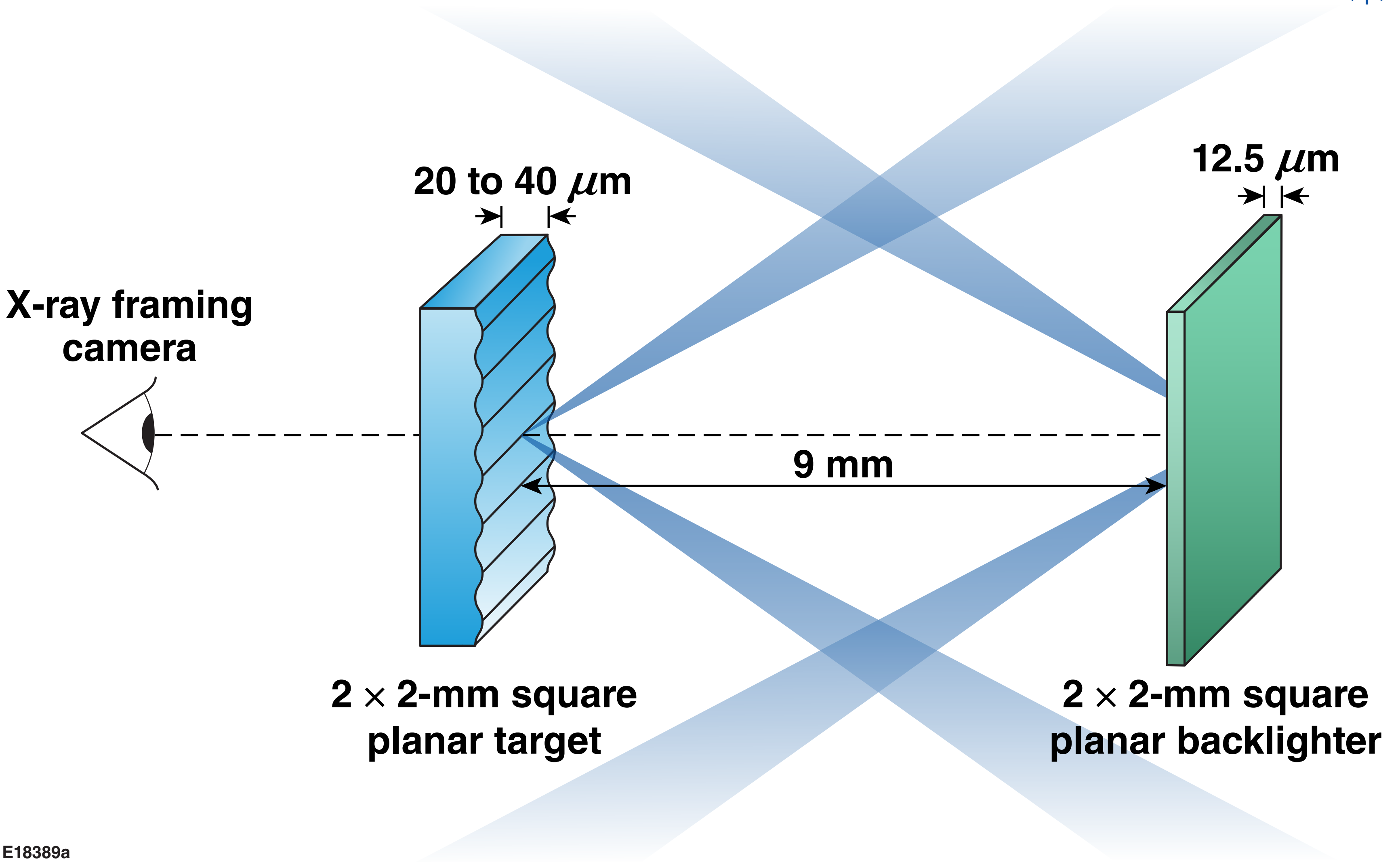
* V. A. Smalyuk *et al*. Phys. Plasmas 15, 082703 (2008).
** R. Betti *et al*., Phys. Plasmas 5, 1446 (1998).

Planar CH, SiO_2, and CH–SiO_2 targets are driven by 10 to 12 drive beams, while an x-ray backlighter is used to measure areal density modulation growth



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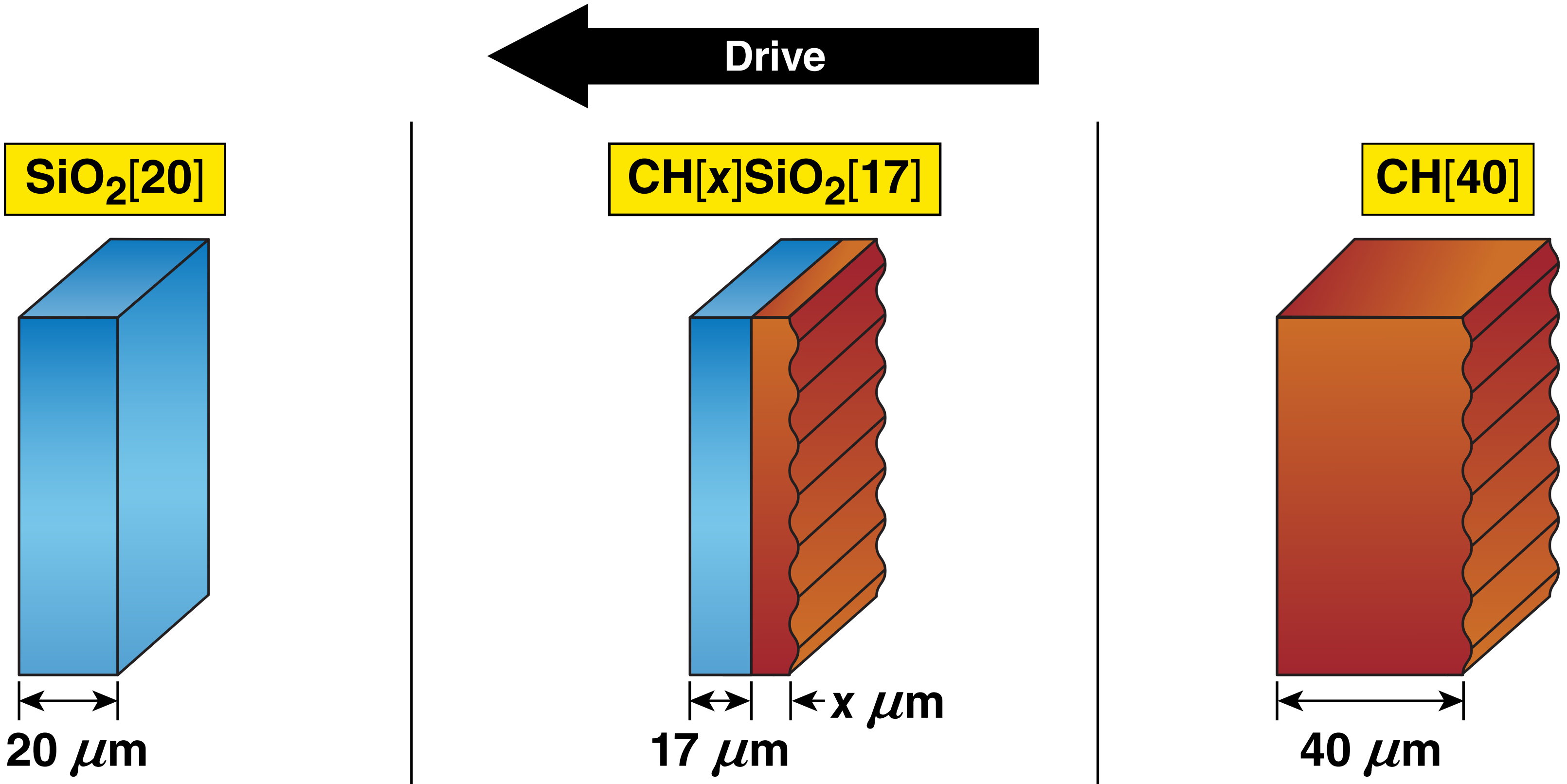
Targets were seeded with an intensity-imprinted 2-D modulation, while pre-imposed mass modulations were also used on CH and CH–SiO_2 targets



a_0 = 0.125 to 0.25 µm
x = 1.5 to 3 µm

2-D intensity modulations imprinted

2-D modulations pre-imposed and imprinted

2-D modulations pre-imposed and imprinted

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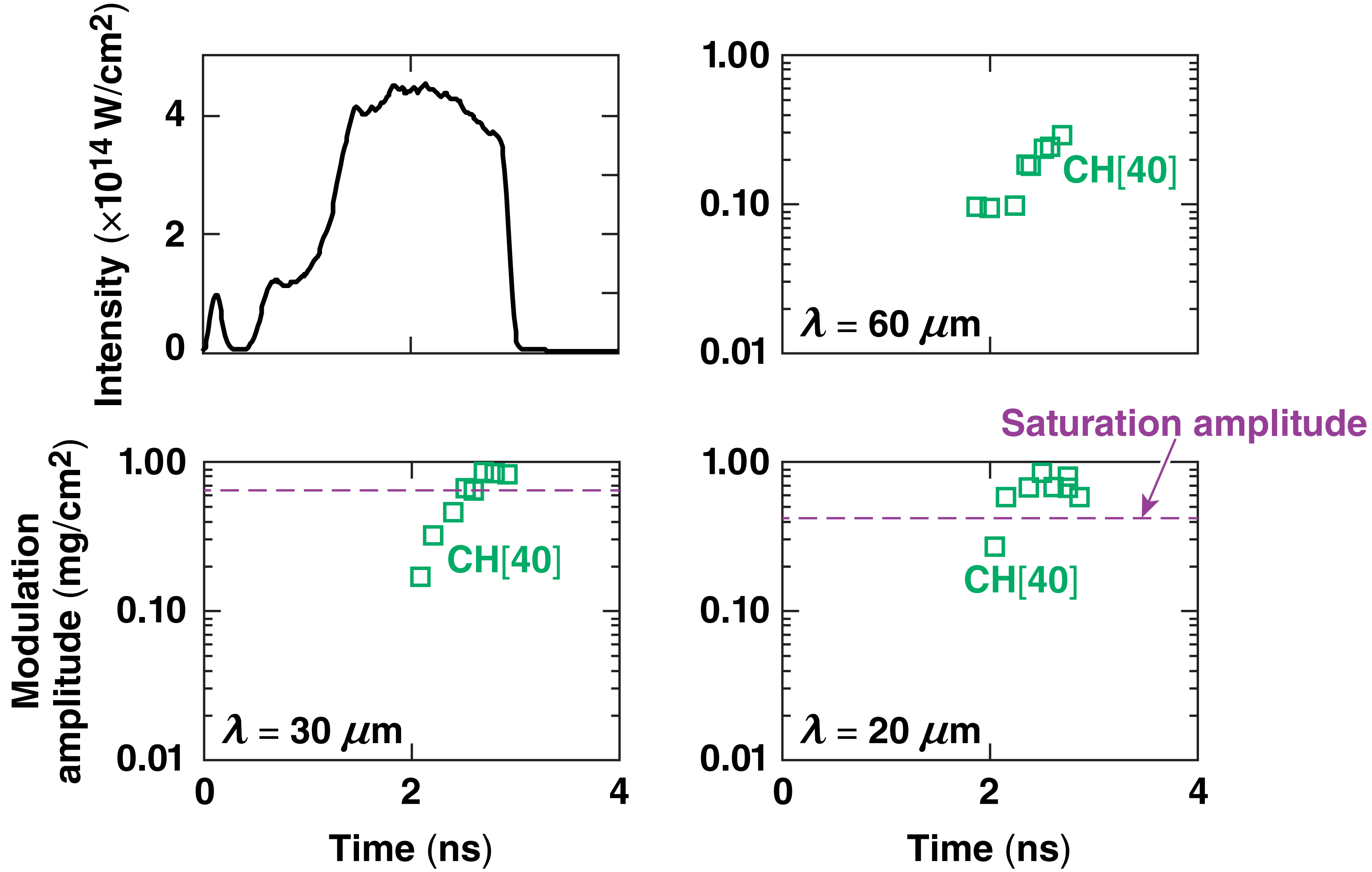
40-μm-thick CH targets driven at low intensities (5×10^{14} W/cm^2) show significant growth up to the modulation saturation amplitude

- **Pre-imposed modulations**



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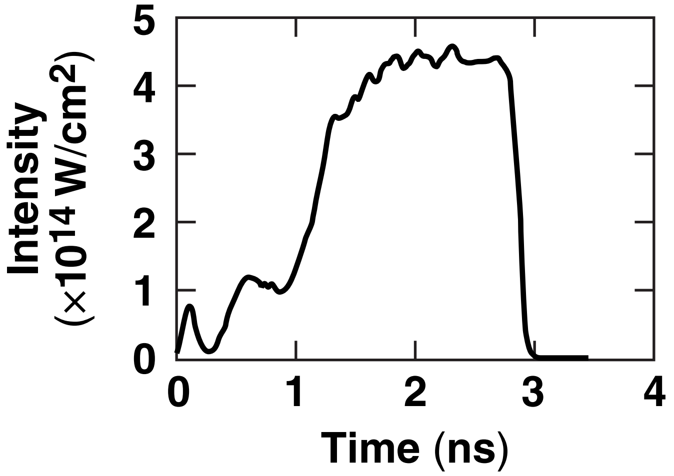
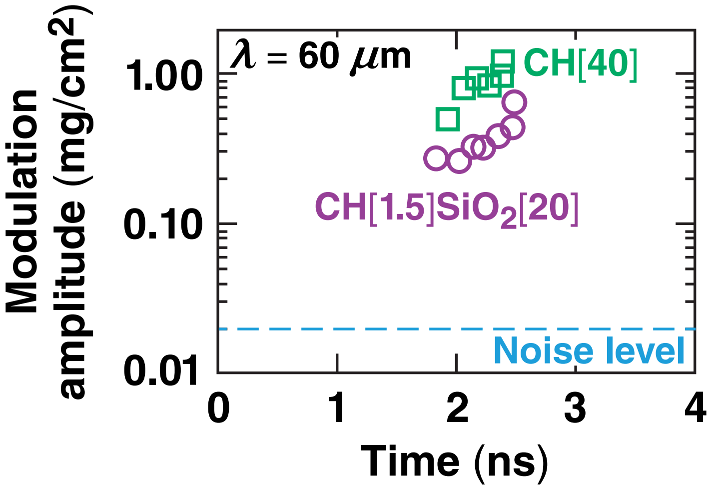
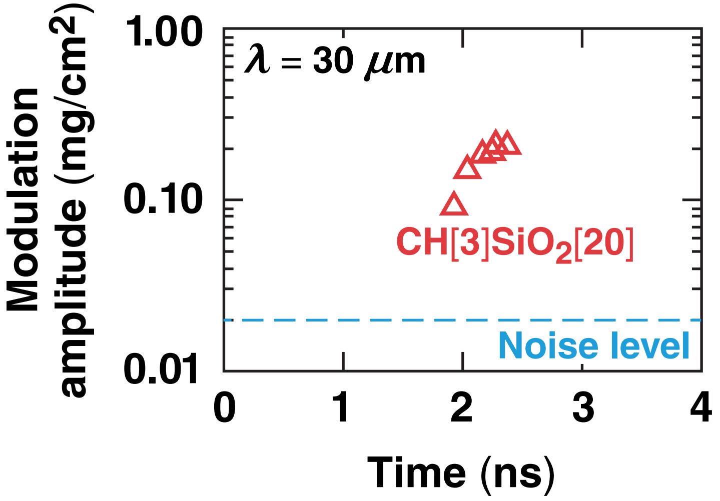
20-μm-thick intensity-imprinted SiO_2 targets with 1.5- and 3-μm CH ablators show modulation growth at low intensities

- **Intensity-imprinted modulations**

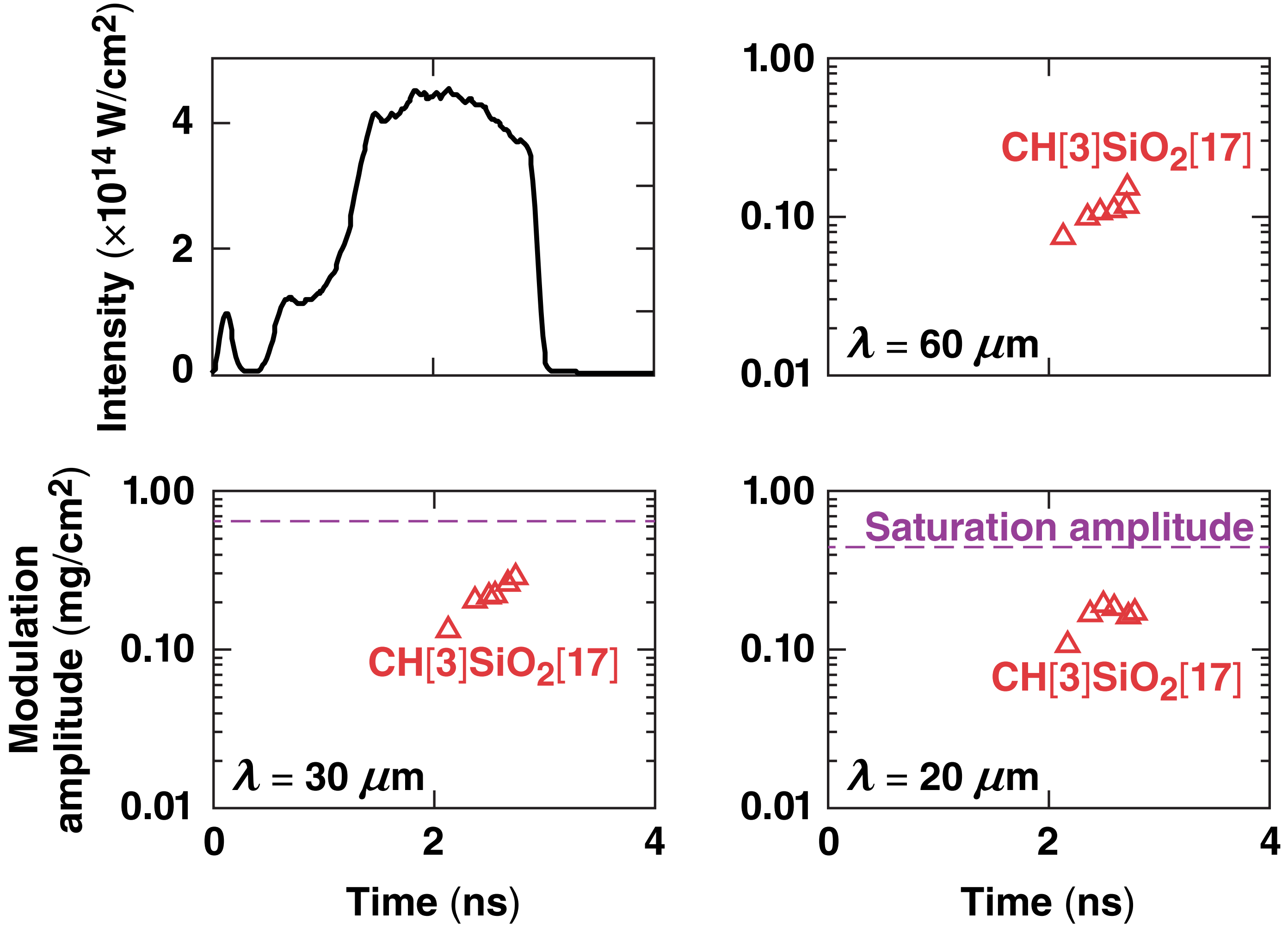






17-μm-thick SiO_2 targets with a perturbed 3-μm CH ablator show significant modulation growth in SiO_2 at low intensities

- **Pre-imposed modulations**



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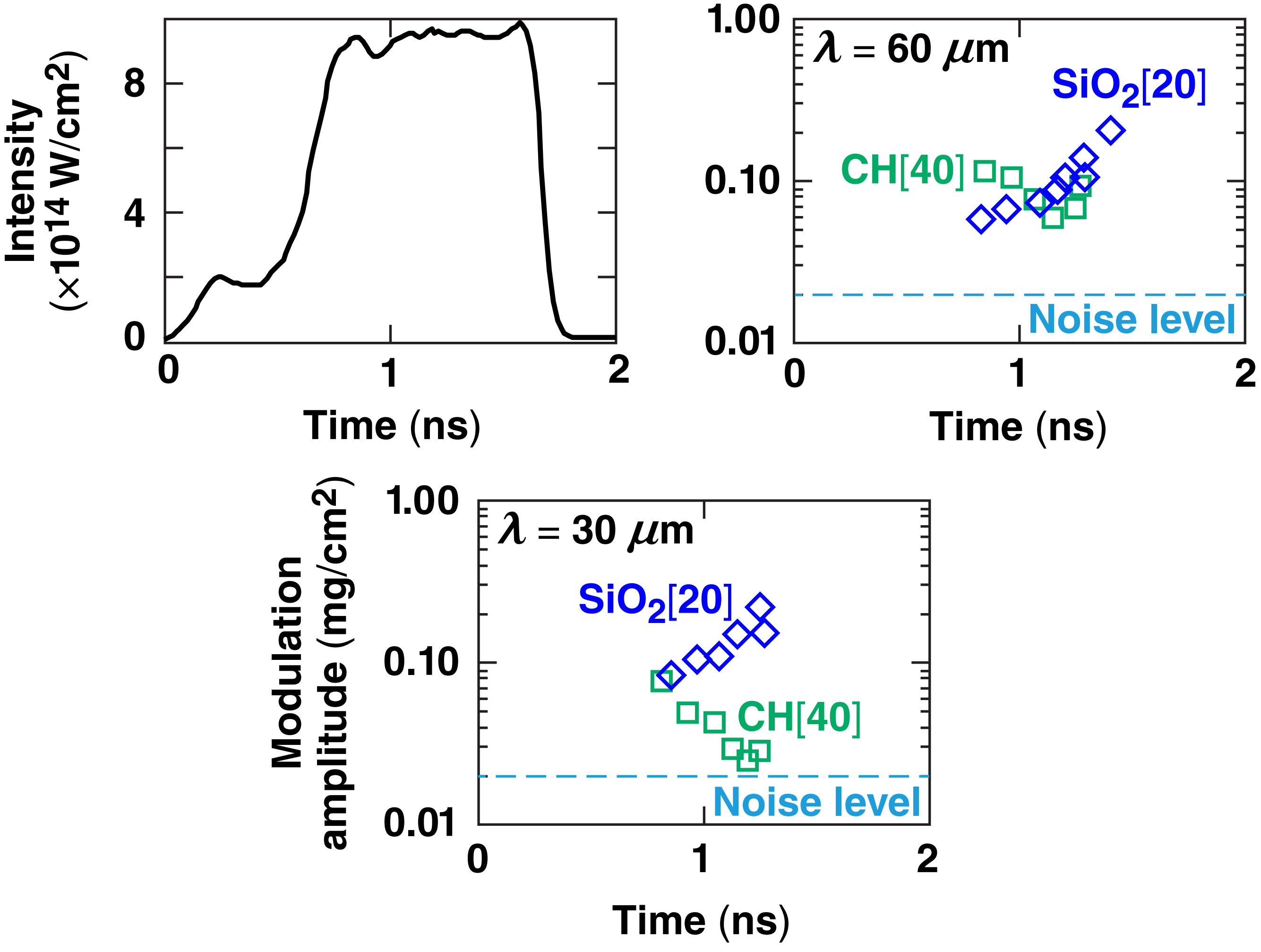
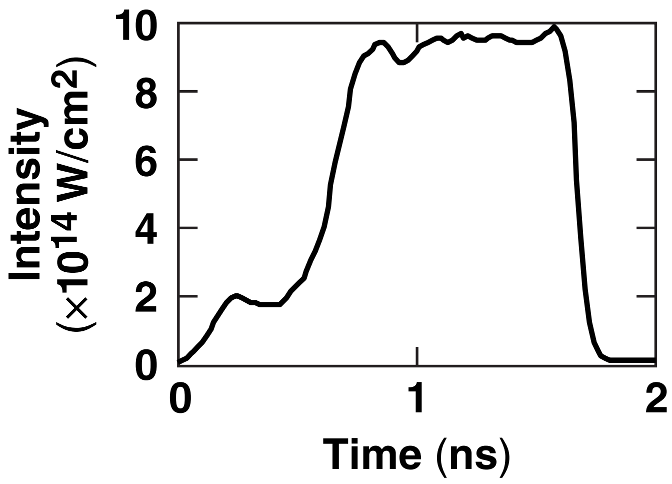
At high intensities (1×10^{15} W/cm^2) imprinted modulations grow in SiO$_2$, while CH targets of comparable mass show no growth

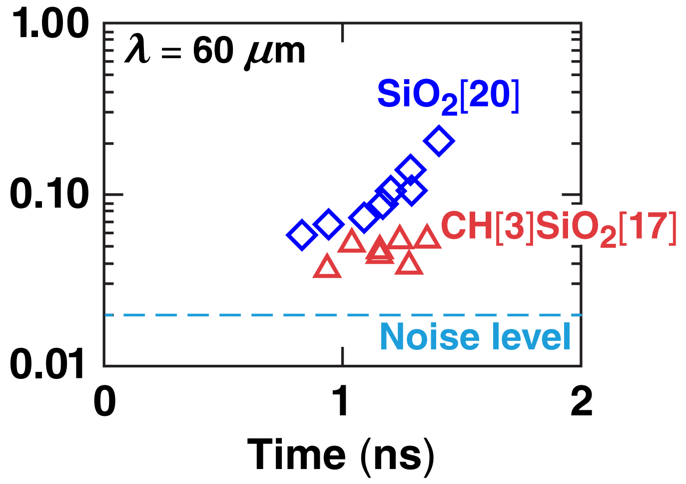
- **Intensity-imprinted modulations**

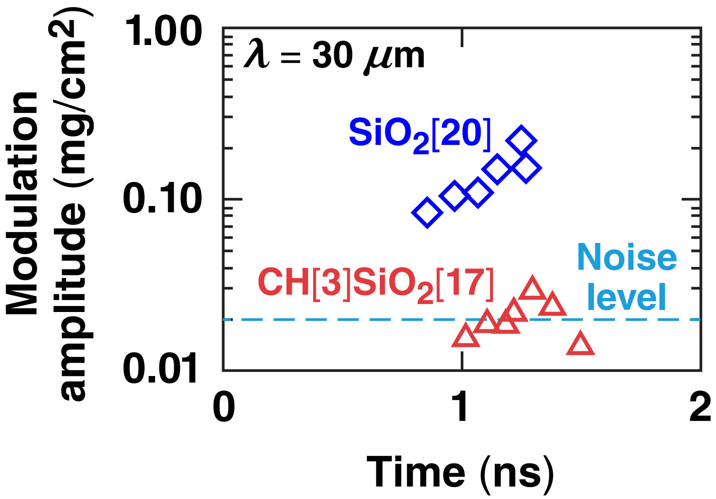


17-μm-thick SiO_2 targets with a perturbed 3-μm CH ablator show no significant instability growth at high intensities, while SiO_2 without CH shows significant modulation growth

- Pre-imposed (CH–SiO_2) and imprinted (SiO_2) modulations







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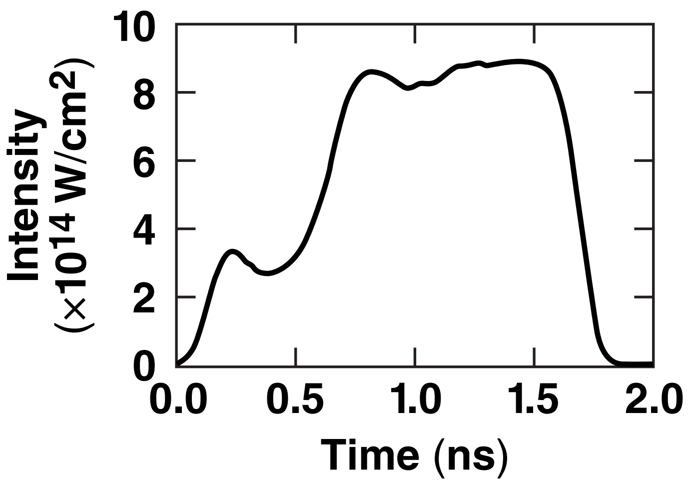
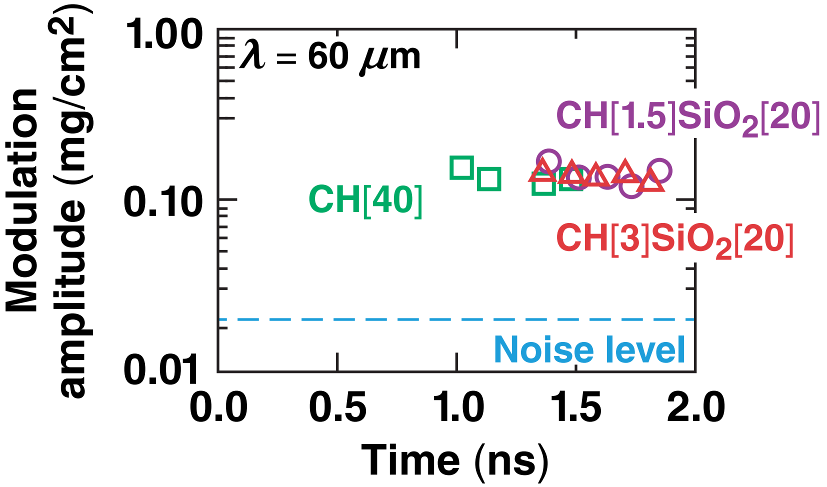
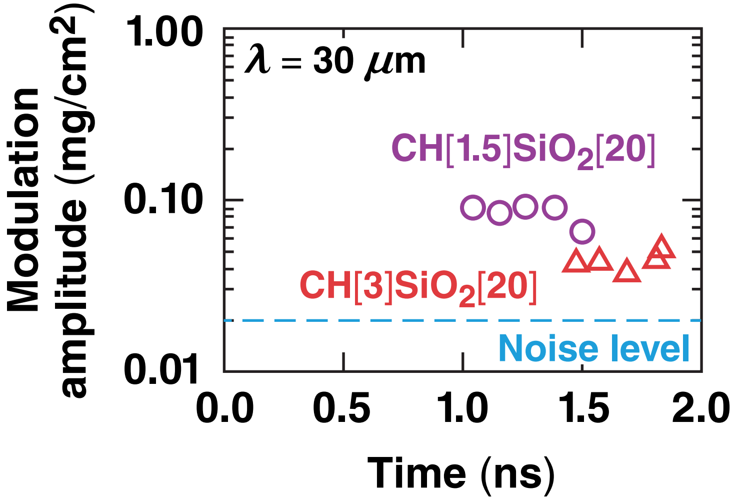
Intensity-imprinted targets with CH ablators show no significant modulation growth at high intensities

- **Intensity-imprinted modulations**







Summary/Conclusions

Rayleigh–Taylor (RT) experiments at 1 × 10^{15} W/cm^2 with CH and SiO$_2$ ablators show significant growth differences

- At peak drive intensities of 5 × 10^{14} W/cm^2, both CH and CH–SiO$_2$ targets show significant 2-D modulation growth
- At peak drive intensities of 1 × 10^{15} W/cm^2
  - CH targets with 2-D modulations (pre-imposed and intensity imprinted) show a reduction in RT growth caused by electron preheat
  - SiO$_2$ targets with 2-D intensity-imprinted modulations show significant RT growth
  - CH–SiO$_2$ targets with 2-D modulations (pre-imposed and intensity imprinted) show a reduction in RT growth