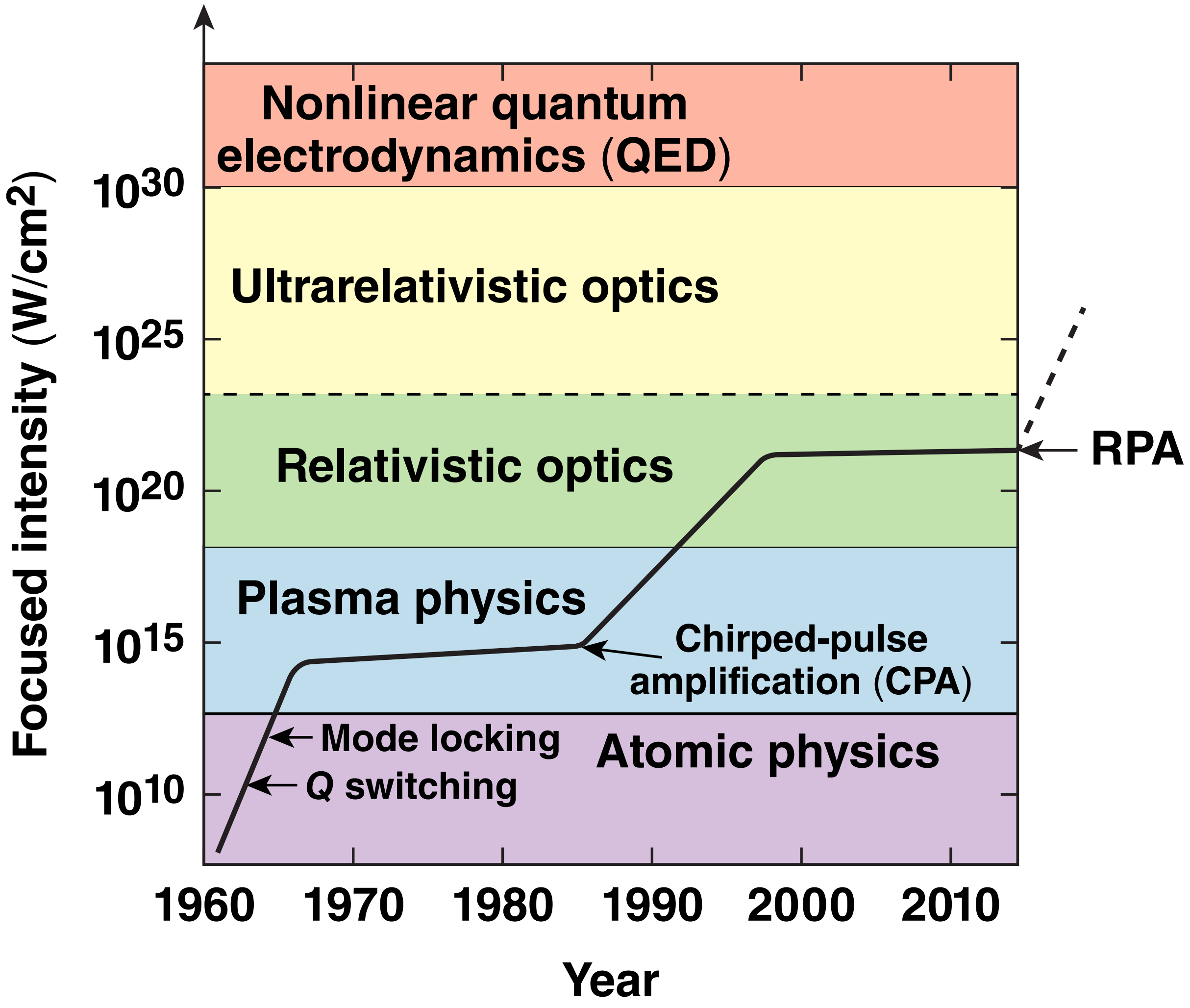
A Tunable (1100-nm to 1500-nm) 50-mJ Laser Enables a Pump-Depleting Plasma-Wave Amplifier



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Summary

A high-energy, tunable Raman amplification experiment is designed to quickly enter the pump-depletion stage

- Raman amplification has the potential to surpass current laser power limitations
- Two independent laser systems will provide the pump (50 J) and seed (50 mJ)
- The pump-depletion stage coincides with the presence of large-amplitude electron plasma waves that will be detected with Thomson scattering

Collaborators

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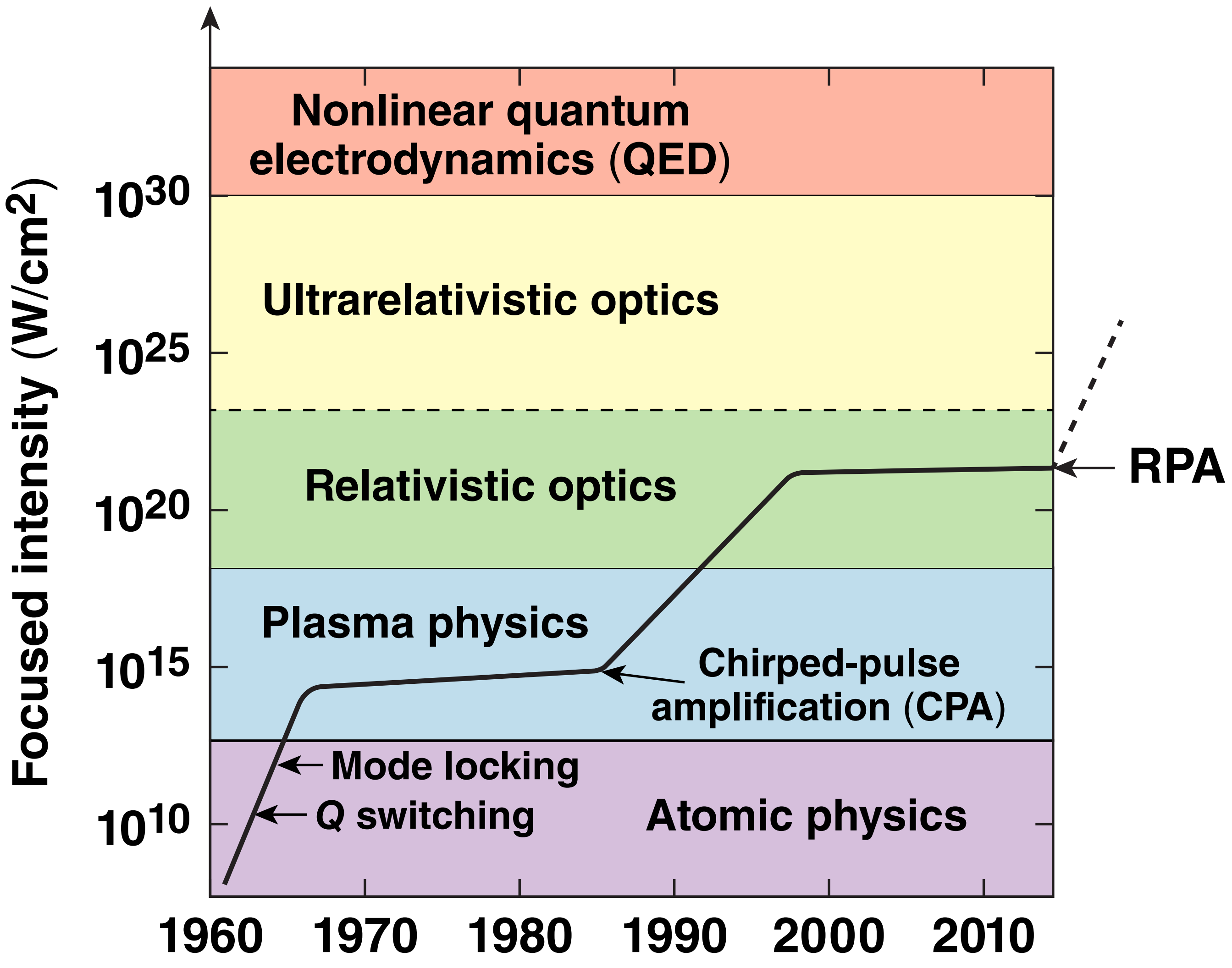
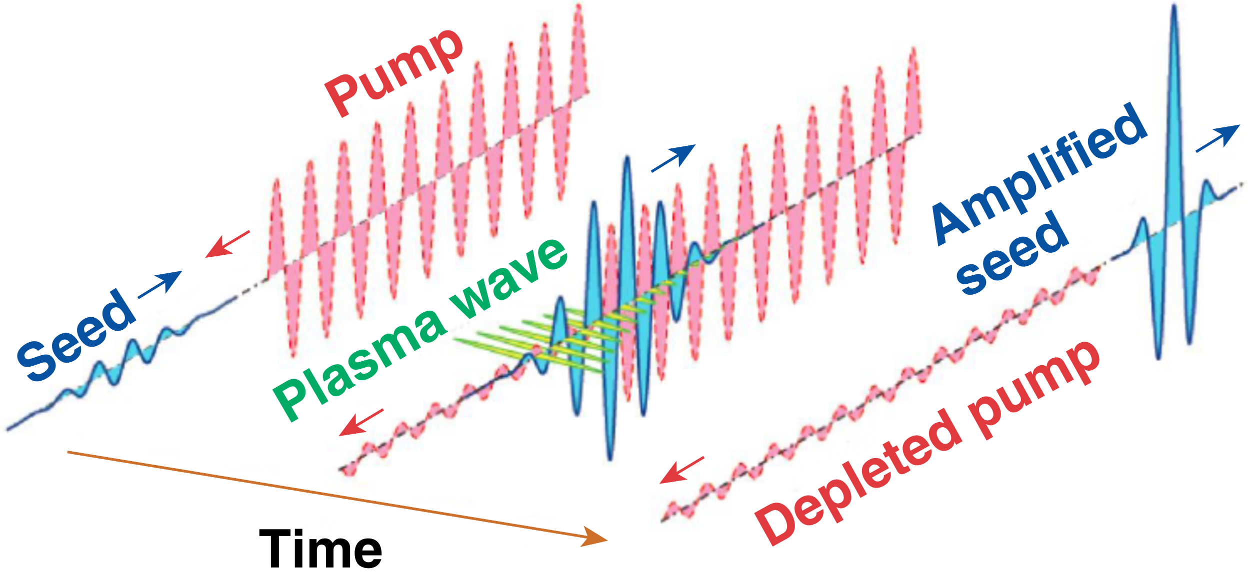
The next generation of high-intensity lasers requires a paradigm shift in technology

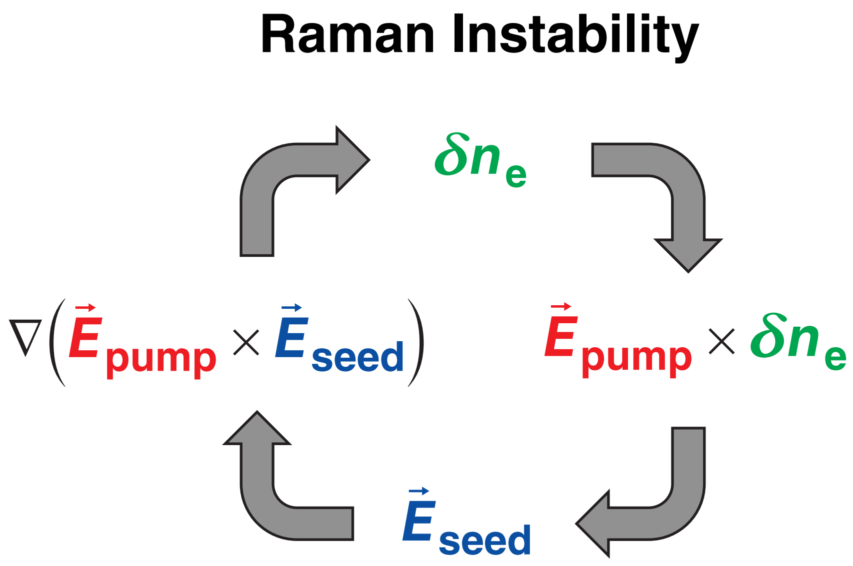
- Present-day petawatt-class lasers are limited by the grating damage threshold
  - broadband gratings: fluence limit ~0.1 J/cm^2
- Plasma amplifiers have the potential to reach higher peak powers by avoiding the damage-threshold obstacle
  - plasma fluence limit: ~1000 J/cm^2 (assuming a 10-fs pulse)



RPA: Raman plasma amplifier

A plasma amplifier works by transferring energy from a long (tens of ps) energetic pump pulse into a short (tens of fs) counter-propagating seed pulse





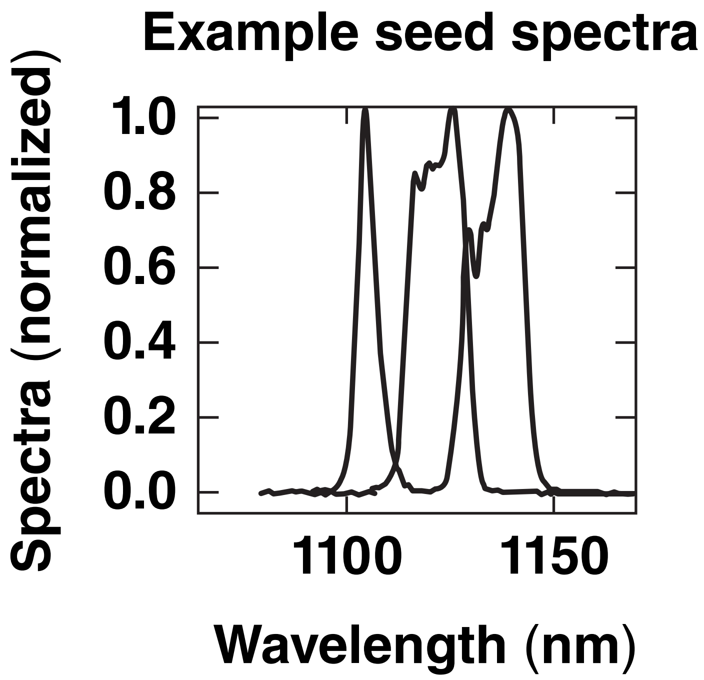
$$\vec{k}_{pump} = \vec{k}_{seed} + \vec{k}_p \qquad \omega_{pump} = \omega_{seed} + \omega_p$$

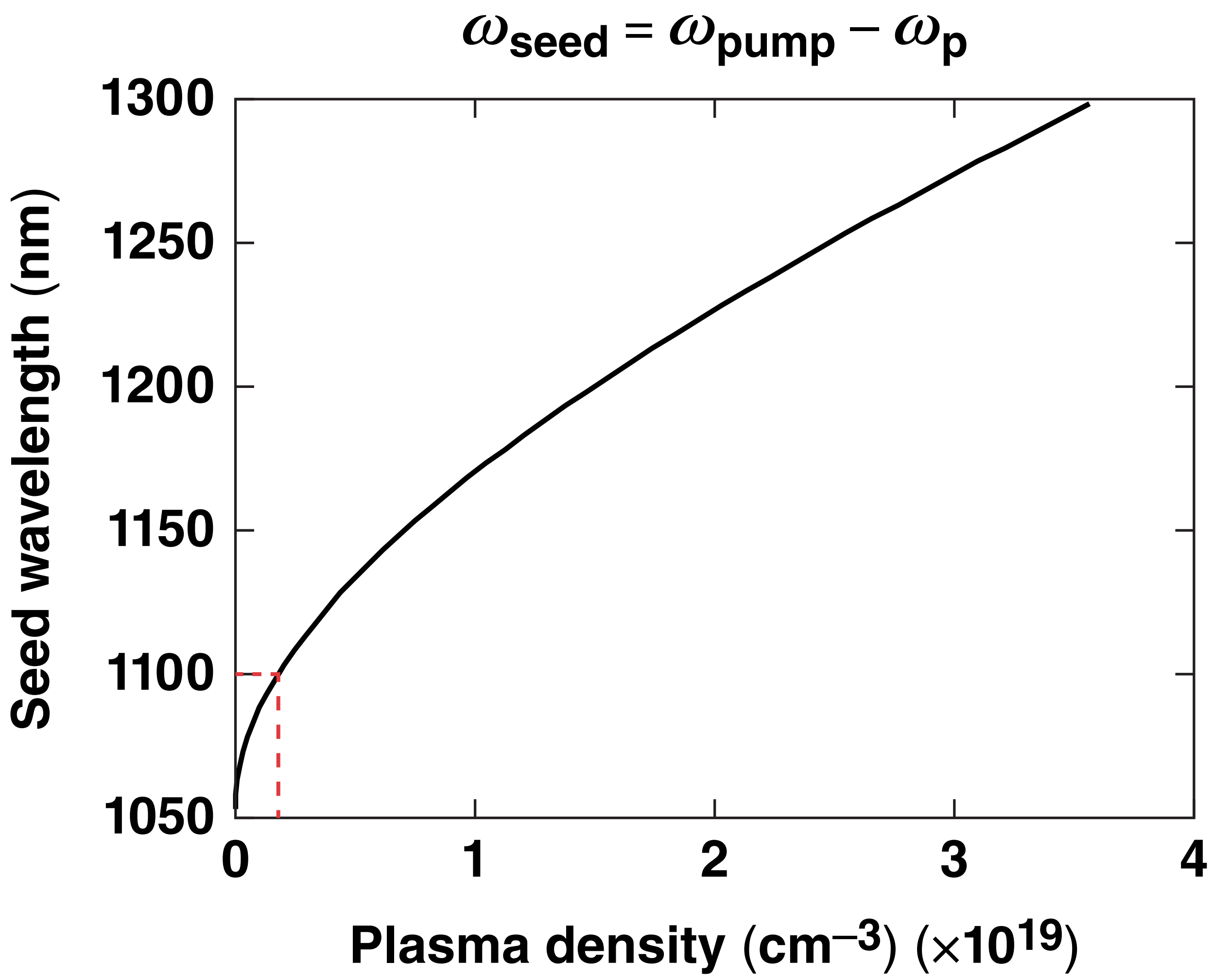
This localized backscattering can effectively compress the high-energy pump into a high-intensity short pulse.

Raman amplification at the Laboratory of Laser Energetics will utilize existing laser systems to provide the pump and seed

UR LLE

Pump	Seed
Multi-Terawatt (MTW) Laser System	Optical parametric amplifier line (OPAL)
λ = 1053 nm	λ = 1100 to 1500 nm
Energy = 50 J	Energy = 50 mJ
Δt = 1 to 100 ps	Δt = 50 fs





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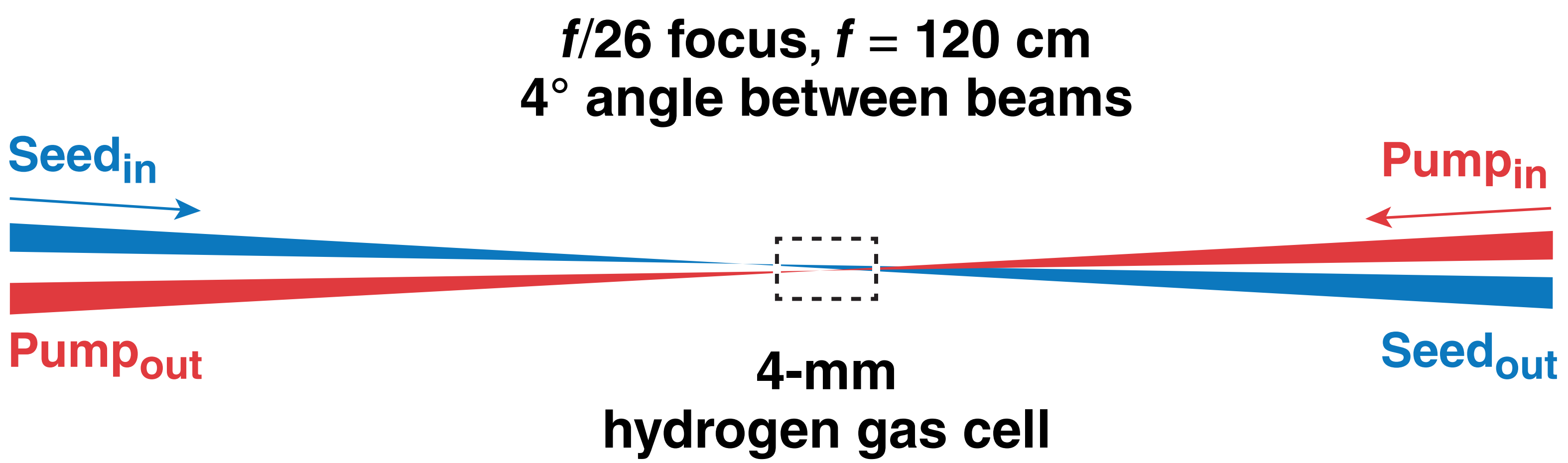
The seed and pump will cross out of focus at a small angle in a 4-mm-long hydrogen gas cell



Pump

Energy = 50 J
Δt = 25 ps
Radius = ~300 μm
Intensity = 10^{15} W/cm^2
λ_{pump} = 1053 W/cm^2

Seed

Energy = 50 mJ
Δt = 50 fs
Radius = ~300 μm
Intensity = 10^{14} W/cm^2
λ_{seed} = 1100 to 1200 nm

Unique conditions

- Gas cell
  - long homogeneous plasma density
- Noncollinear interaction
  - isolate scattering sources
- High energy
  - practical energies for PW laser system
- High-intensity seed
  - quickly enter pump-depletion stage

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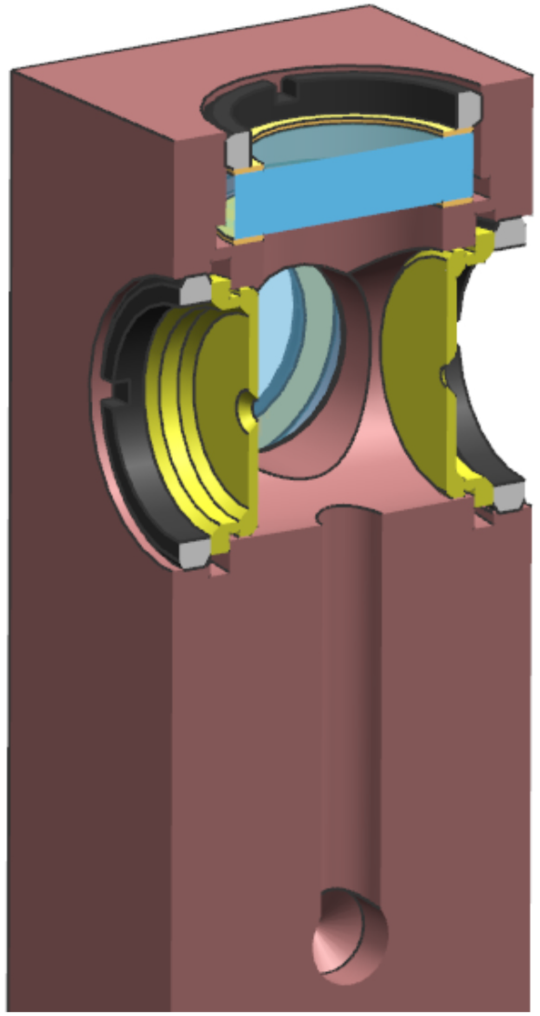
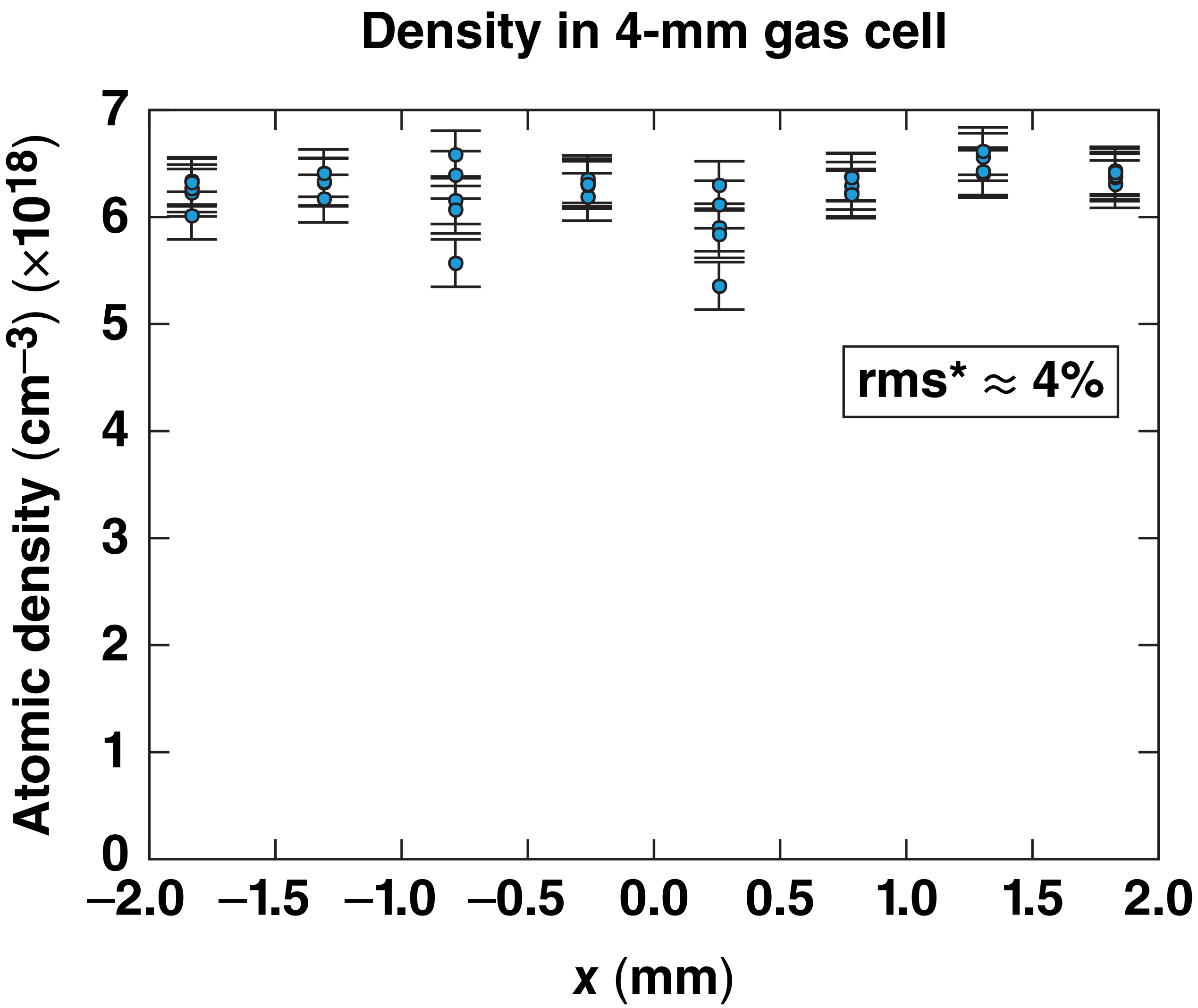
To create a long homogenous plasma target, a gas cell target has been constructed and characterized using interferometry





*rms: root mean square

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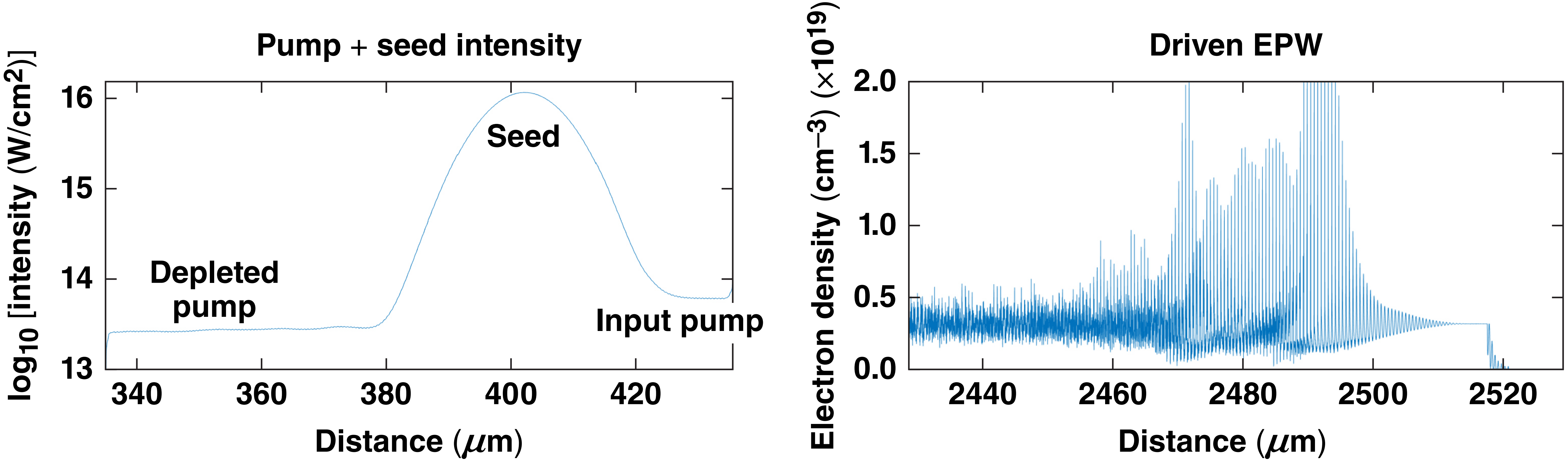
Particle-in-cell simulations predict 40% pump depletion and a nonlinear electron plasma wave (EPW)



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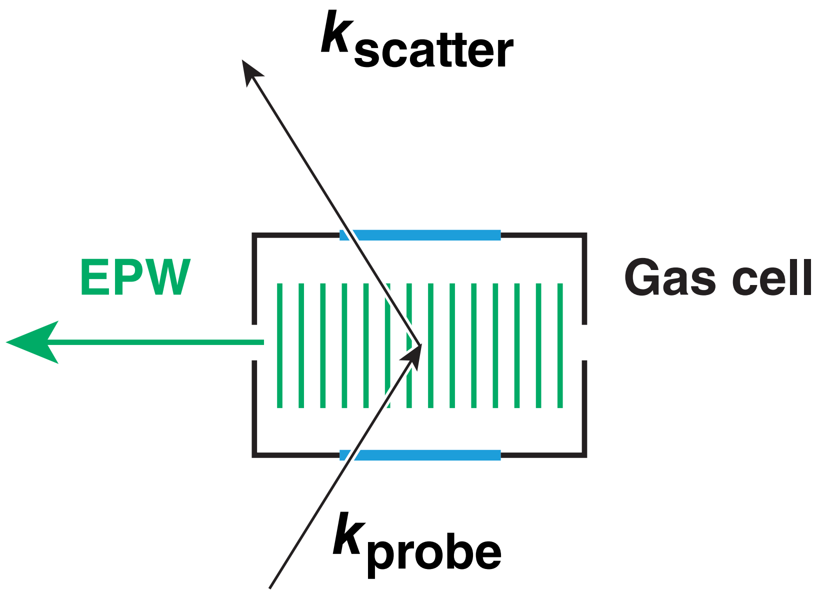
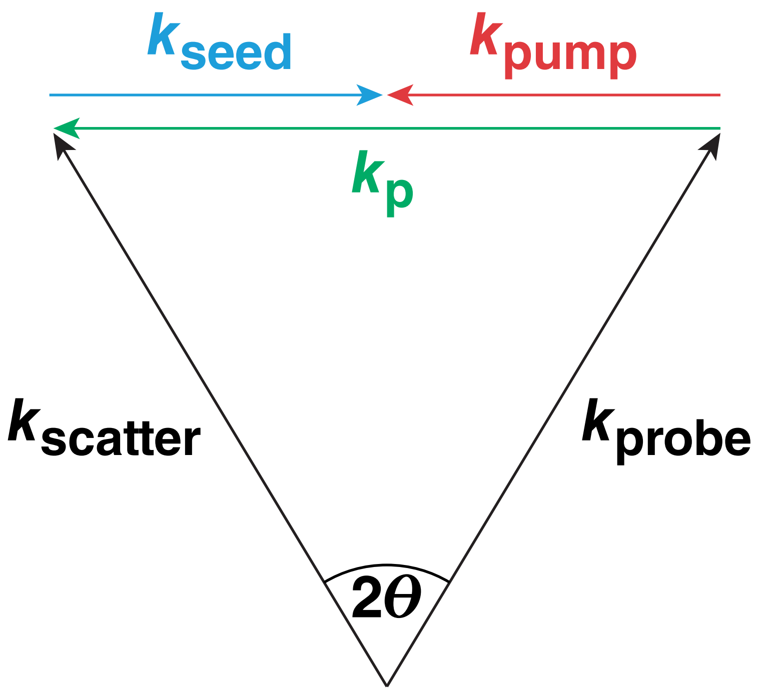
Thomson scattering will spatially and temporally resolve the driven EPW's frequency and amplitude



$$\eta = \sin \frac{\pi L_p \frac{\Delta n_e}{2n_c}}{\sqrt{\lambda_{probe}\lambda_{scatter}} \cos\theta}$$

$$\vec{k}_{scatter} = \vec{k}_{probe} + \vec{k}_p$$



$$\omega_{scatter} = \omega_{probe} + \omega_p$$

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A high-energy, tunable Raman amplification experiment is designed to quickly enter the pump-depletion stage

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