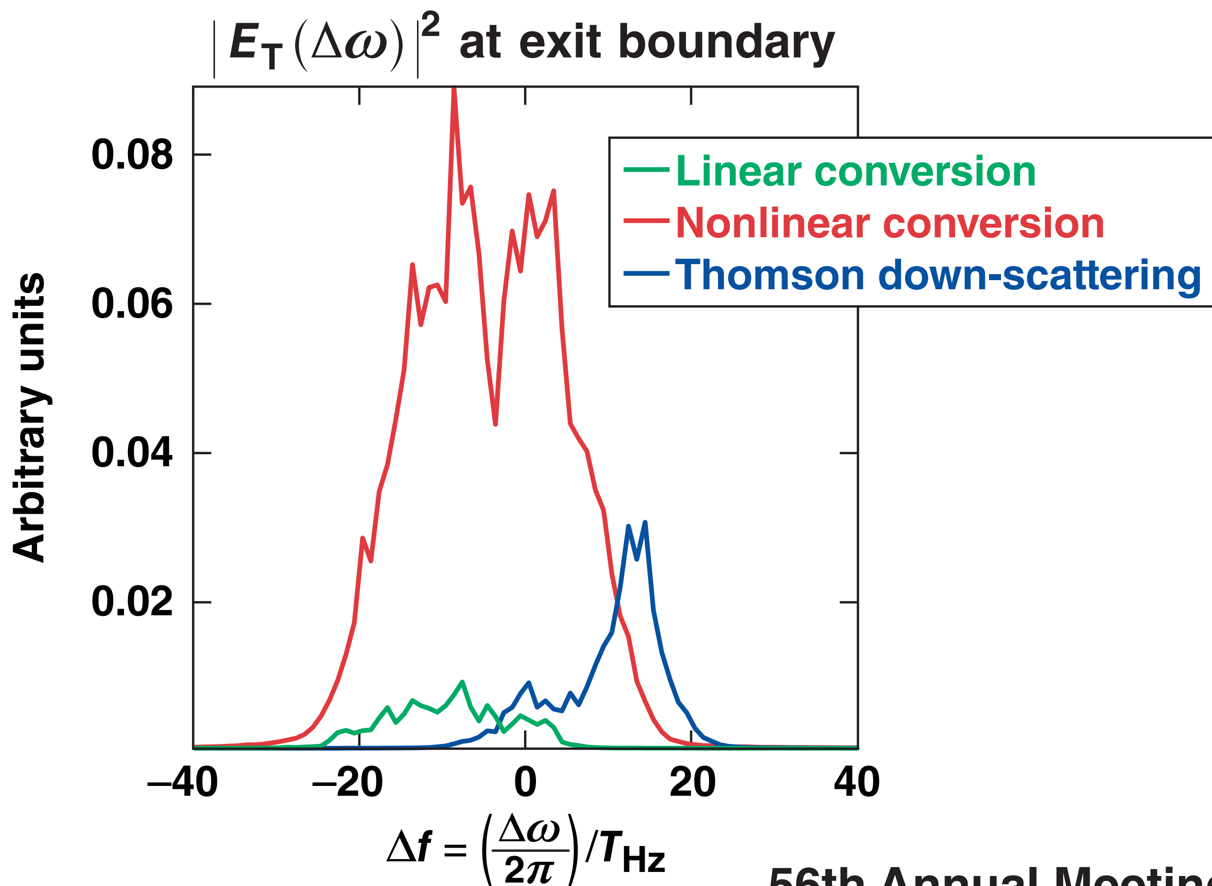
Calculation of Half-Harmonic Emission Generated by the Two-Plasmon–Decay Instability



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Summary

Half-harmonic emission generated by two-plasmon decay (TPD) is calculated with a new code, *EMZAK*

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- Half-harmonic emission is one of the few experimental* observables of TPD
- The Zakharov equations** are expanded to include transverse fields and are solved with a new code
- Half-harmonic emission can be generated by three different mechanisms
  - linear conversion
  - nonlinear conversion
  - Thomson down-scattering

For the case shown, nonlinear-mode conversion is dominant.

* W. Seka *et al*., Phys. Rev. Lett. 112, 145001 (2014).
** D. F. DuBois, D. A. Russell, and H. A. Rose, Phys. Rev. Lett. 74, 3983 (1995); D. A. Russell and D. F. DuBois, Phys. Rev. Lett. 86, 428 (2001); J. Zhang *et al*., Phys. Rev. Lett. 113, 105001 (2014).

Collaborators

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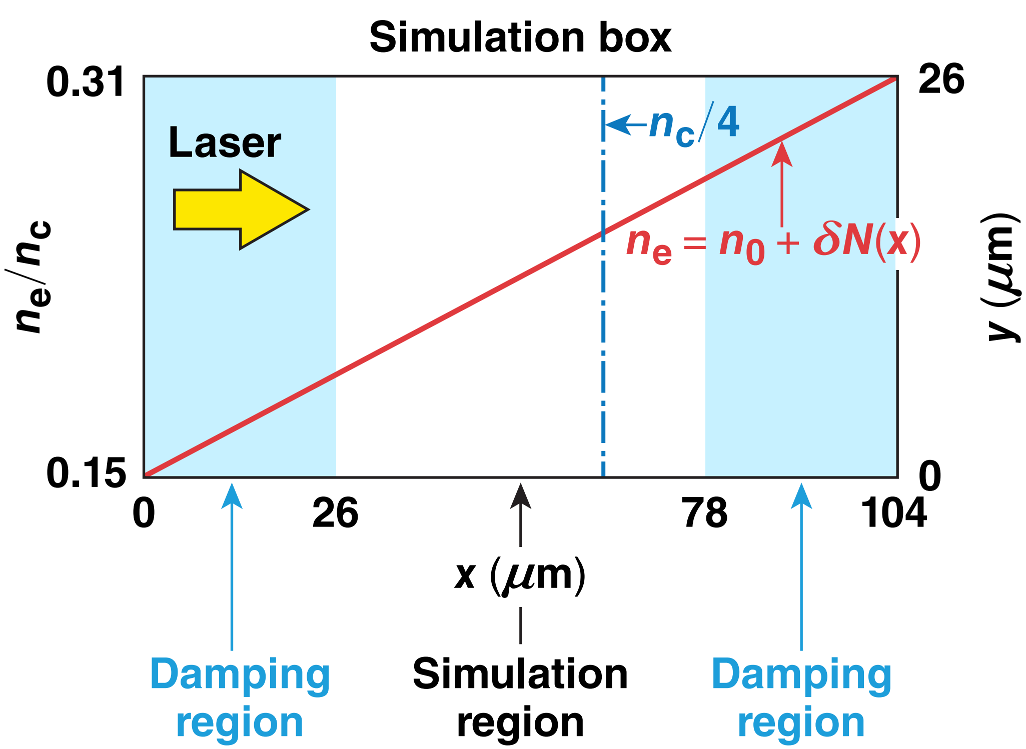
The generation of half-harmonic transverse waves occurs near quarter-critical density where TPD Langmuir waves (LW's) turn



- Parameters are relevant to an OMEGA spherical implosion
- Single laser beam

$I_{14} = 8$; $L_n = 150\ \mu$m;

$T_{e,keV} = T_{i,keV} = 2$;

$$\eta = \frac{L_n \lambda_{\mu m} I_{14}}{T_{e,keV}} \approx 2;$$

$$\nu_{ei} = 1.88 \times 10^{-4}\ \omega_0$$

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The electrostatic Zakharov equations are extended* to include the transverse field (in 2-D so far)

- **Electromagnetic Zakharov equations**
  - here $E = E_L + E_T$ contains both longitudinal and transverse components
    - δN density inhomogeneity
    - δn density fluctuation

$$\left[2i\omega_{\mathrm{pe0}}\left(D_t + \nu_{\mathrm{e}}\right) + 3V_{\mathrm{te}}^2\left(\nabla\nabla\cdot\right) - c^2\left(\nabla\times\nabla\times\right) - \frac{4\pi e^2}{m_{\mathrm{e}}}\left(\delta n + \delta N\right)\right]\vec{E} =$$

$$\frac{e}{4m_{\mathrm{e}}}\underbrace{\left[\nabla\left(\vec{E}_0\cdot\vec{E}^{\,*}\right) - \left(\nabla\cdot\vec{E}^{\,*}\right)\vec{E}_0\right]}_{\text{TPD, stimulated Raman scattering (SRS), and Thomson down-scattering (TDS)}} e^{-i\Delta\omega_{\mathrm{i}}t} + S_E$$

$$\left[D_t^2 + 2\nu_{\mathrm{i}}\circ D_t - c_s^2\nabla^2\right]\delta n = \frac{\nabla^2\left|E\right|^2}{16\pi m_{\mathrm{i}}} + \frac{1}{4}\,\frac{\nabla^2\left|E_0\right|^2}{16\pi m_{\mathrm{i}}}$$

EMZAK is able to simulate the three competing half-harmonic–generation mechanisms

$(\delta N\vec{E}_\mathrm{L})_\mathrm{T}$: linear-mode conversion (inverse resonance absorption);

$\omega_\mathrm{T} = \omega_\mathrm{L}$

$(k_\mathrm{T})_\perp = (k_\mathrm{L})_\perp$

$(\delta n\vec{E}_\mathrm{L})_\mathrm{T}$: nonlinear-mode conversion;

$\omega_\mathrm{T} \approx \omega_\mathrm{L}$

$k_\mathrm{T} = k_\mathrm{IAW} + k_\mathrm{L}$

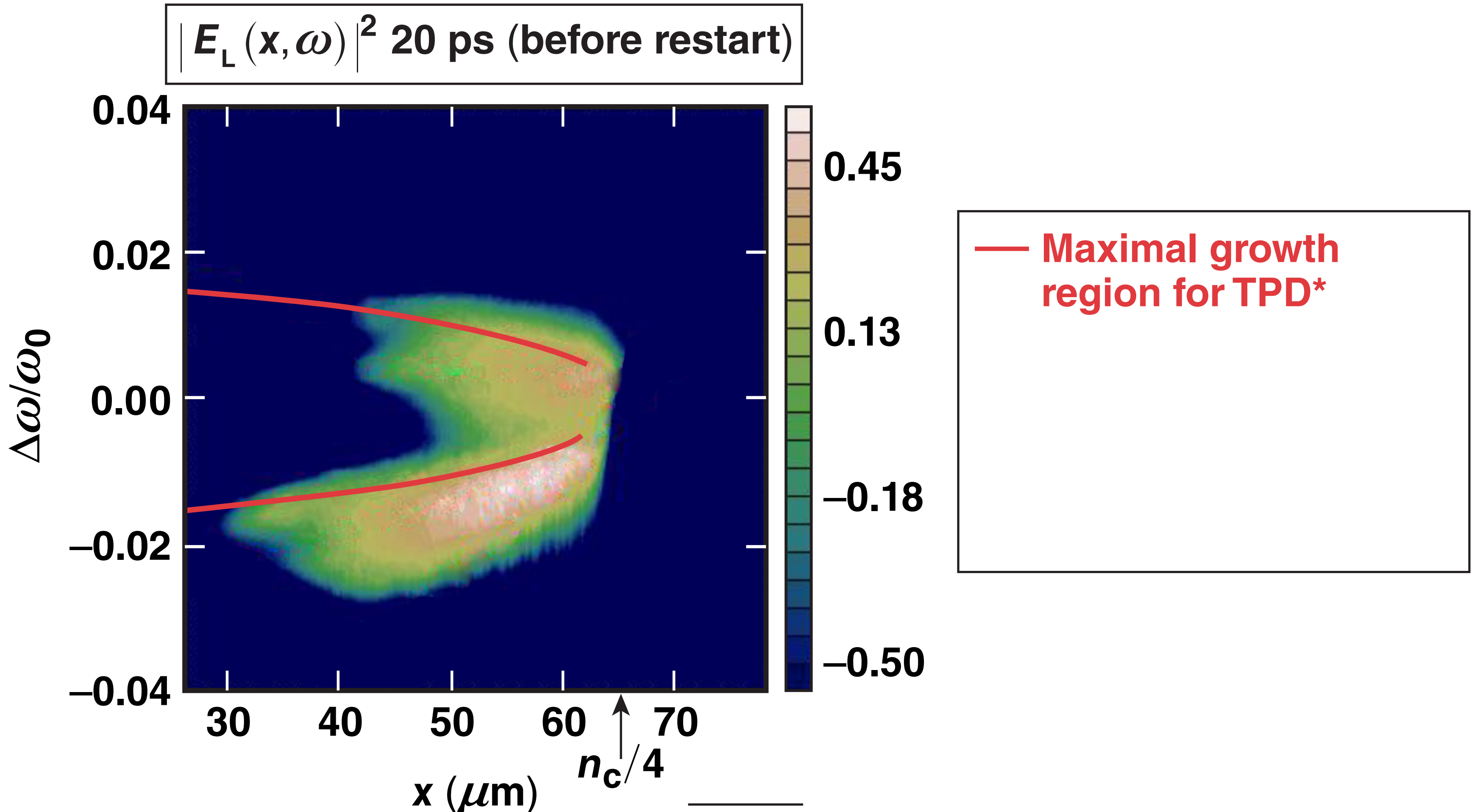
$\left[(\nabla \cdot \vec{E}^*)\vec{E}_0\right]_\mathrm{T}$: Thomson down-scattering;

$\omega_\mathrm{T} = \omega_0 - \omega_\mathrm{L}$

$k_\mathrm{T} = k_0 - k_\mathrm{L}$

The simulation is first run without coupling to transverse fields to obtain the saturation stage of TPD

$$|E_L(x,\omega)|^2 = \left(\int \left| \int E_L(x,y) e^{i\omega t} dt \right| dy\right)^2 ; \Delta\omega = \omega - \omega_0/2$$



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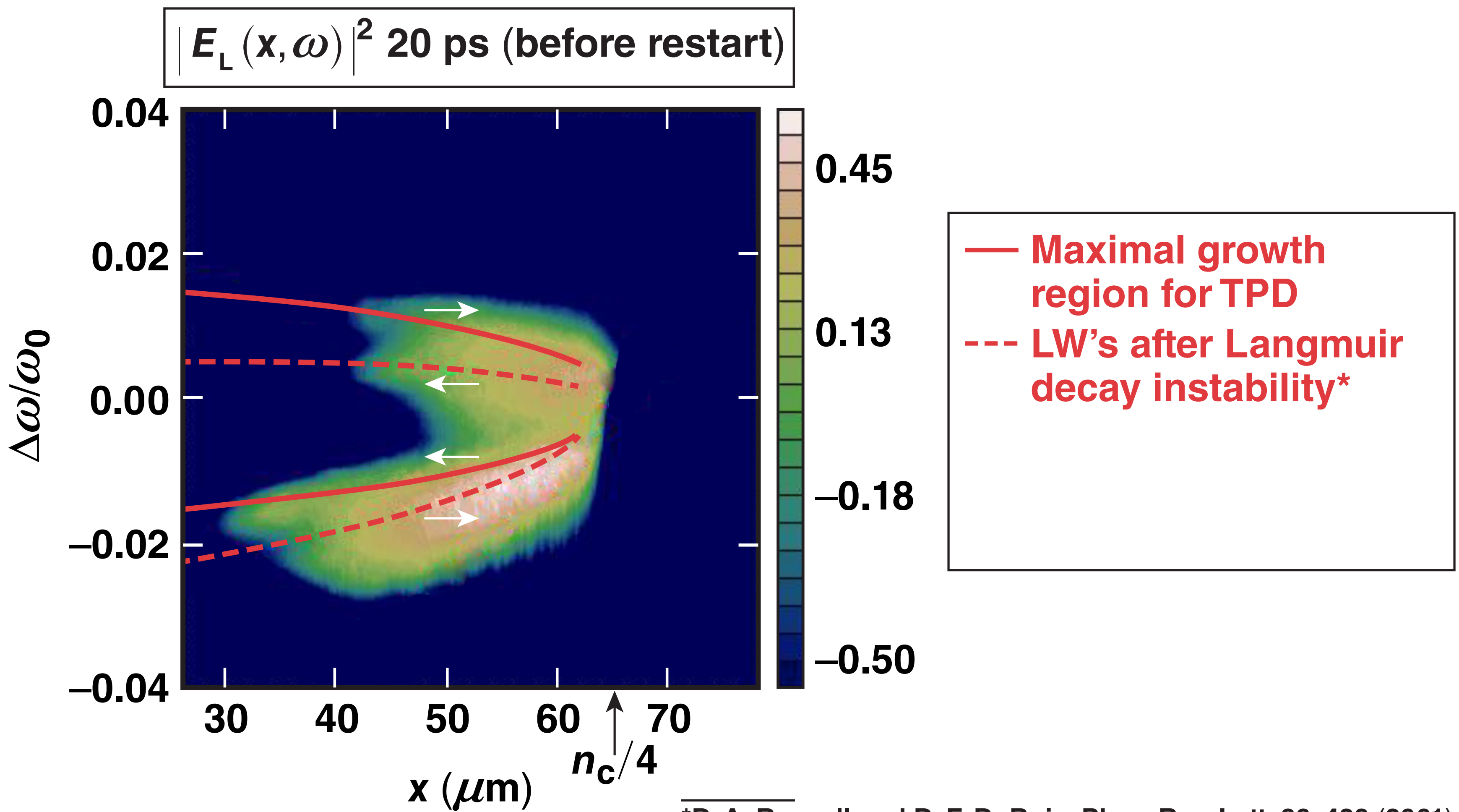
*D. A. Russell and D. F. DuBois, Phys. Rev. Lett. 86, 428 (2001).

The wave spectrum shows strong signatures of the Langmuir wave decay instability

$$\left|E_L(x,\omega)\right|^2 = \left(\int\left|\int E_L(x,y)e^{i\omega t}\,dt\right|dy\right)^2; \Delta\omega = \omega - \omega_0/2$$



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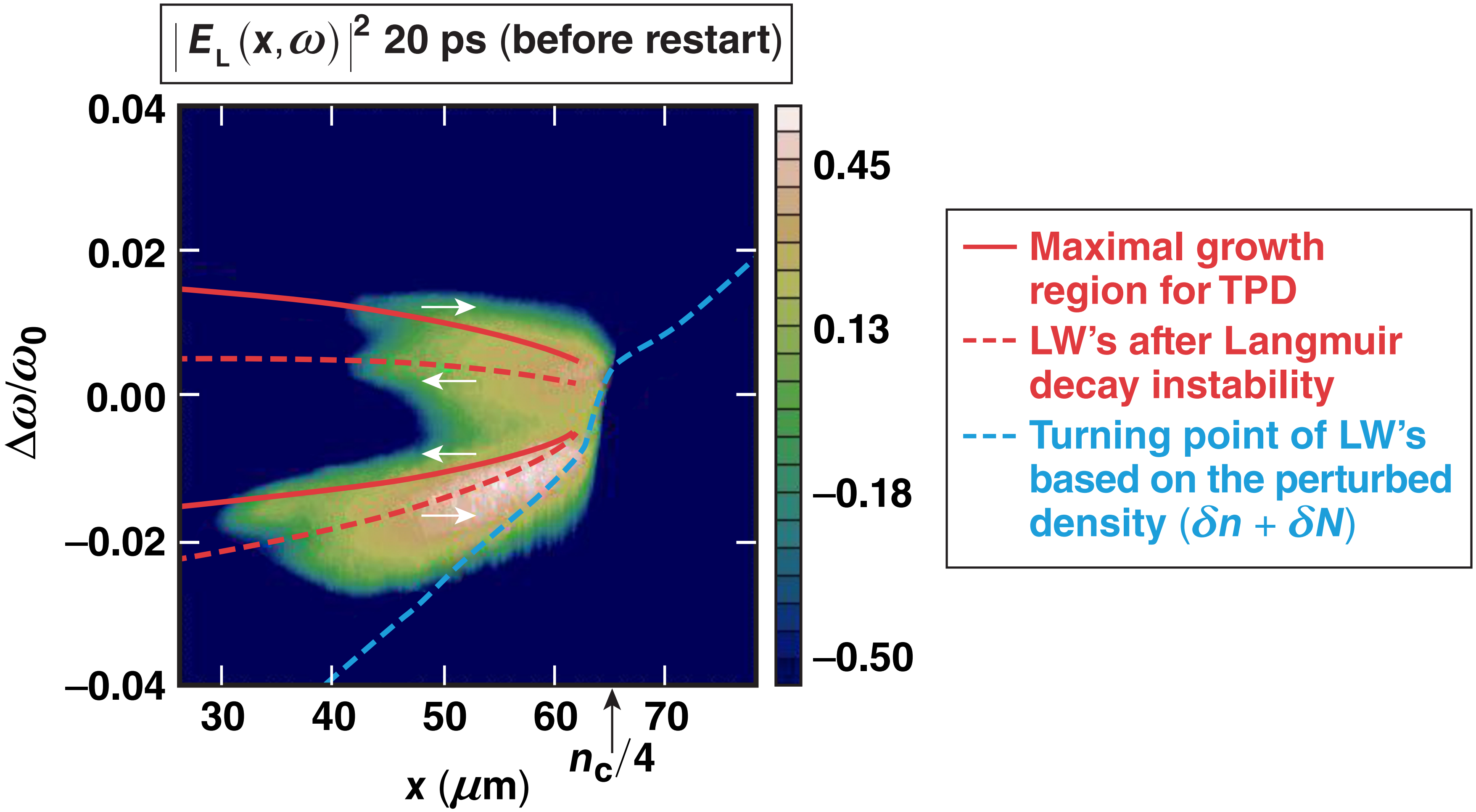
The frequency spectrum of LW's at their turning points can be determined

$$\left|E_L(x,\omega)\right|^2 = \left(\int \left| \int E_L(x,y) e^{i\omega t} dt \right| dy\right)^2; \Delta\omega = \omega - \omega_0/2$$



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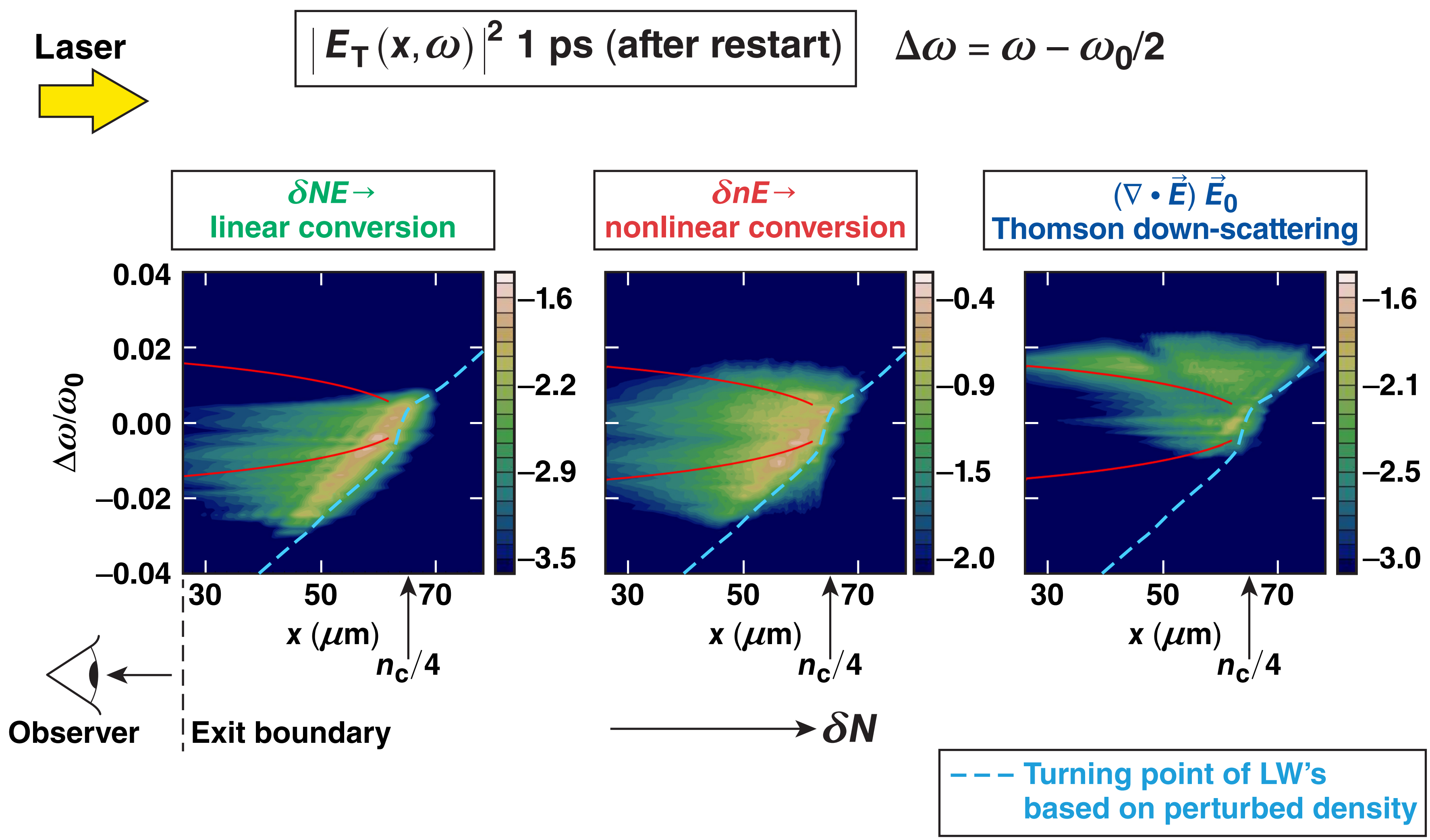
The simulation is restarted with coupling to the half-harmonic emission enabled



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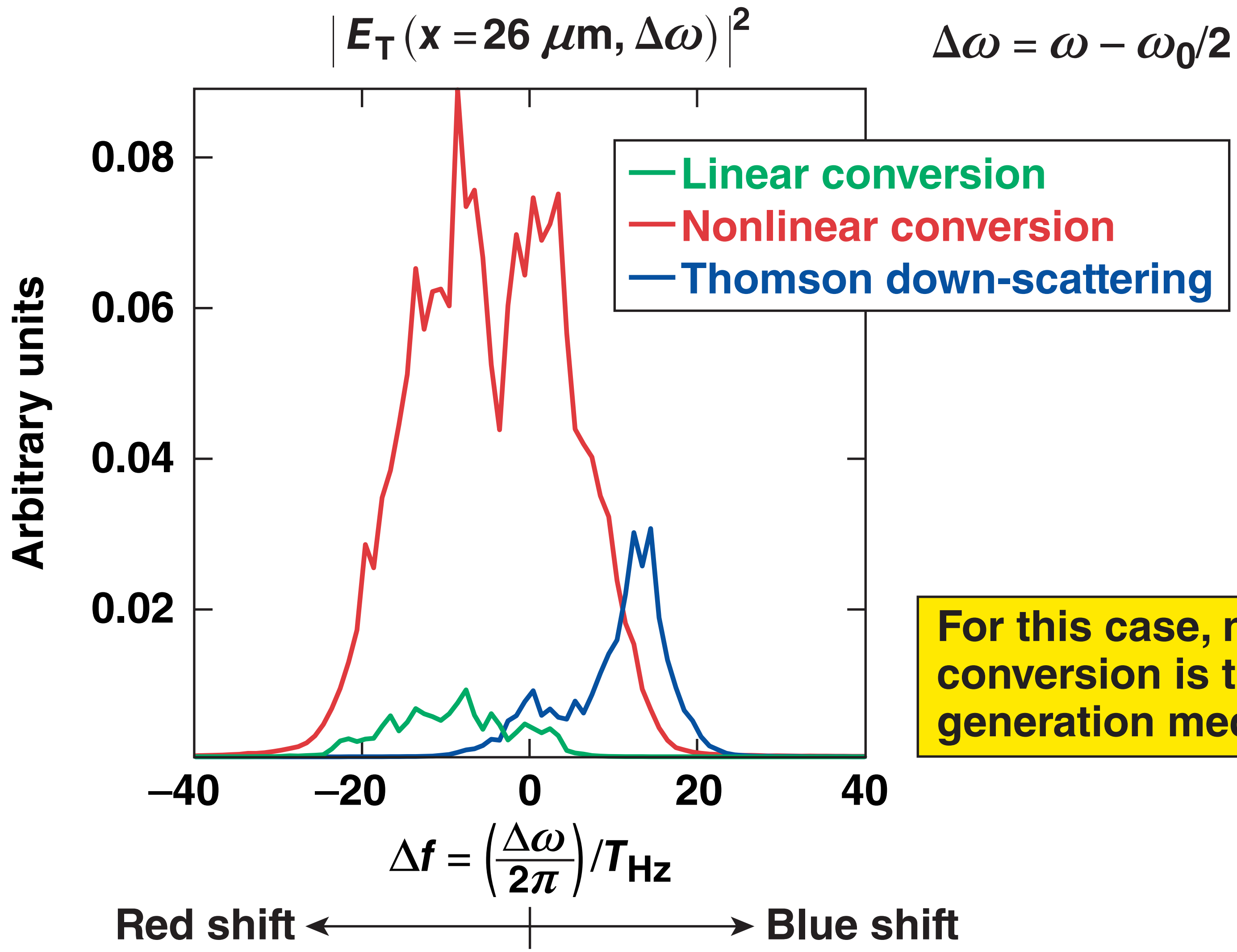
The half-harmonic emission is collected at the left (exit) boundary



For this case, nonlinear conversion is the dominant generation mechanism.

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More conclusions can be inferred through manipulating some parameters

- Incorporating all three sources in a single run, half-harmonic emission is the sum of the three shown in the previous slide, indicating that the three sources act independently
- In another set of simulations with smaller collisional damping, the level of half-harmonic emission is higher; the reason is that more LW's are able to propagate to the turning point and convert to half-harmonic light

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