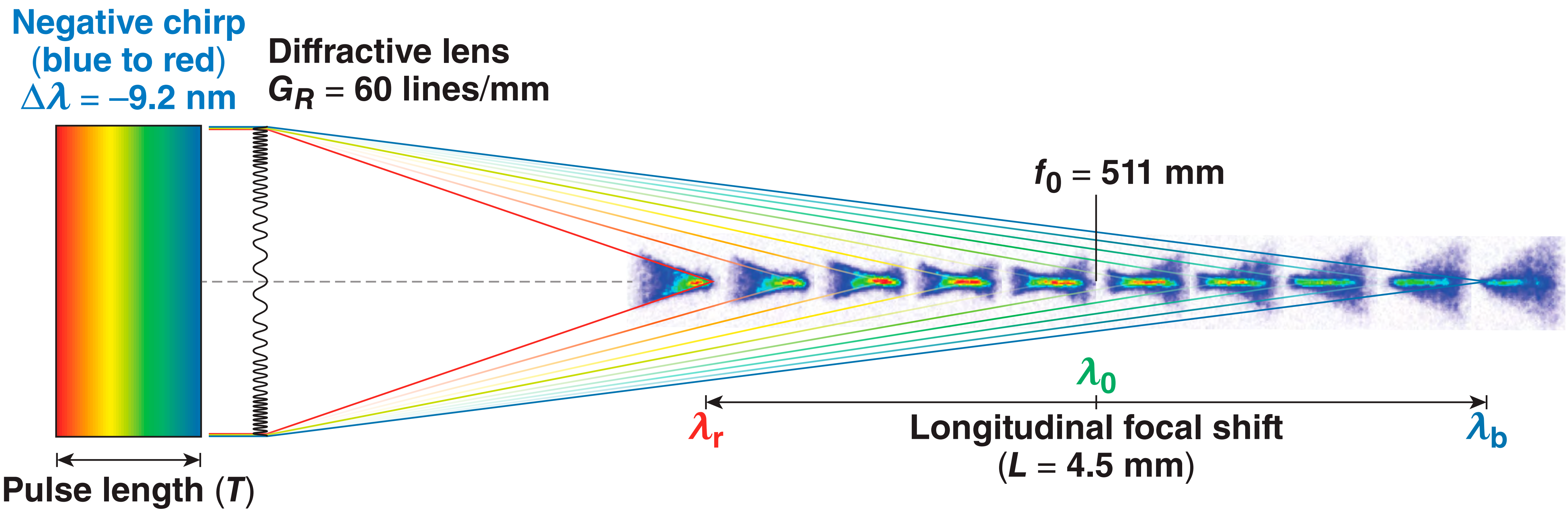
Flying Focus: Spatiotemporal Control of Longitudinal Intensity



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59th Annual Meeting of the
American Physical Society
Division of Plasma Physics
Milwaukee, WI
23–27 October 2017

Summary

Flying focus provides unprecedented control over laser–plasma interactions

- Flying focus
  - decouples the diameter of the laser focus from the longitudinal focal range
  - decouples the velocity of the focus from the group velocity of light
- Experiments
  - demonstrated the flying focus over 100× the Rayleigh length of the system
  - demonstrated control over the focal velocity from –0.2*c* to nearly 50*c*
- Flying focus could be the enabling technology of several laser–plasma devices

Collaborators

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I. A. Begishev, R. Boni, S. Bucht, J. Katz, J. Palastro, and J. L. Shaw**

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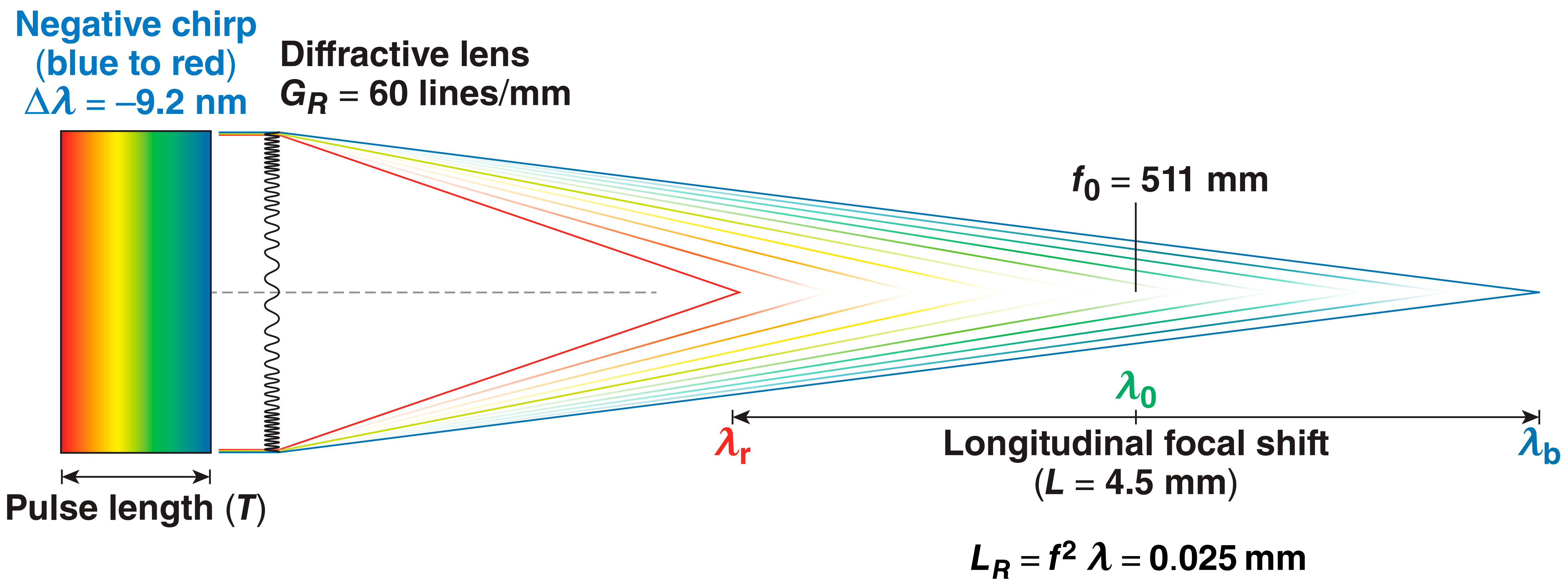
Combining a diffractive lens with a broadband laser provides spatiotemporal control over the focus



With 10 nm of bandwidth, the separation between focused colors is nearly 200× longer than the Rayleigh length of the system.

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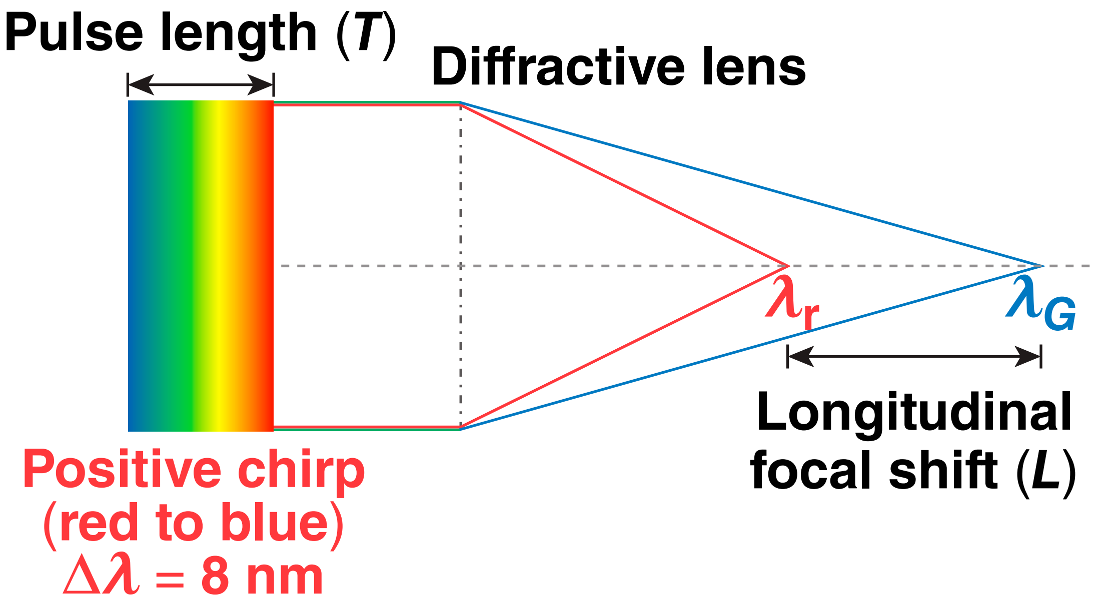
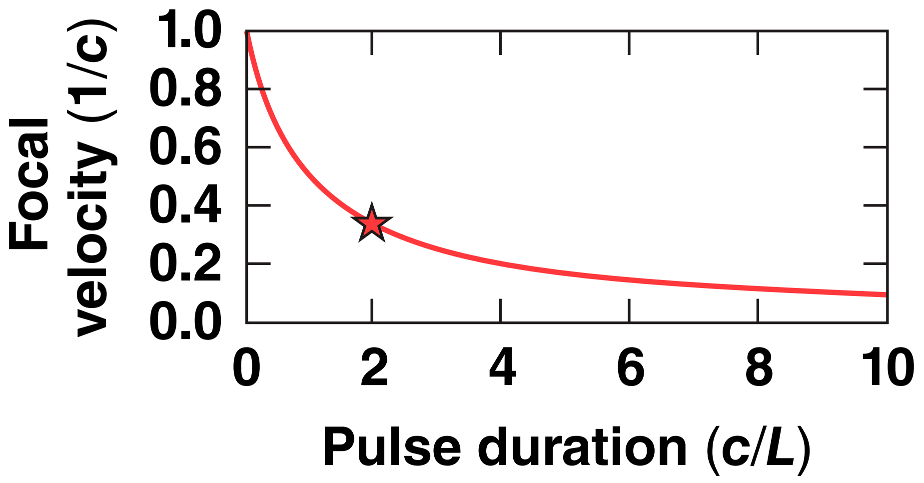
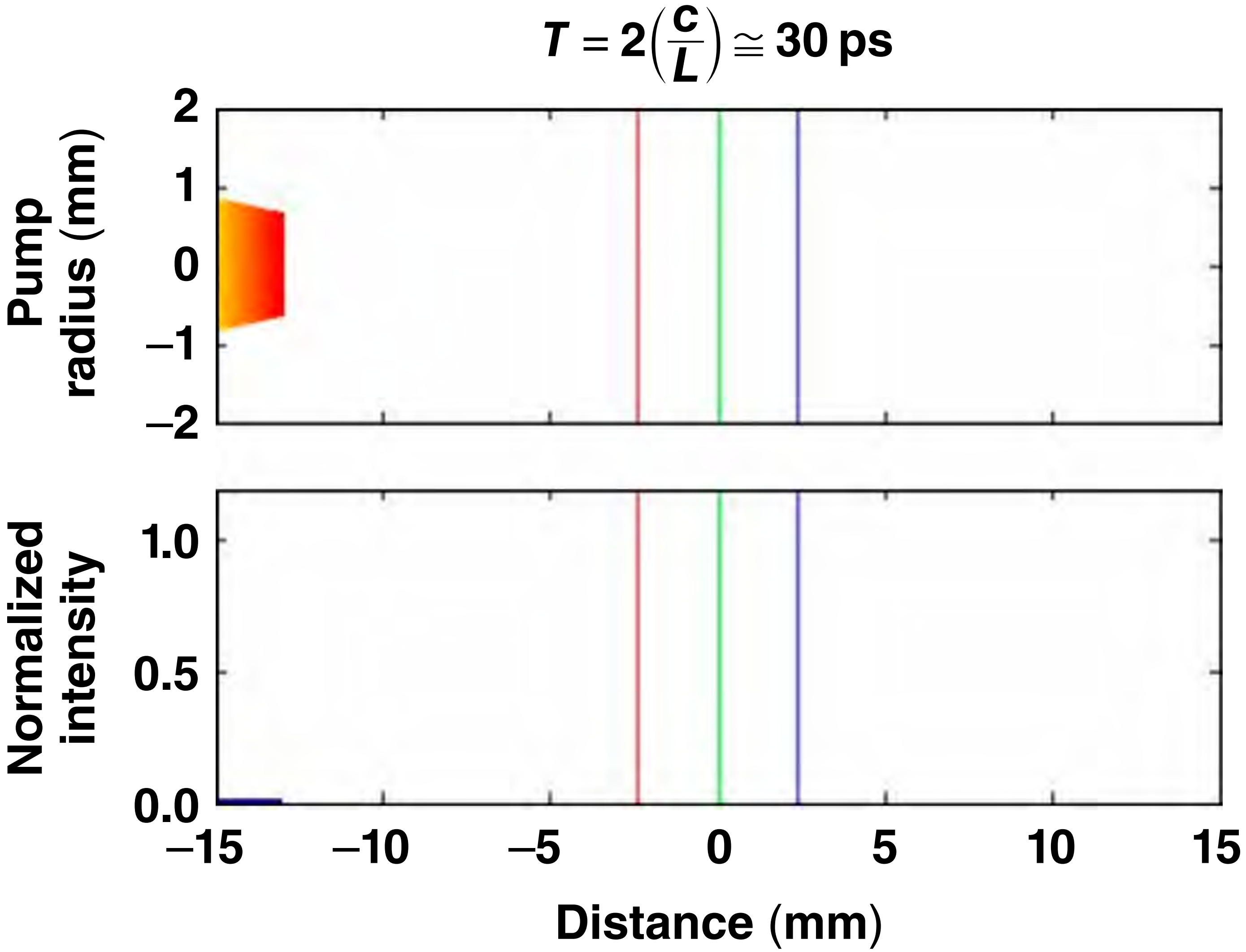
The velocity of the focus can be controlled by varying the pulse duration of the laser (*T*)

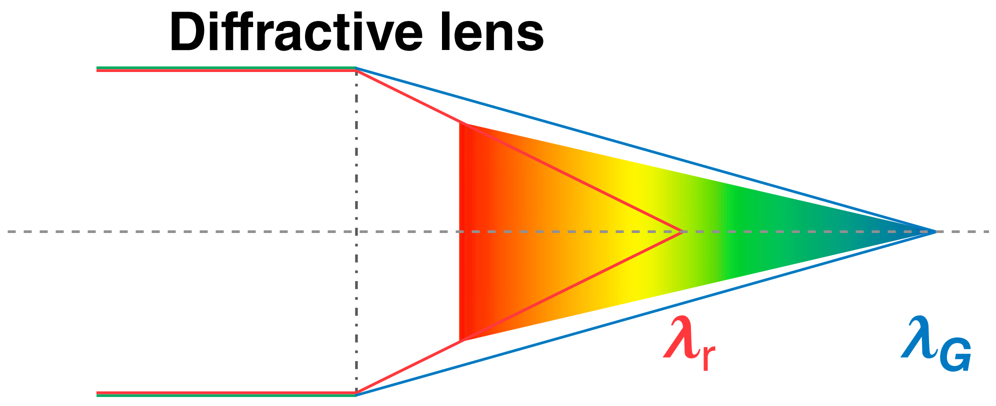


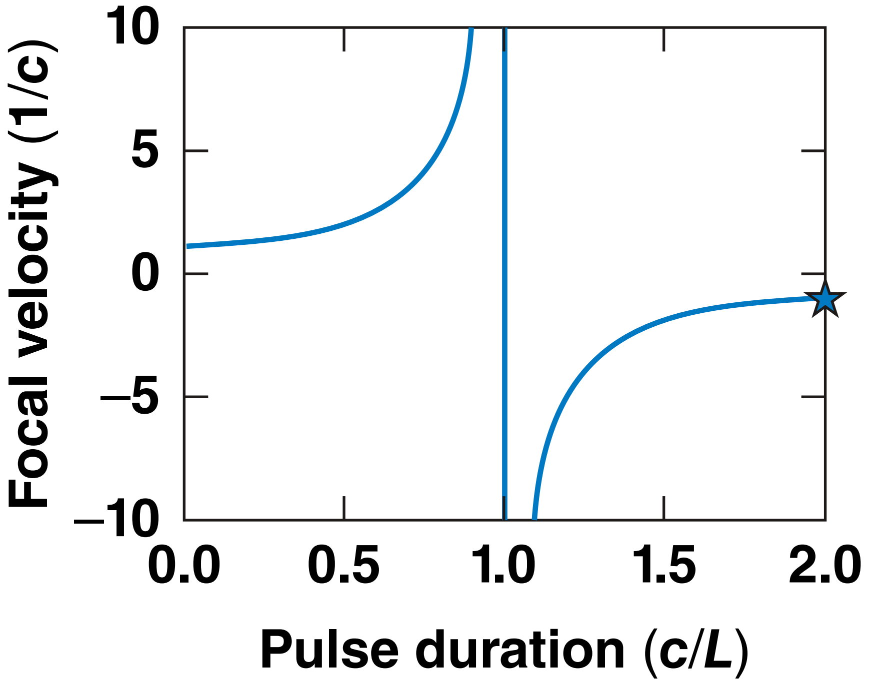


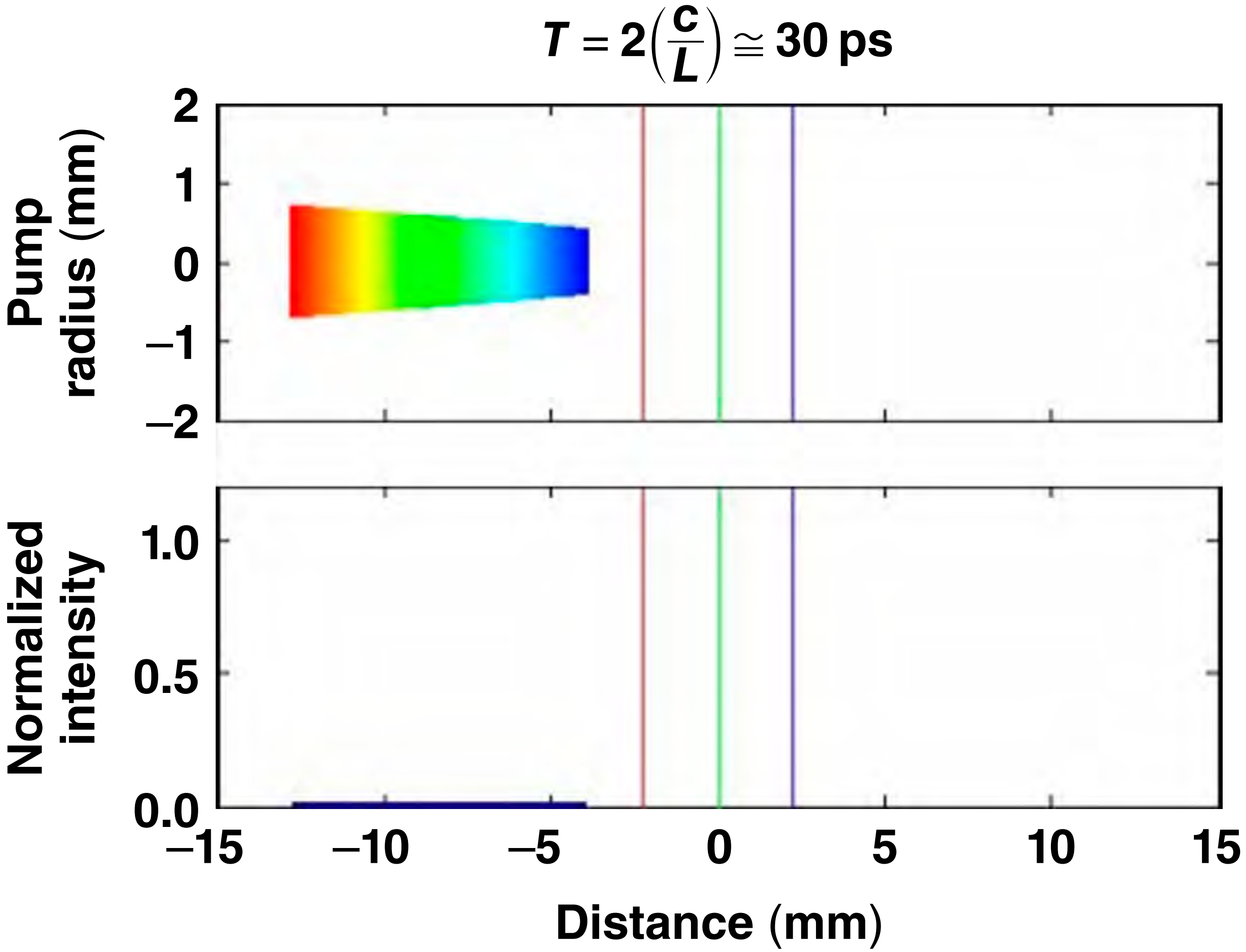


The longer the pulse duration, the slower the focus will propagate.

By changing the direction of the chirp (blue to red), the velocity of the focus can propagate at any velocity and in either direction







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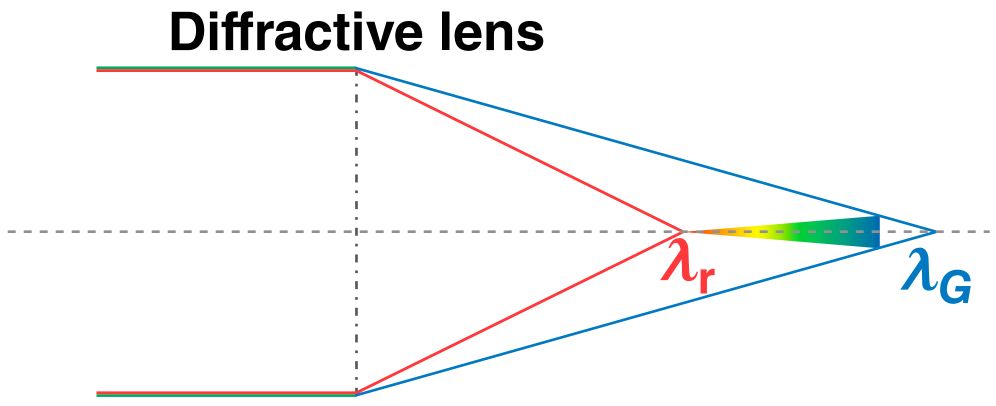
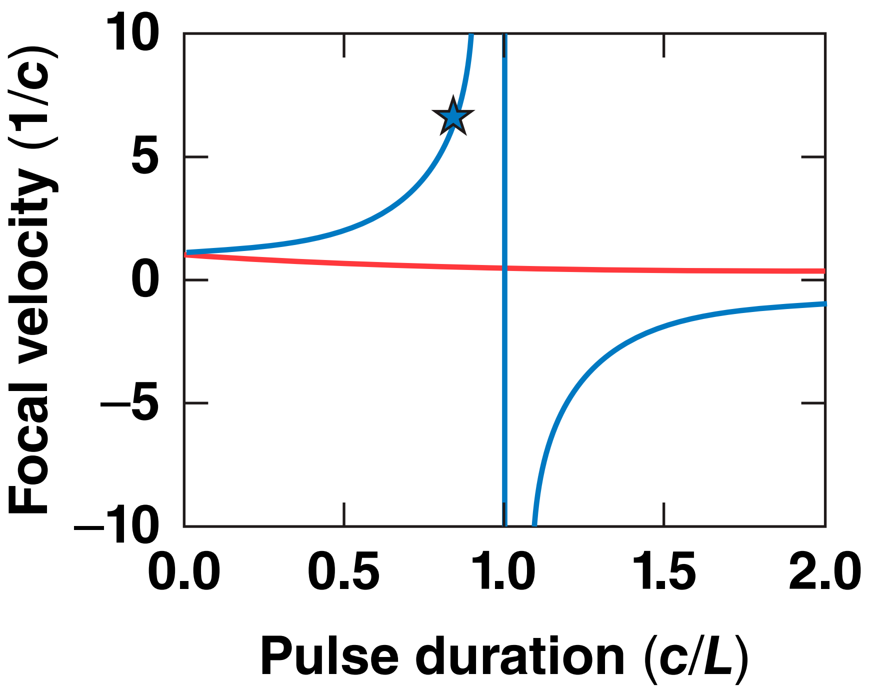
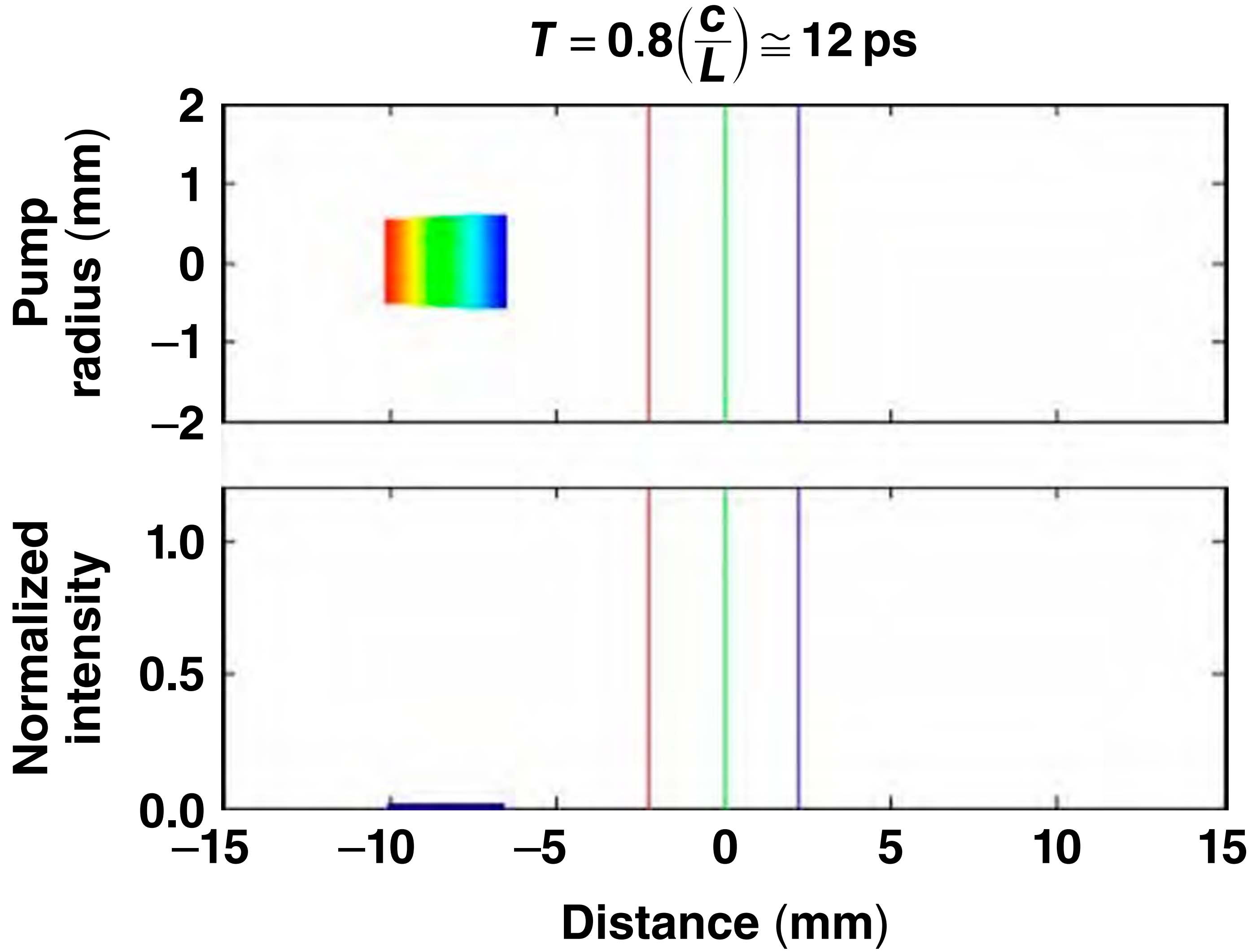
Pulse durations less than $2L/c$ (negative chirp) produce superluminal focal velocities







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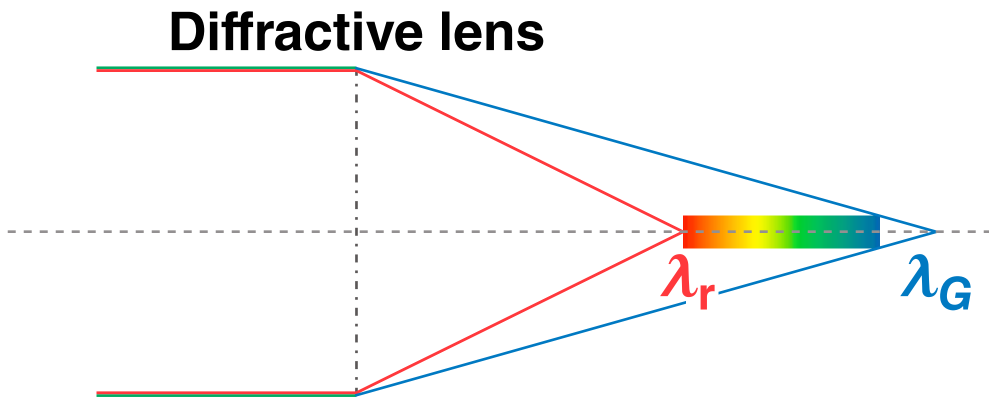
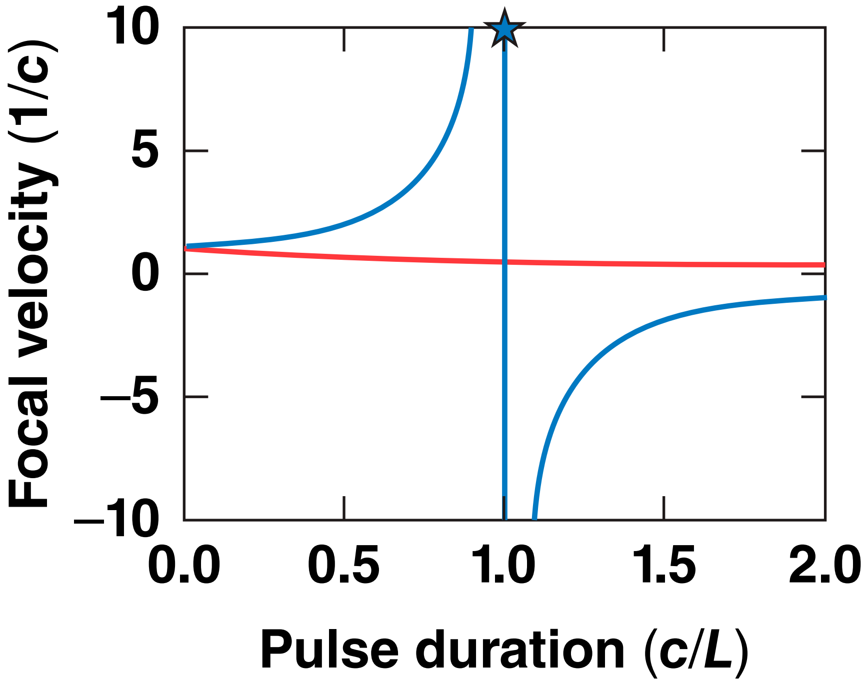
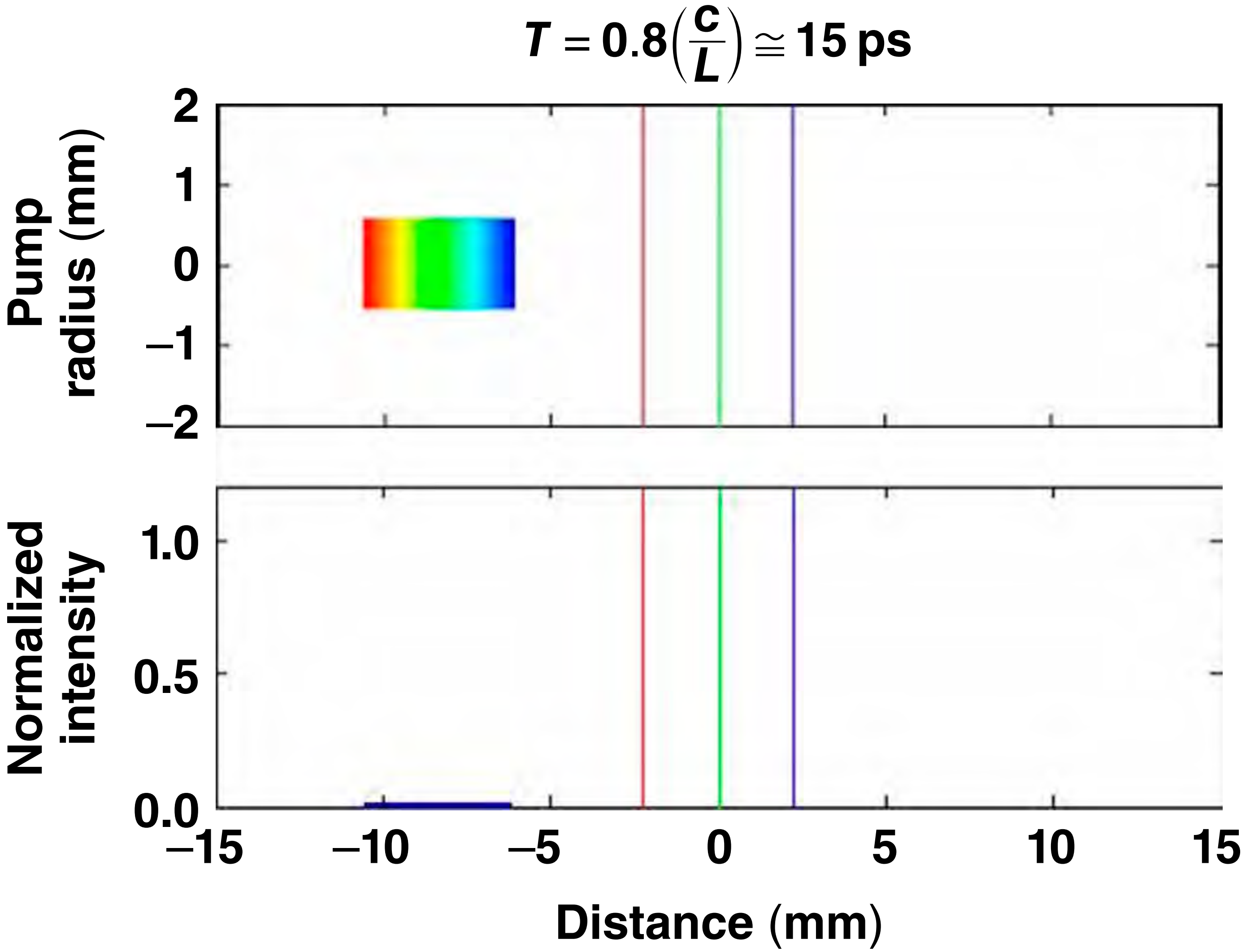
Setting the pulse duration equal to the focal range (*L*/*c*) results in an "infinitely" fast focal velocity (line focus)







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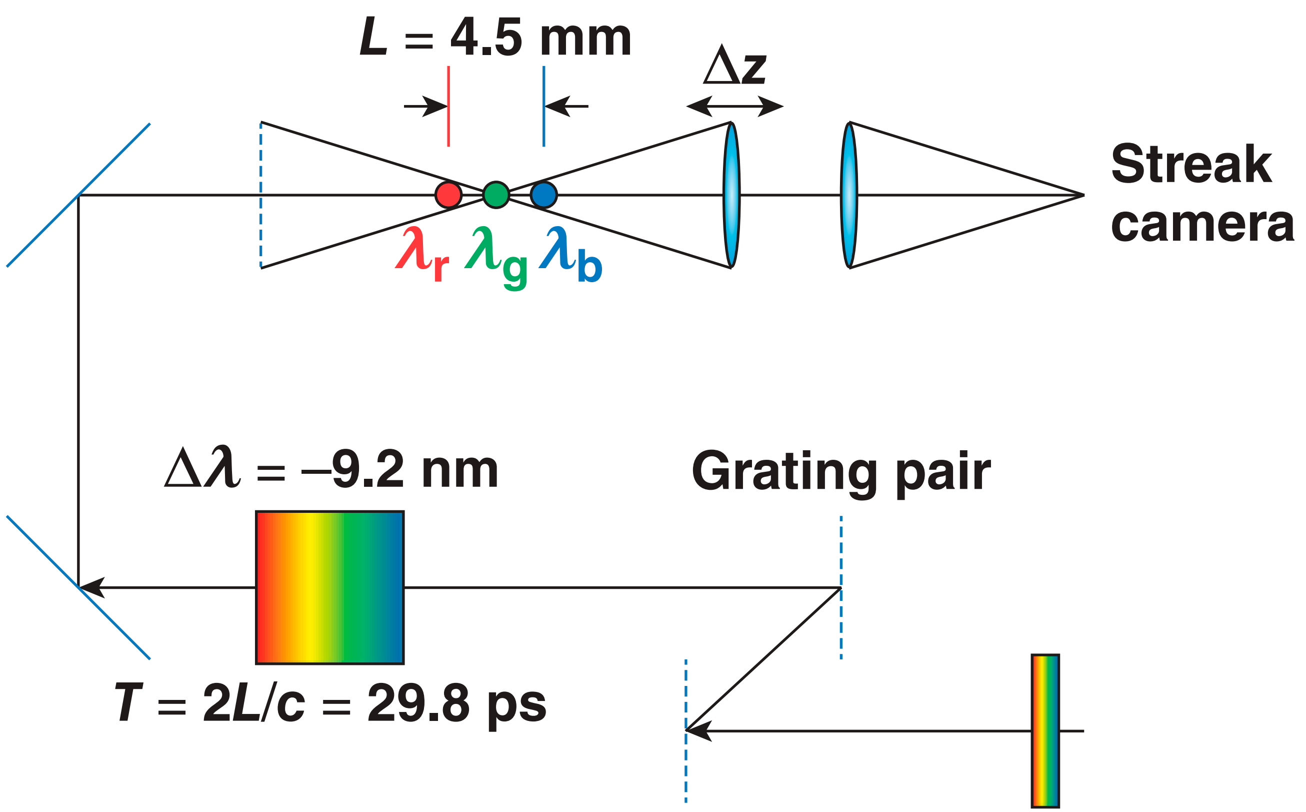
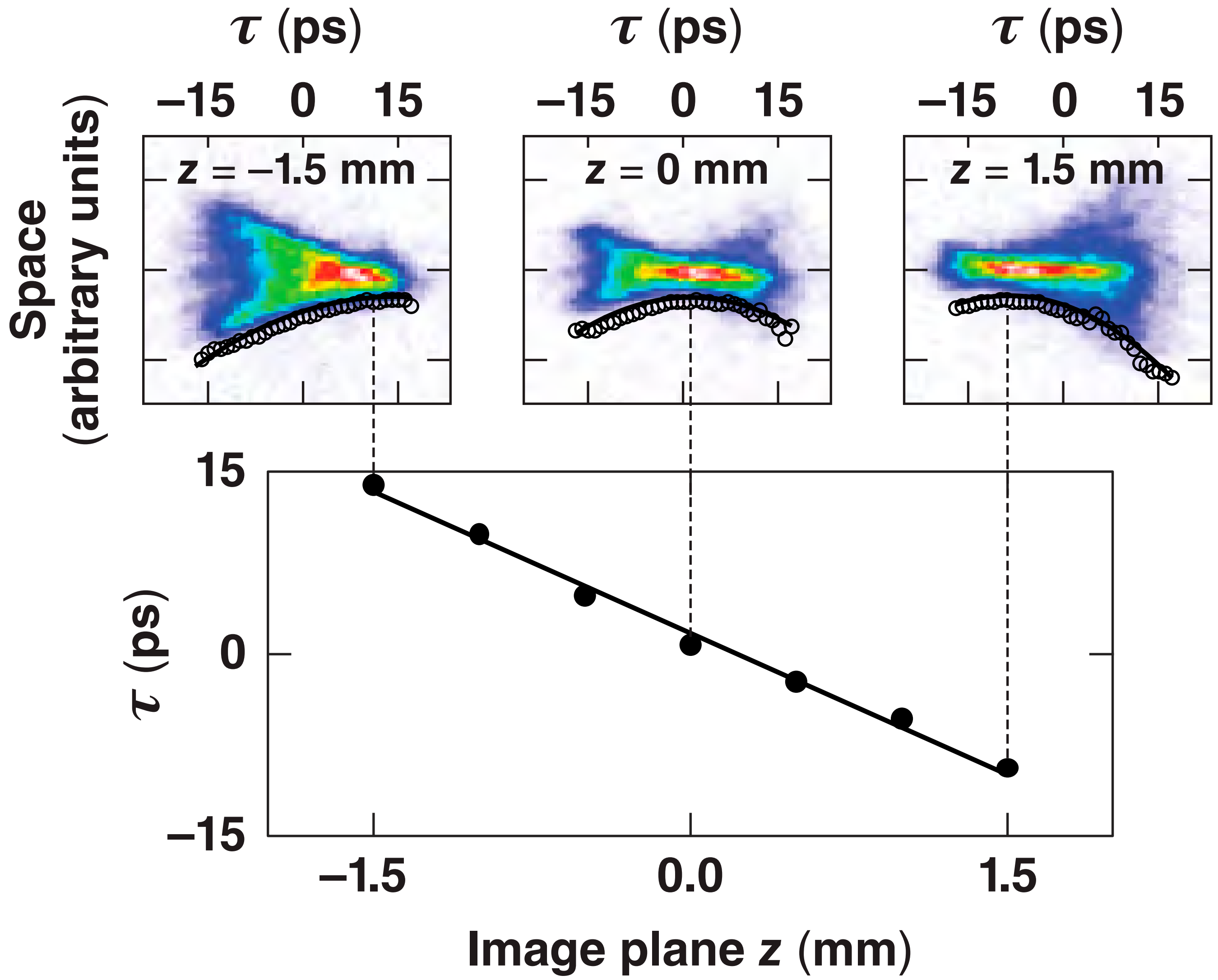
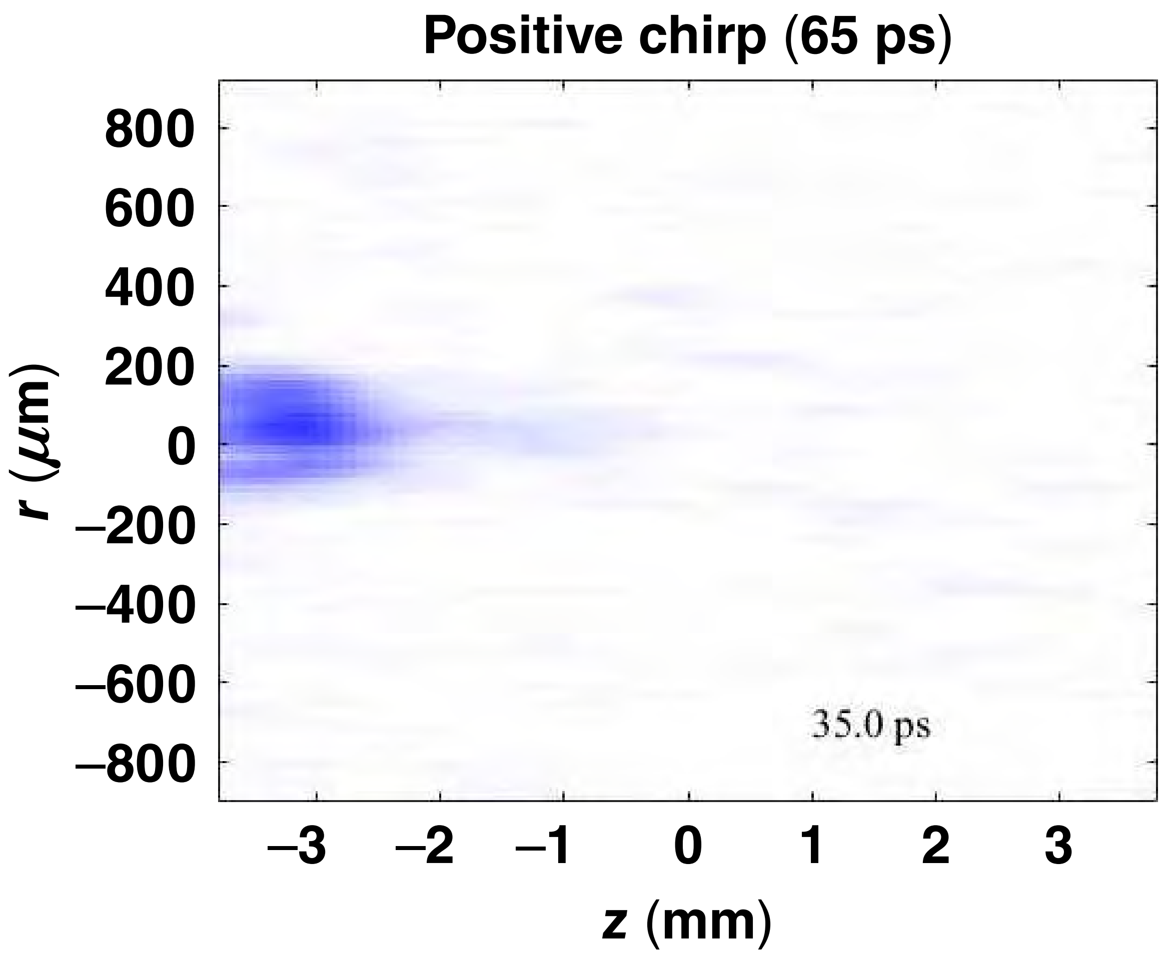
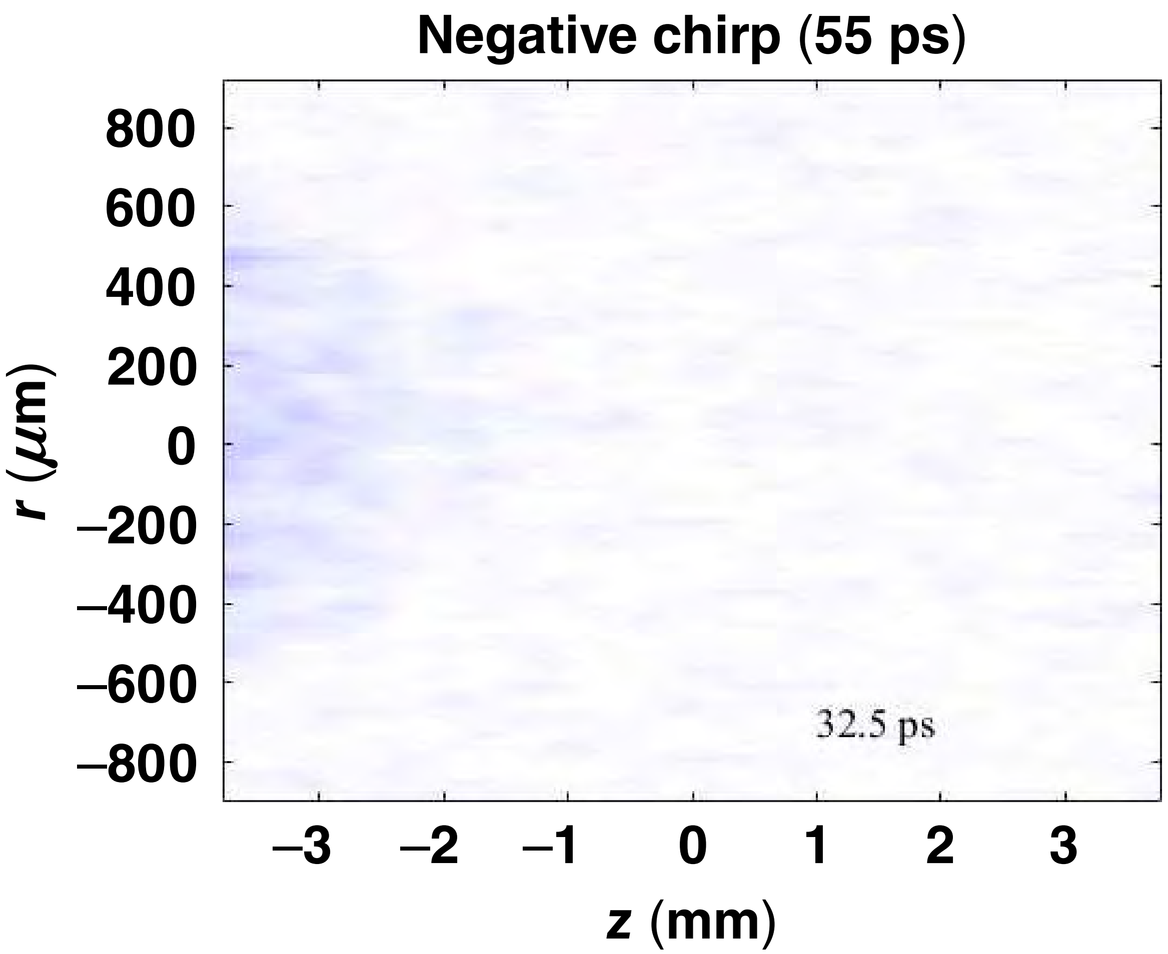
Experiments were performed on the Multi-Terawatt (MTW) laser to demonstrate the flying focus





The measurements provided space and time information that was reconstructed to generate the flying focus intensity profile





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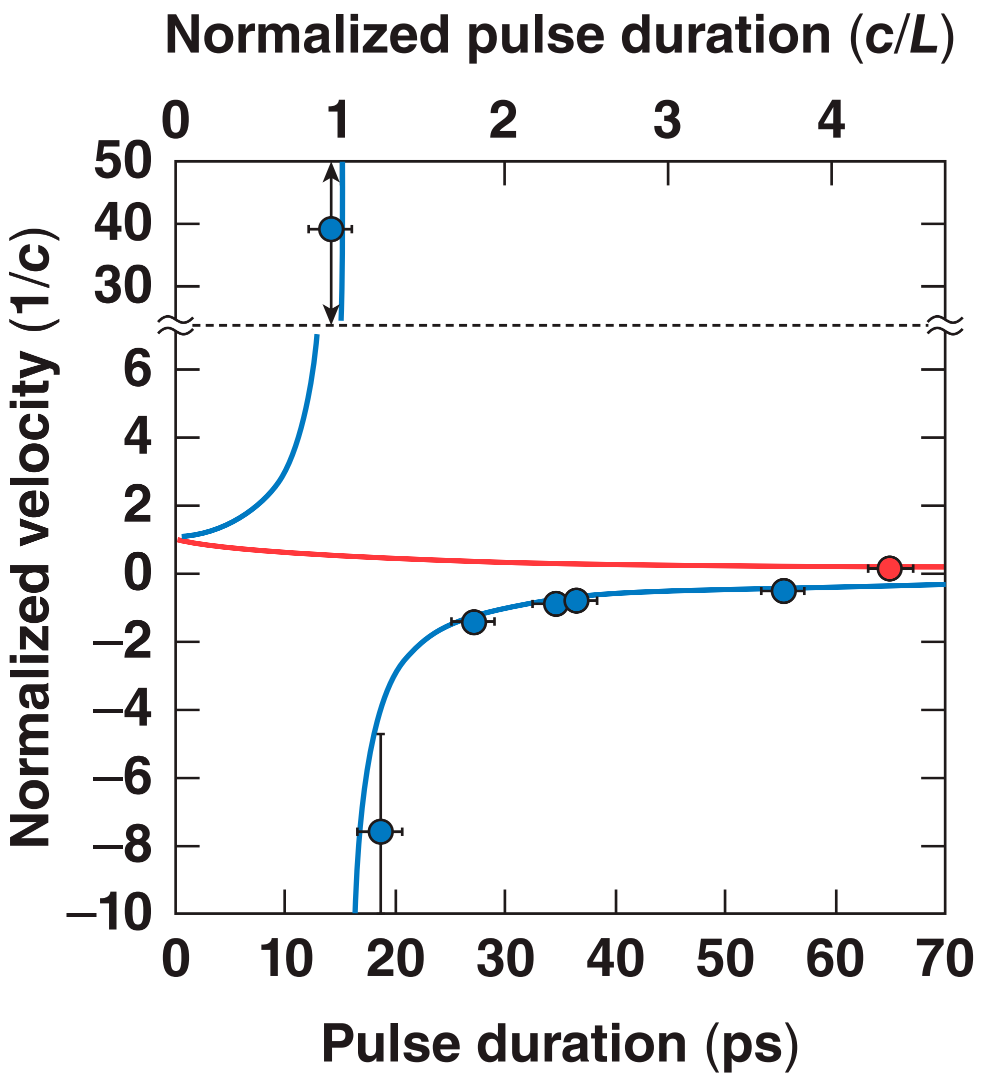
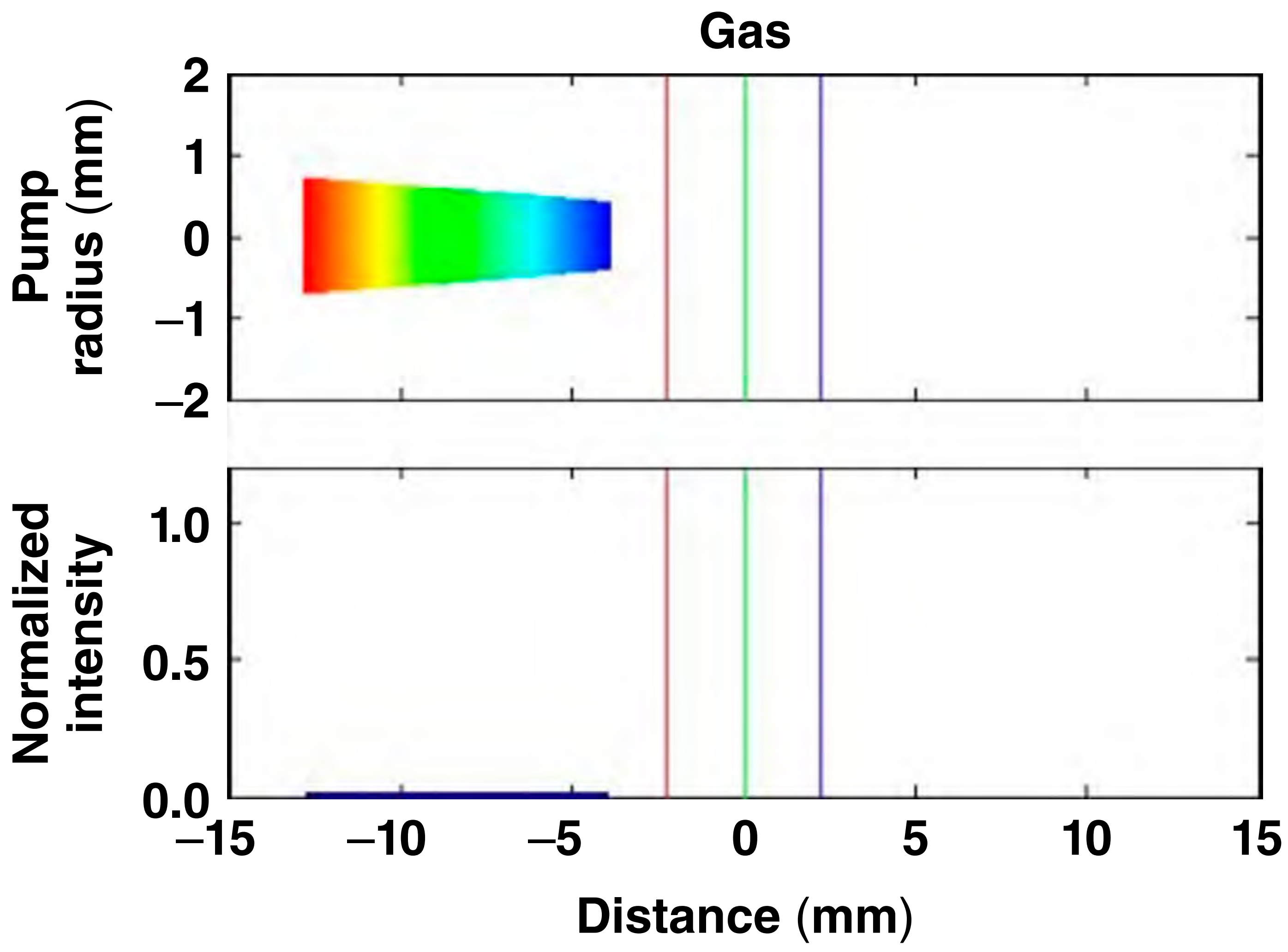
The measurements agree well with analytic and Fresnel calculations

$$v = \frac{L}{T \pm L/c} = c\left(1 \pm \frac{Tc}{L}\right)^{-1}$$



The flying focus could be the enabling technology for laser-plasma amplifiers*



Injecting the seed behind the ionization wave will provide constant plasma conditions and intensity throughout the amplifier.

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* D. Turnbull *et al.*, "Raman Amplification with a Flying Focus," submitted to Physical Review Letters.

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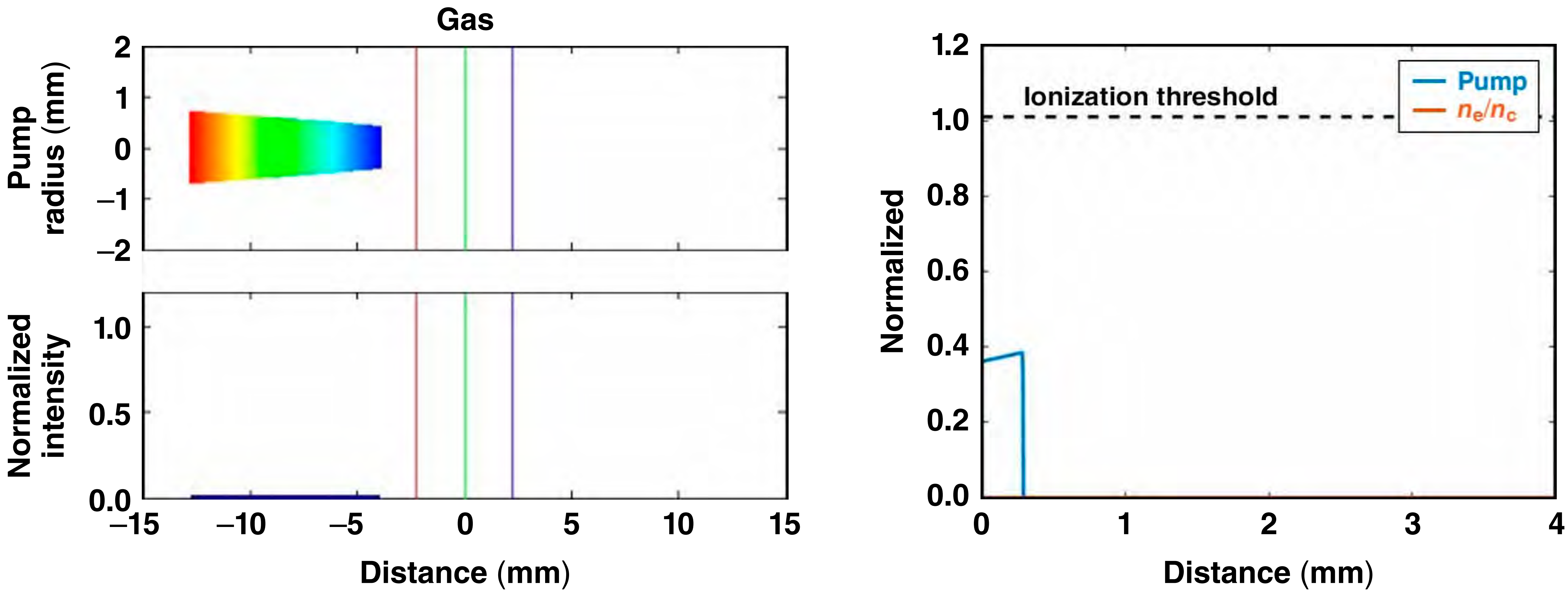

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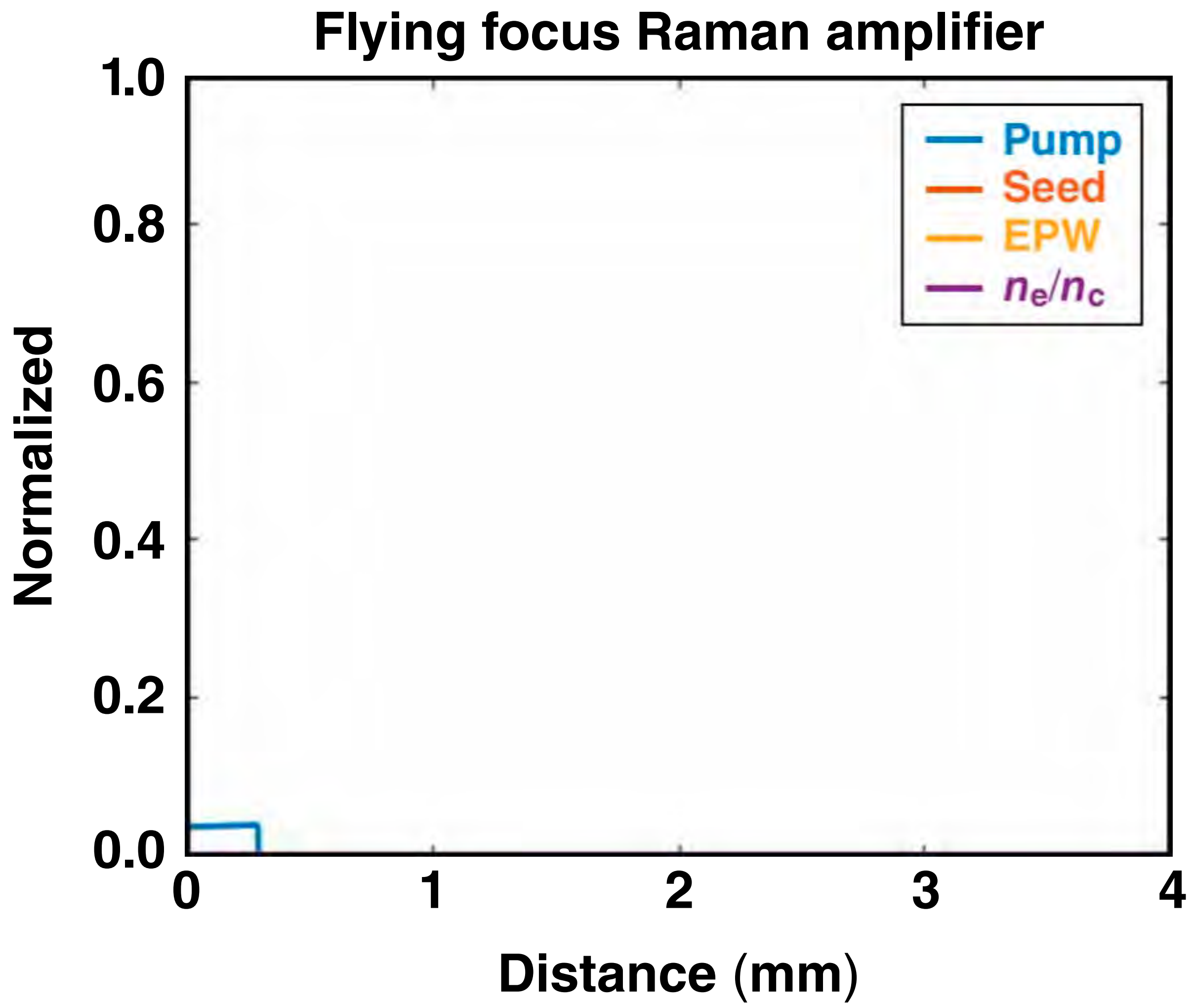
The flying focus provides significant advantages for a laser-plasma amplifier

- **Constant longitudinal intensity:** the seed laser observes a constant intensity over many millimeters (hundreds of times the optical Rayleigh length)
- **Counter-propagating ionization wave:** the pump beam will propagate through gas, eliminating spontaneous instabilities (SRS,* filamentation…)
- **Plasma conditions:** the plasma conditions observed by the seed will be constant and controllable



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*SRS: stimulated Raman scattering

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Summary/Conclusions

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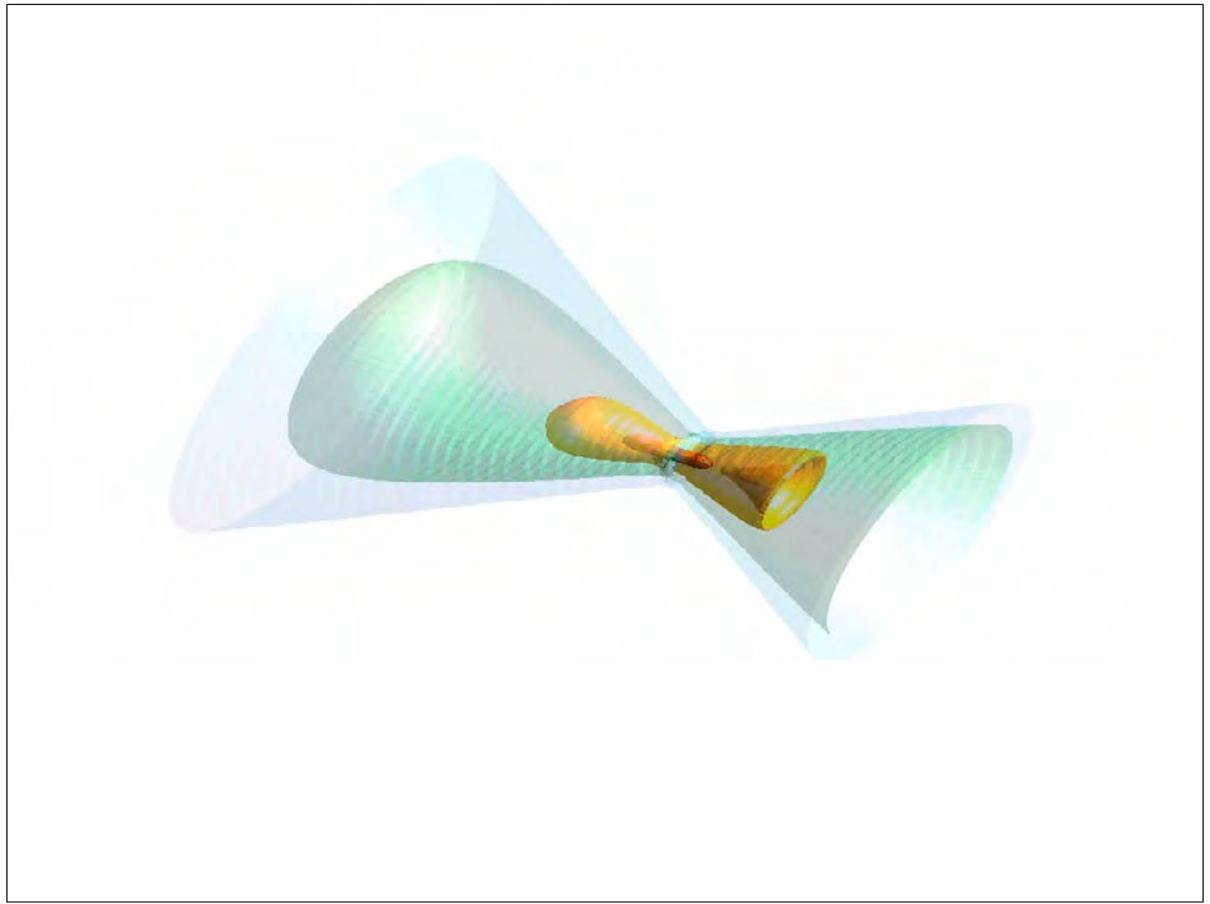

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