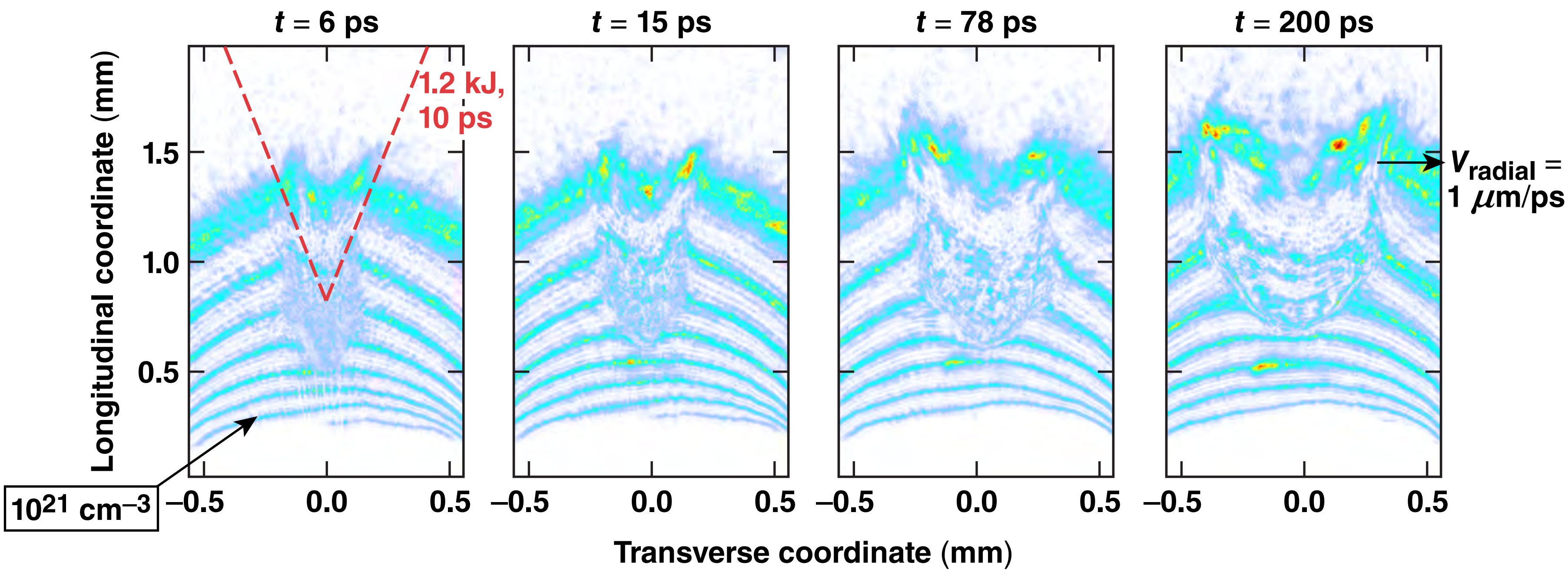
Optical-Probe Measurements of a Plasma Channel for Fast Ignition



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Summary

Channels bored up to 5×10^{20} cm^{-3} into long-scale-length plasmas have been observed using an optical probe

- The background plasma density is measured using a 10-ps UV optical-probe pulse ($\lambda = 0.263$ μm) and shows good agreement with 2-D hydrodynamic simulations
- The channeling beam undergoes filamentation at 5×10^{20} cm^{-3}, breaking into individual filaments that reach the IR critical surface
- The velocity of the resulting radial shock wave has been measured to be 1±0.1 μm/ps in the unperturbed plasma

Channeling experiments on OMEGA EP with 1.2-kJ, 10-ps IR pulses have been performed in long-scale-length (L_s ~ 275 μm) plasmas.

Collaborators

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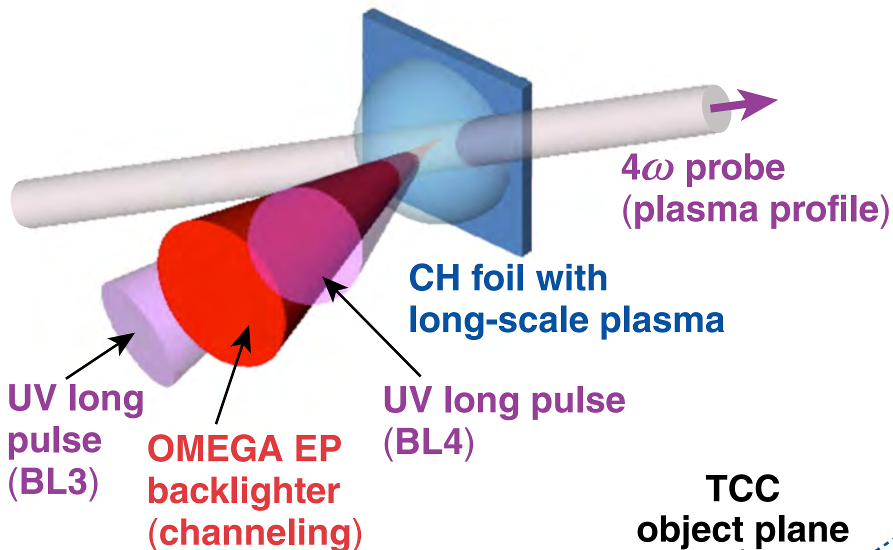
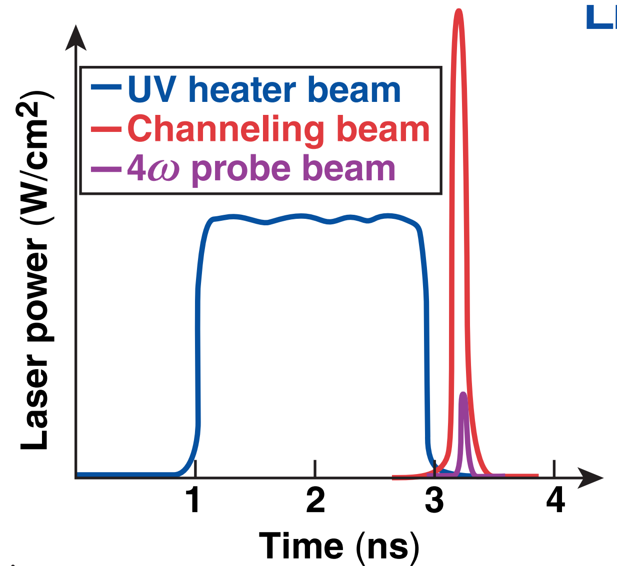
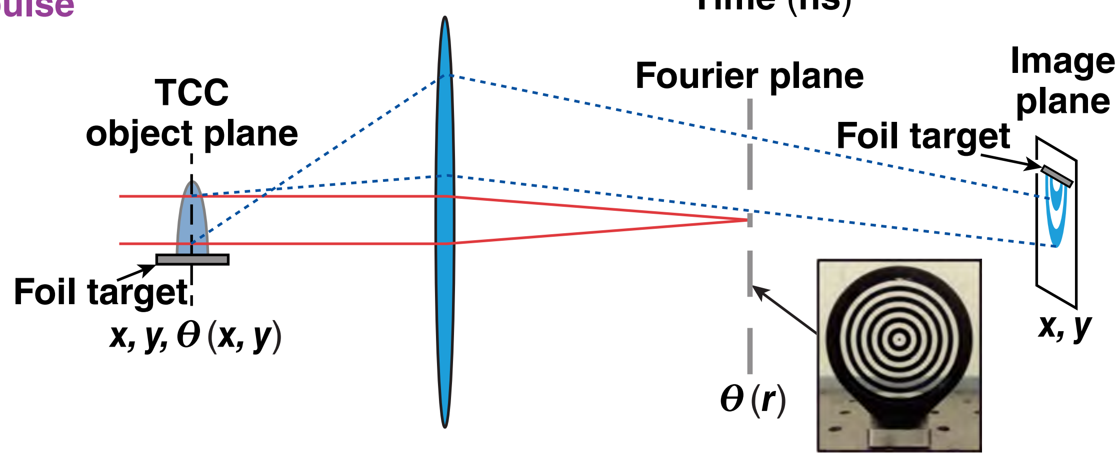
An experiment to measure channeling depth and residual density inside the channel was performed on OMEGA EP

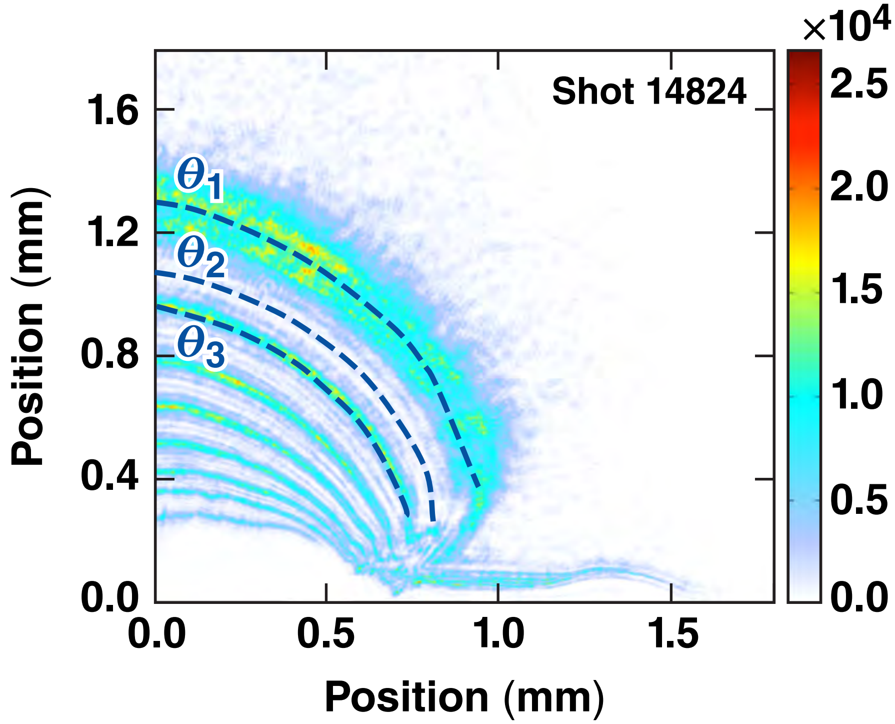


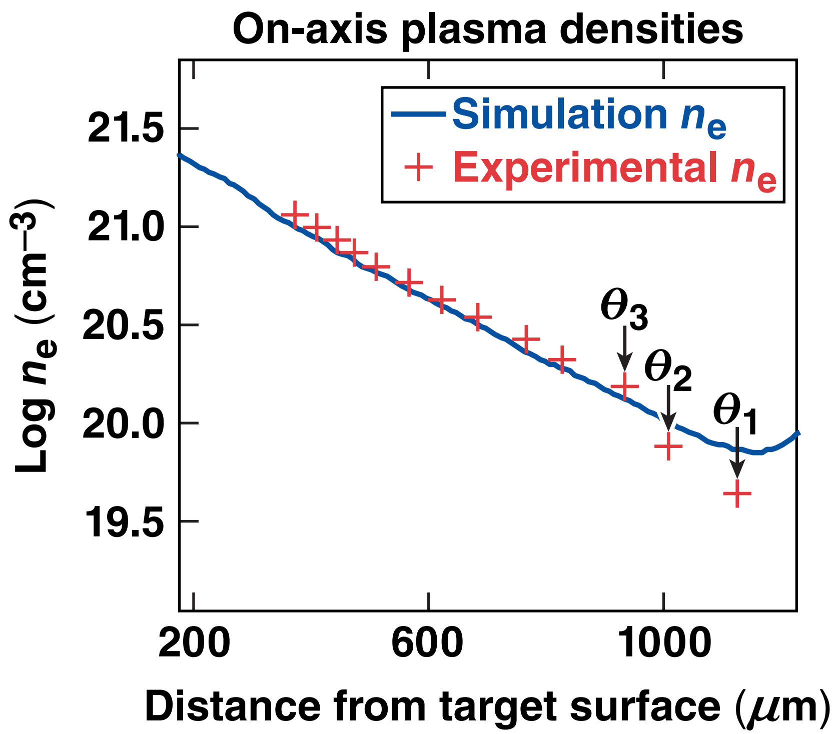




Angular filter refractometry (AFR) maps the refraction of the probe beam at target chamber center (TCC) to contours in the image plane.

The background plasma density is characterized using angular filter refractometry (AFR)*



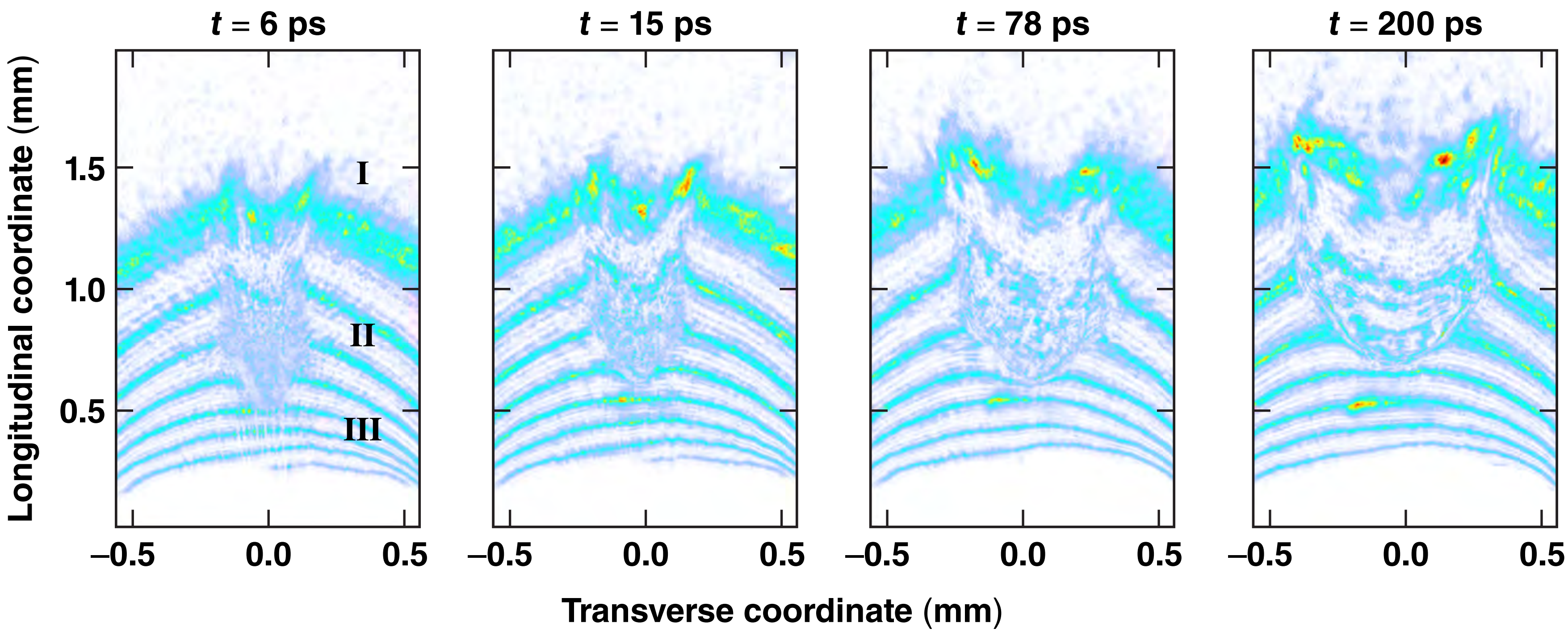


$$n_e = \frac{n_{c,\text{probe}}\,\theta}{\sqrt{1+\dfrac{2r}{L_x}}}$$

$$L_x = (x_2 - x_1) \Big/ \left[\log\left(\frac{\theta_1}{\theta_2}\right)\right]$$

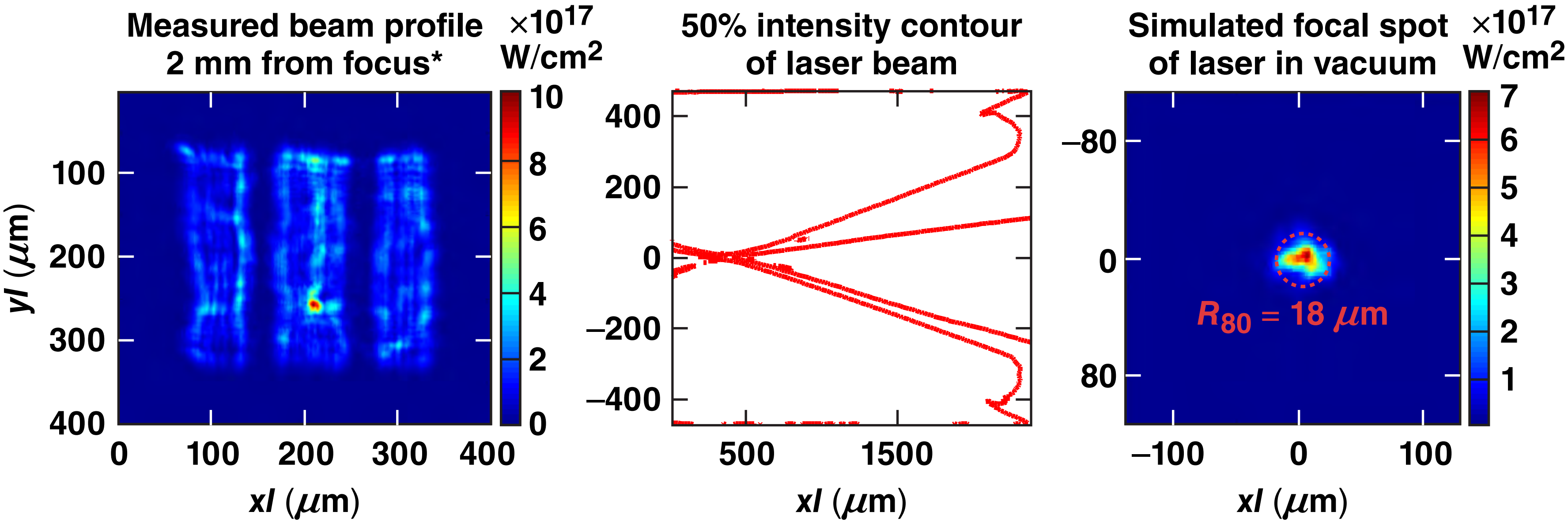
*D. Haberberger, GI3.00003, this conference (invited).

The AFR image of the channel shows three distinct regions



- Optical image of channel formation and subsequent expansion from a 1.2-kJ, 10-ps channeling pulse
- Laser filaments are observed to reach 1×10^{21} cm^{-3}

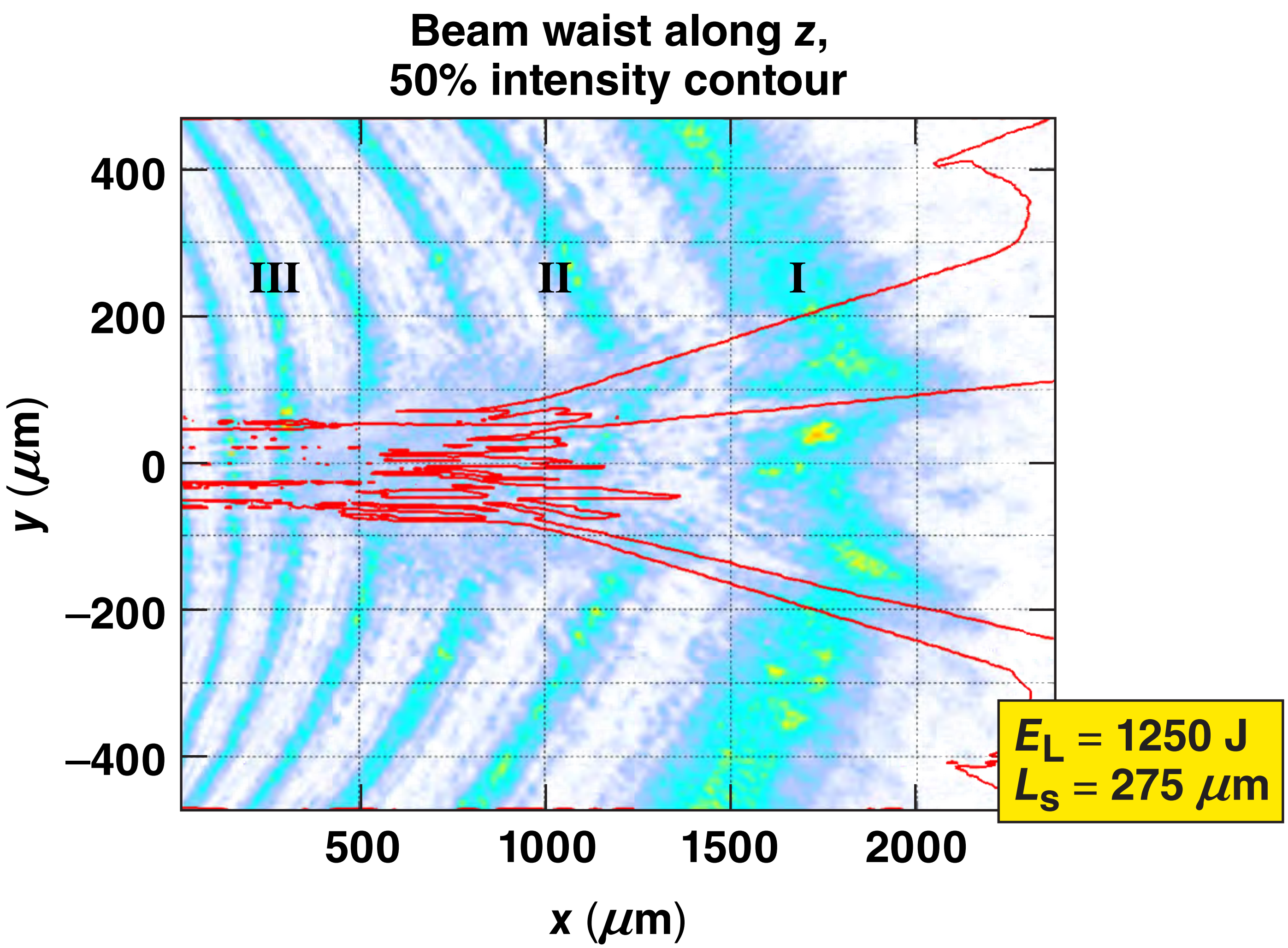
The simulated channeling beam focuses to an ~18-μm spot in the absence of plasma according to the simulation using a split-step propagation code



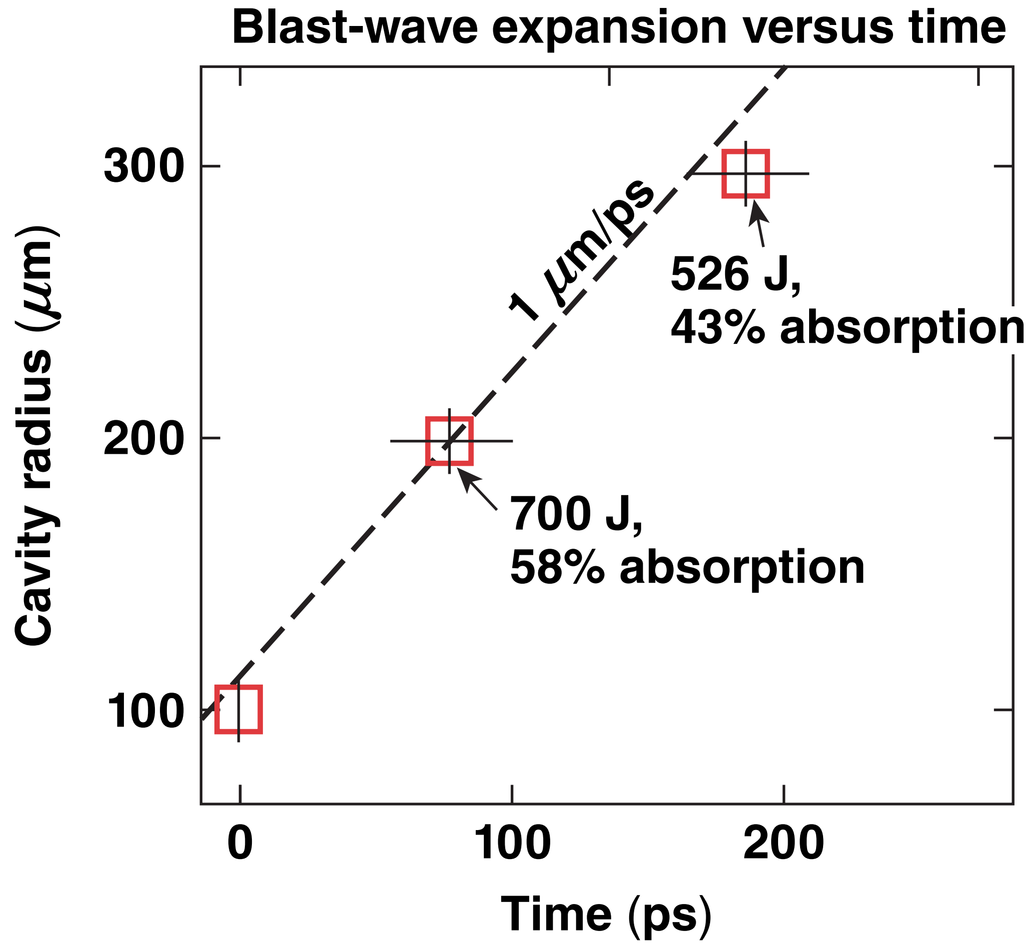
- The complex wavefront of the laser beam is sampled* and used as the input to the beam-propagation code

*B. Krushwitz, Opt. Express 20, 874 (2012).

A simulation with the plasma as measured by the 4ω probe visually reproduces the regions observed in the channel



The blast wave moves through the unperturbed plasma at 1 μm/ps



The kinetic energy in the blast wave is estimated from a 1-D cylindrical expansion to be >500 J.

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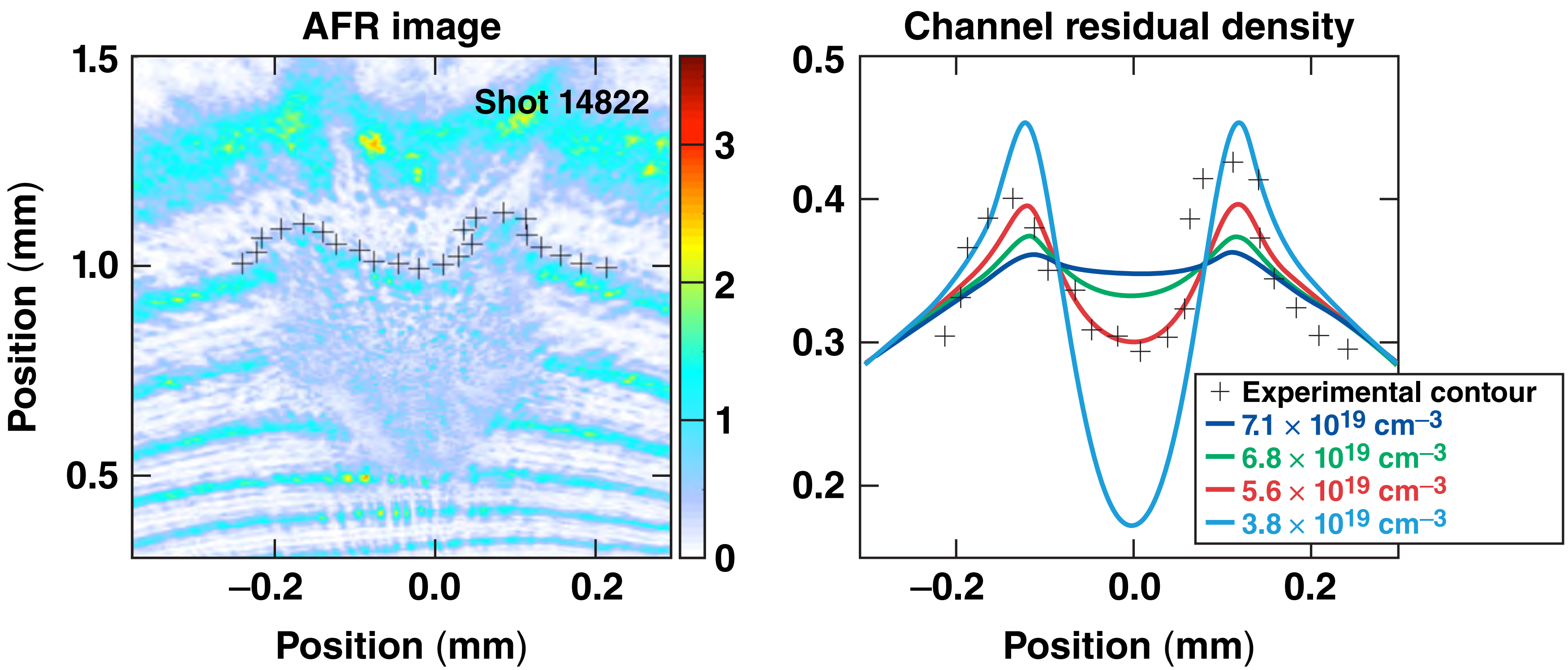
The residual density in the channel is inferred by measuring the distortion of the contours



- The residual density in the channel is 5×10^{19} cm^{-3} in agreement with the particle-in-cell result* of a channeling beam with comparable intensity and duration

*G. Li, Phys. Plasmas 18, 042703 (2011).

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Summary/Conclusions

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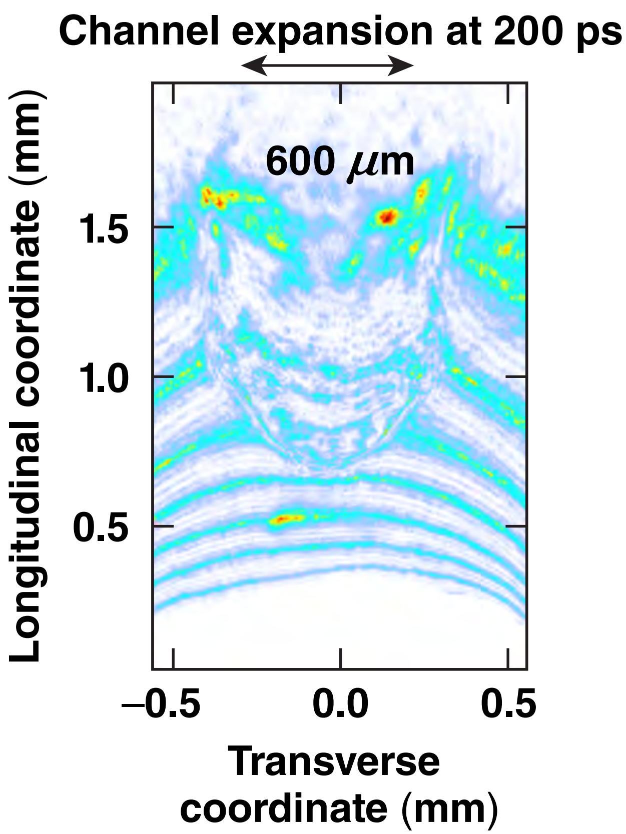
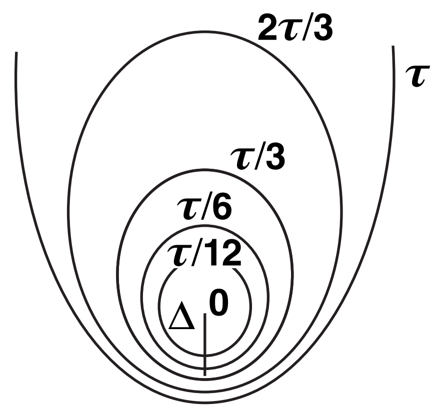
Channeling experiments on OMEGA EP with 1.2-kJ, 10-ps IR pulses have been performed in long-scale-length (L_s ~ 275 μm) plasmas.

The size and shape of the shock front at 200 ps is consistent with strong explosion of 300 J in a layered atmosphere



R_c	D_t	V_s (μm/ps)
100	6	n/a
200	86	1.16
300	200	0.86

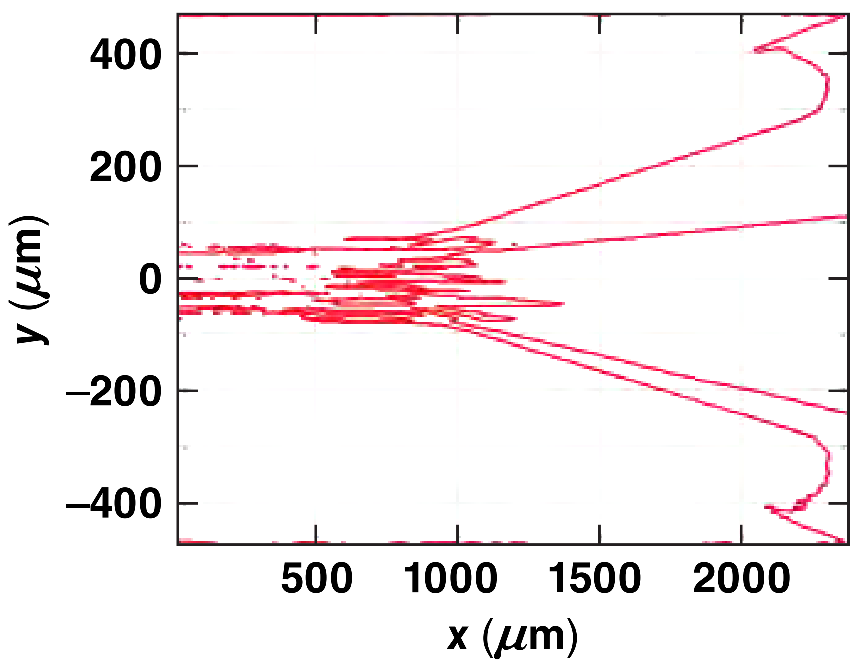


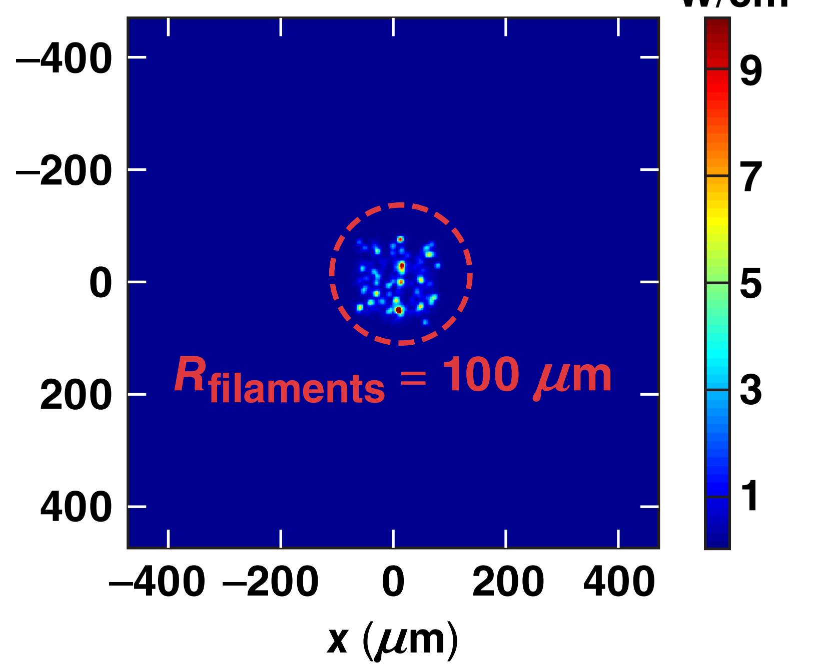
$$\tau = \int_0^\infty \frac{dR}{D} \sim \frac{\rho_c^{1/2}}{E^{1/2}} \int_0^\infty R^{3/2} e^{-R/2\Delta} dR$$

$$\Delta = 275\ \mu m, R = 300\ \mu m, \partial_c = \frac{1\ kg}{m^3}, \tau = 200\ ps$$

$$E \sim 300\ J$$

The calculated beam profile when propagated through the plasma shows individual filaments inside a radius of ~100 μm





Each of these small laser filaments creates the fine structures we see at the end of the channel in the 4ω probe image.

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