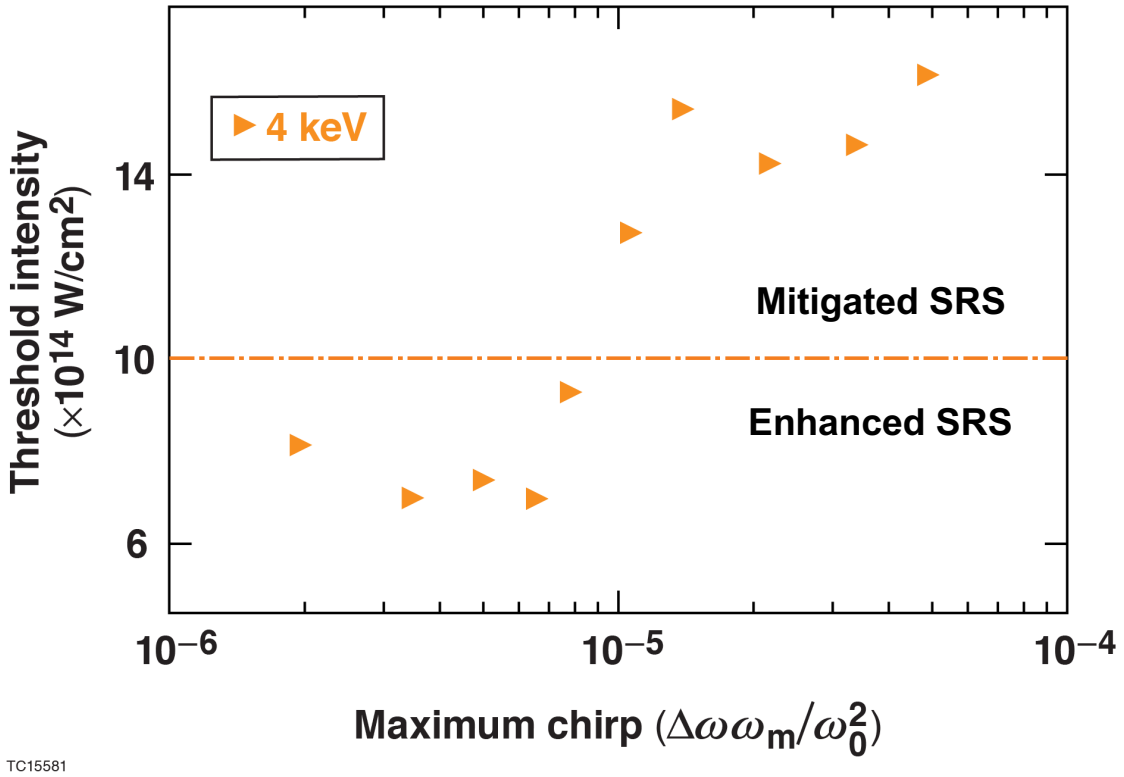
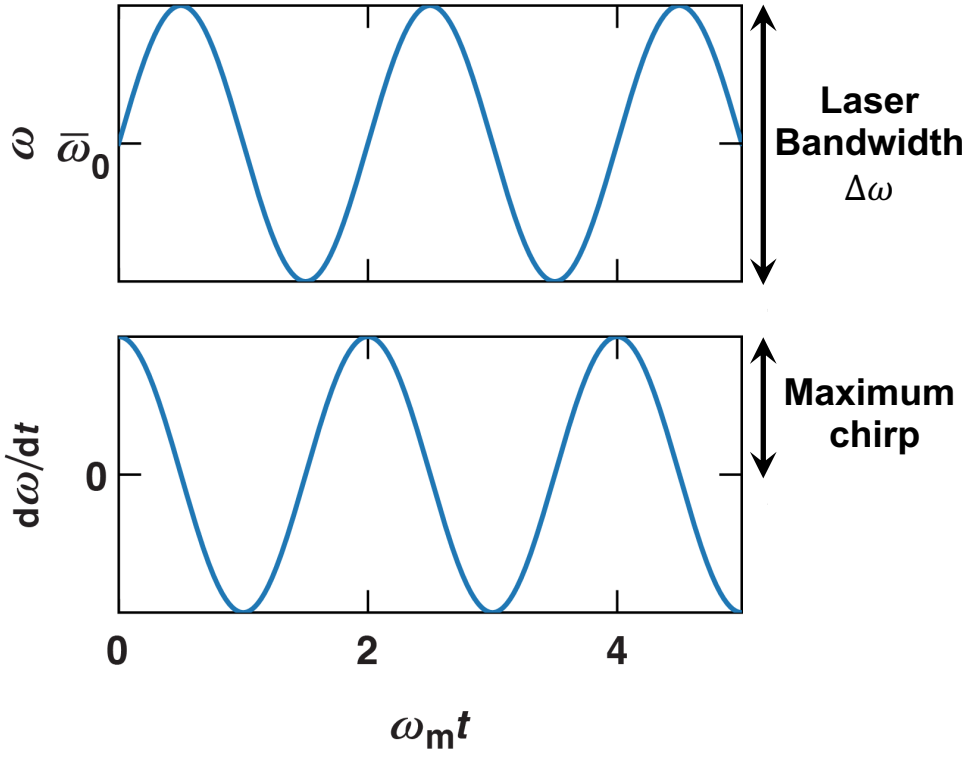
Kinetic Inflation of Stimulated Raman Scattering Driven by a Broadband, Frequency-Modulated Laser Pulse





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Summary

Bandwidth can increase the inflationary stimulated Raman scattering (SRS) threshold when the frequency varies rapidly

- In the long-scale-length plasmas characteristic of direct-drive ignition, convective SRS could inhibit laser–target coupling and generate hot electrons
- SRS gain* for a Maxwellian plasma is greatly enhanced in the inflationary SRS due to flattening of the electron distribution
- One-dimensional (1-D) simulations using the particle-in-cell (PIC) code *OSIRIS* were performed in the fluid and kinetic regimes to explore SRS mitigation with broadband lasers
- The convective SRS gain is enhanced when the spatial detuning caused by the density inhomogeneity is canceled by the frequency modulation of the broadband pump along the trajectory of the scattered light ($\Delta\omega\omega_{\mathrm{m}} \approx \omega_{\mathrm{p}} c/8L_{\mathrm{n}}$)

* M. N. Rosenbluth, Phys. Rev. Lett. 29, 565 (1972).

Collaborators

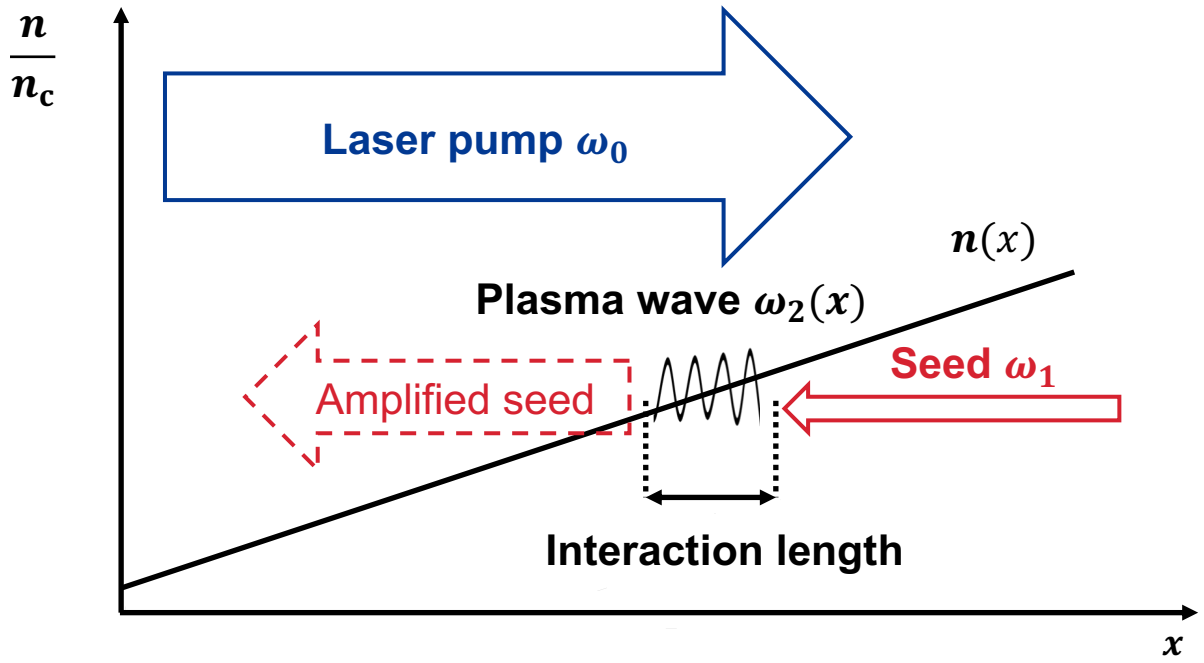
R. K. Follett, A. V. Maximov, D. H. Froula, and J. P. Palastro

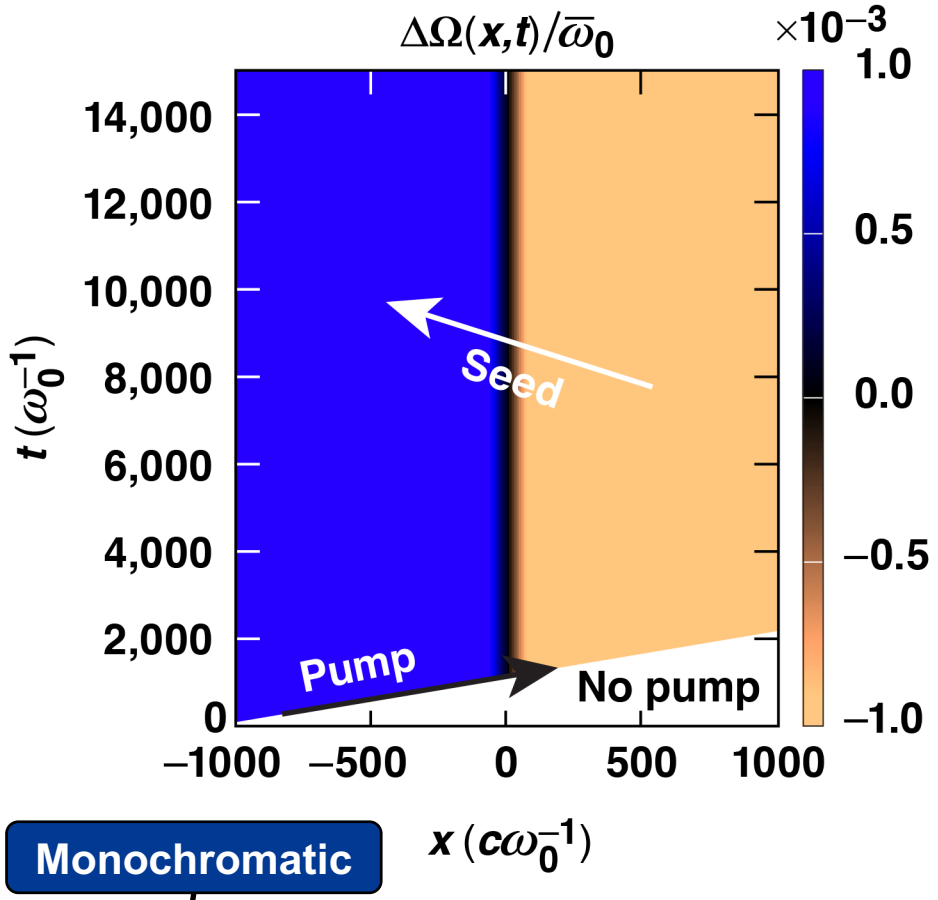
University of Rochester, Laboratory for Laser Energetics

F. S. Tsung

University of California, Los Angeles

In SRS, the scattered light is amplified over an interaction region with a characteristic length





Monochromatic

In the interaction region, the frequency mismatch $\Delta\Omega(x) \equiv \omega_0 - \omega_1 - \omega_2(x) \approx 0$

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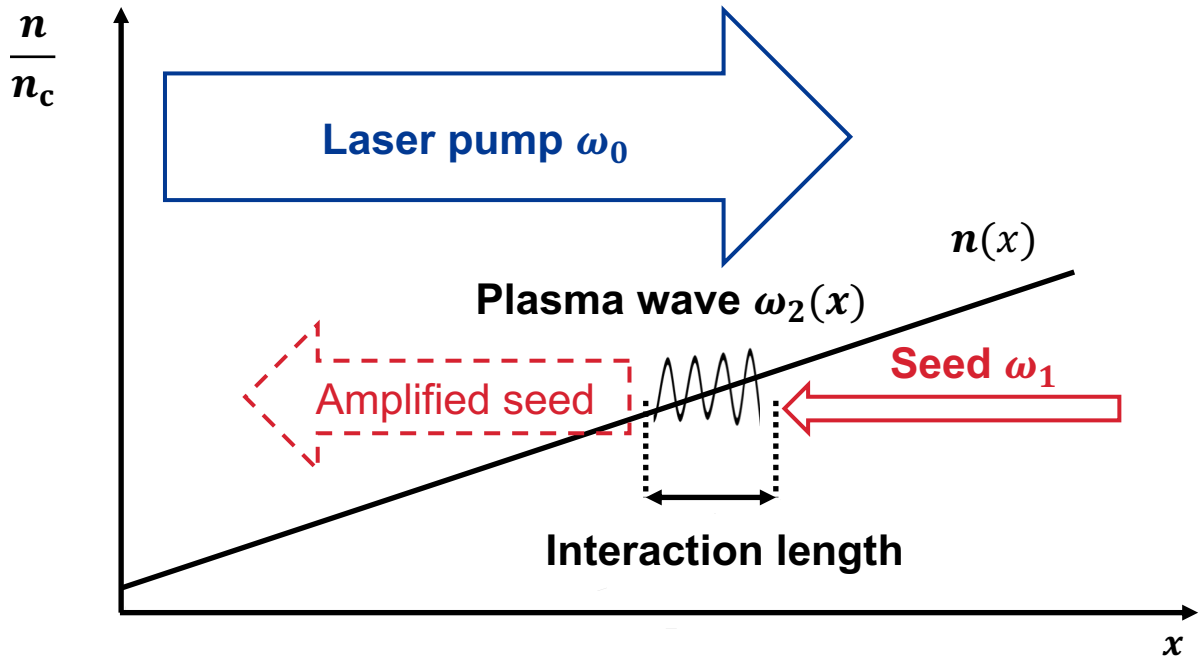
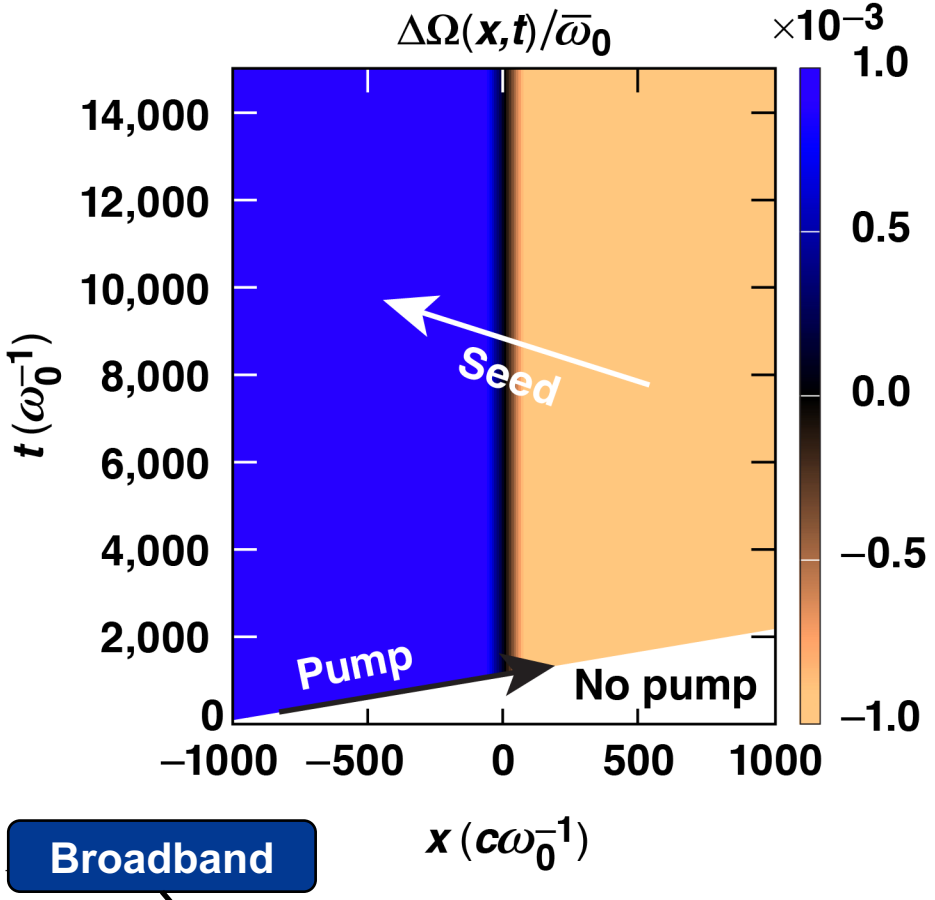




In the interaction region, the frequency mismatch $\Delta\Omega(x,t) \equiv \omega_0(x,t) - \omega_1 - \omega_2(x) \approx 0$

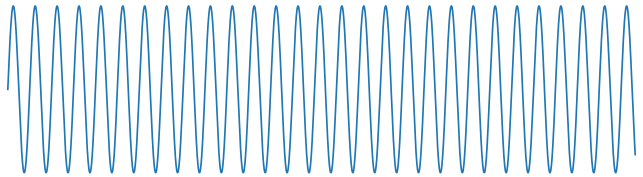
The effective interaction length can be lengthened or shortened depending on the local chirp rate of the pump

- **Broadband laser frequency**

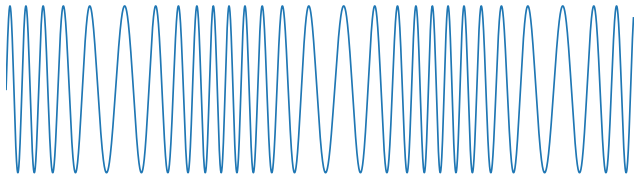
$$\omega_0(x,t) = \bar{\omega}_0 - \frac{\Delta\omega}{2}\sin\left(\omega_m t - \frac{\omega_m}{c}x\right)$$

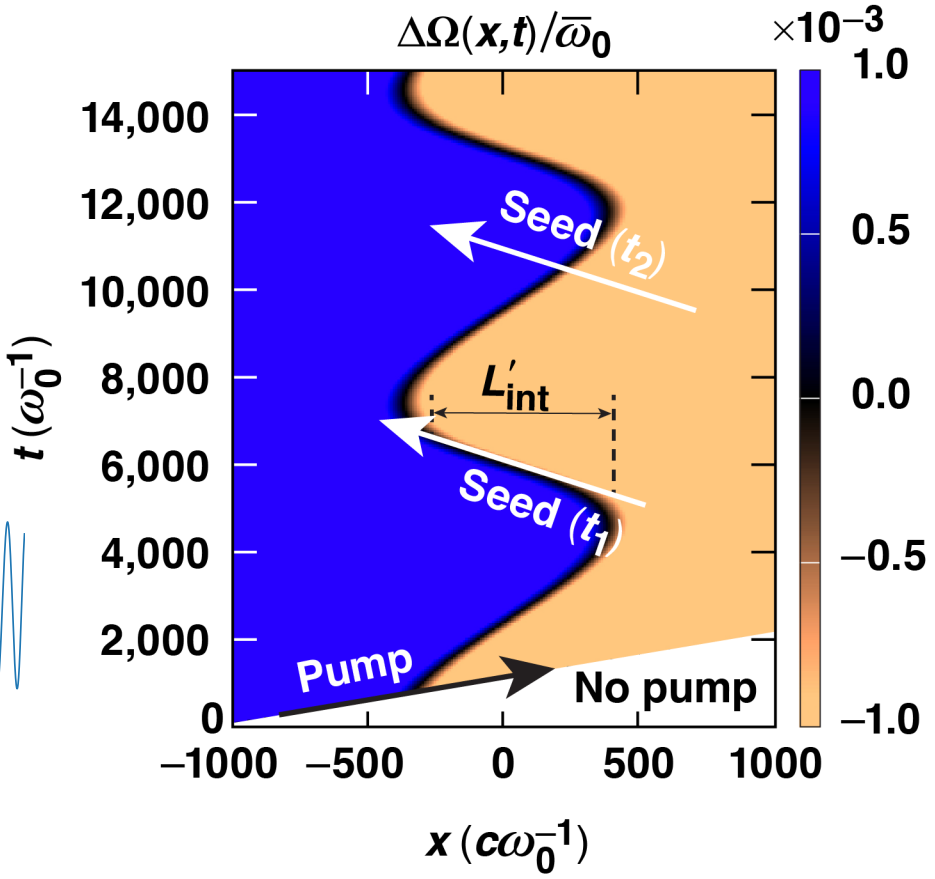
Central frequency | **Laser bandwidth** | **Modulation frequency**

Monochromatic



Phase modulated

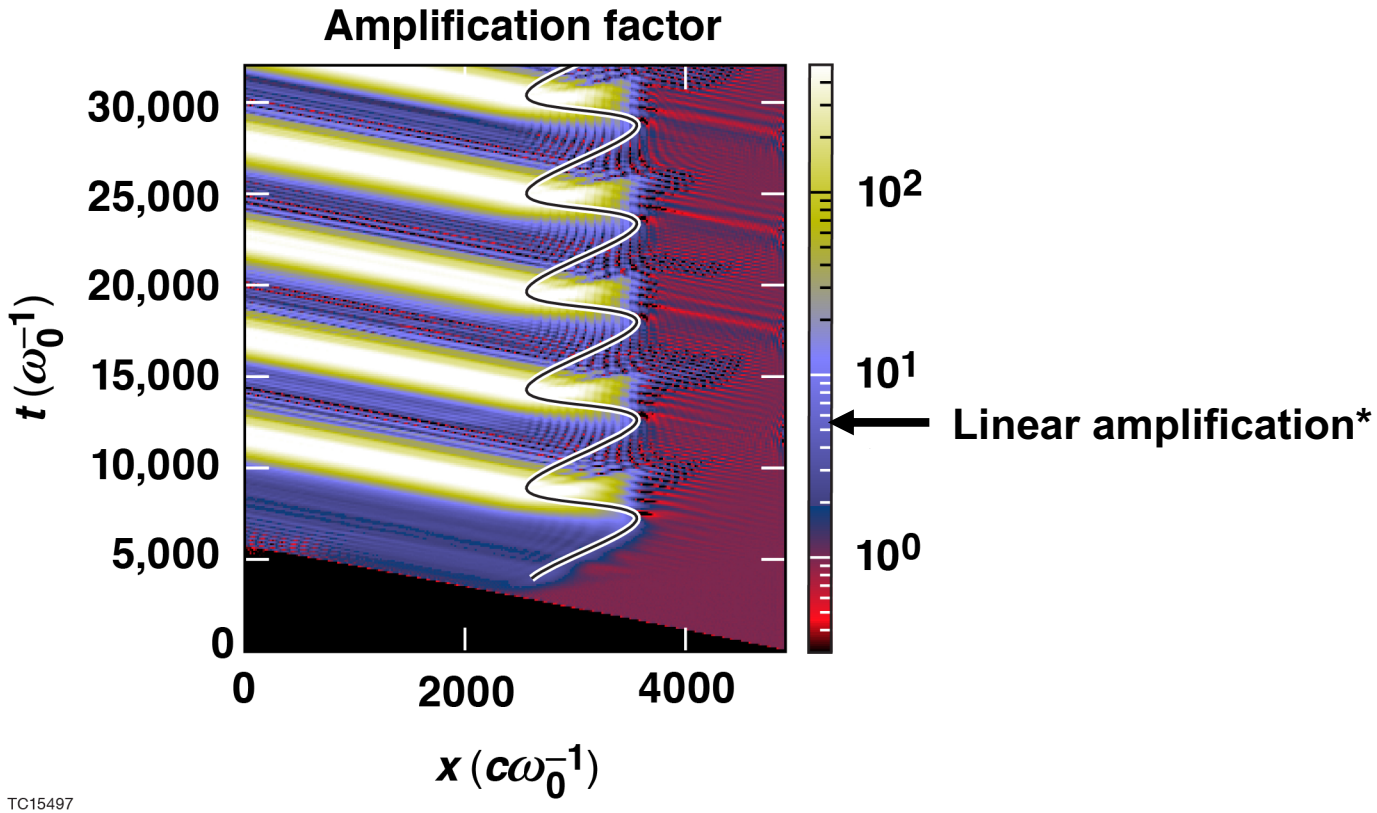




When $\Delta\omega\omega_m \approx \omega_p c/8L_n$,
the scattered light follows the trajectory of the resonance, leading to maximum gain

PIC simulations were performed to study the bandwidth effects on the convective SRS instability

- A typical simulation in the fluid regime $(k\lambda_D < 0.1)$



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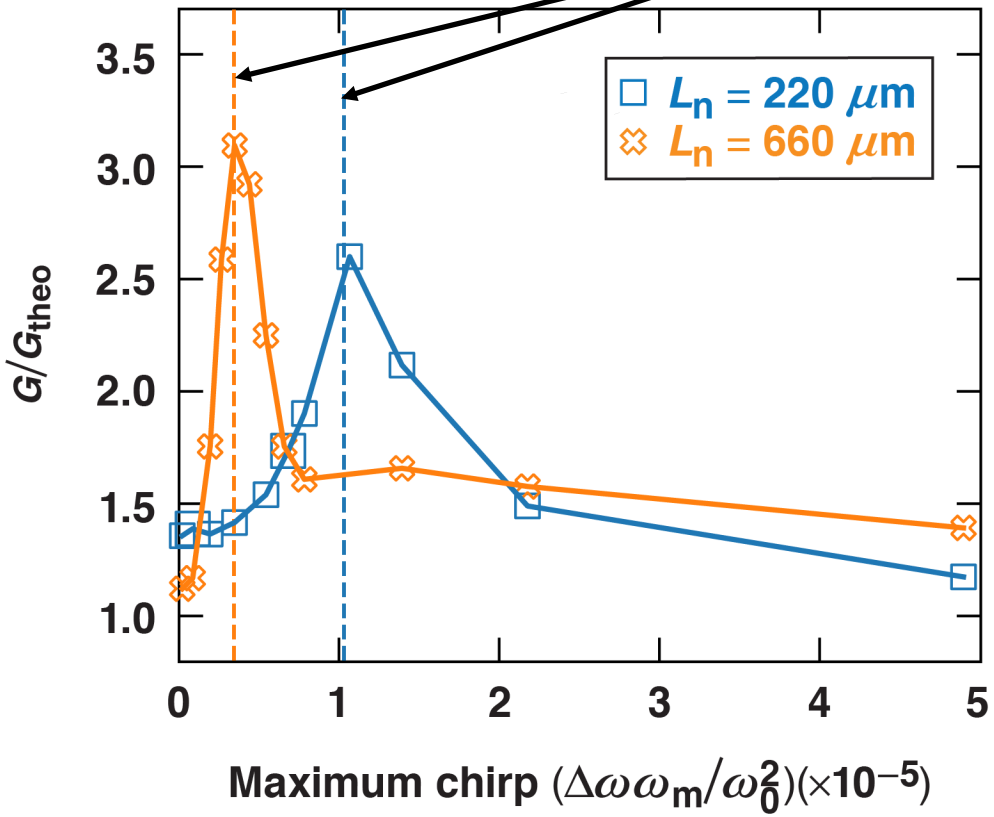
PIC simulations verify the expected gain enhancement when $\Delta\omega\omega_m \approx \omega_p c/8L_n$

$$\Delta\omega\omega_m = \frac{\omega_p c}{8L_n}$$



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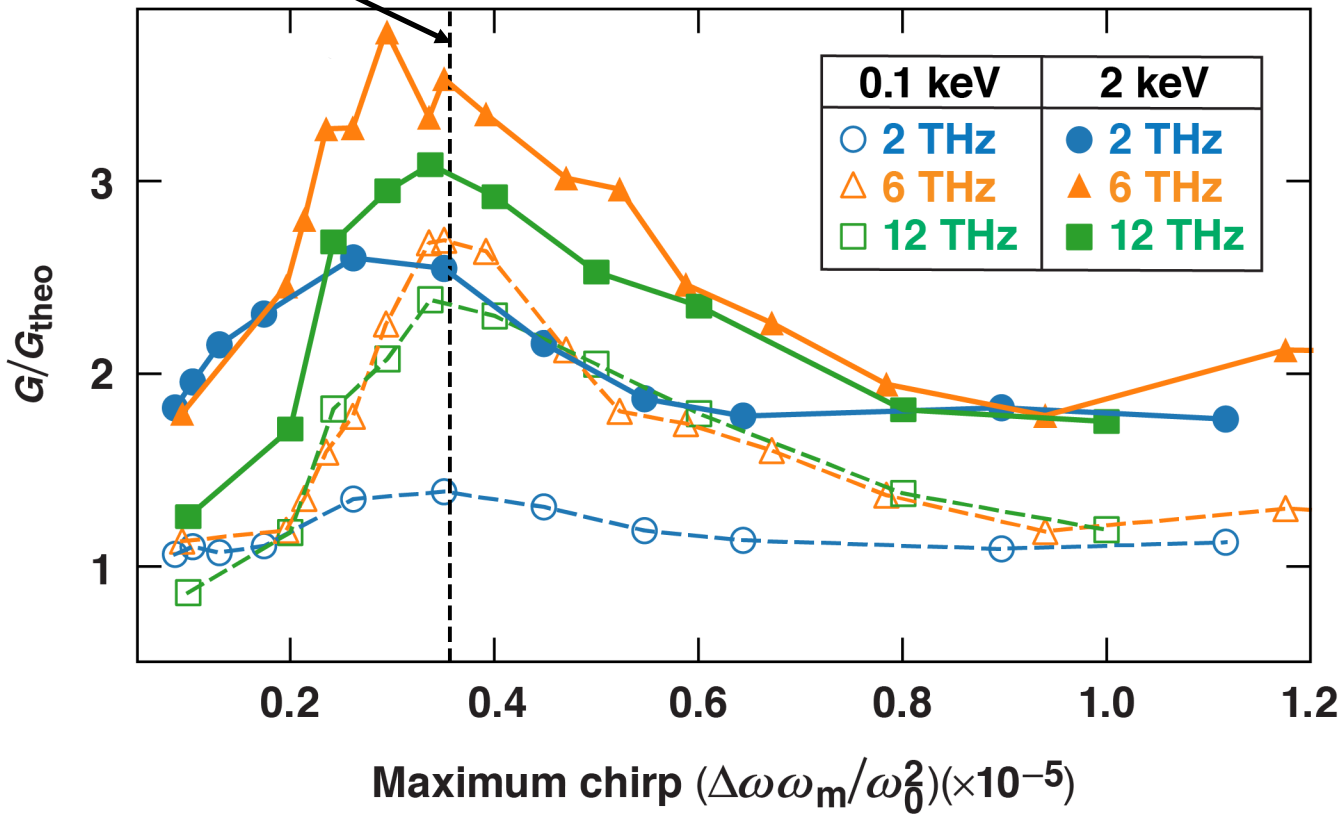

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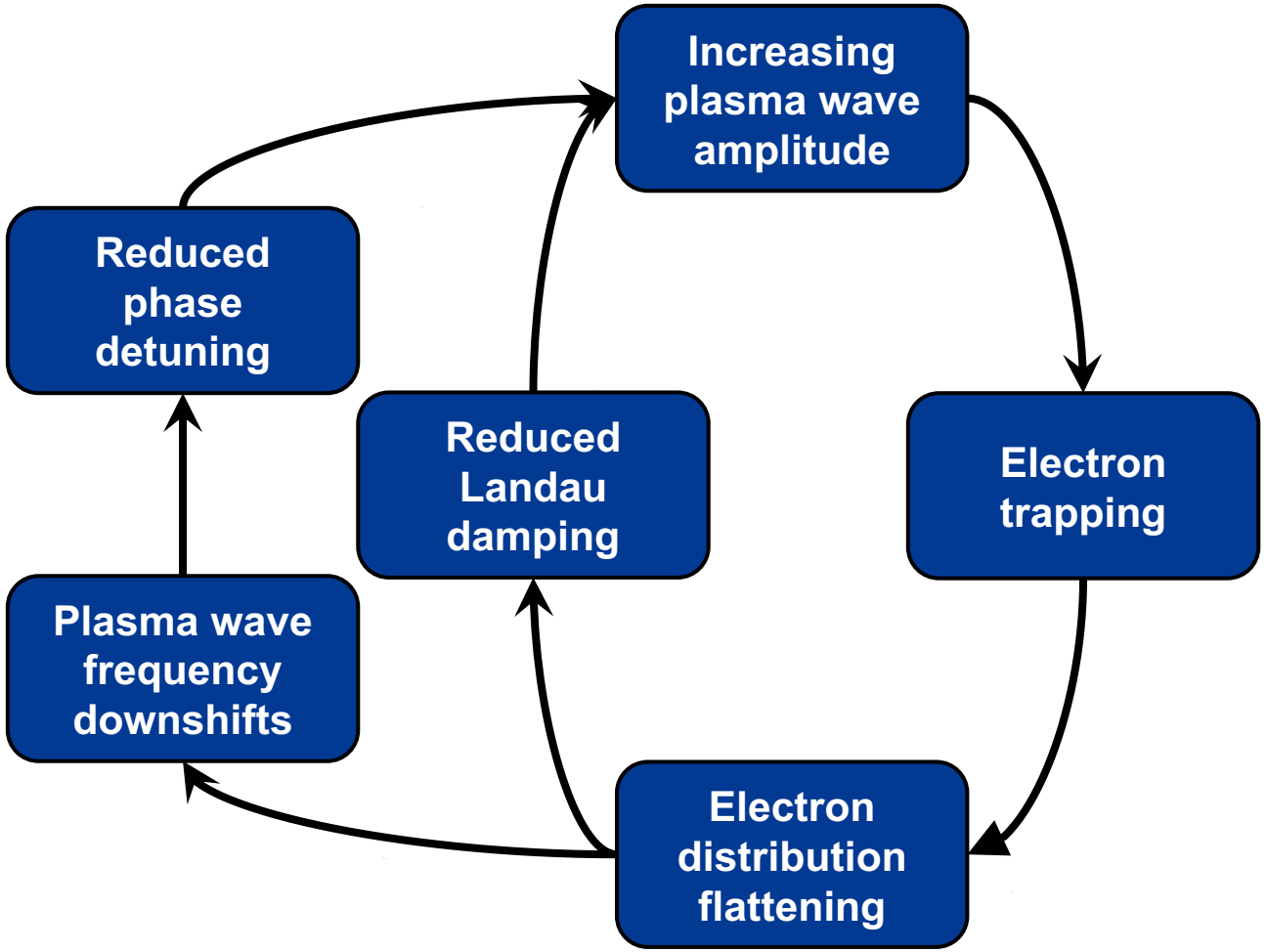
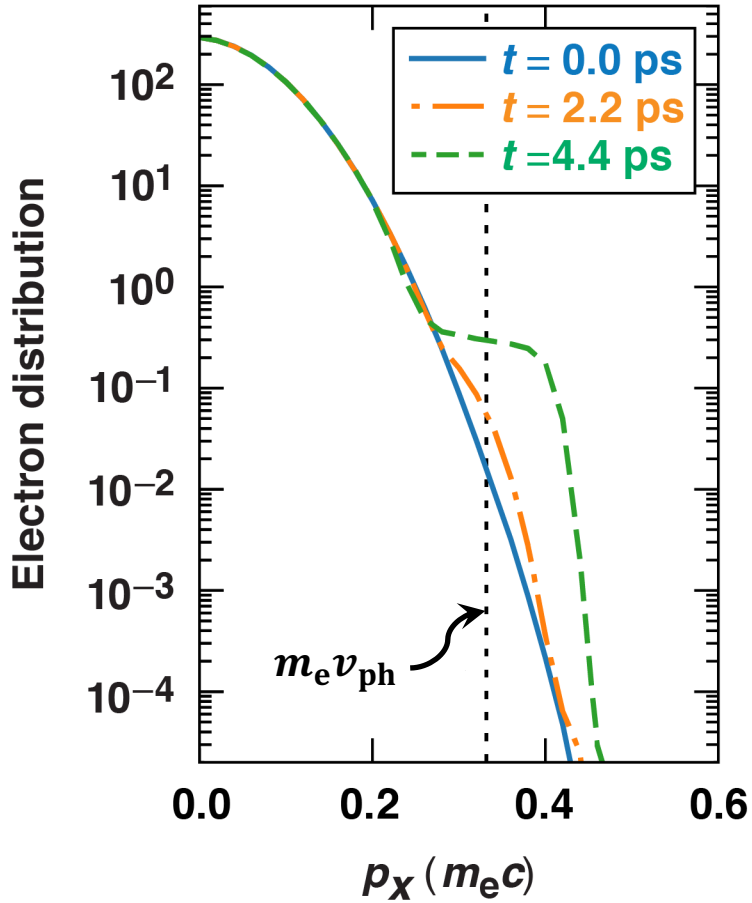
Kinetic inflation* occurs when particle trapping flattens the electron distribution





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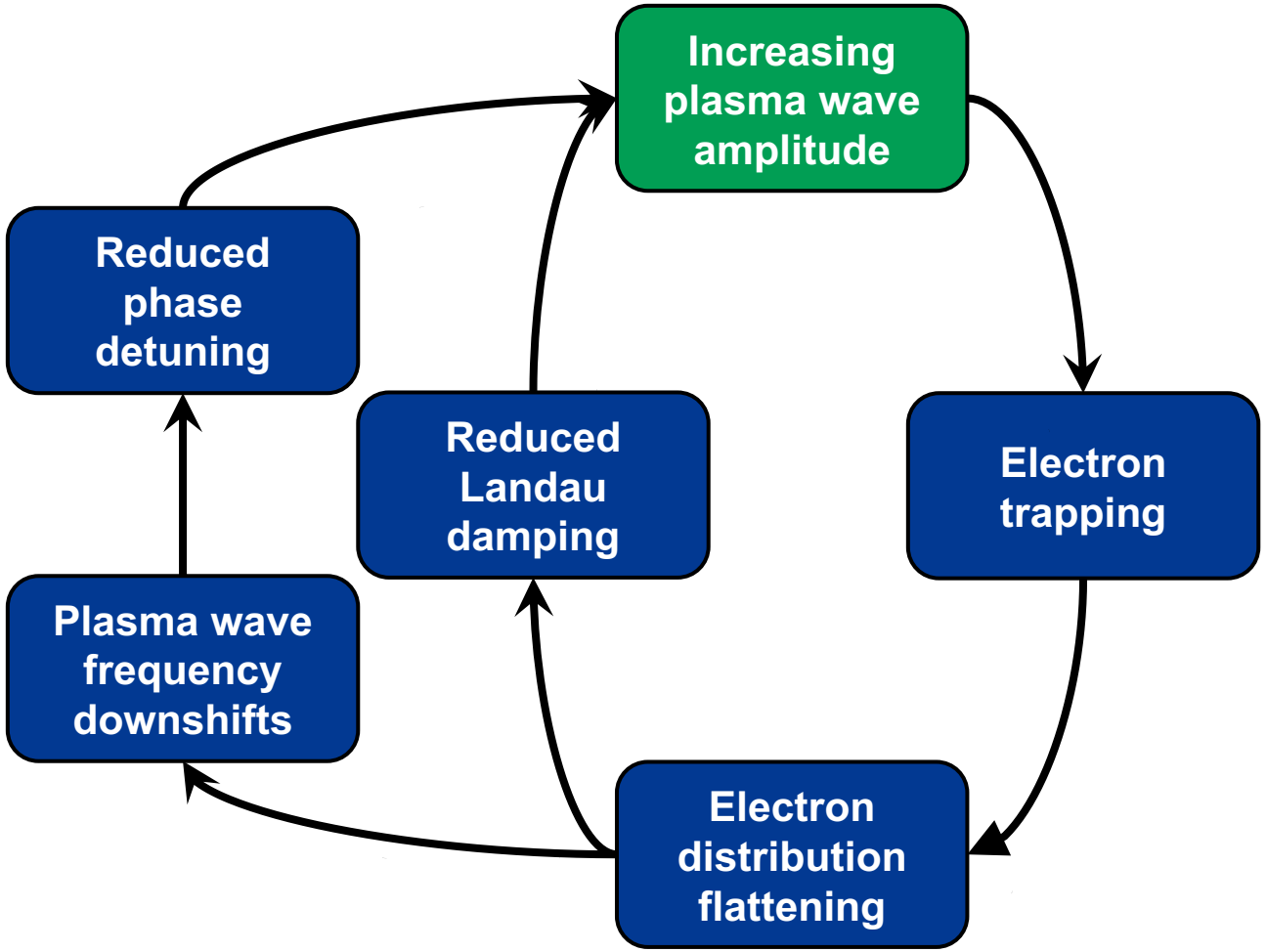

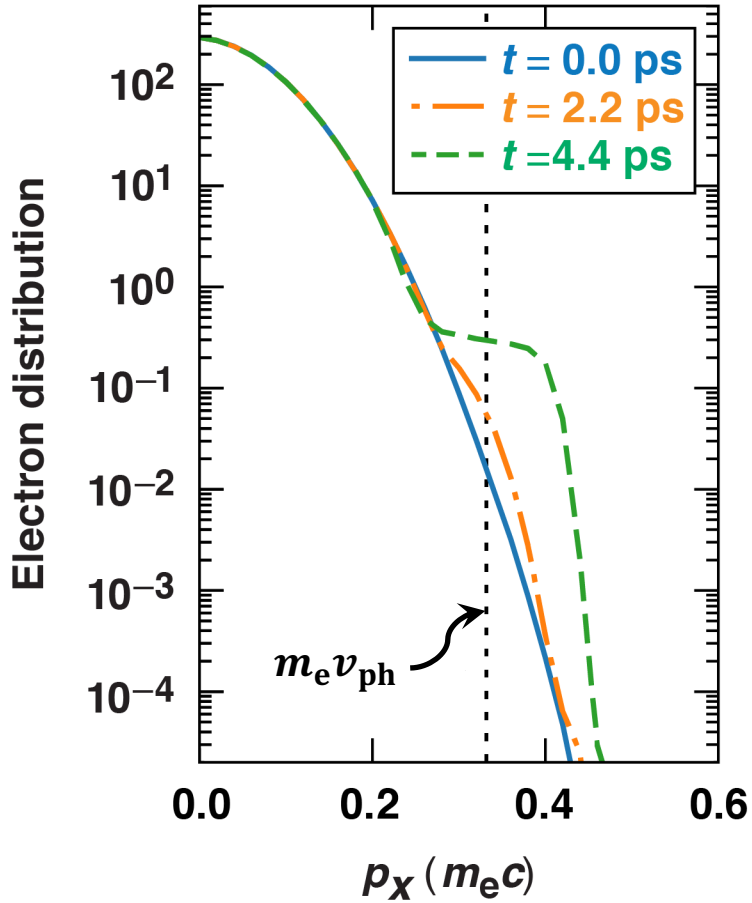

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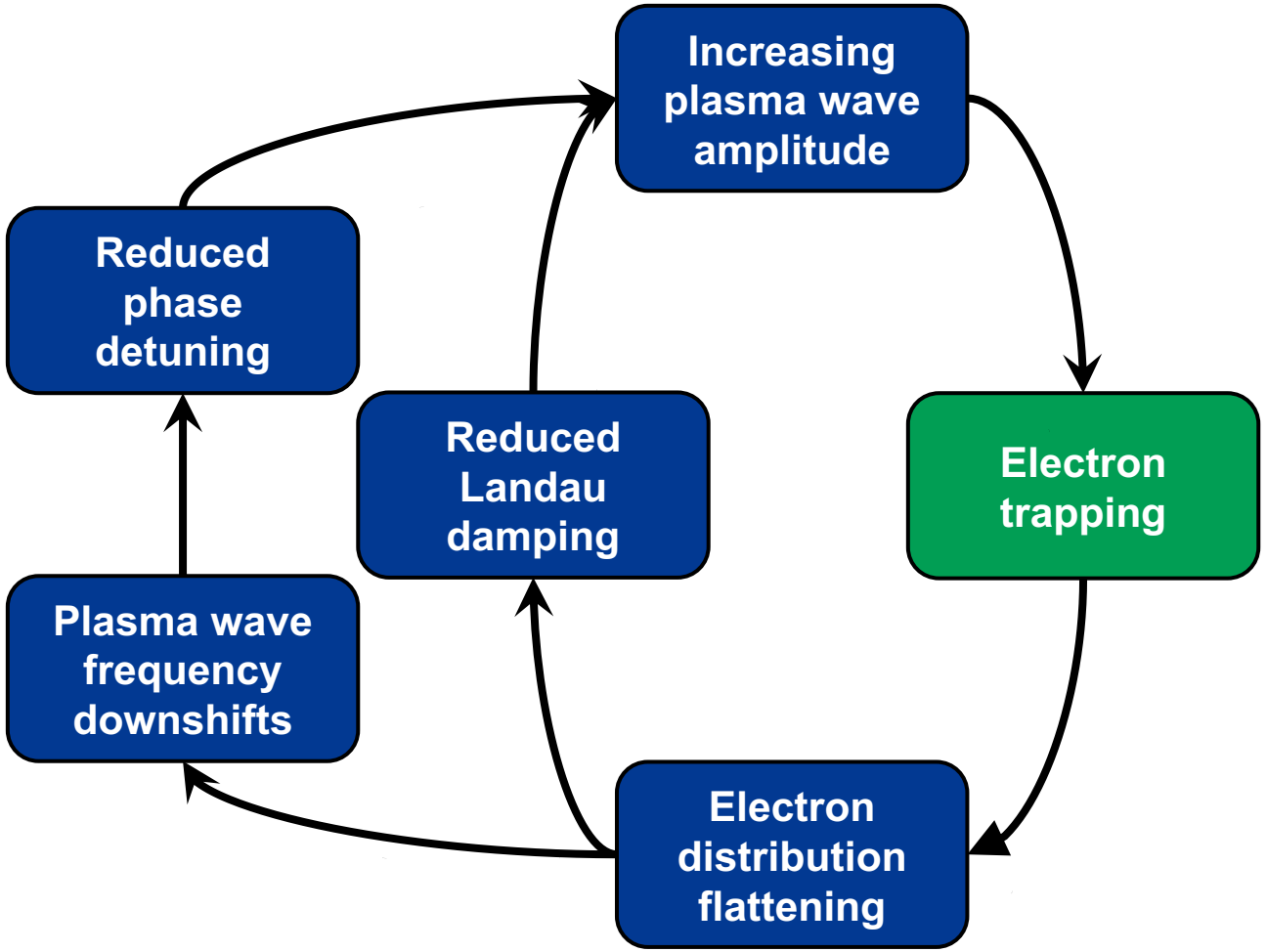

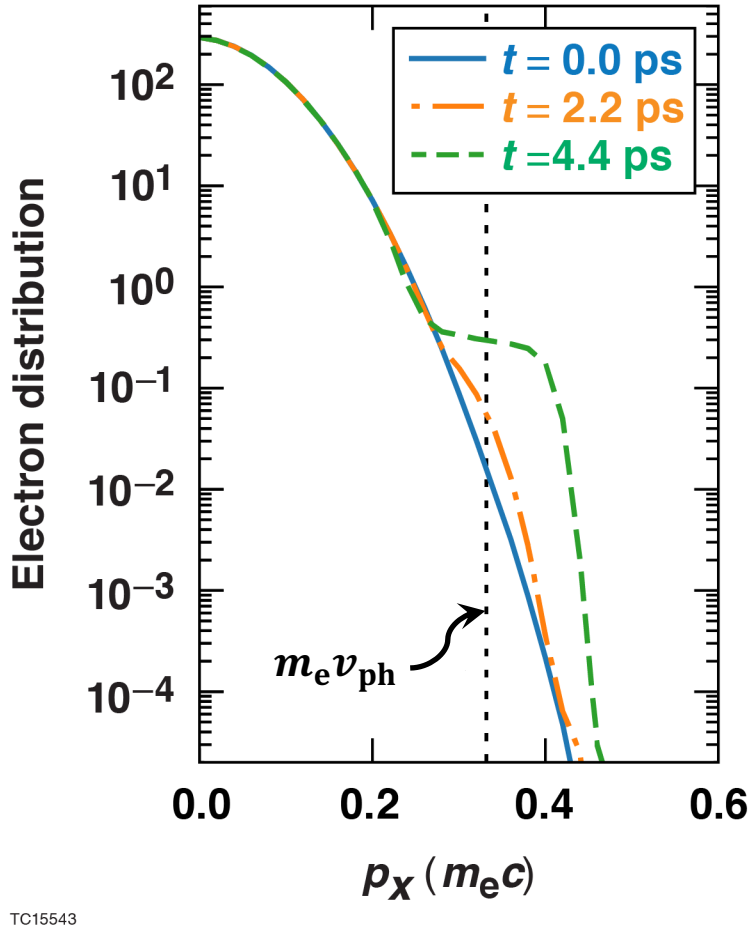

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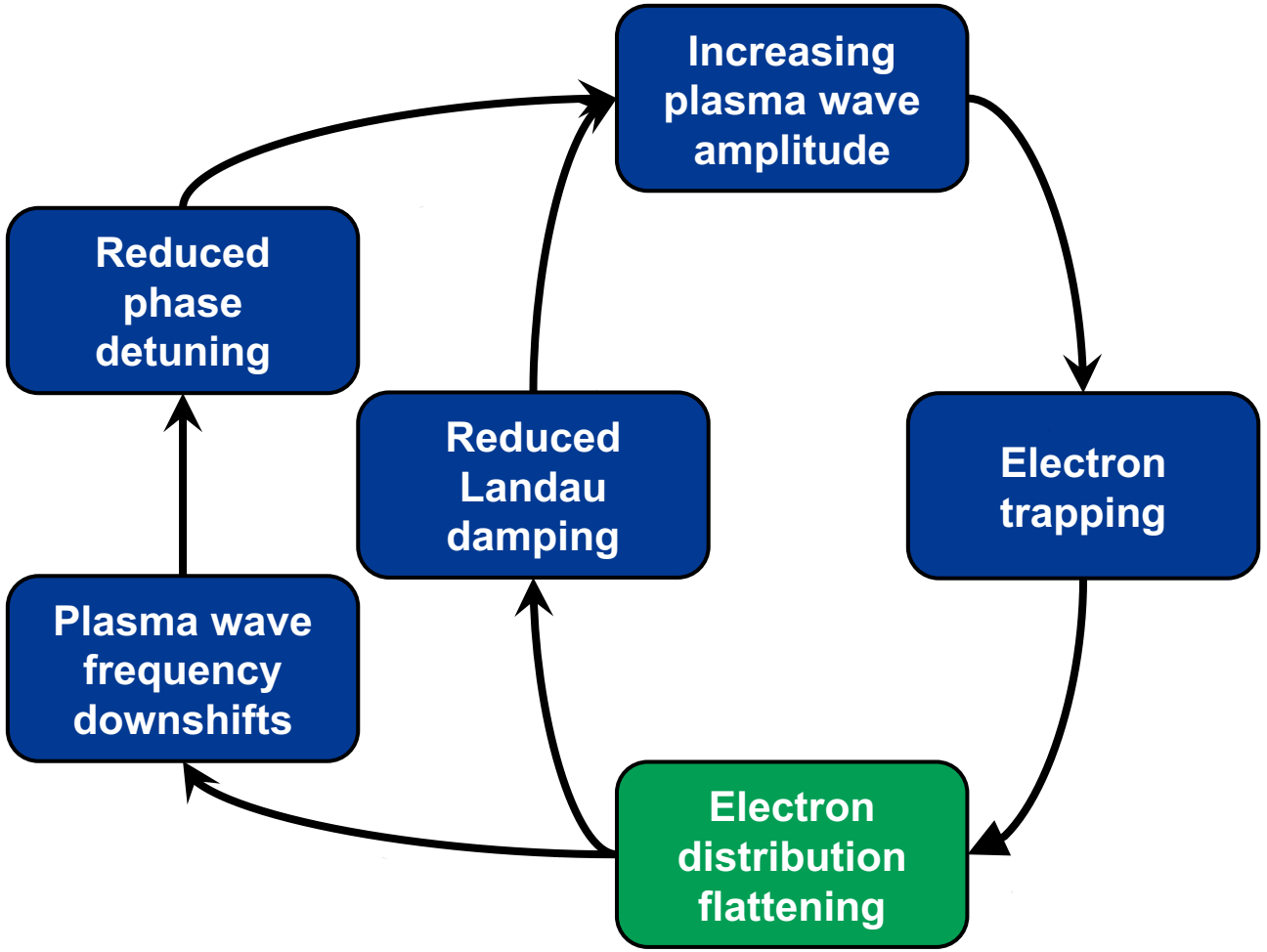

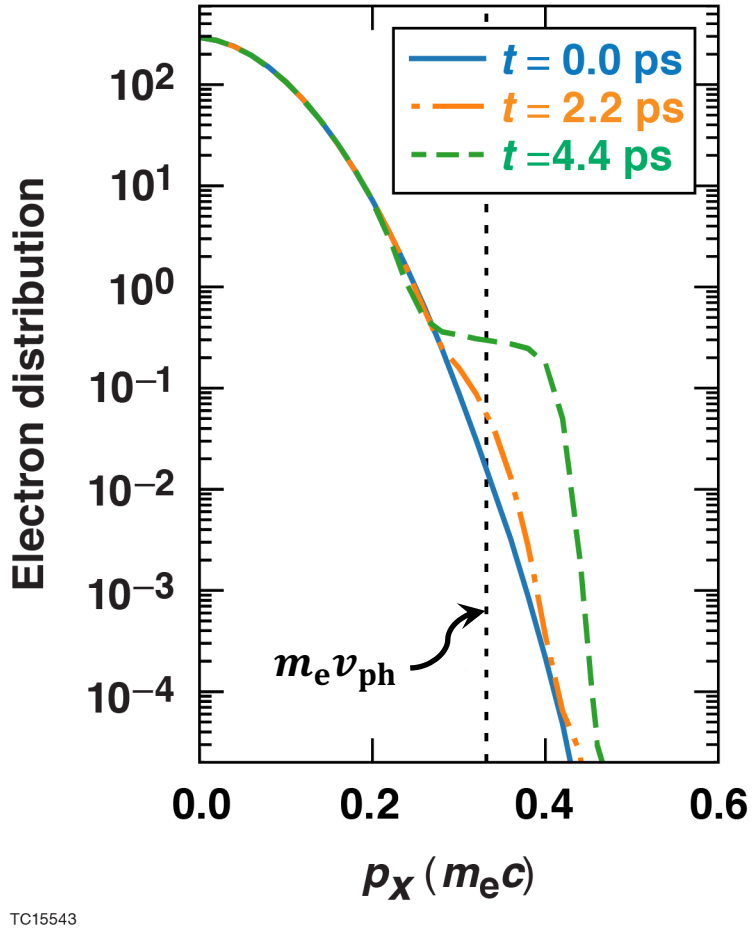

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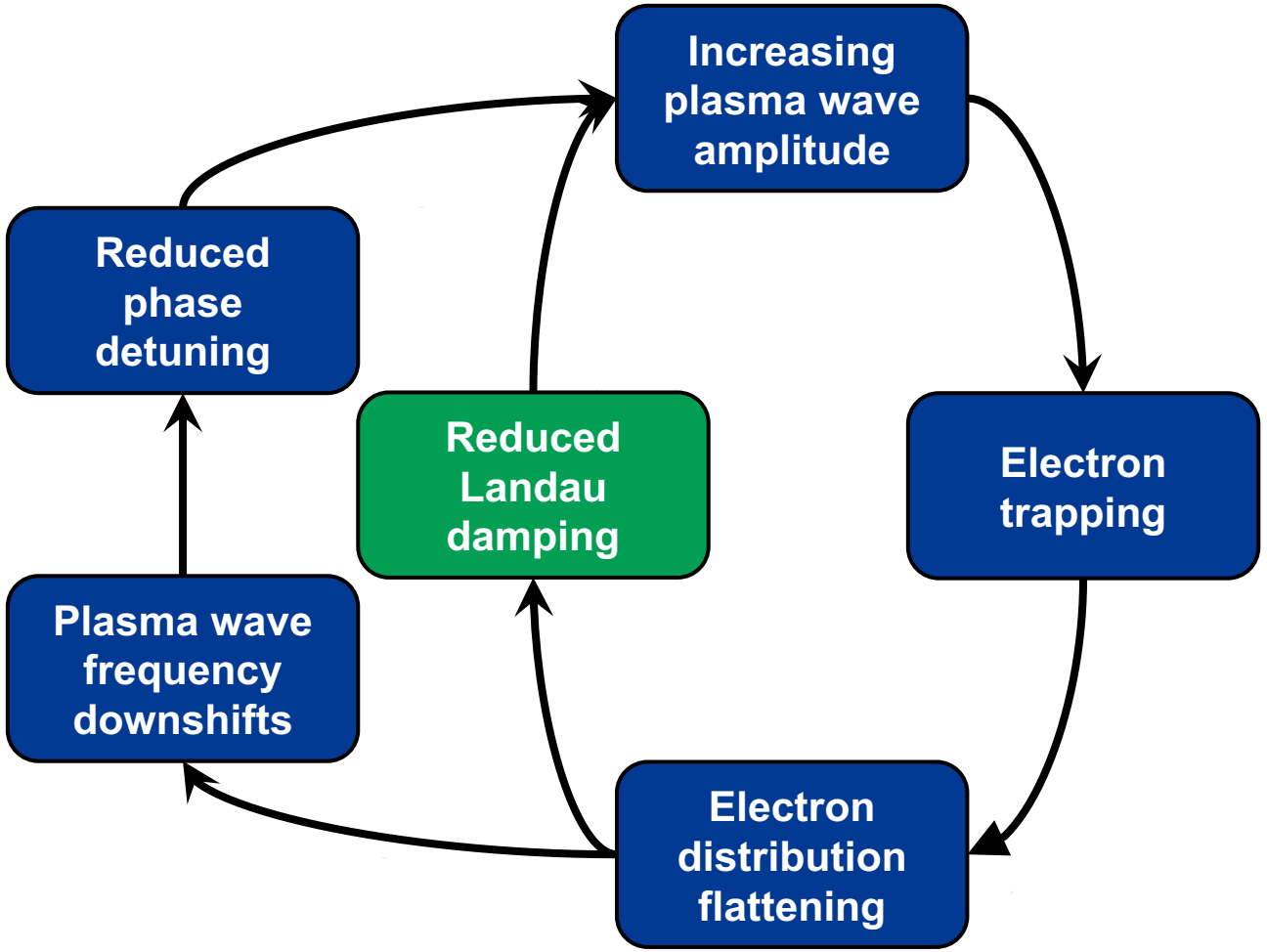

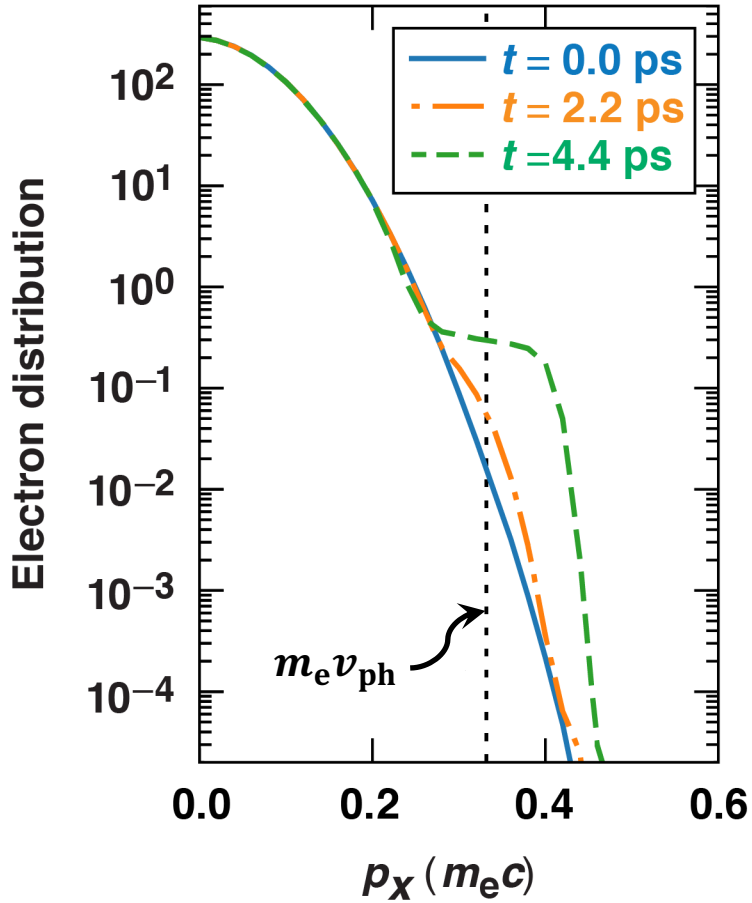

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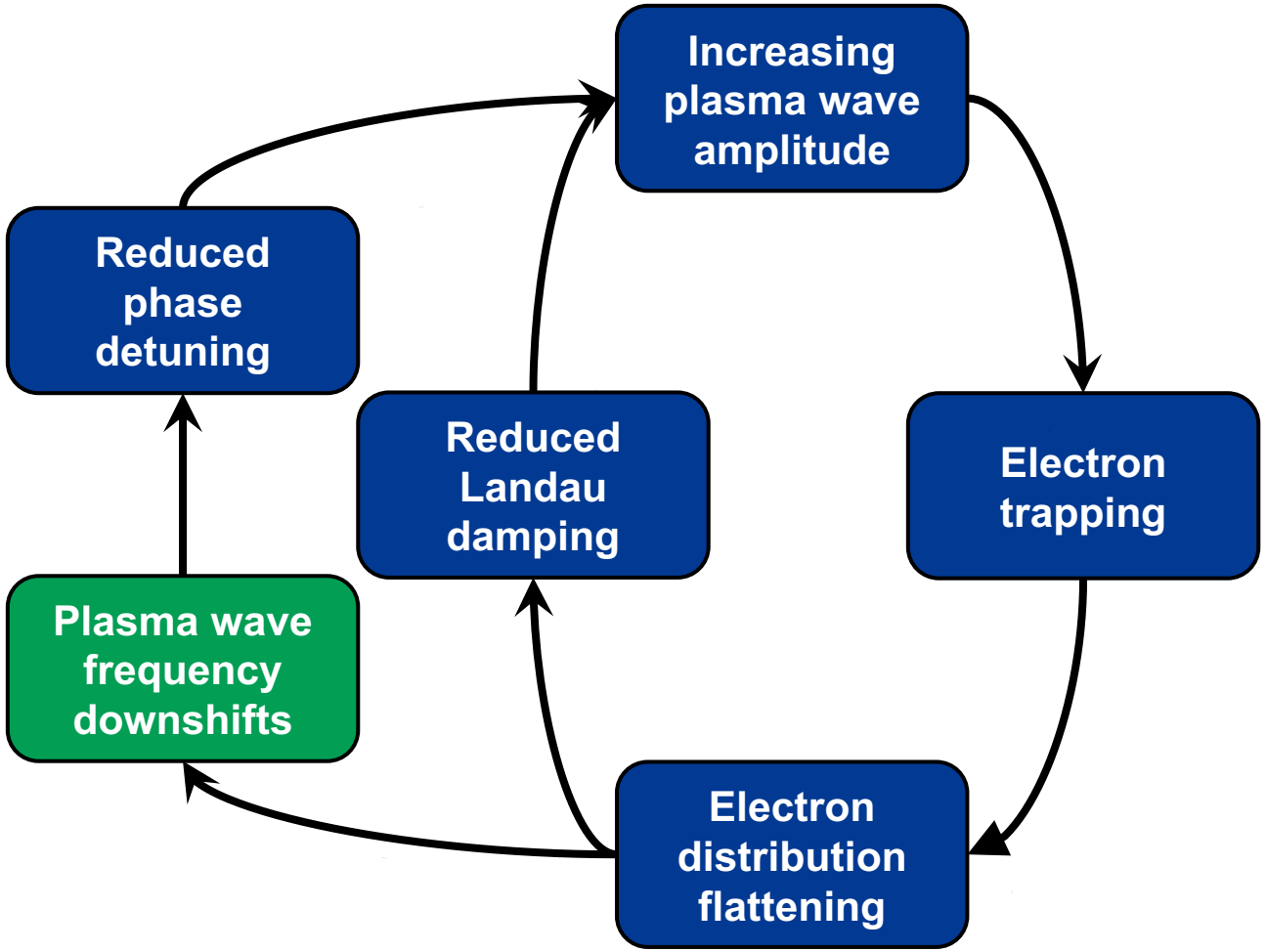

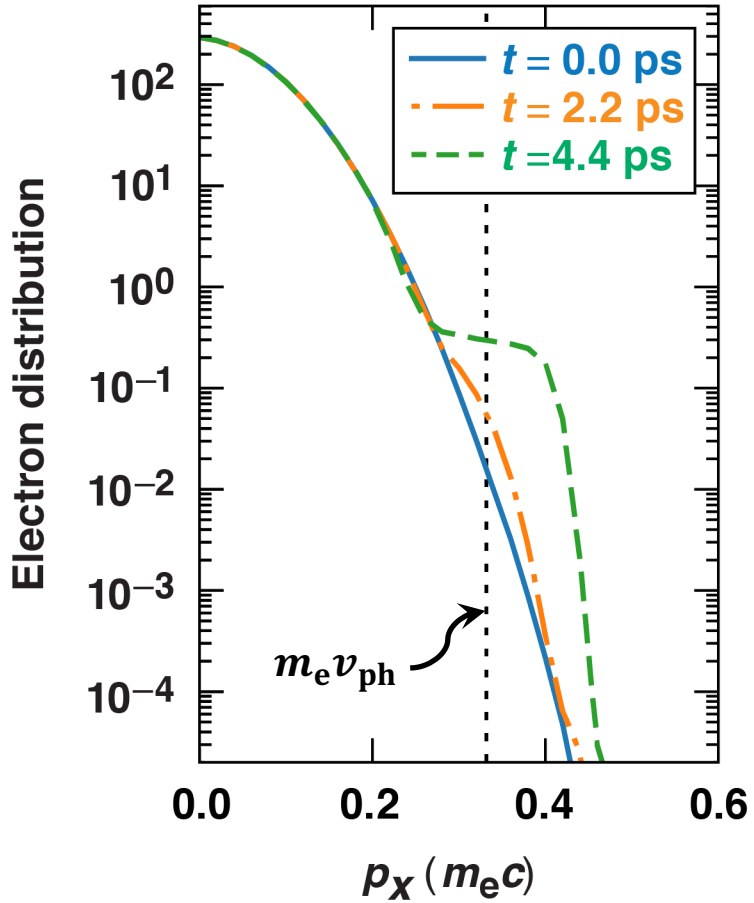

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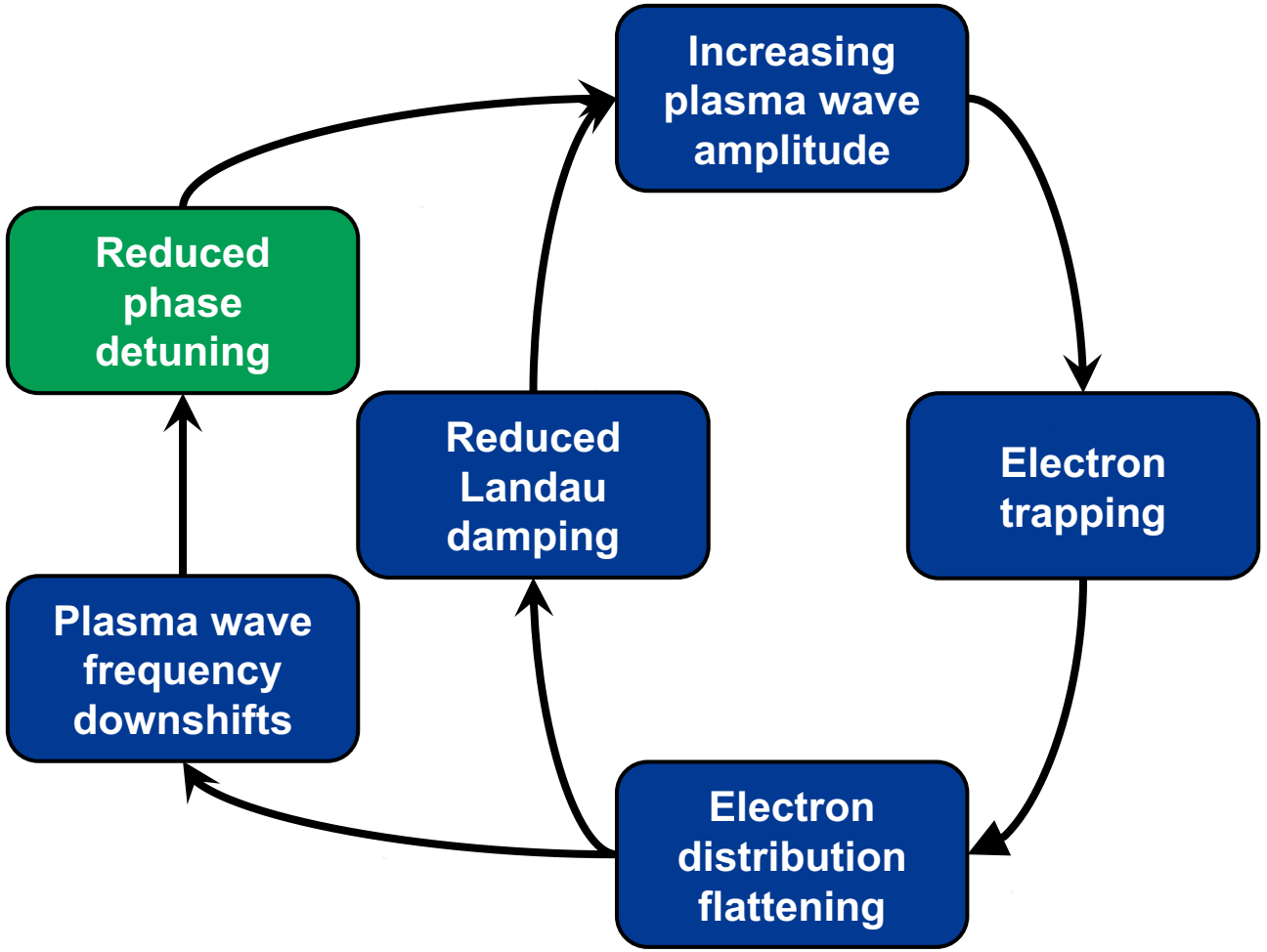

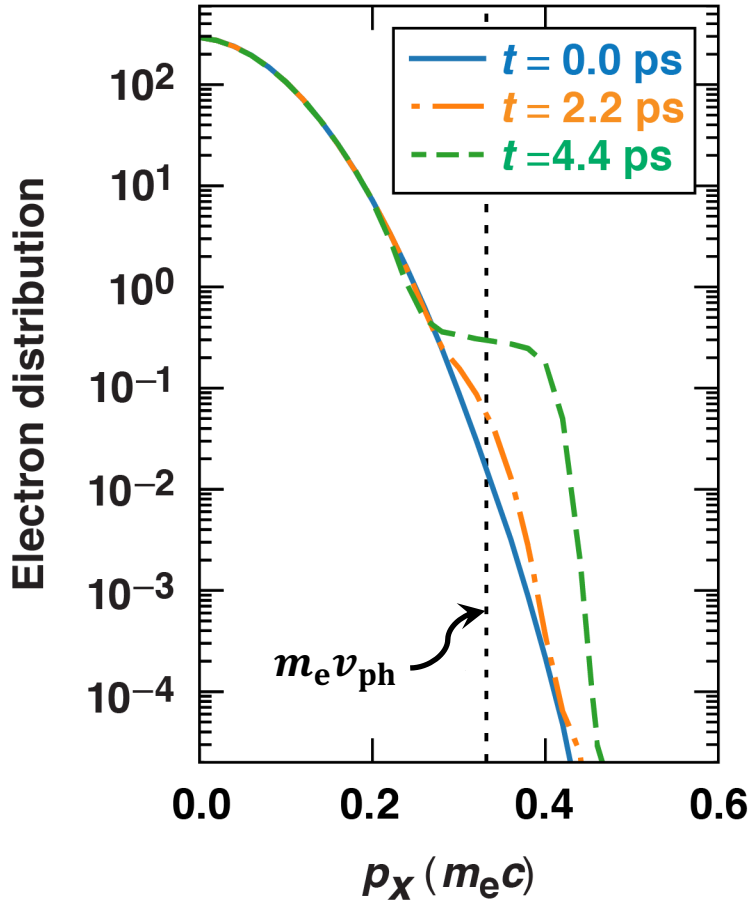

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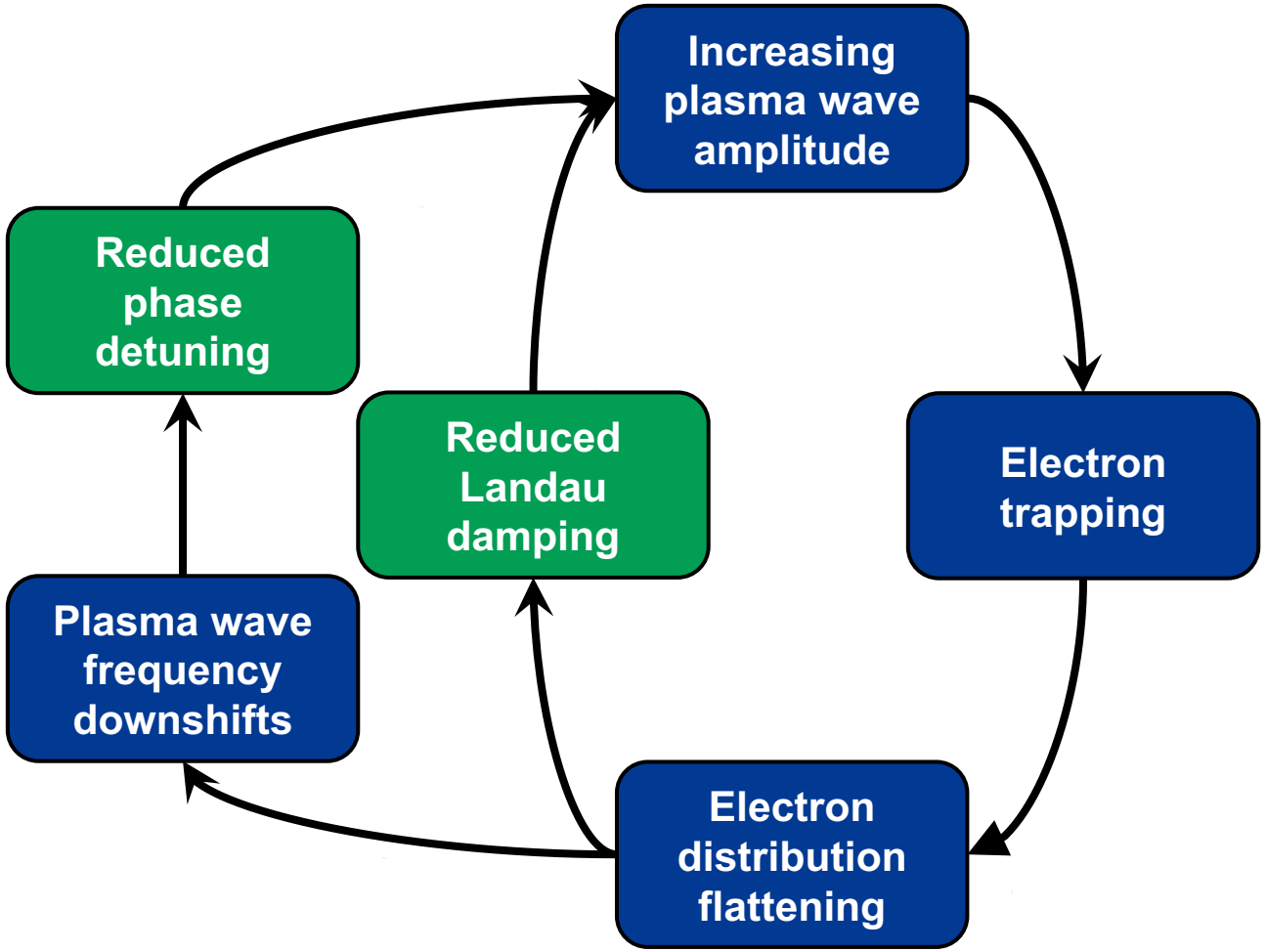

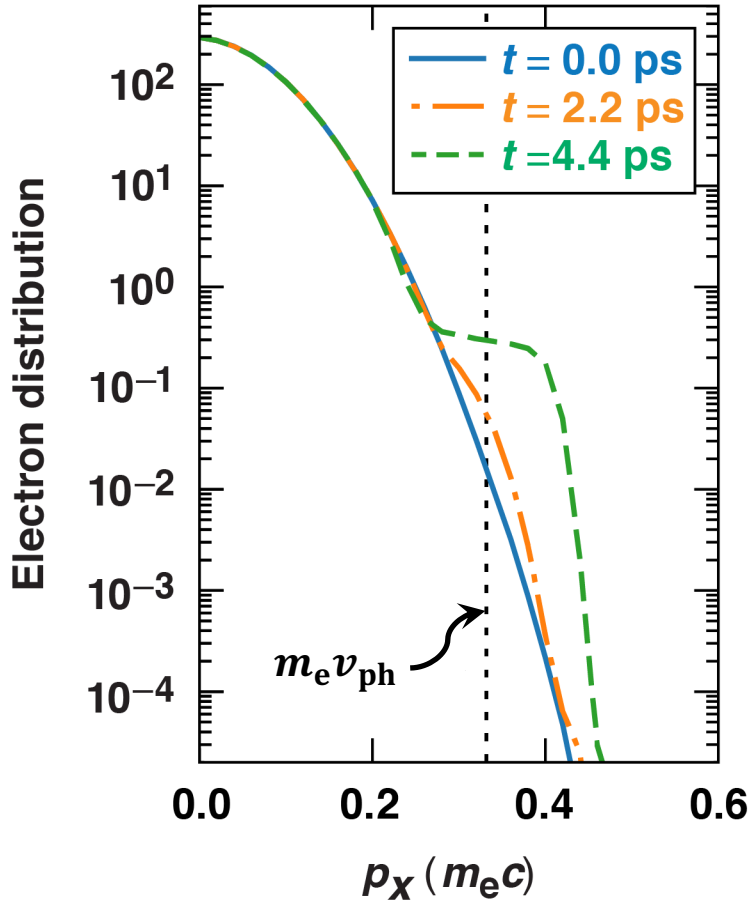

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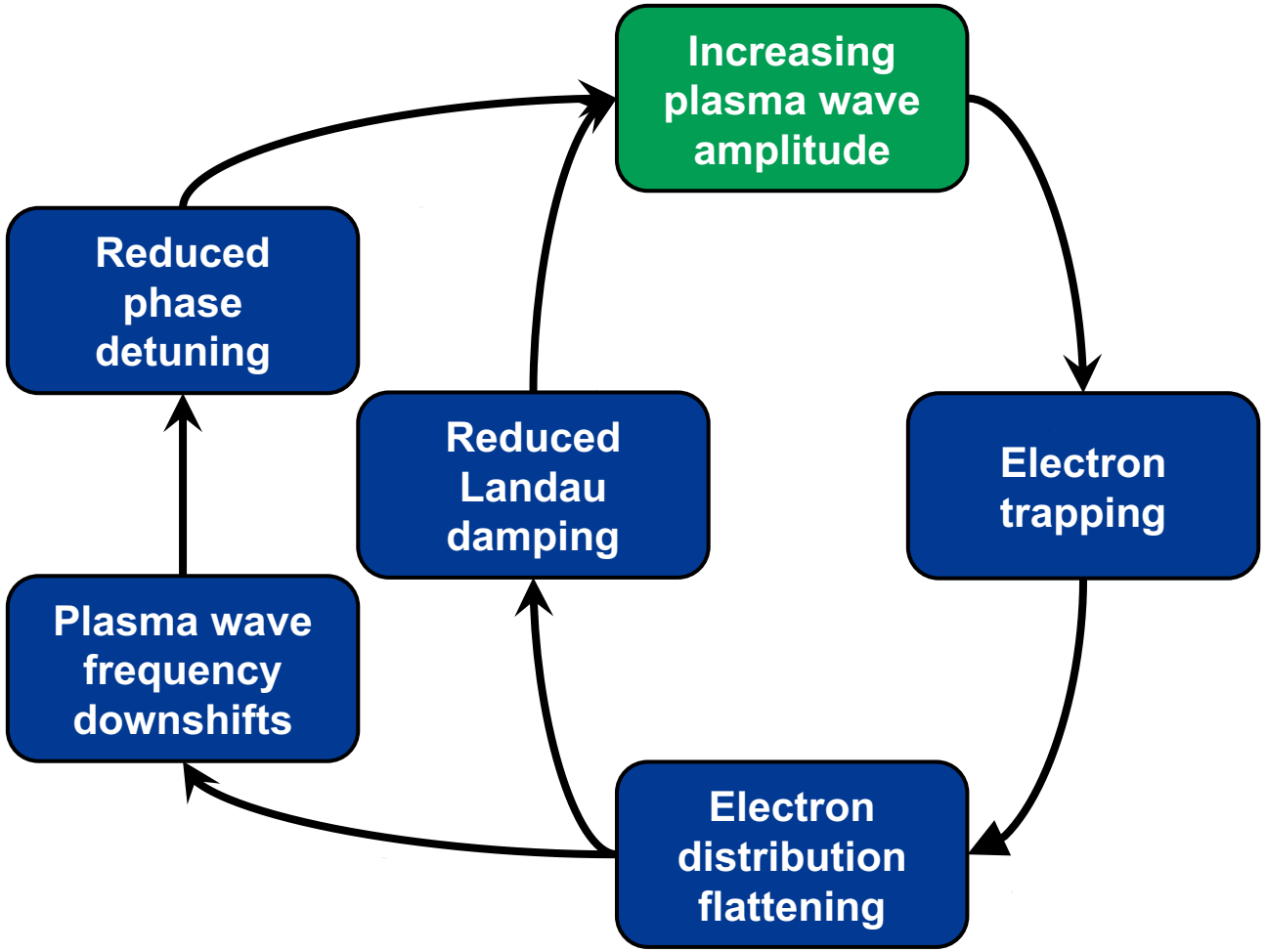

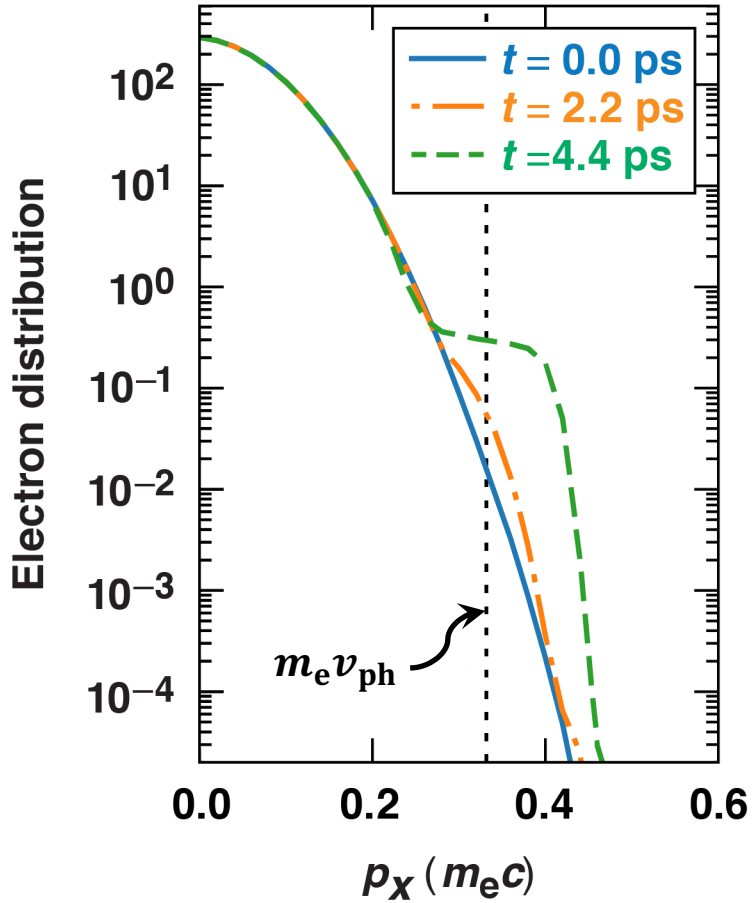

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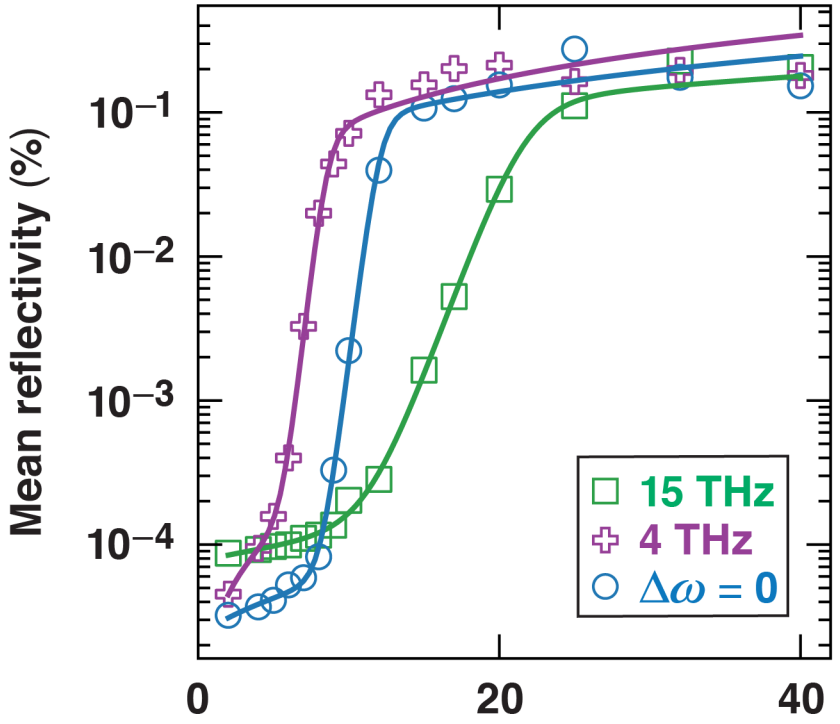
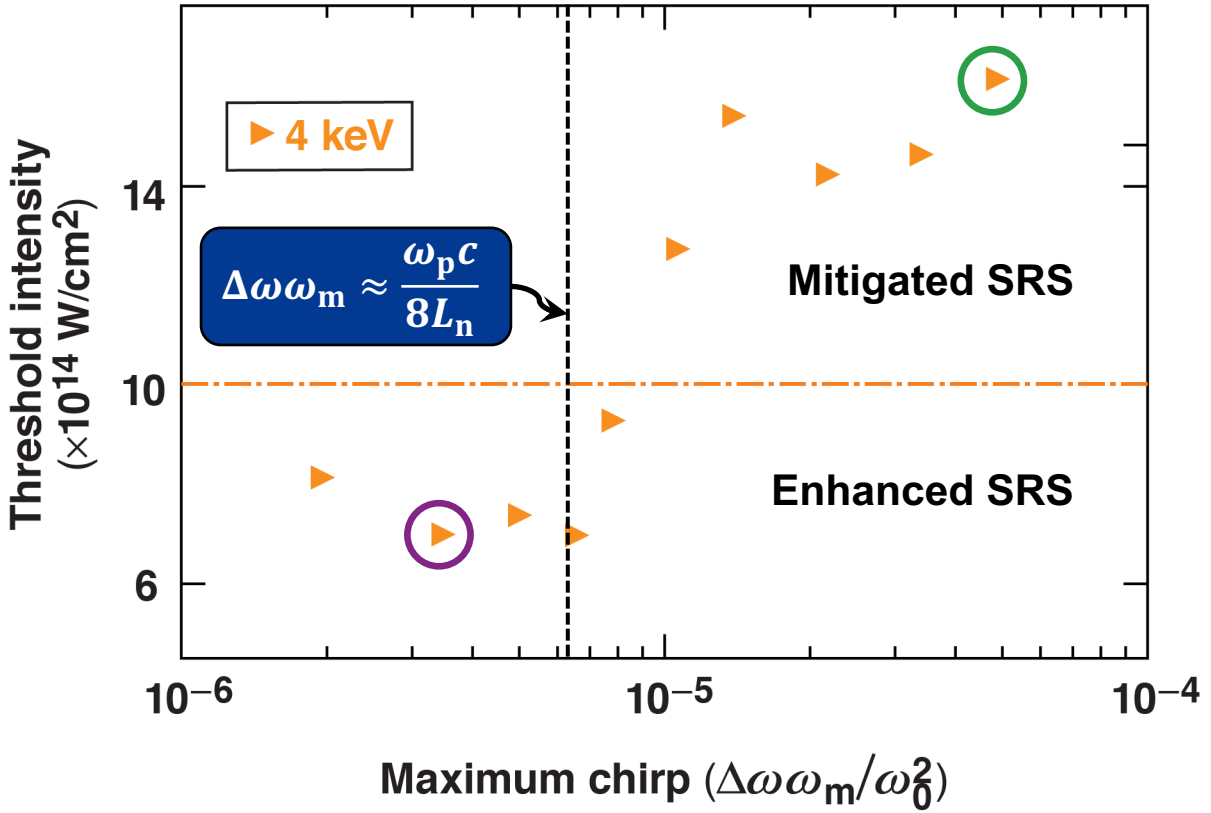
The inflationary SRS threshold reaches a minimum when $\Delta\omega\omega_m \approx \omega_p c/8L_n$





TC15544

Fitting function $f(x) = \tanh(g(x - I_0) + a)(px + q)$

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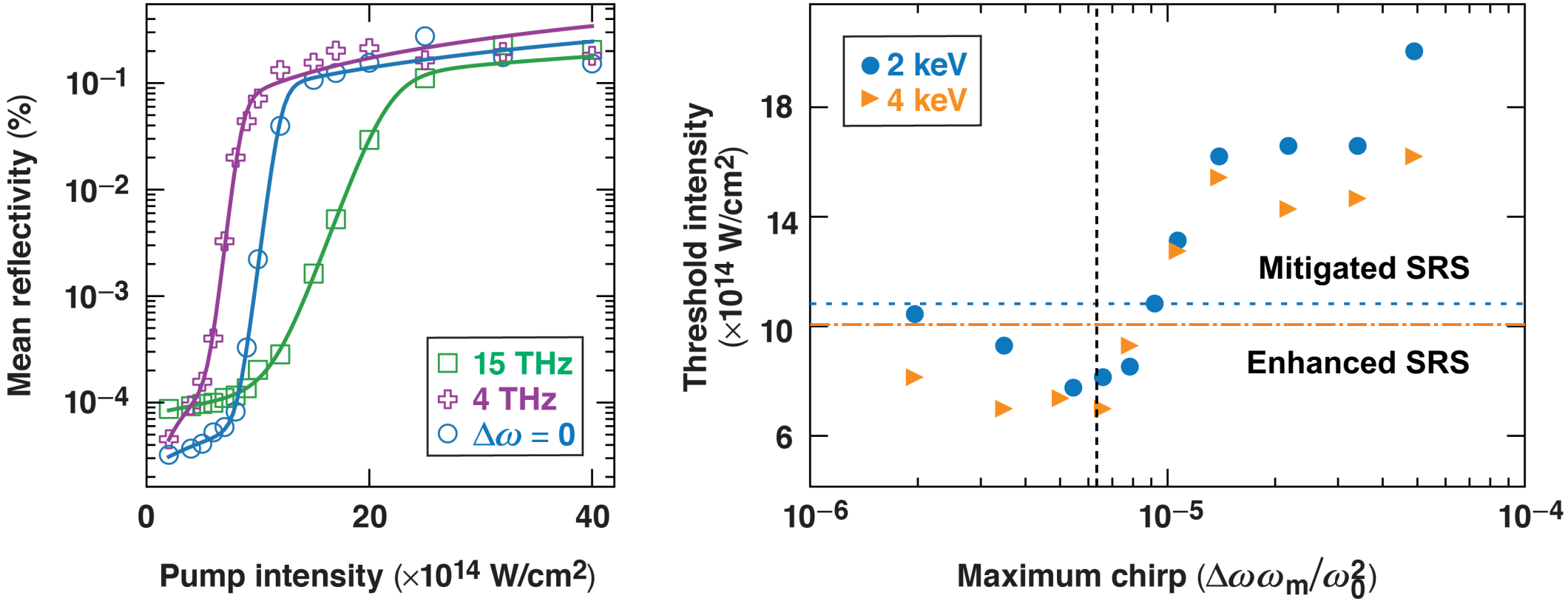

TC15701

The inflationary SRS threshold is not sensitive to the plasma temperature.

Fitting function $f(x) = \tanh(g(x - I_0) + a)(px + q)$

Summary/Conclusions

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- SRS gain* for a Maxwellian plasma is greatly enhanced in the inflationary SRS due to flattening of the electron distribution
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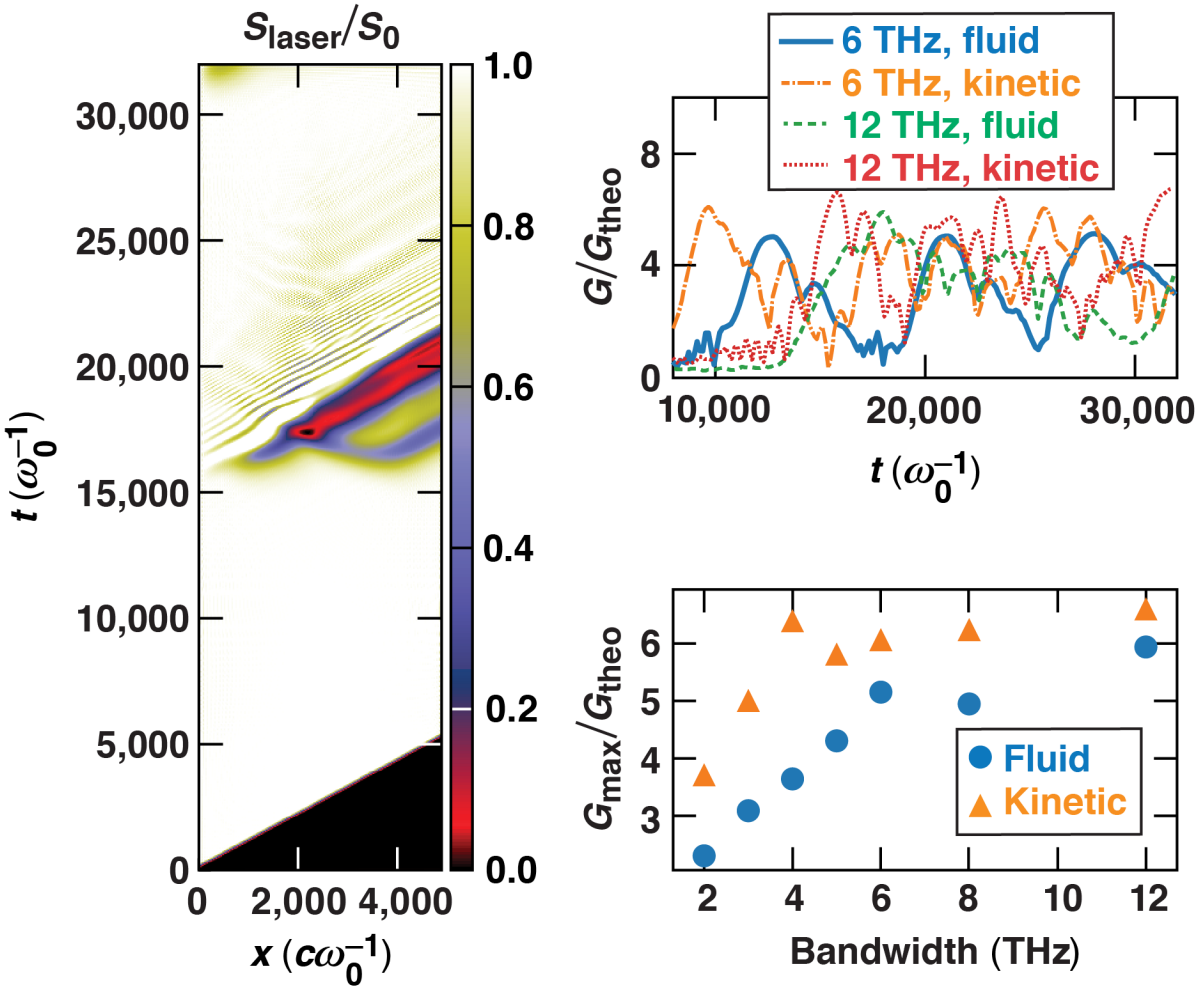
Backup slide

The maximum gain scales linearly with increasing bandwidth until pump depletion becomes important

- Significant pump depletion is observed for the $\Delta\omega = 12$ THz simulation in the fluid regime
- The instantaneous gain G has the same period as the phase modulation
- G_{max} is obtained for parameters satisfying the maximum-gain condition
- The effective interaction length $L'_{int} \propto \Delta\omega$ when $L'_{int} \gg L_{int}$



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