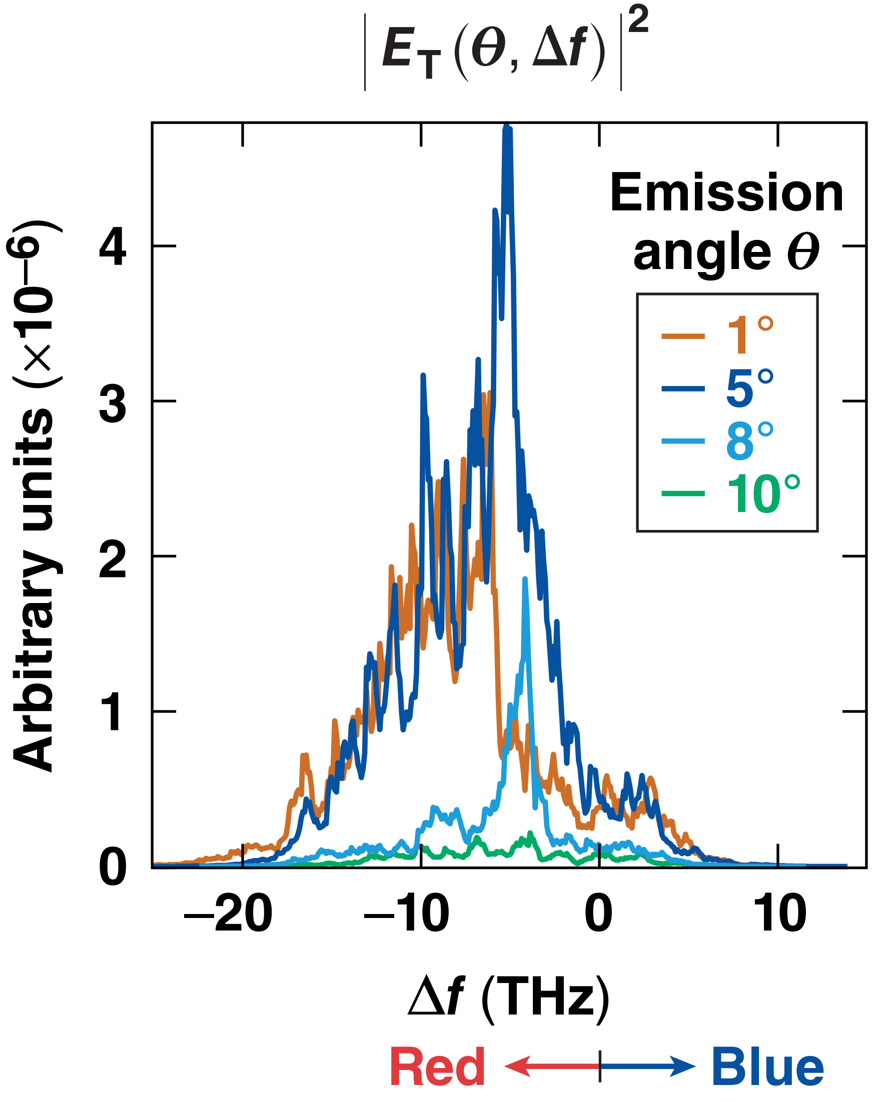
Self-Consistent Calculation of Half-Harmonic Emission Generated by the Two-Plasmon–Decay Instability



$\omega_0/2$ emission generated by linear mode conversion of two-plasmon–decay plasma waves

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Summary

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

- Half-harmonic emission is an important experimental observable of TPD*
- Reduced and driven Zakharov equations** are expanded to include transverse fields
- For small scattering angles, linear and nonlinear conversion dominates at the red shift; for large scattering angles, nonlinear conversion and Thomson down-scattering (TDS) dominates at the blue shift

*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. Russel 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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EMZAK is used to simulate three competing half-harmonic–generation mechanisms driven by TPD

- Electromagnetic (EM) Zakharov equations† in 2-D
  - here $E = E_L + E_T$ contains both longitudinal and transverse components
    - δN static density inhomogeneity
    - δn evolving density fluctuation

$$\left[2i\omega_{pe_0}\left(D_t + \nu_e \circ\right) + 3V_{te}^2\left(\nabla\nabla\cdot\right) - c^2\,\nabla\times\nabla\times - \frac{4\pi e^2}{m_e}\left(\delta n + \delta N\right)\right]\vec{E} =$$

$$\frac{e}{4m_e}\underbrace{\left[\nabla\left(\vec{E}_0\cdot\vec{E}^*\right) - \left(\nabla\cdot\vec{E}^*\right)\vec{E}_0\right]}_{\text{TPD (longitudinal part), TDS (transverse part)}} e^{-i\Delta\omega_i t} + S_E$$

Linear-mode conversion (δN)

Nonlinear-mode conversion (δn)

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

†D. F. DuBois, D. A. Russell, and H. A. Rose, Phys. Rev. Lett. 74, 3983 (1995);
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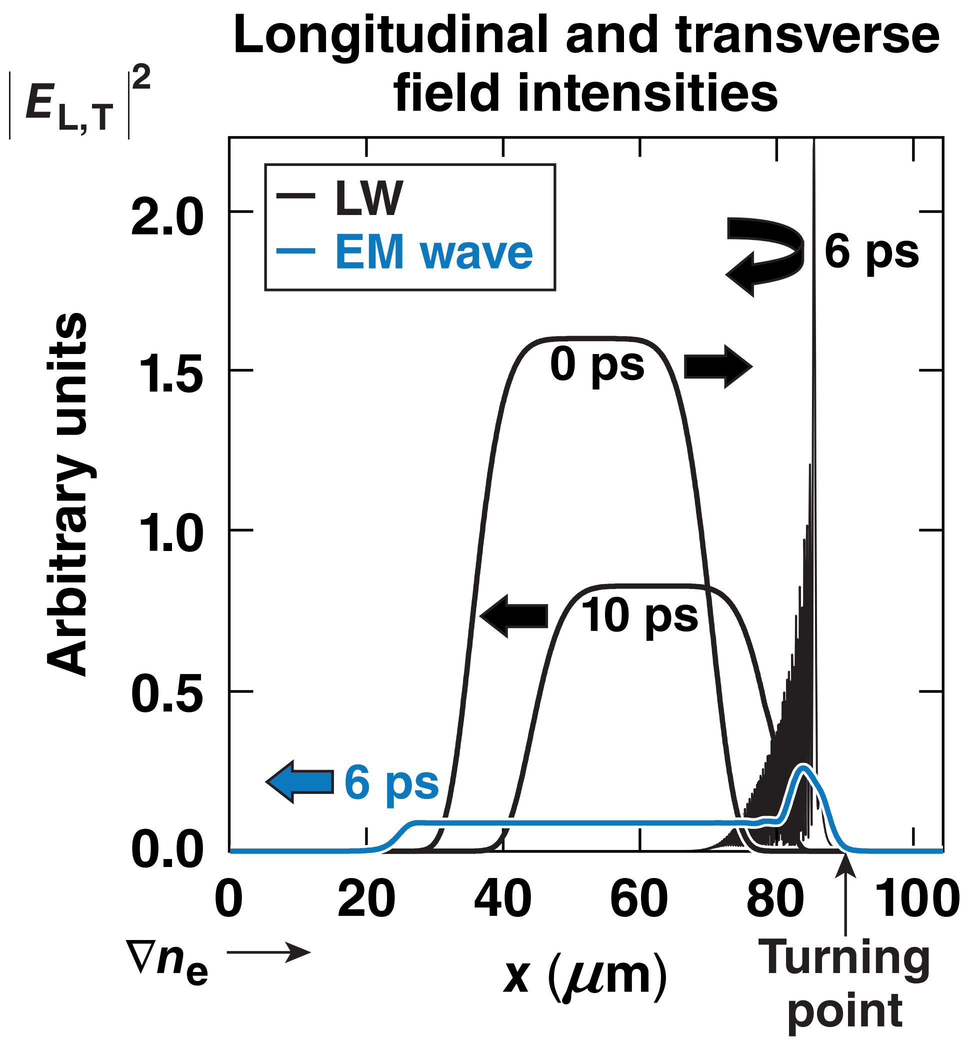
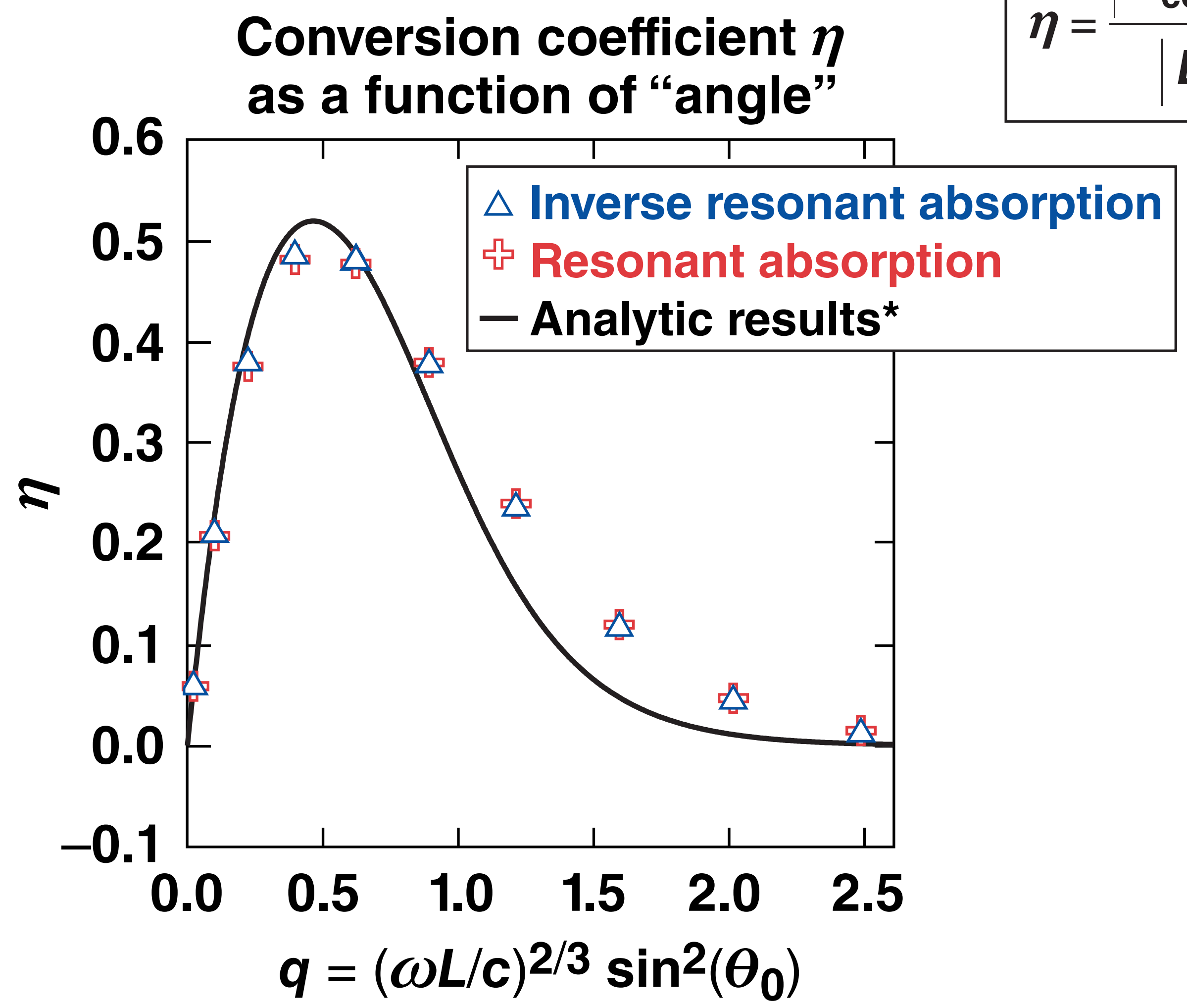
Linear-mode conversion is the inverse of the more-familiar resonant absorption

- Mode conversion is illustrated from a plane incident Langmuir wave (LW)

$$\eta = \frac{|E_{\text{converted}}|^2}{|E_{\text{total}}|^2}$$





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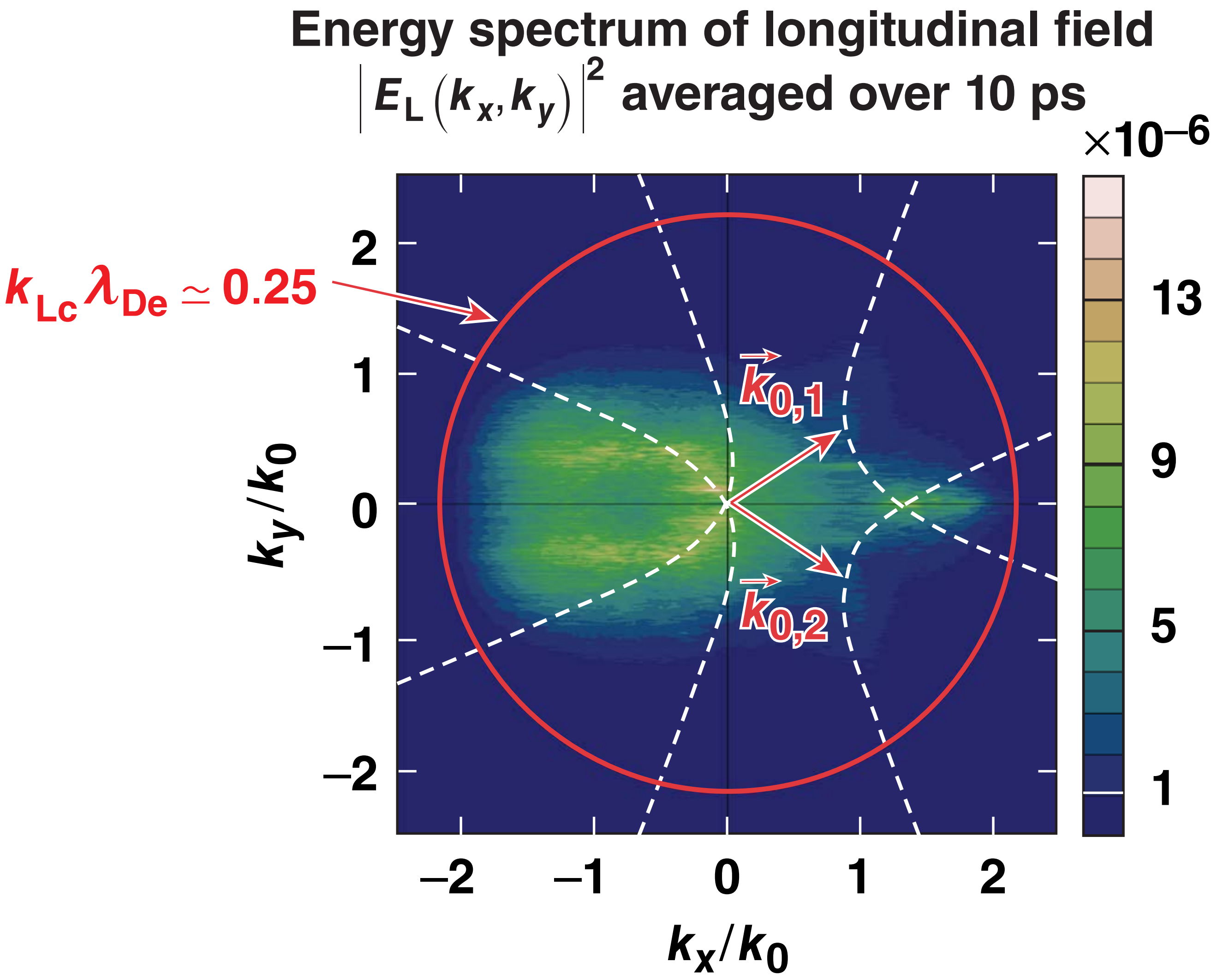
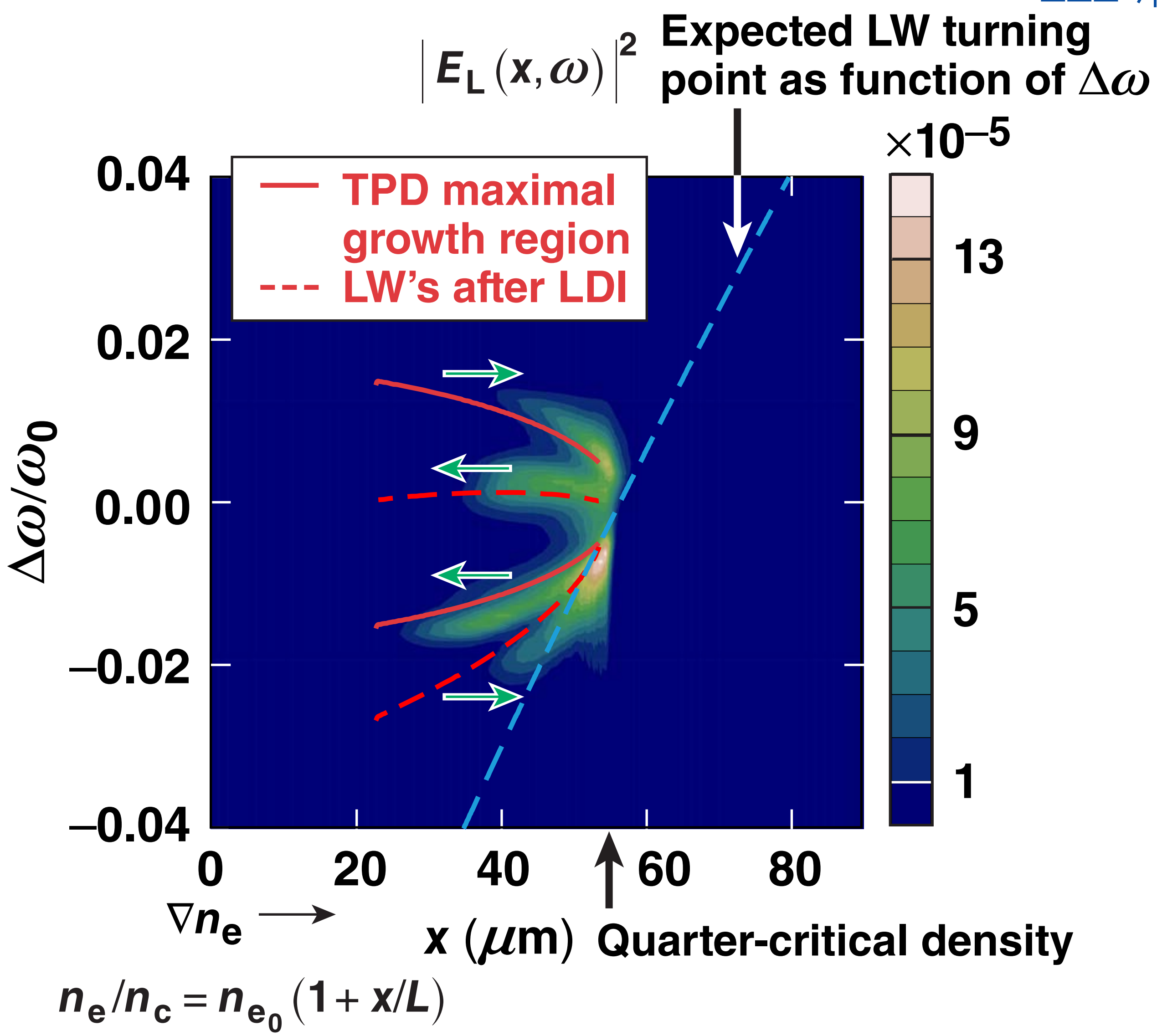
*D. E. Hinkel-Lipsker, B. D. Fried, and G. J. Morales, Phys. Fluids B 4, 559 (1992).

When TPD is the source of Langmuir waves, Langmuir-decay instability (LDI) and density-profile modification create more possibilities for half-harmonic emission generation





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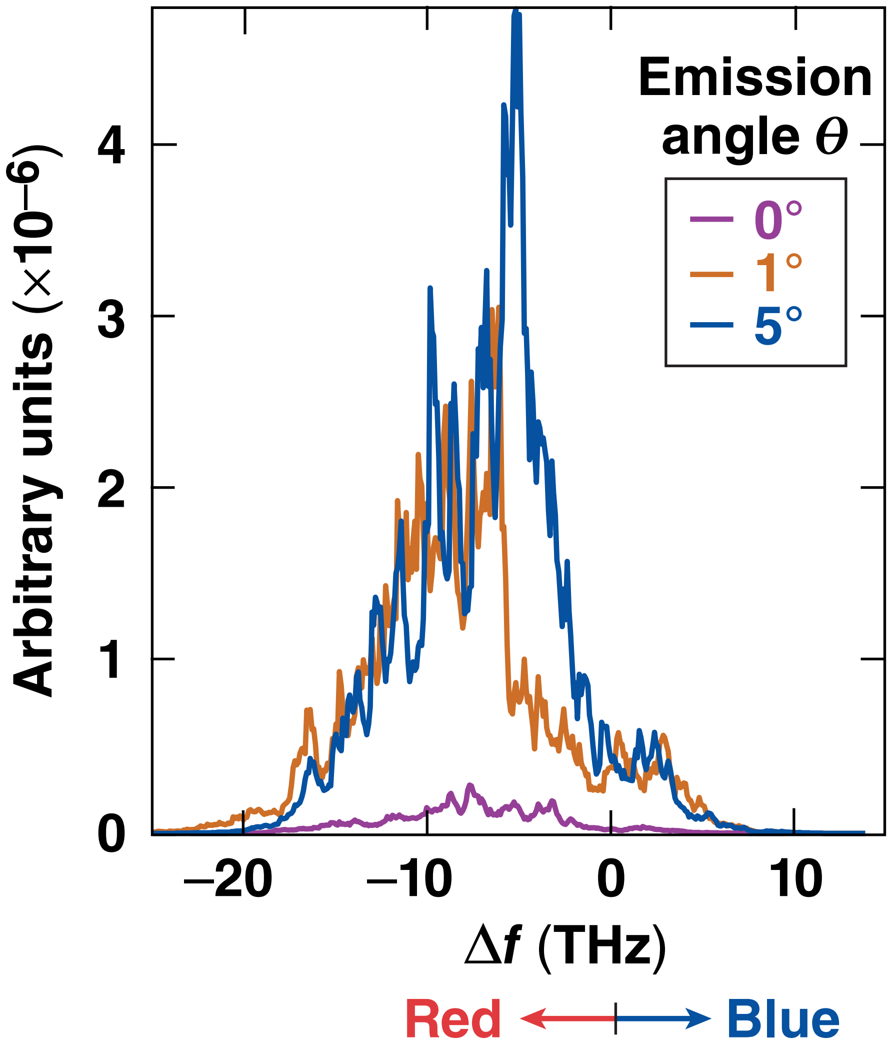
Linear-mode conversion has a strong dependence on emission angle

$$\left| E_T\left(x = 26\ \mu m, \theta, \Delta f\right)\right|^2$$



- $\left| E_T \right|^2$ is the square of the absolute value of the scattered EM wave

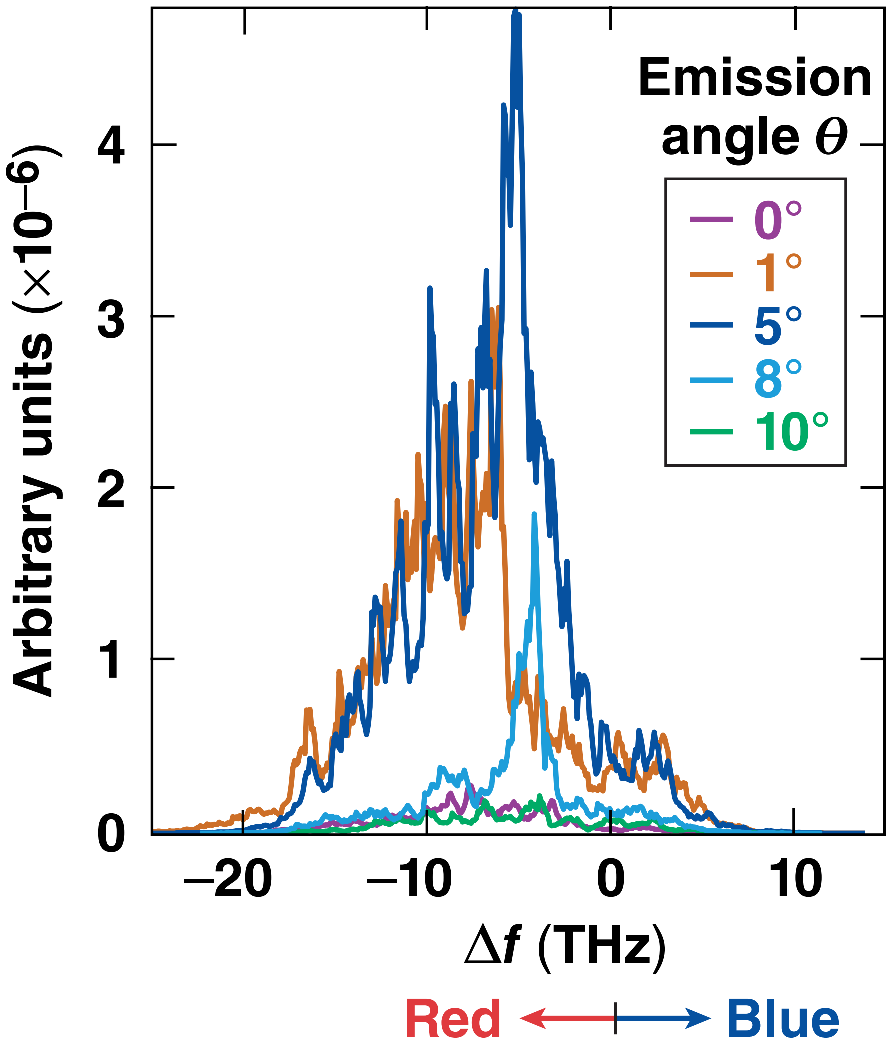
$$\Delta f = \Delta\omega / 2\pi$$

$$\Delta\omega = \omega - \omega_0 / 2\pi$$

TC12540

Linear-mode conversion has a strong dependence on emission angle

$\left| E_T(x = 26\ \mu m, \theta, \Delta f) \right|^2$



- $\left| E_T \right|^2$ is the square of the absolute value of the scattered EM wave

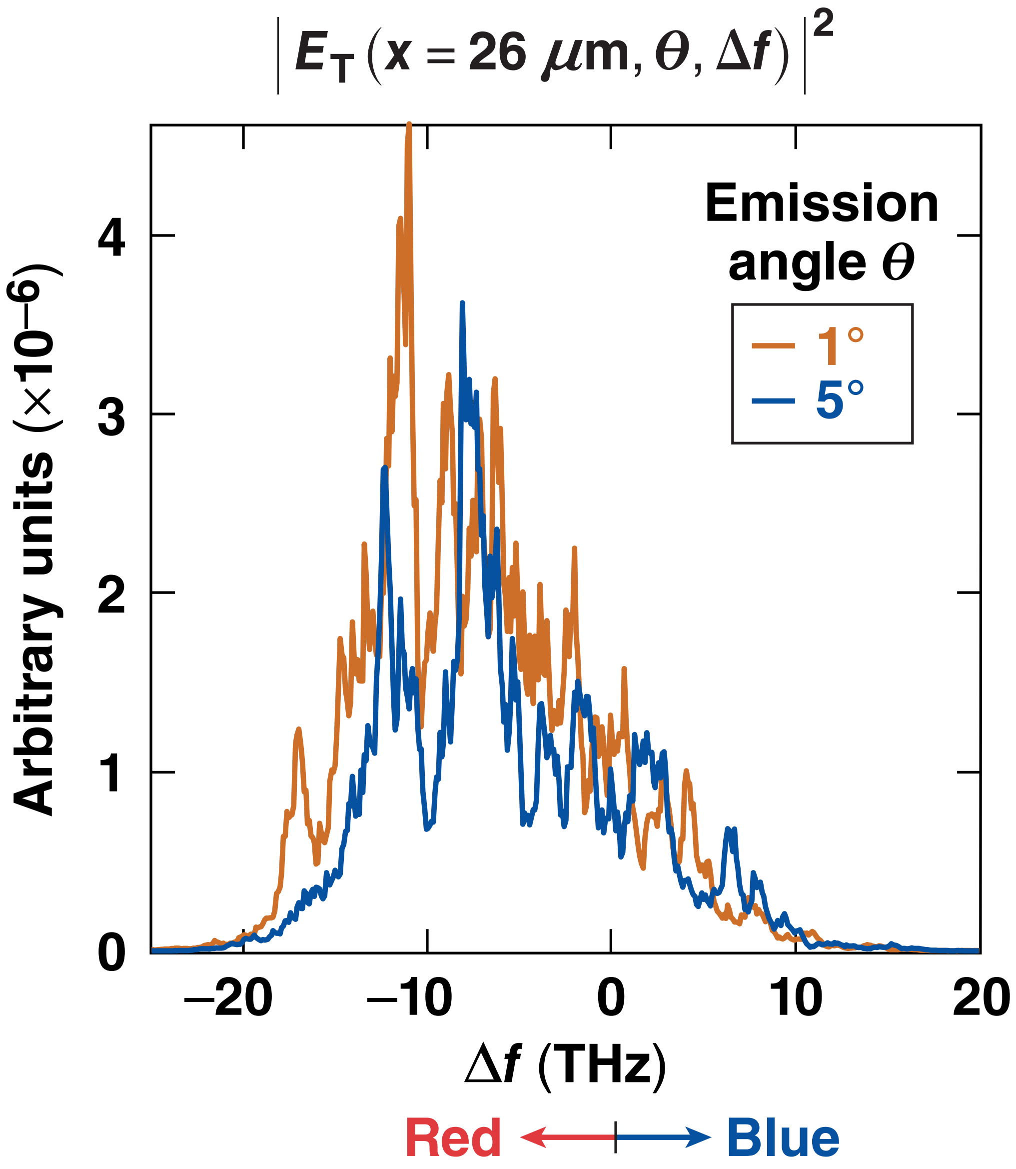
$$\Delta f = \Delta\omega / 2\pi$$

$$\Delta\omega = \omega - \omega_0 / 2\pi$$

Peak emission occurs at $\theta \lesssim 5°$ and is red shifted by ~10 THz; there is very little emission for $\theta \gtrsim 8°$

TC12540a

The nonlinear conversion happened mainly near the turning point of the Langmuir wave

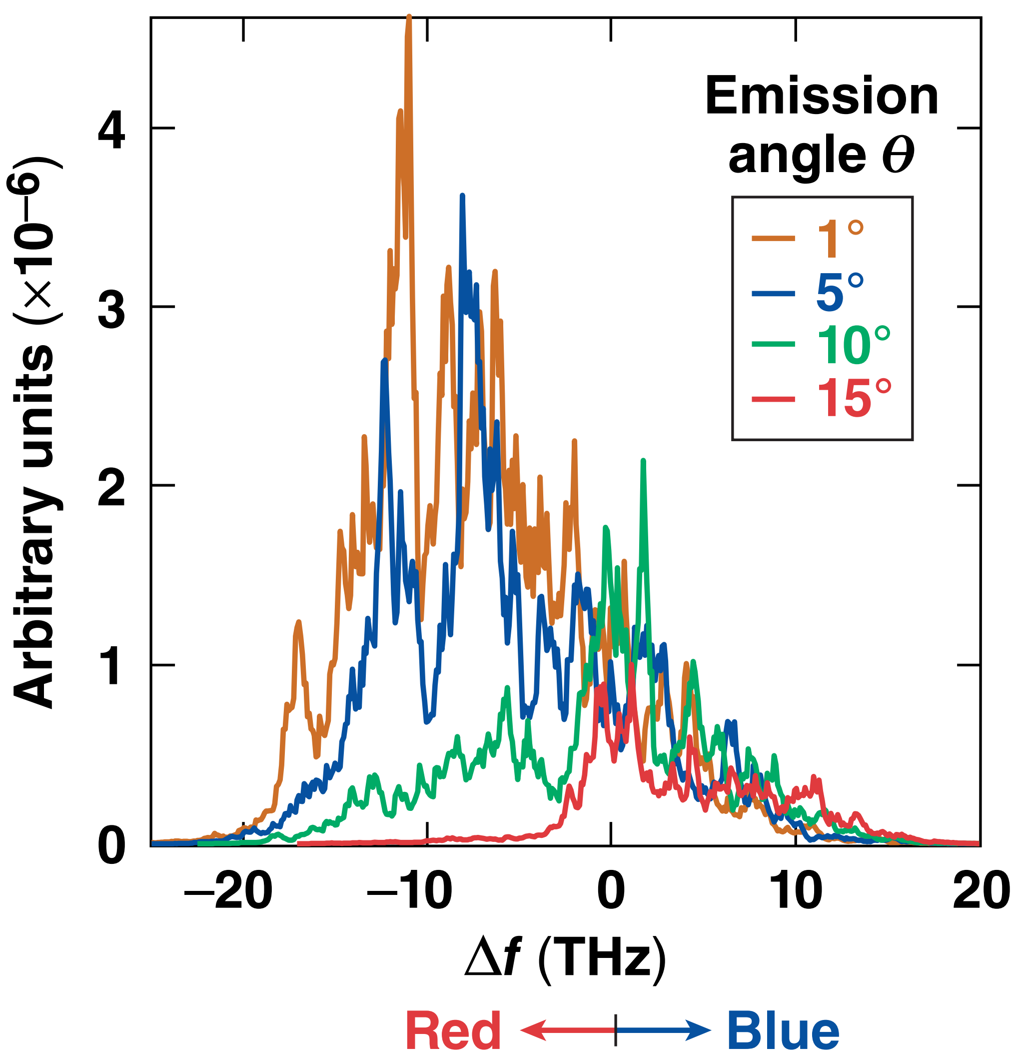


- Similar amplitude to linear-mode conversion

TC12541

The nonlinear conversion happened mainly near the turning point of the Langmuir wave

$\left| E_T\left(x = 26\ \mu\text{m}, \theta, \Delta f\right)\right|^2$



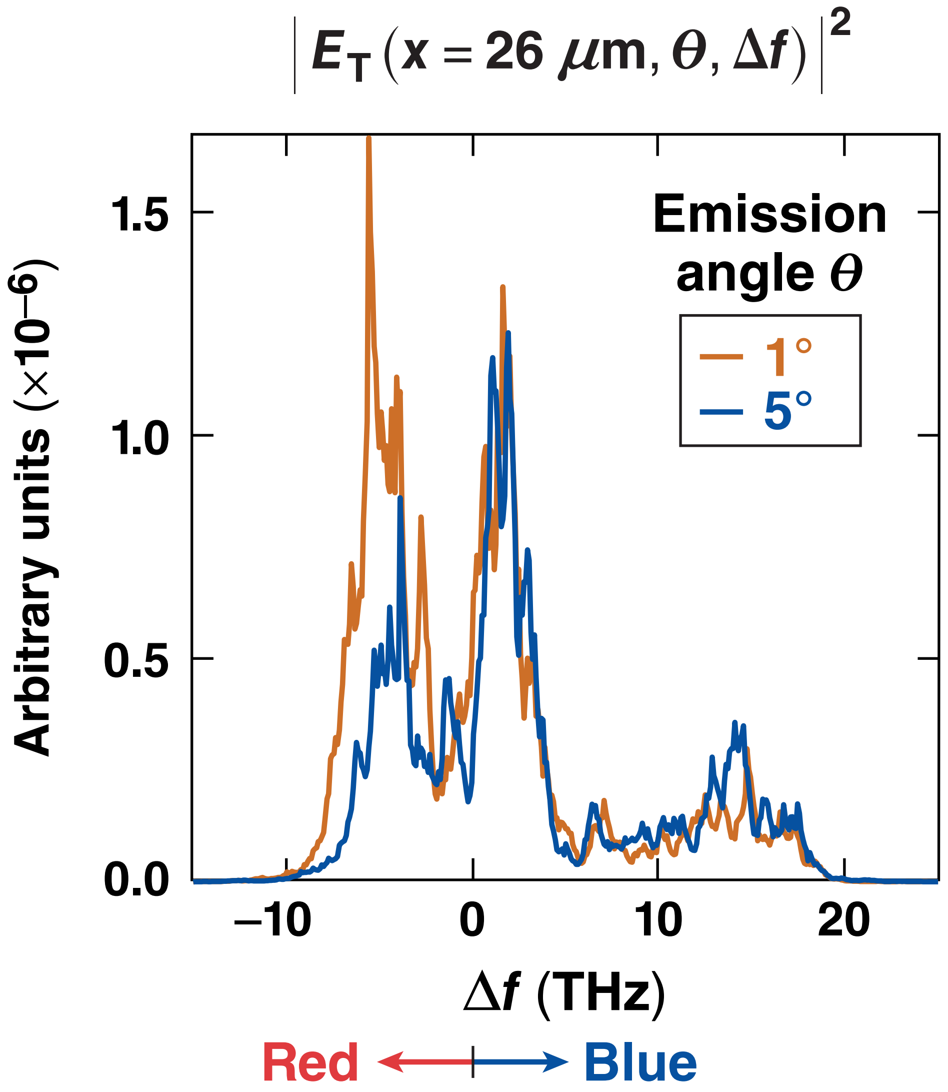
- Similar amplitude to linear-mode conversion

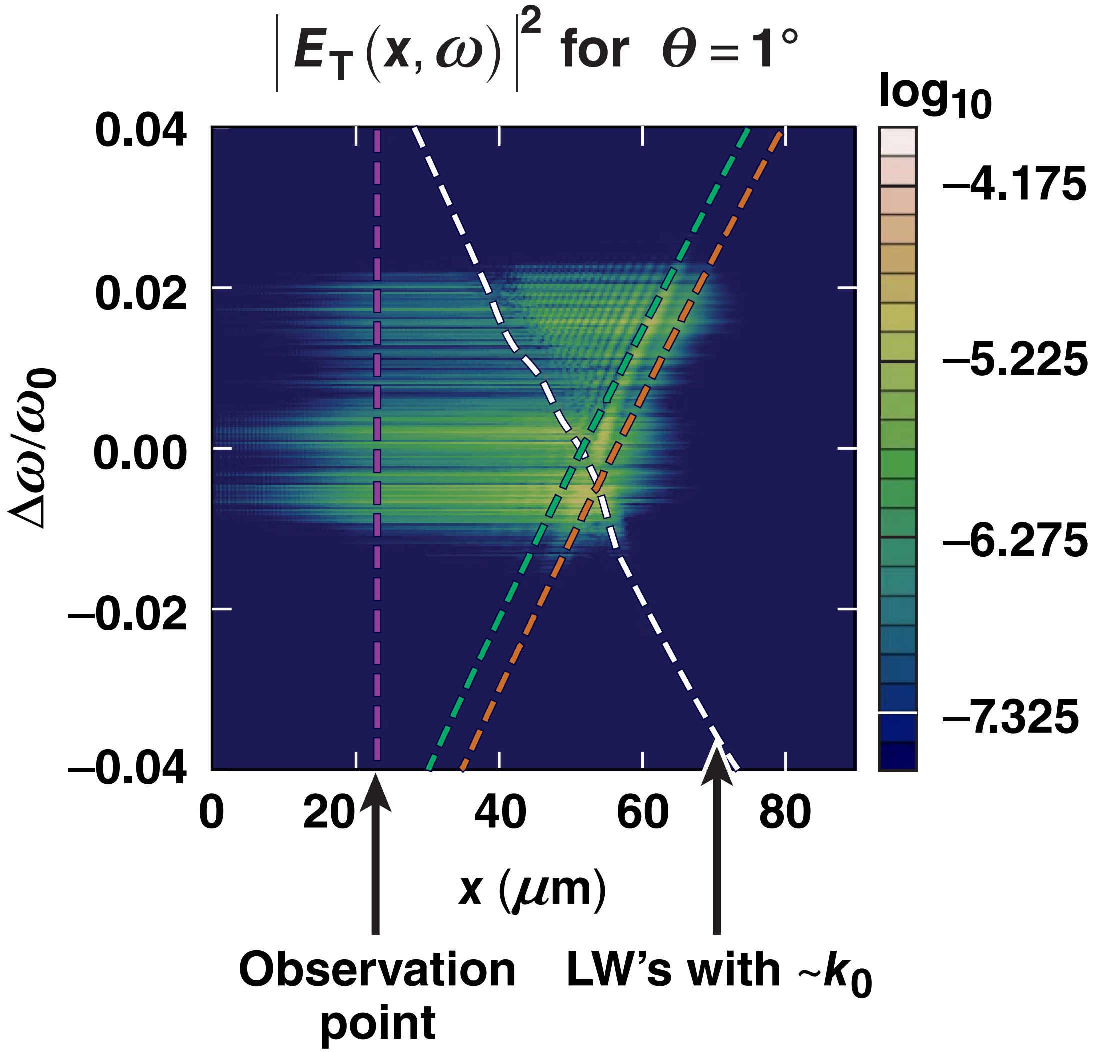
Peak emission occurs again for small angle $\theta \lesssim 5°$; a significant blue component persists for $\theta \gtrsim 10°$.

- We speculate that this is associated with the TPD common wave interacting with ion-acoustic wave (IAW) turbulence

TC12541a

Only plasmons with a similar *k* vector to that of the laser are able to generate half-harmonic emission through Thomson down-scattering





For $\theta \gtrsim 10°$, all emissions are blue shifted.

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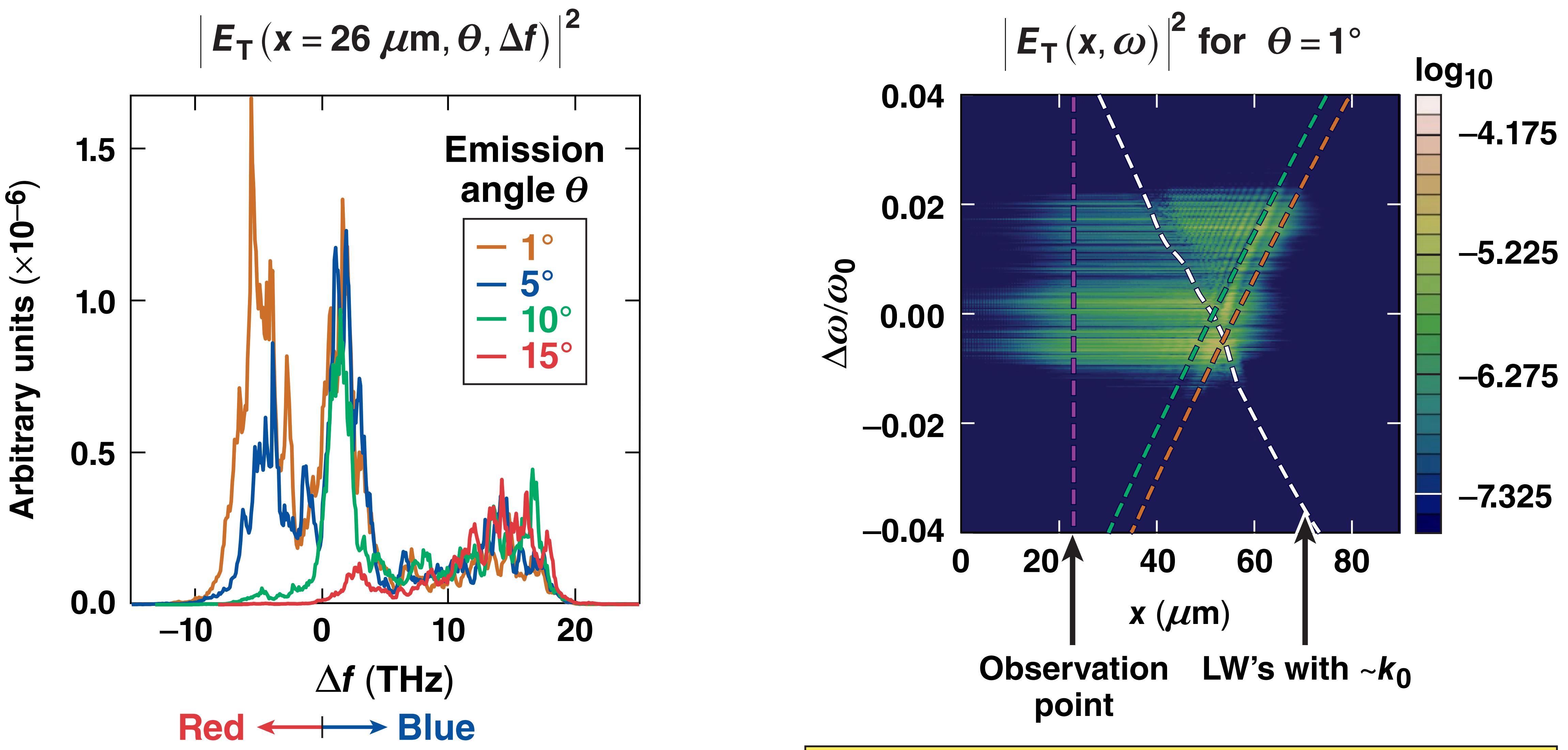
Only plasmons with a similar *k* vector to that of the laser are able to generate half-harmonic emission through Thomson down-scattering



For $\theta \gtrsim 10°$, all emissions are blue shifted.

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Summary Conclusions

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