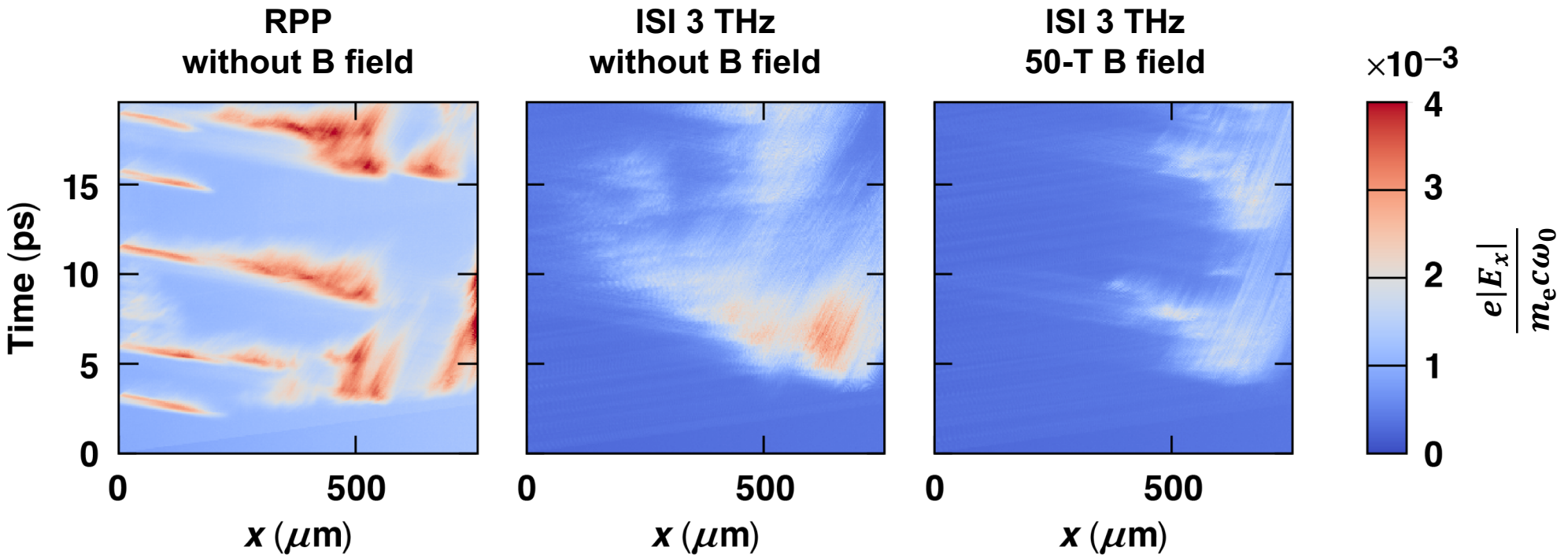
Mitigation of Stimulated Raman Scattering with Laser Bandwidth and an External Magnetic Field



TC15119

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Summary

Both laser bandwidth and magnetic fields reduce the reflectivity of stimulated Raman scattering (SRS) for NIF-like plasma conditions

- Multiple speckles can collectively drive SRS and cause bursts in SRS reflectivity
- Laser bandwidth shortens the interaction length of the pump and scattering light, reducing the reflectivity
- Surfatron motion in the combined magnetic field and electrostatic field of SRS-driven plasma waves results in nonlinear damping

A laser bandwidth of ~3 THz or a magnetic field of ~50 T are effective in mitigating convective SRS.

NIF: National Ignition Facility

Collaborators

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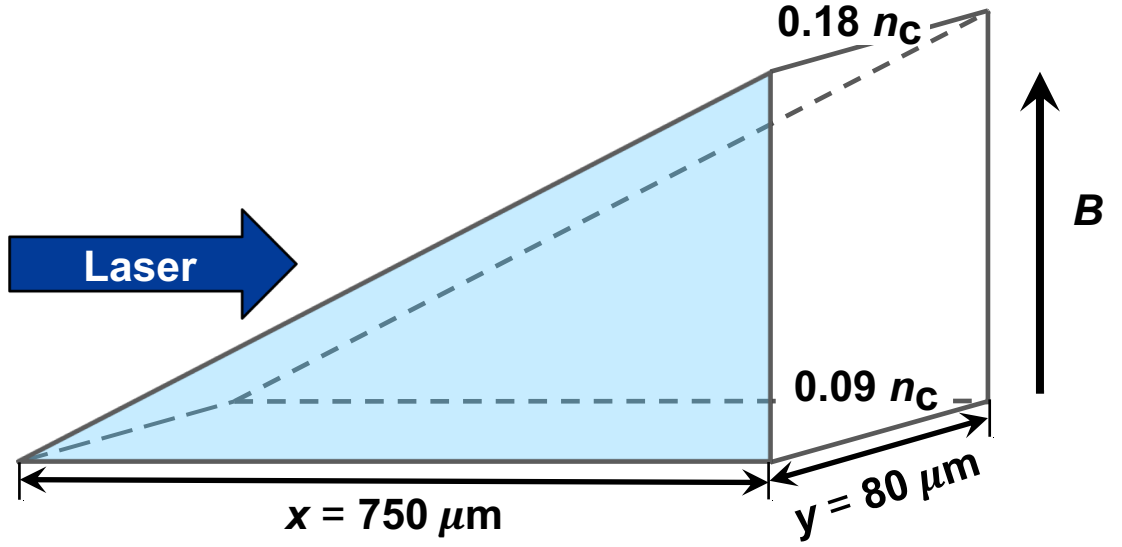
SRS in NIF-scale plasma conditions was modeled using the *OSIRIS* PIC simulations

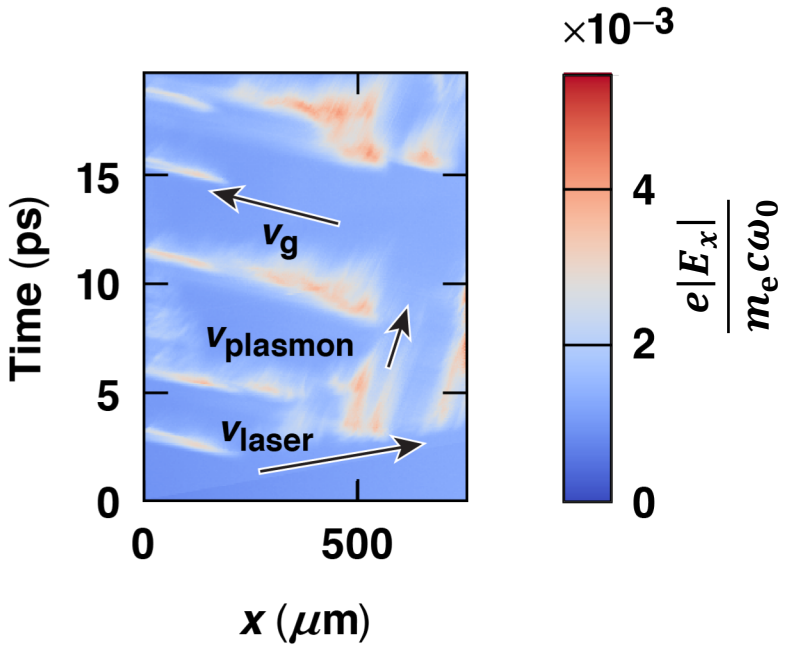
- **Simulation parameters**
  - **immobile ions**
  - **electron temperature T_e = 3 keV**
  - **density scale length L_n = 0.75 mm to 1.5 mm**
  - **$k\lambda_D \approx 0.33$ at $x = 290\ \mu$m**
  - **laser intensity $I = 5 \times 10^{14}$ W/cm^2**
  - **f/8 speckle length $L_s = 180\ \mu$m**
  - **convective gain $G \approx 1.6$**
  - **optional external magnetic field**

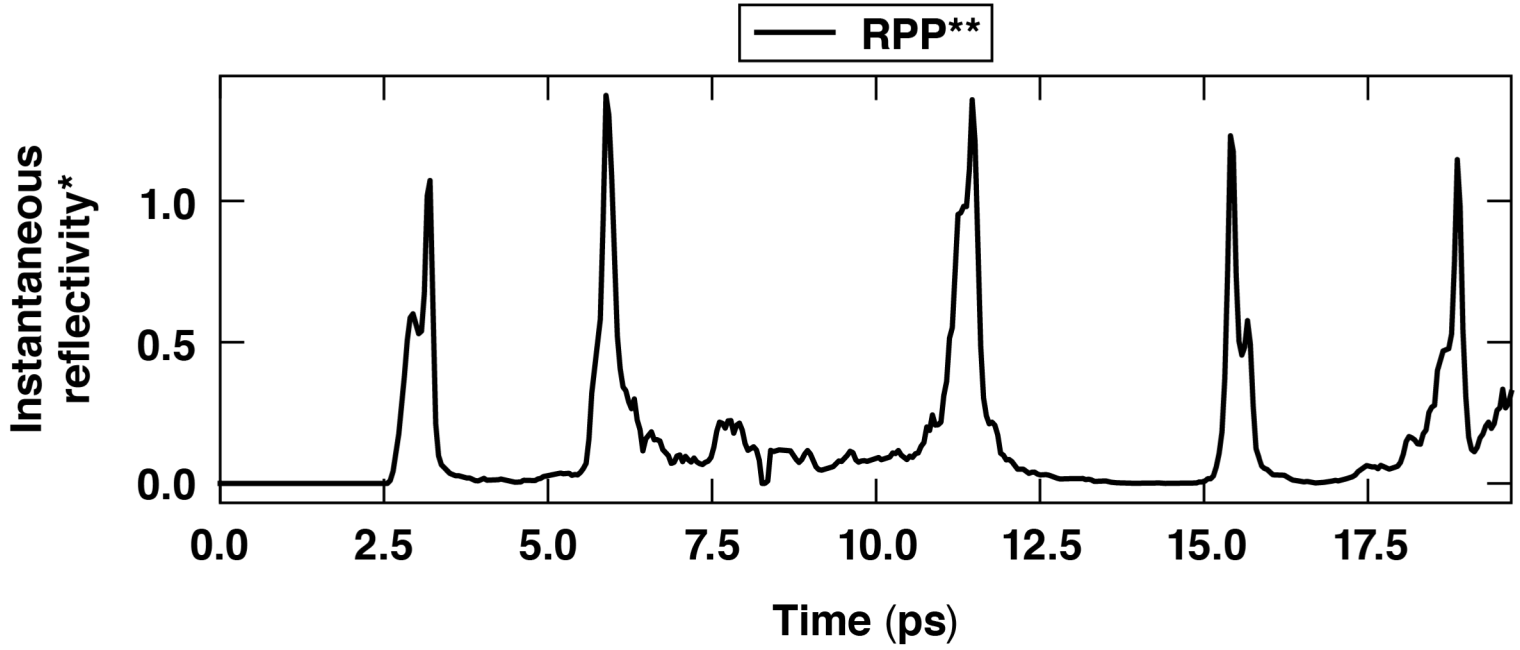


PIC: particle in cell

The SRS reflectivity exhibits bursty behavior

- The rise of the reflectivity spikes results from scattered light originating at higher densities, seeding SRS at lower densities, and flattening of the distribution function
- Damping of the plasma waves (through side loss) and pump depletion causes the spikes to decay





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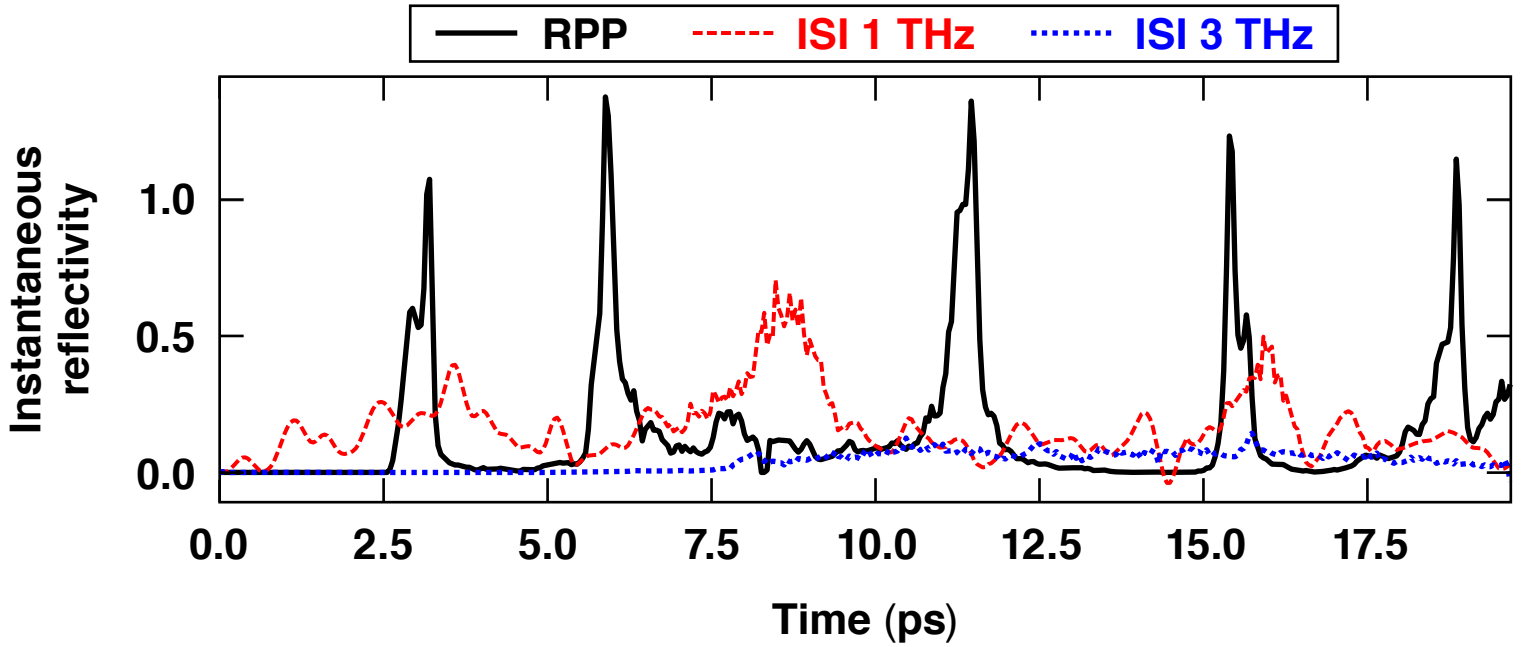
* Instantaneous reflectivity is measured at laser entrance and normalized to instantaneous incident laser
** RPP: random phase plate

As the laser bandwidth increases, the SRS reflectivity transitions from multiple, greater-than-100% spikes to a low nearly constant level

	Average reflectivity
RPP	15%
ISI* 1 THz	11%
ISI 3 THz	4%



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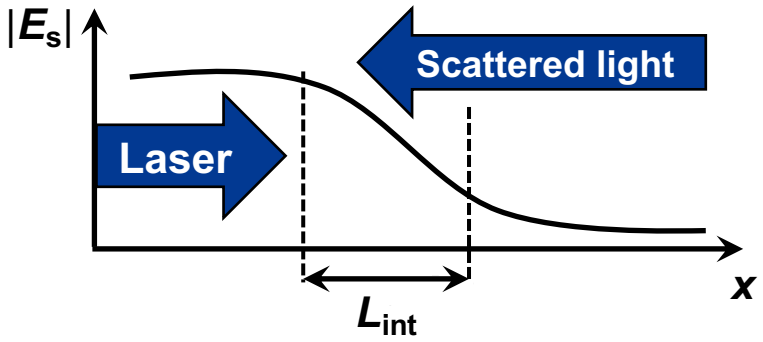
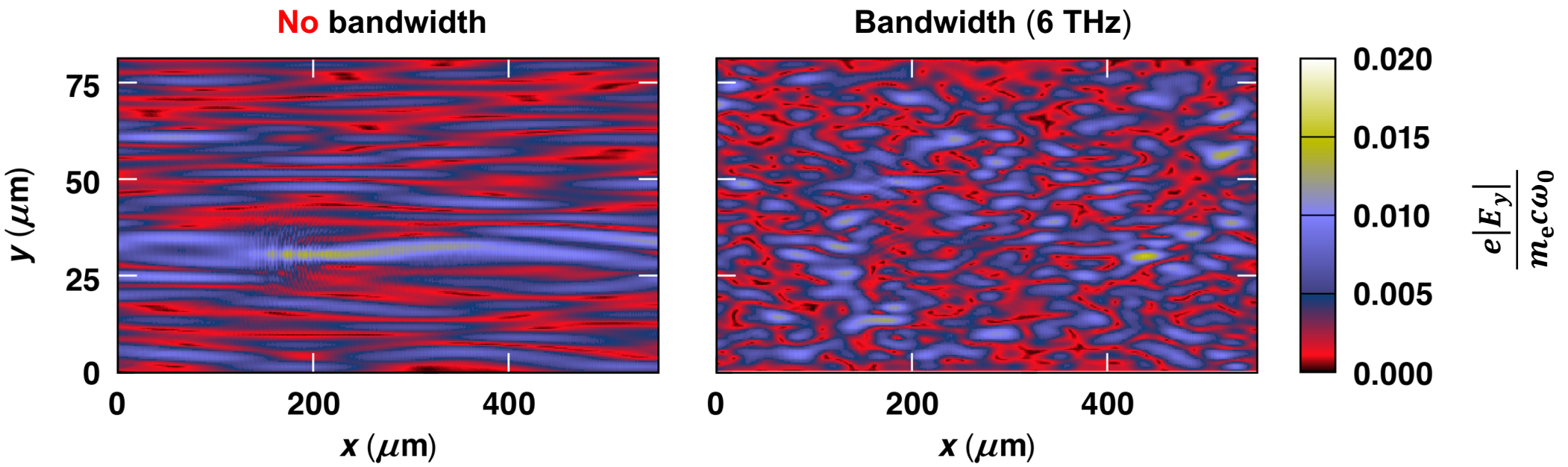
* ISI: induced spatial incoherence

Laser bandwidth decreases the effective interaction length for SRS

- The SRS scattered light is amplified after interacting with the laser pump over a distance $L_{int} \approx 84\ \mu m$*
- The effective length with laser bandwidth:

$$L_{eff} \approx \min\left(\frac{2\pi c}{\Delta\omega}, 8f^2\lambda_0\right)$$





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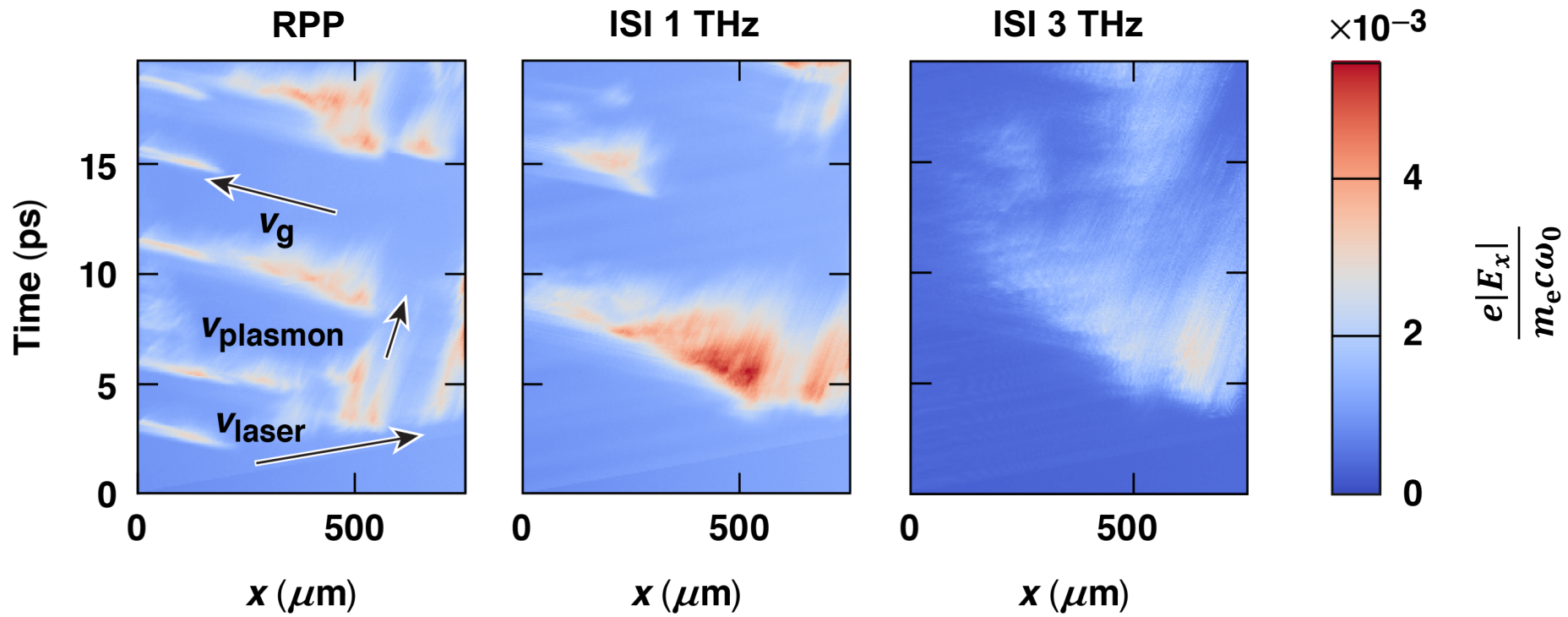
* B. Afeyan and S. Hüller, EPJ Web of Conferences 59, 05009 (2013).

By reducing the effective interaction length ($L_{\text{eff}} < L_{\text{int}}$), the laser bandwidth prevents the scattered light from seeding SRS at lower densities



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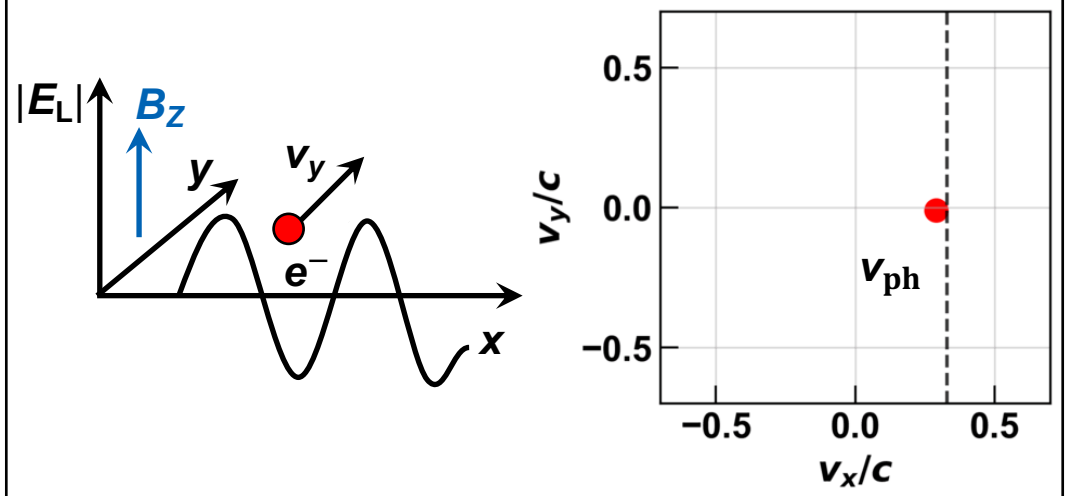
- The remaining plasma waves can still trap and accelerate electrons, so the threat of SRS has not been entirely eliminated

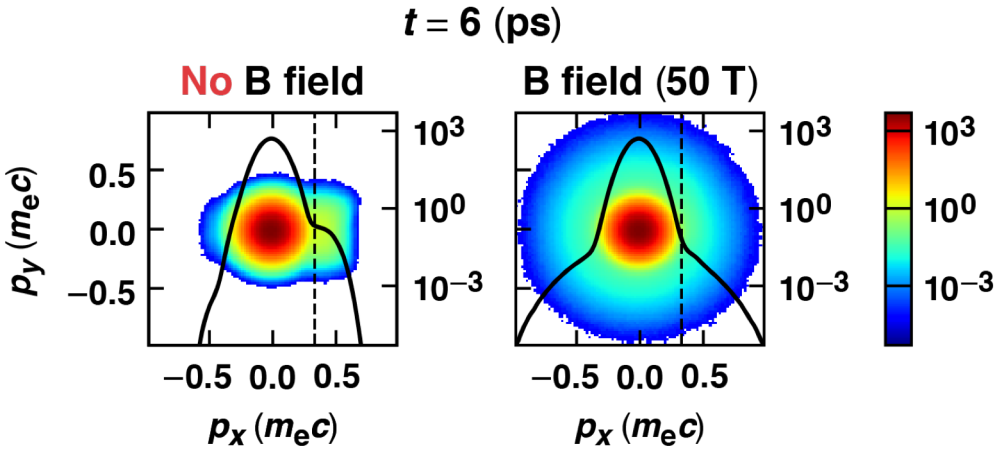
An external magnetic field introduces additional damping to the plasma waves* and prevents the flattening of the distribution function

Trapped electrons are accelerated across the wave fronts of plasma waves



The nonlinear damping is still effective after time ≫ cyclotron period

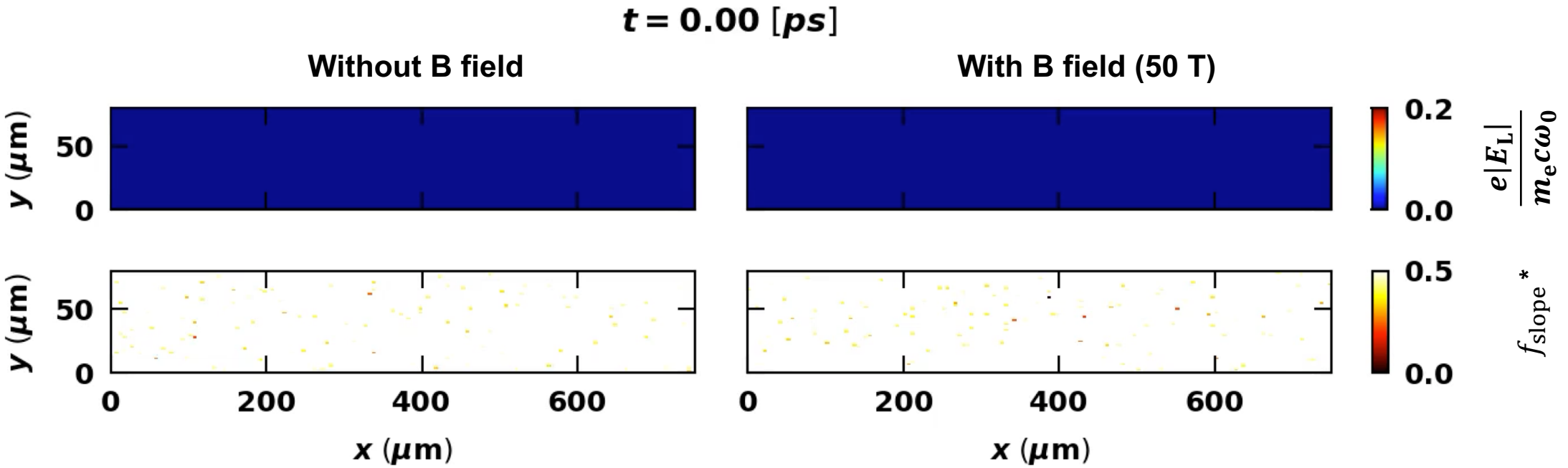
- For a 50 T external magnetic field, $\omega_c = 0.002\omega_0$, $T_c \approx 0.6$ ps, Lamor radius $r_c \approx 2\ \mu$m



* J. M. Dawson *et al.*, Phys. Rev. Lett. 50, 1455 (1983); V. L. Krasovsky, Plasma Phys. Rep. 33, 839 (2007).

The external magnetic field greatly reduces the plasma wave activity

- **Laser bandwidth: 3 THz**



Applying an external transverse magnetic field decreases the SRS reflectivity from 4% to 0.8%

$$^{*}f_{\text{slope}} = \frac{\mathrm{d}\log f[\gamma(p)]}{\mathrm{d}\,p_x} \Big/ \frac{\mathrm{d}\gamma(p)}{\mathrm{d}\,p_x}\Big|_{p(v_\phi)}$$

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