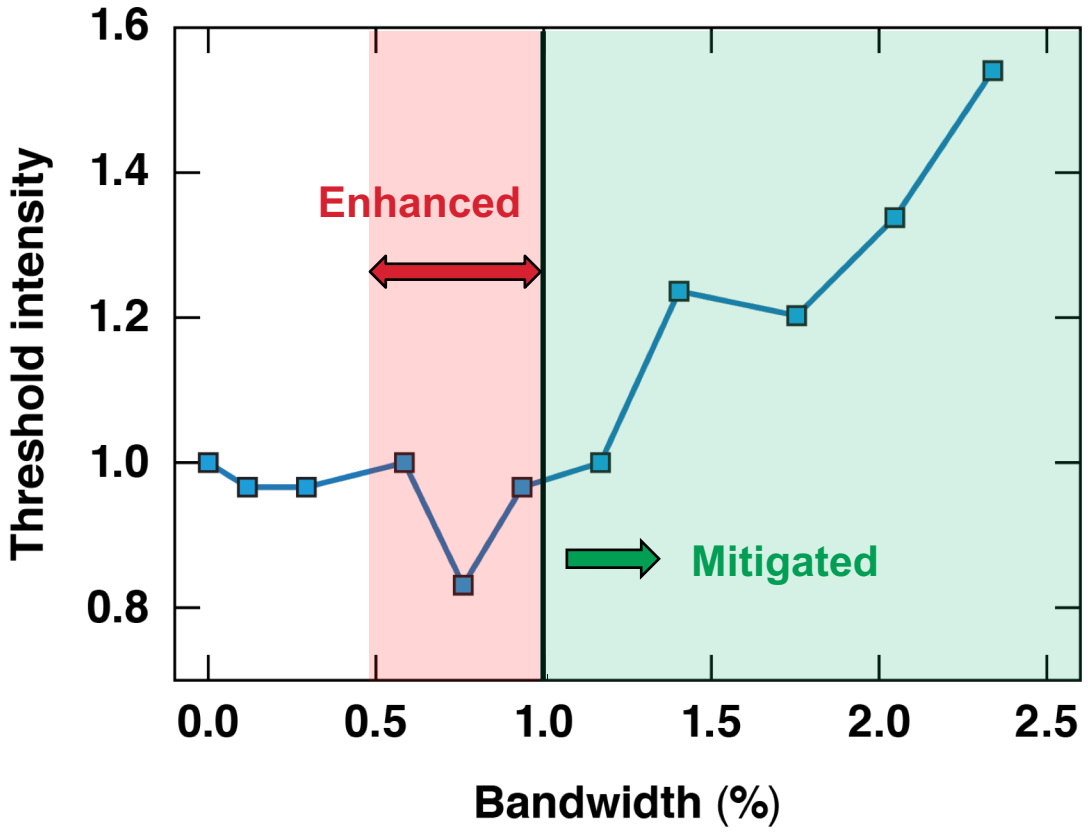
Mitigation of Inflationary Stimulated Raman Scattering with Laser Bandwidth



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Summary

Laser bandwidth in the form of frequency modulation can mitigate inflationary stimulated Raman scattering

- Stimulated Raman scattering (SRS) can inhibit the performance of ICF implosions by redirecting laser energy into unwanted directions and generating hot electrons that preheat the target fuel
- Inflationary SRS (ISRS) in inhomogeneous plasma occurs when electron trapping in the driven plasma wave creates a frequency shift that maintains phase matching over long distances, greatly enhancing the gain
- Laser bandwidth enhances SRS when the scattered light follows the SRS resonance over a time long enough for electron trapping
- Laser bandwidth mitigates ISRS by shortening the interaction time

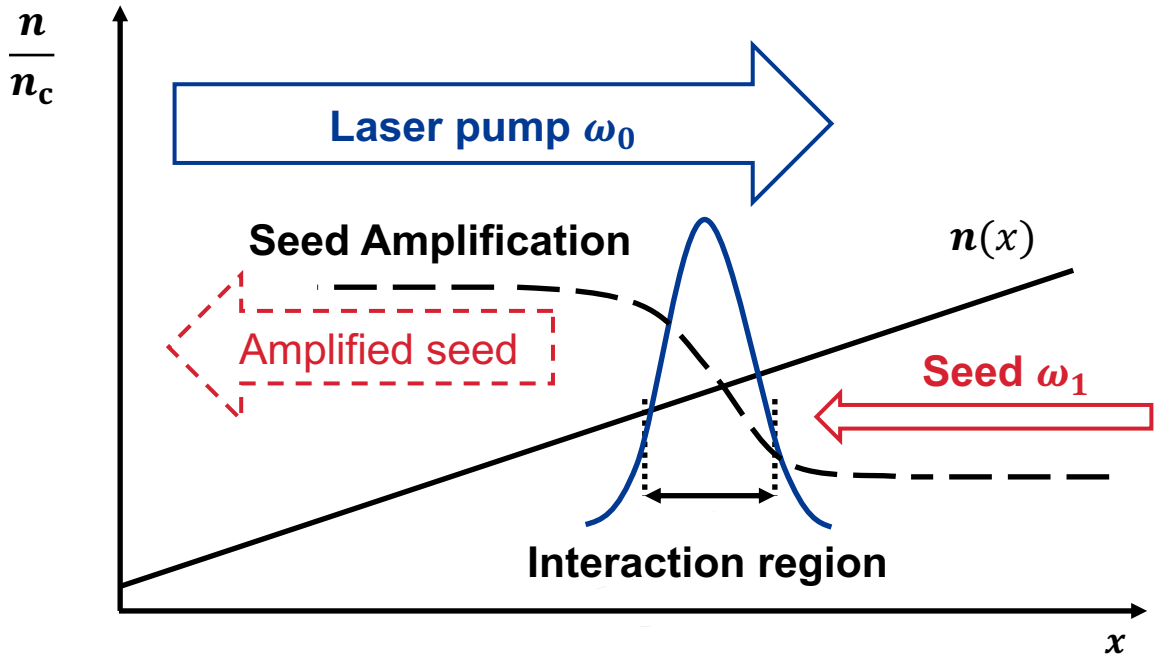
Broadband drivers in development at LLE (FLUX) have enough bandwidth to mitigate ISRS at ignition scale

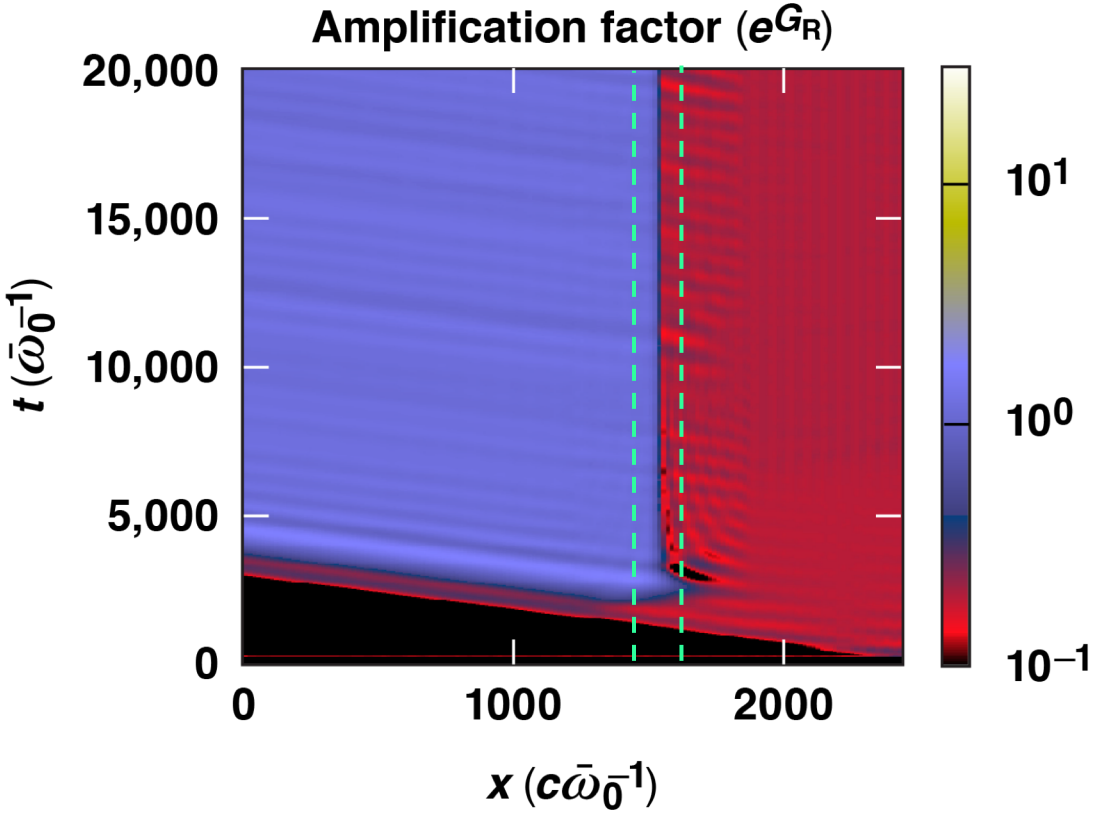
Collaborators

R.K. Follett, A.V. Maximov, and J.P. Palastro
Laboratory for Laser Energetics, University of Rochester

In an inhomogeneous plasma, stimulated Raman scattering is resonant over a finite interaction length

A seed beam is amplified over a region where the frequency mismatch between the waves is close to zero ($\Delta\Omega(x) \equiv \omega_0 - \omega_1 - \omega_2(x) \approx 0$), leading to a fixed amplification*

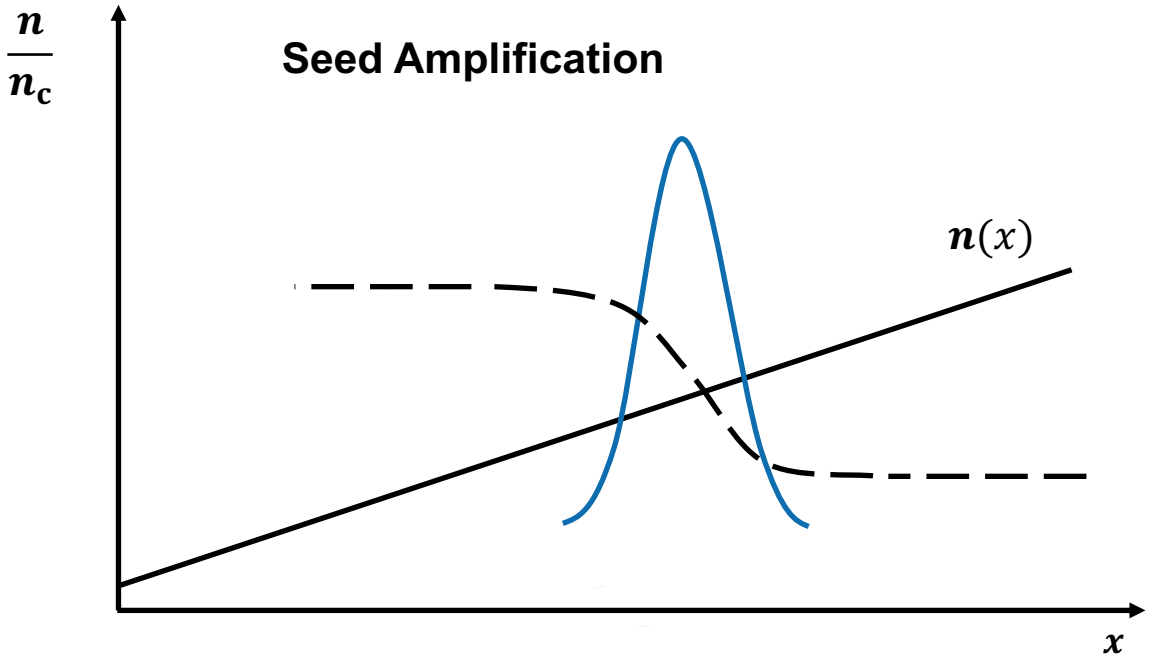




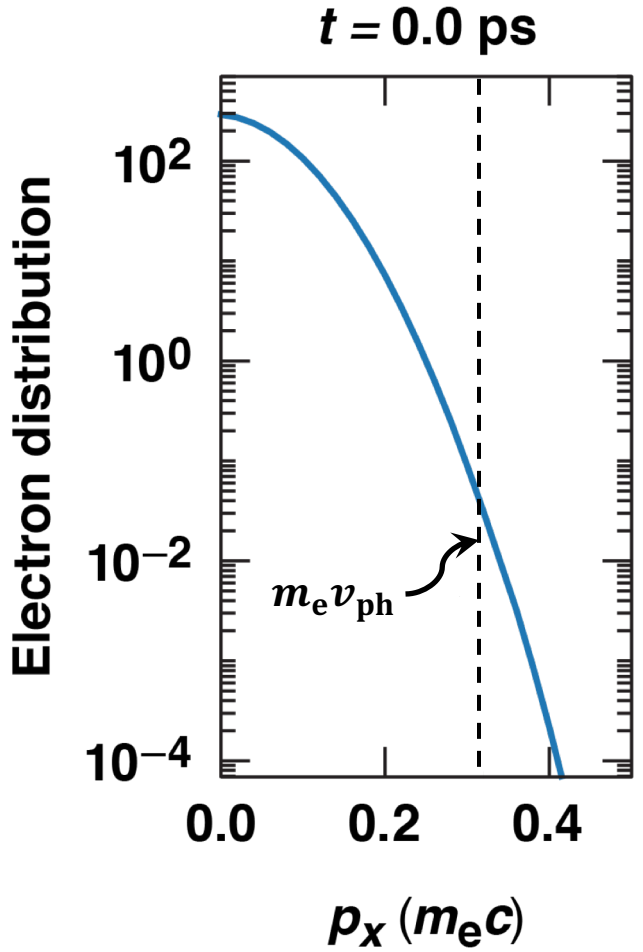
TC15836

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

Particle trapping modifies the local Langmuir wave frequency, which increases the interaction length and consequently the linear gain



A large linear gain can generate Langmuir waves capable of trapping electrons, initiating kinetic inflation*



TC15837

* H. X. Vu, D. F. DuBois, and B. Bezzerides, Phys. Plasmas 9, 1745 (2002)

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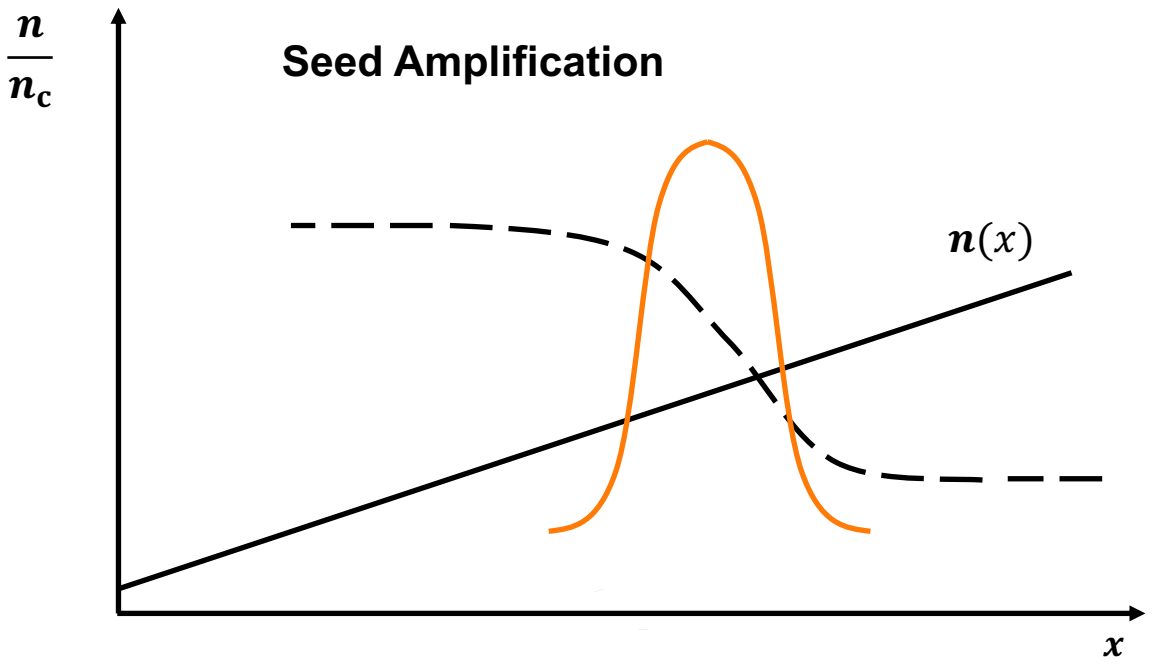

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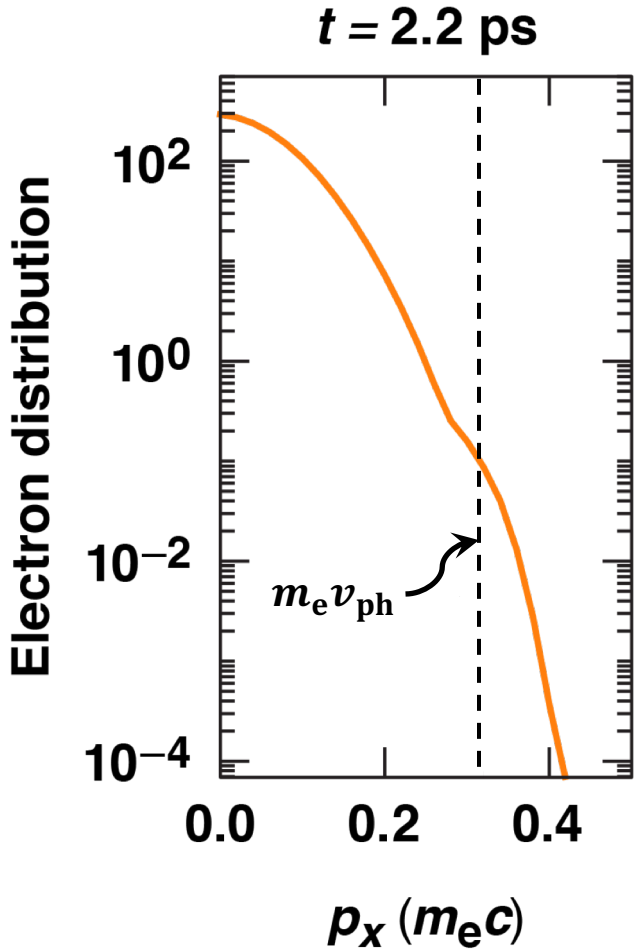

TC15838

* H. X. Vu, D. F. DuBois, and B. Bezzerides, Phys. Plasmas 9, 1745 (2002)

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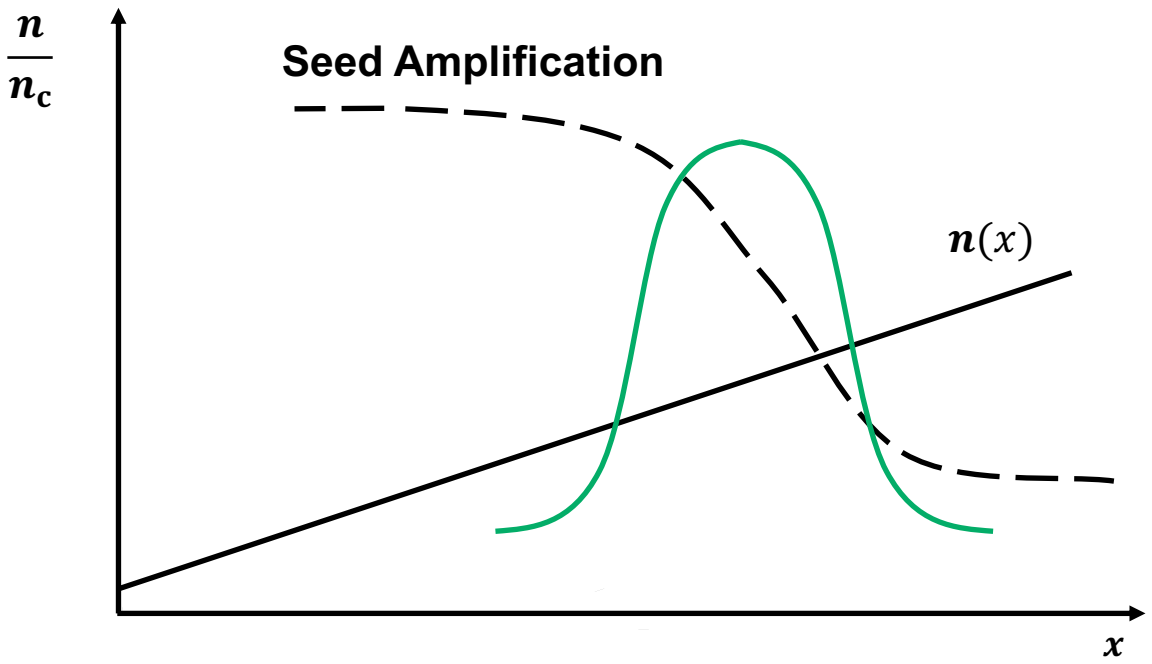

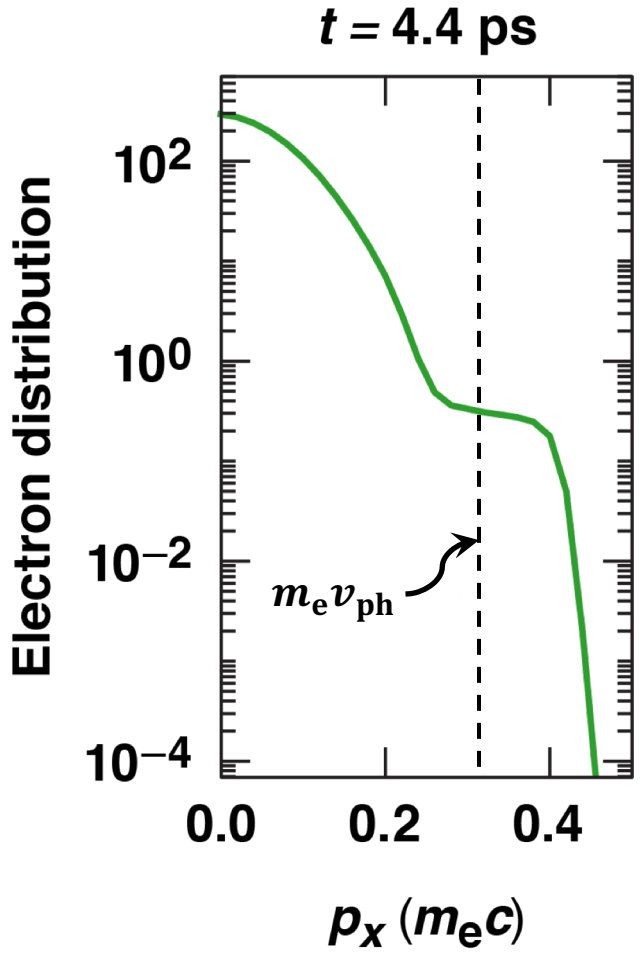

TC15839

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* H. X. Vu, D. F. DuBois, and B. Bezzerides, Phys. Plasmas 9, 1745 (2002)

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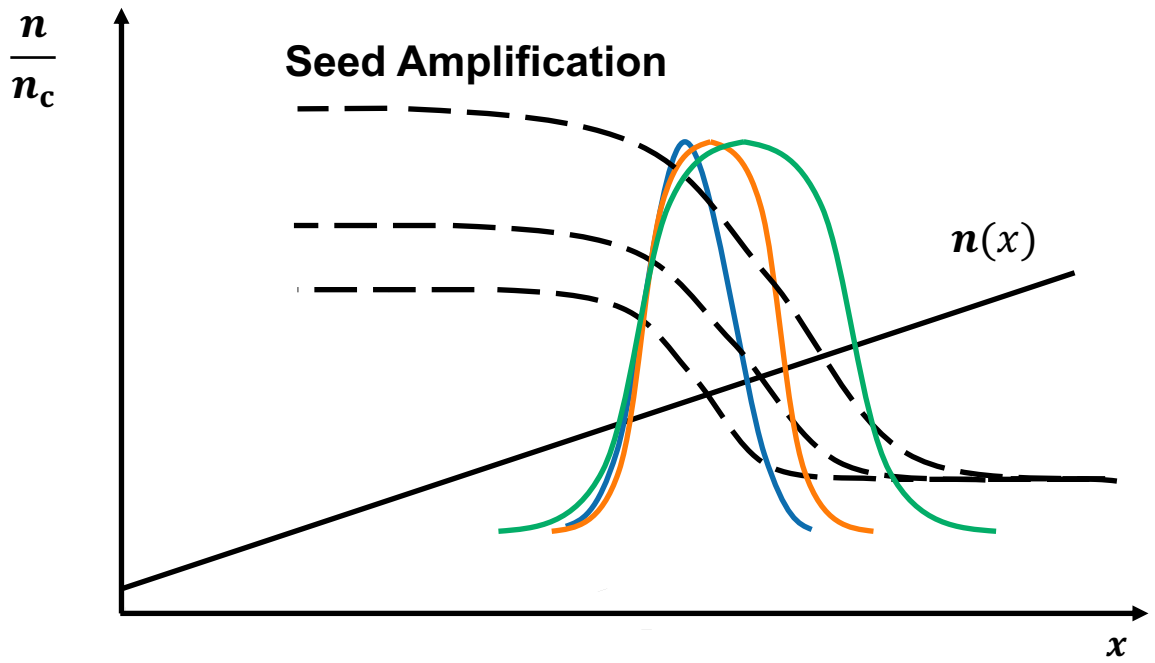

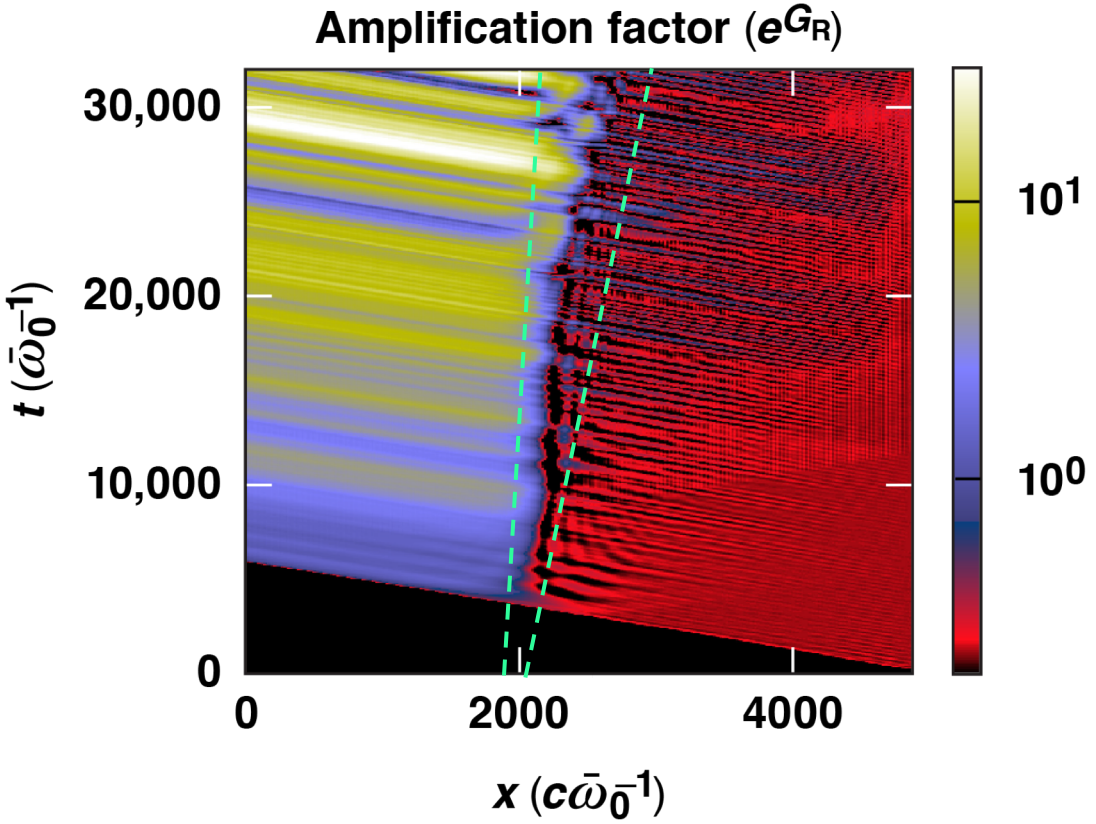

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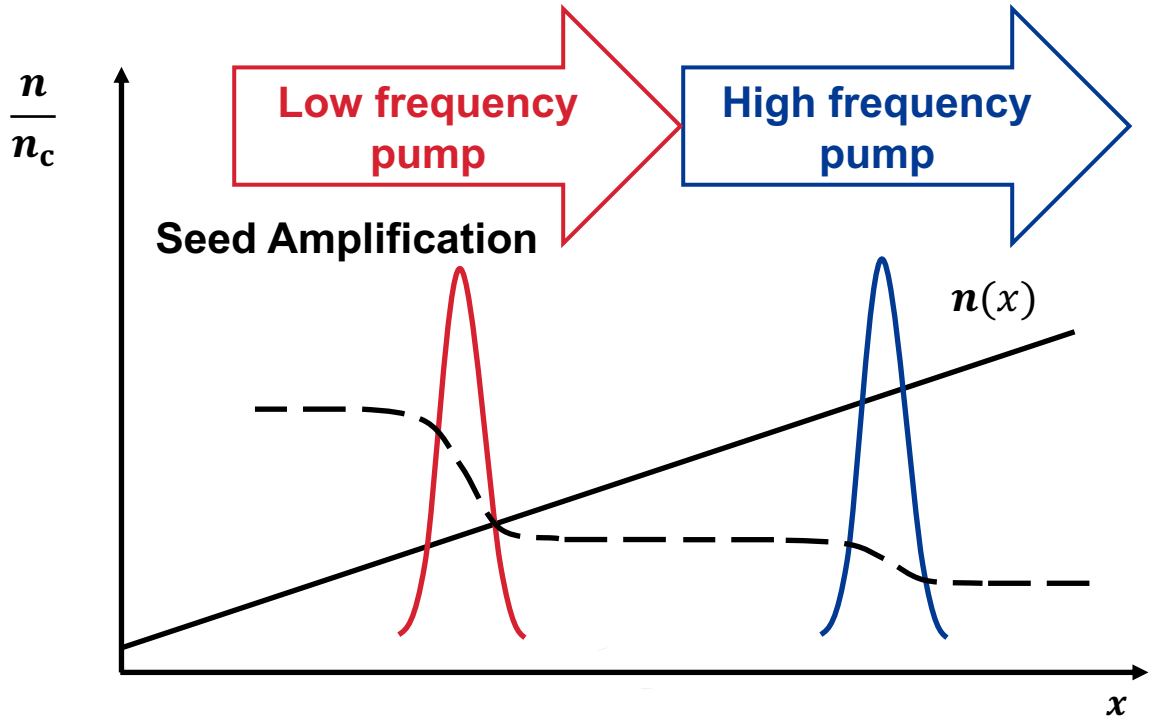
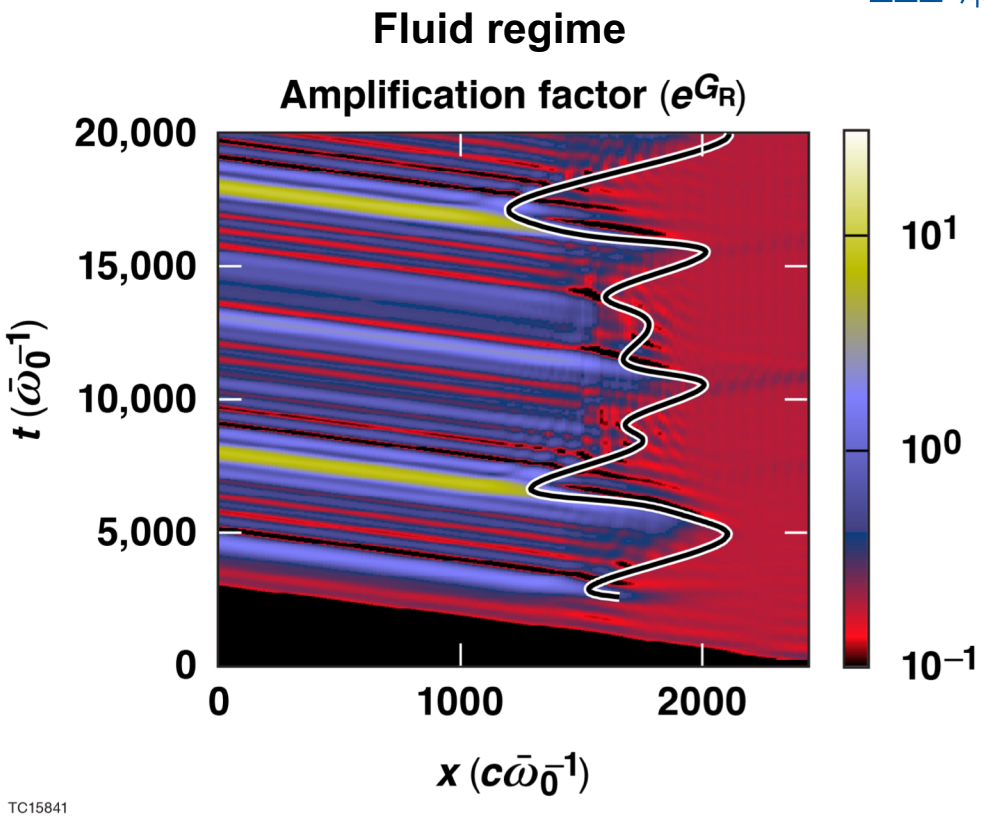
TC15840

* H. X. Vu, D. F. DuBois, and B. Bezzerides, Phys. Plasmas 9, 1745 (2002)

The transient gain is enhanced when the scattered light follows the SRS resonance





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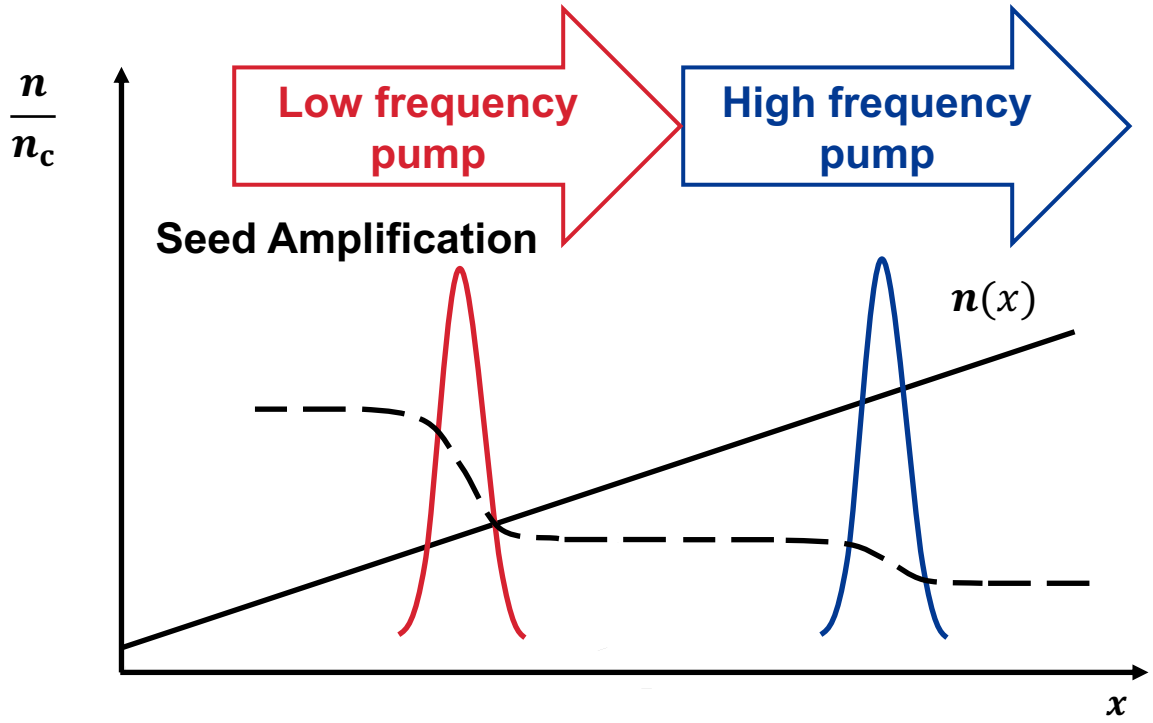

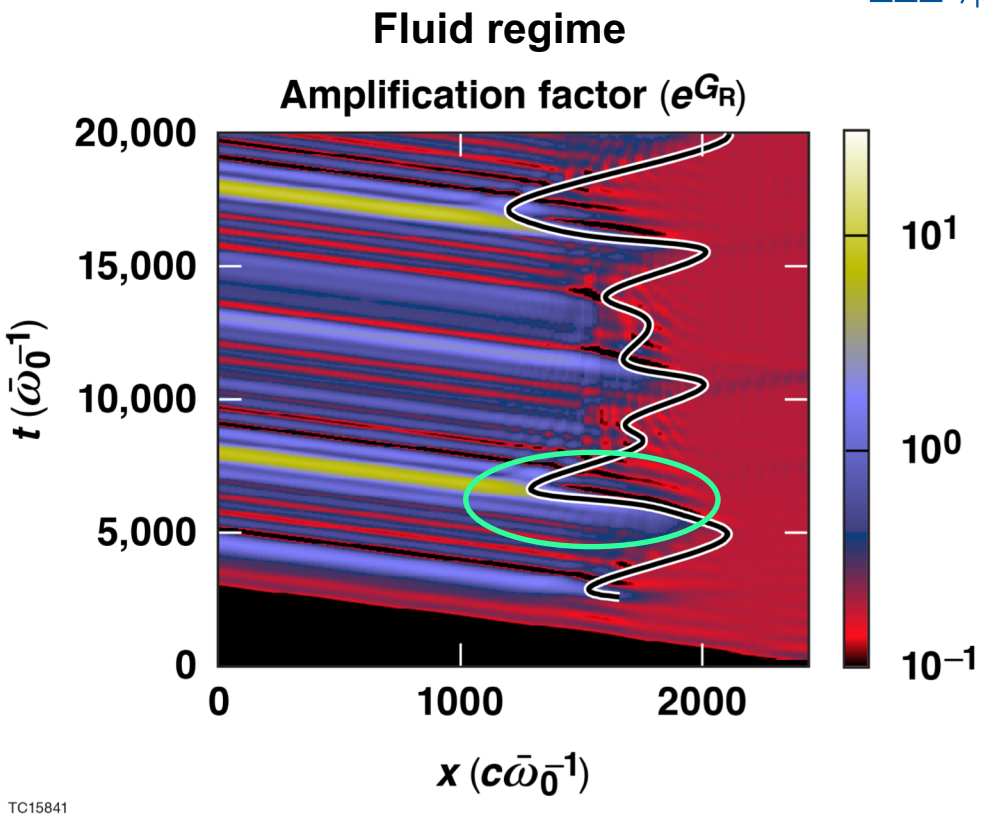

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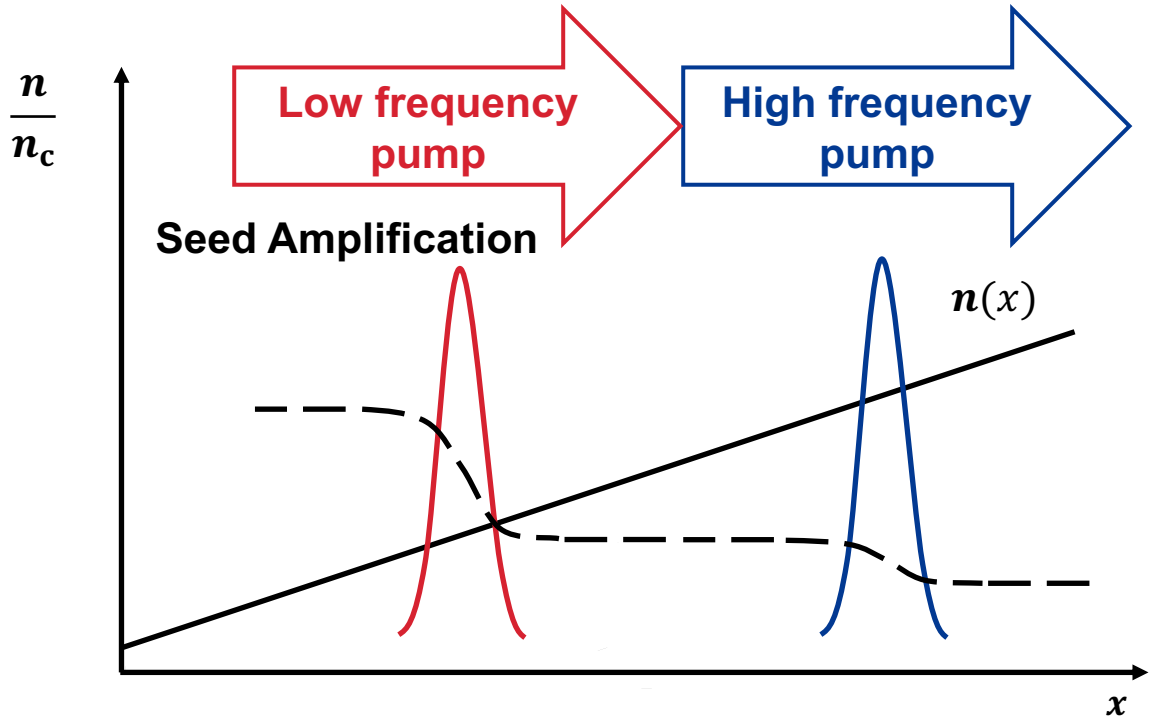
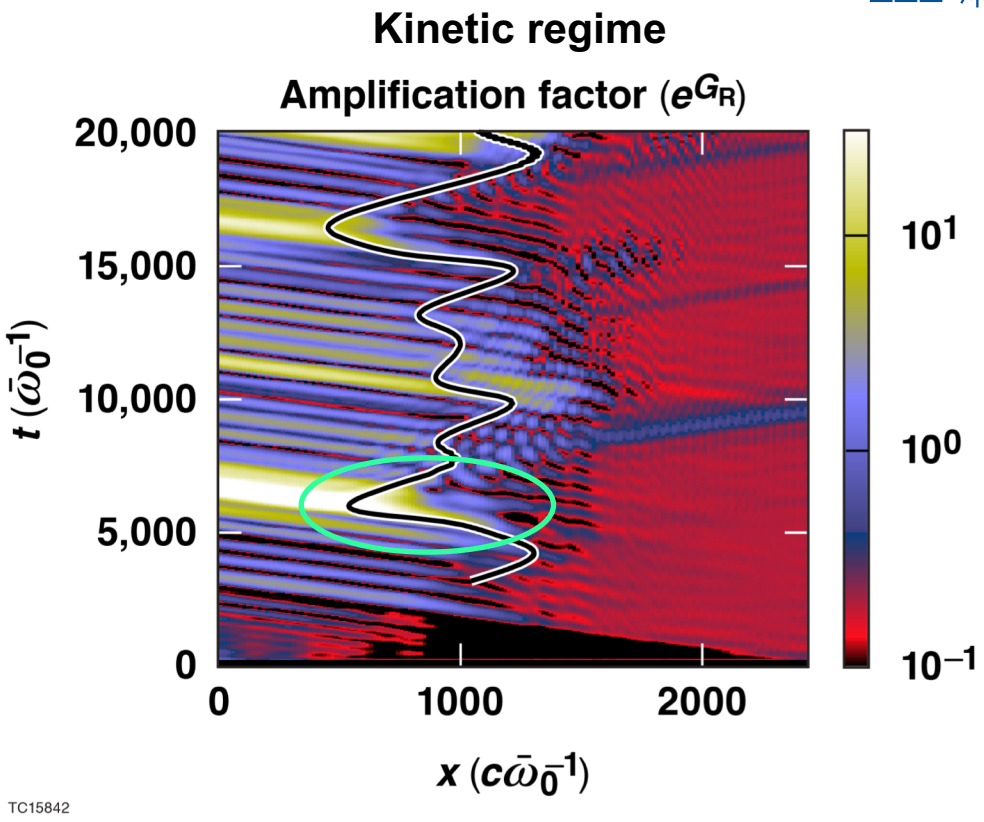
This transient gain enhancement requires a delicate balancing of plasma and pump parameters:* $\frac{d\Delta\omega}{dt} = -\frac{\omega_p c}{4L_n}$

* H. Wen *et al*, Phys. Plasmas 28, 042109 (2021)

The enhanced transient gain can trigger kinetic inflation





9x larger amplification factor than that without kinetic inflation

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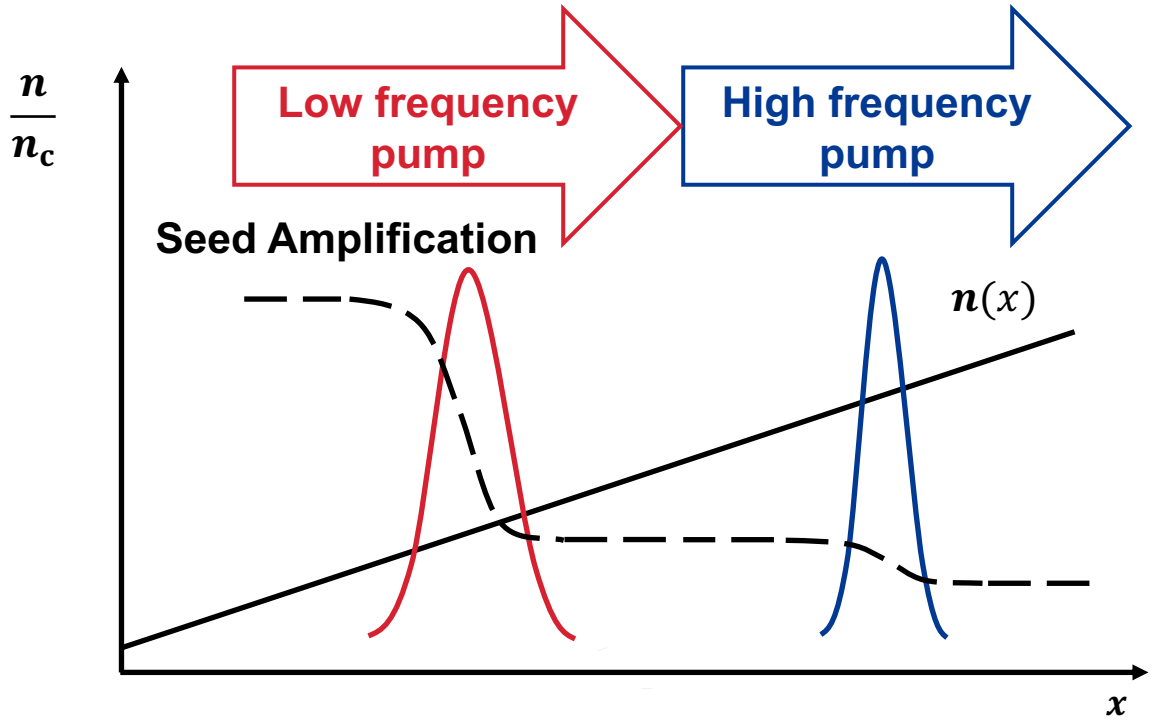

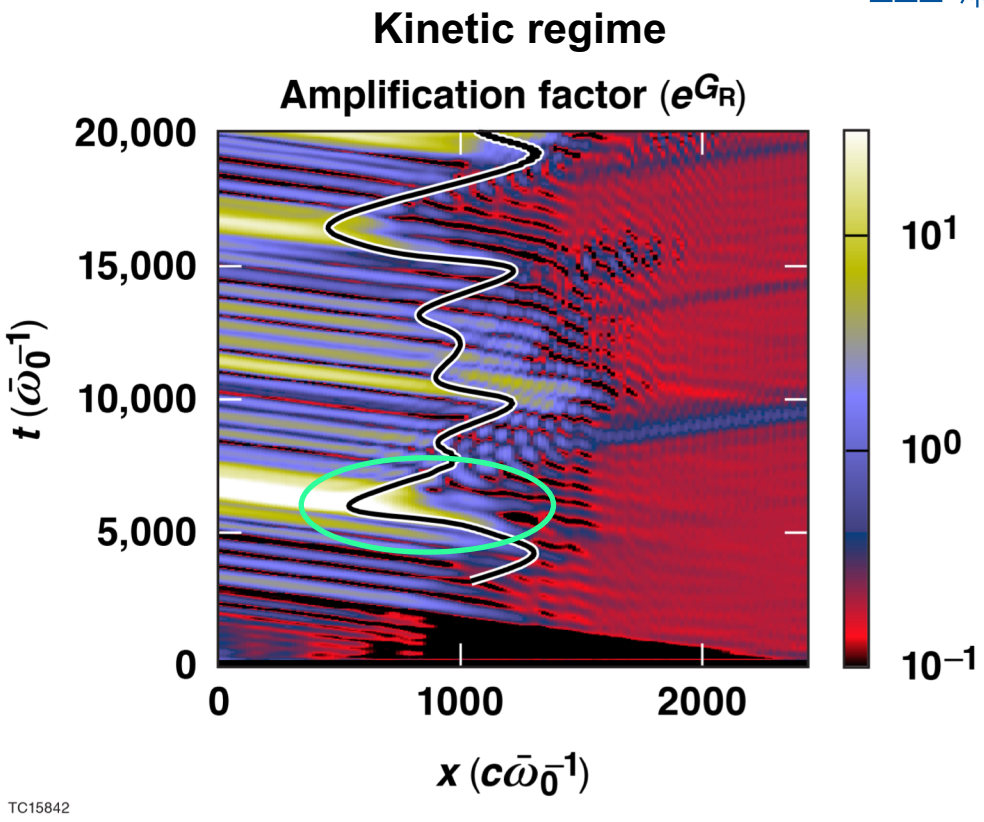

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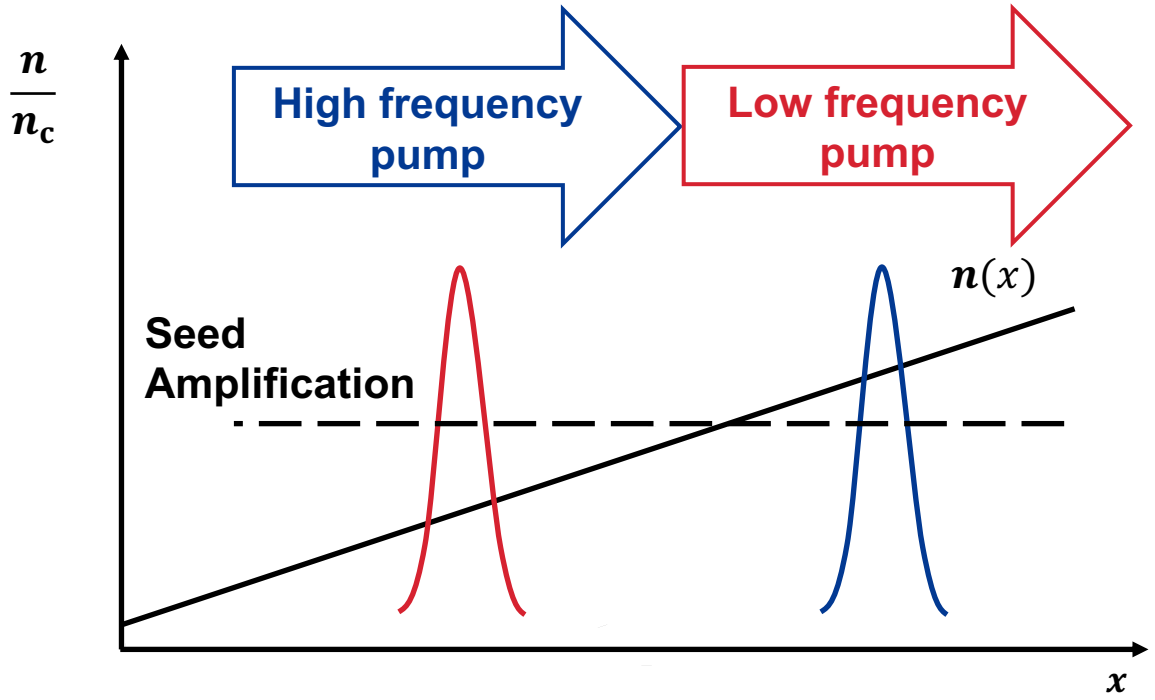
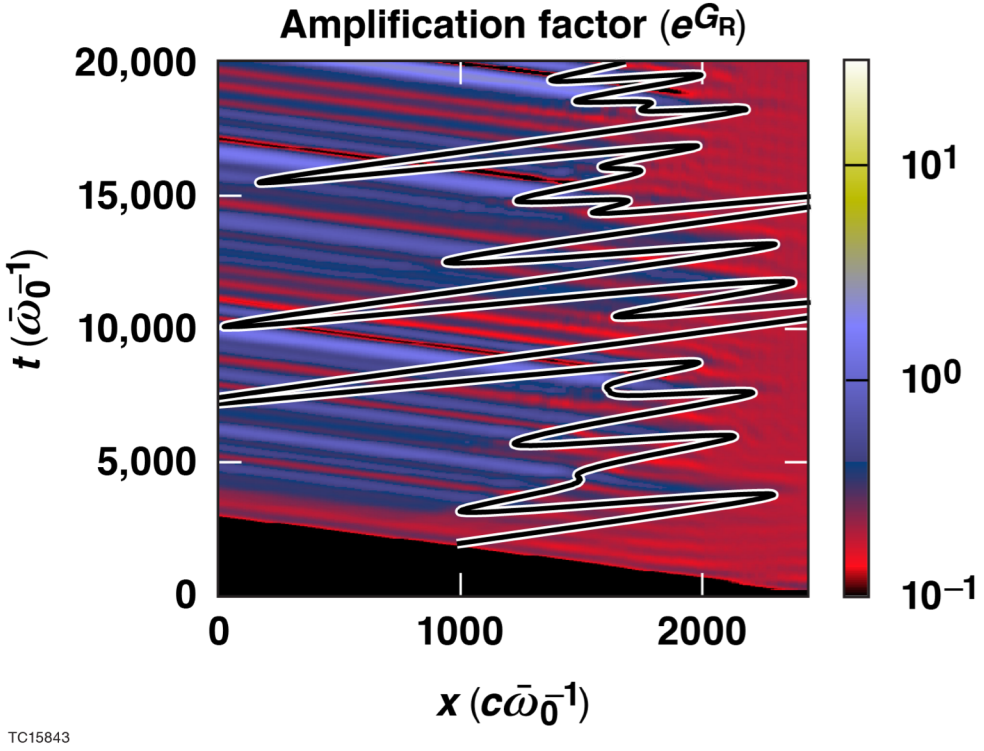
The transient gain is reduced when the scattered light propagates in the opposite direction of the SRS resonance

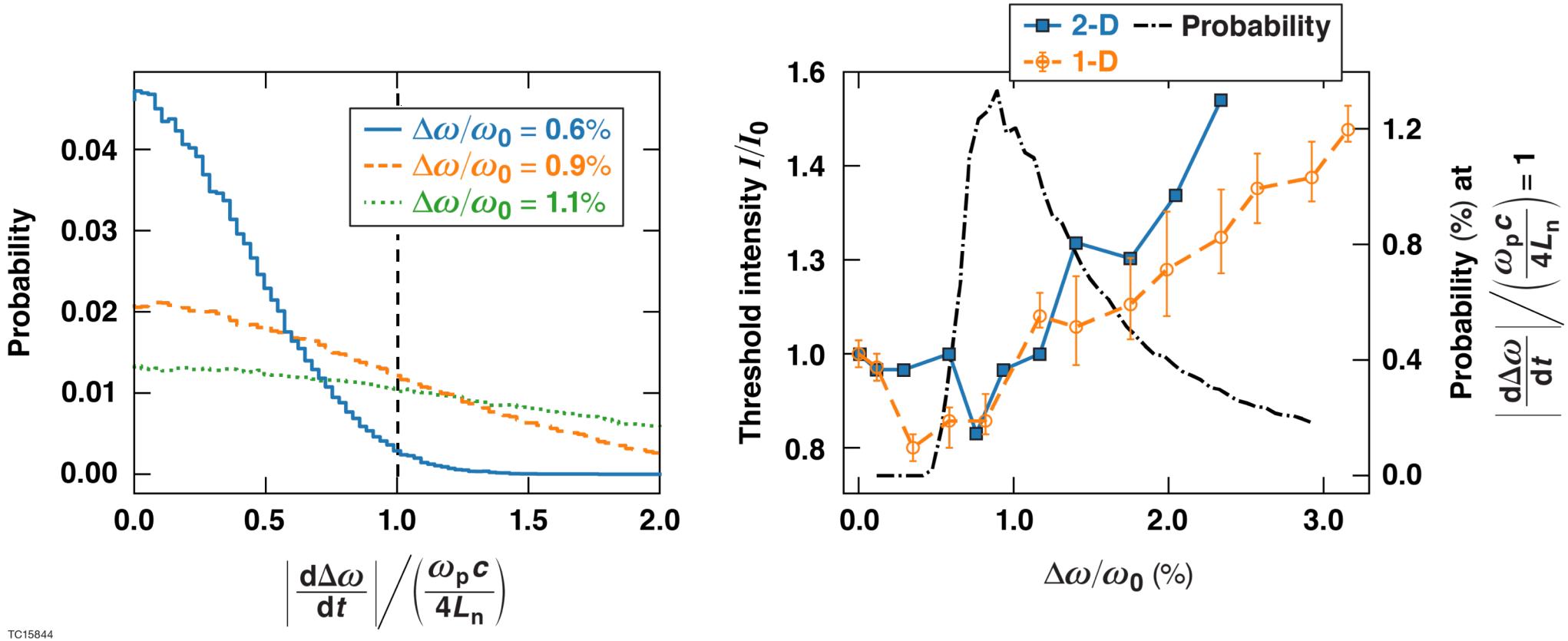




A large bandwidth mitigates the transient gain enhancement of SRS

The inflationary SRS threshold reaches a minimum at the bandwidth when the SRS gain enhancement is most likely to occur

- Exponential density profile $L_n = 400\ \mu m$
- 1D $I_0 = 1.31\times10^{15}\ W/cm^2$, 2D $I_0 = 2.24\times10^{15}\ W/cm^2$



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