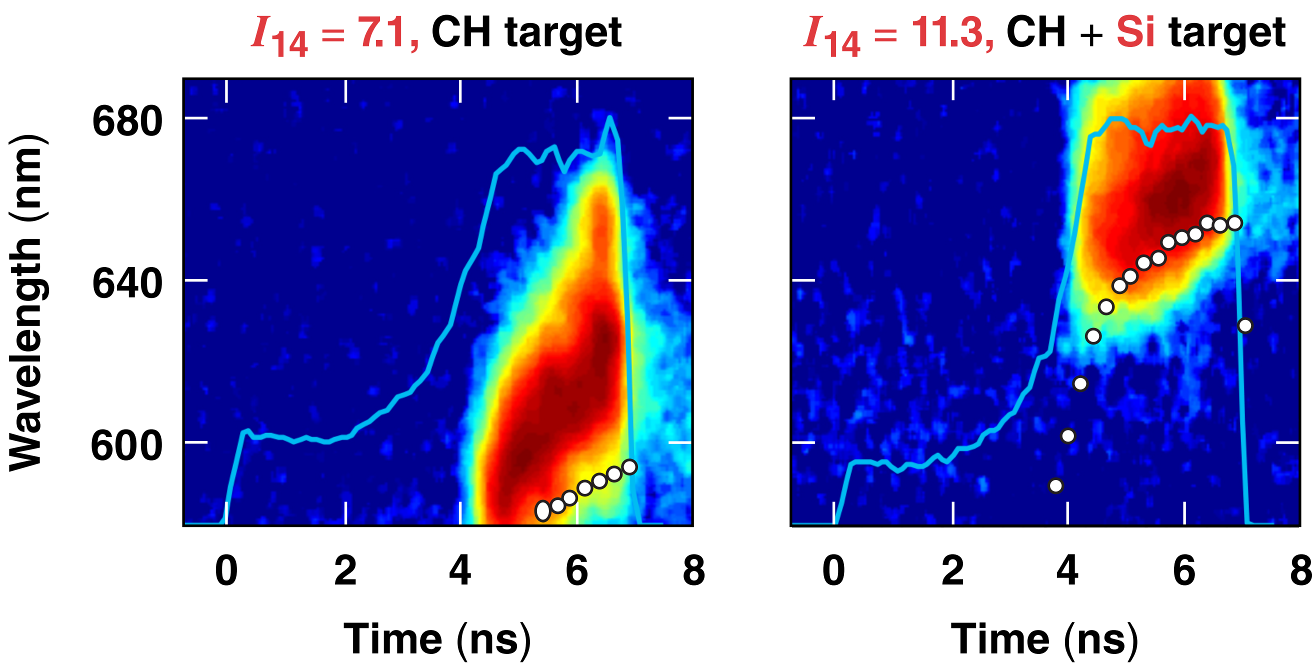
Kinetic Analysis of Convective Stimulated Raman Scattering and its Potential as a Temperature Diagnostic



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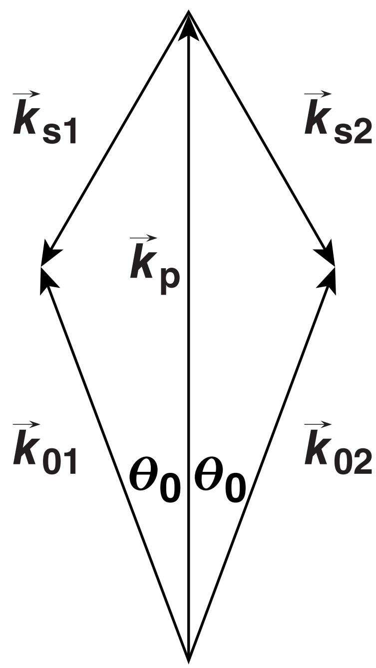
Summary

Stimulated Raman Scattering (SRS) spectra show promise as a plasma temperature diagnostic

- The "Landau cutoff" has long been used as a temperature diagnostic, but is somewhat ambiguous (should it be $k\lambda_D$ = 0.2? 0.25? 0.3?)
- Recent advances in obtaining detailed time-resolved SRS spectra make it desirable to employ a more-detailed kinetic model of these spectra
- The peak of the SRS gain curve and the peak of the observed SRS spectra are more easily identified than the "cutoff"
- Preliminary results show good agreement between temperatures obtained from the peak of the observed spectrum and the peak of the gain curve
- The gain does not show a well-defined peak above ~4 keV; a more-detailed analysis of the shape of the gain curve may provide a diagnostic of temperatures in this range

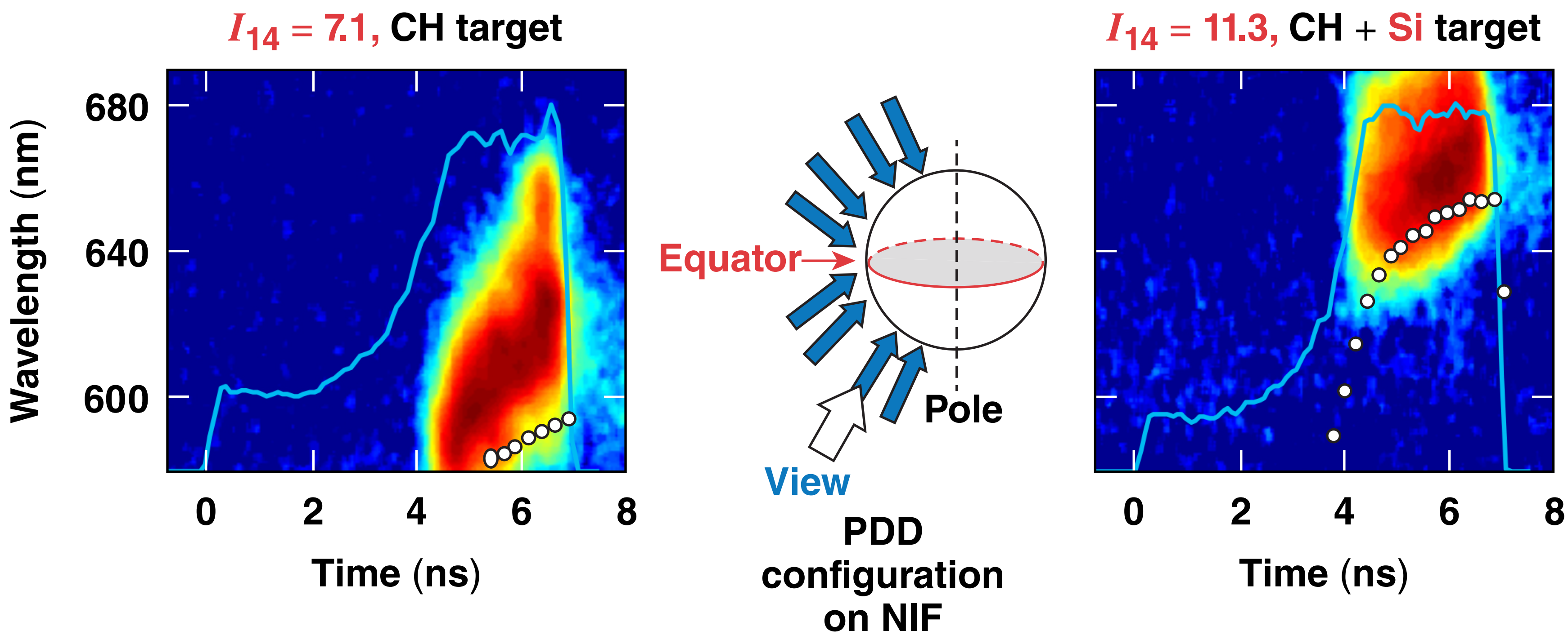
Multiple pump beams can drive a common plasma wave in convective SRS



- **All pump polarizations contribute for a common plasma wave: the polarization of each $\vec{k}_{sj}$ matches that of the corresponding $\vec{k}_{0j}$**
- **In 3-D, the common wave will be the centroid of a cone**

TC12808

SRS is used as a coronal T_e diagnostic for polar-direct-drive (PDD) implosions at the National Ignition Facility (NIF)



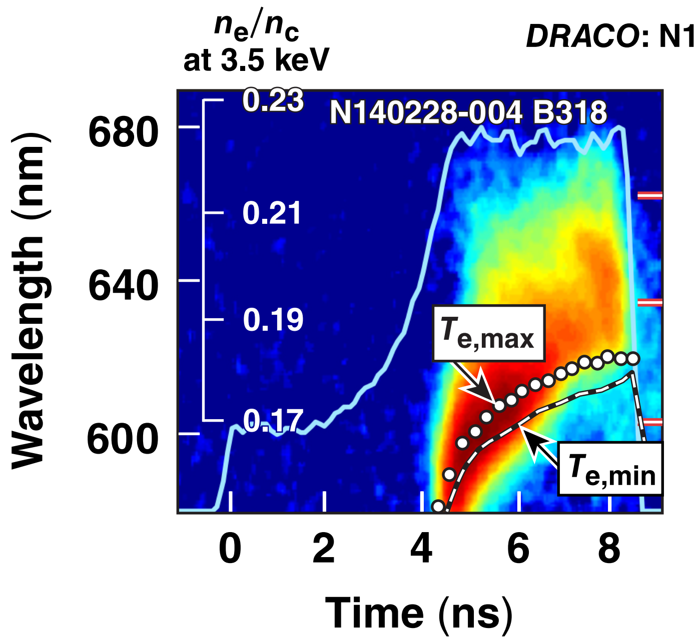
Temperatures are estimated by identifying the lower boundary of the spectrum with the Landau cutoff.

TC12809

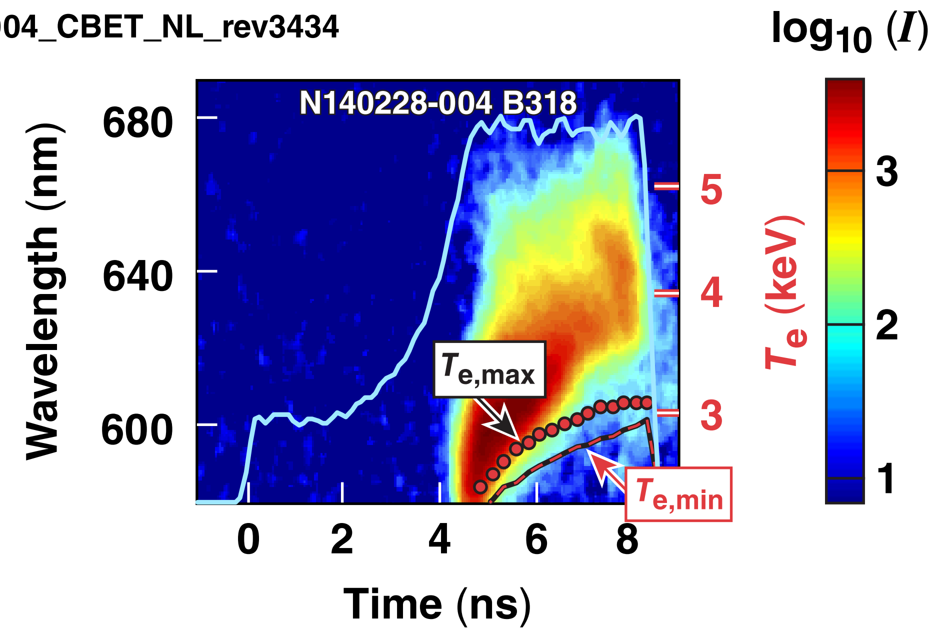
The Landau cutoff interpretation of the lower SRS wavelength limit varies with assumed sidescatter angle

NIF PDD shot N140228-004, I_{14} = 7.8, CH target

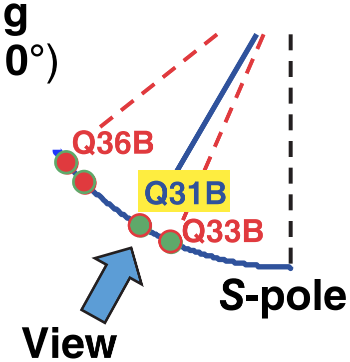
DRACO: N140228-004_CBET_NL_rev3434



Landau cutoff assuming backscattering only ($\theta = 0°$)



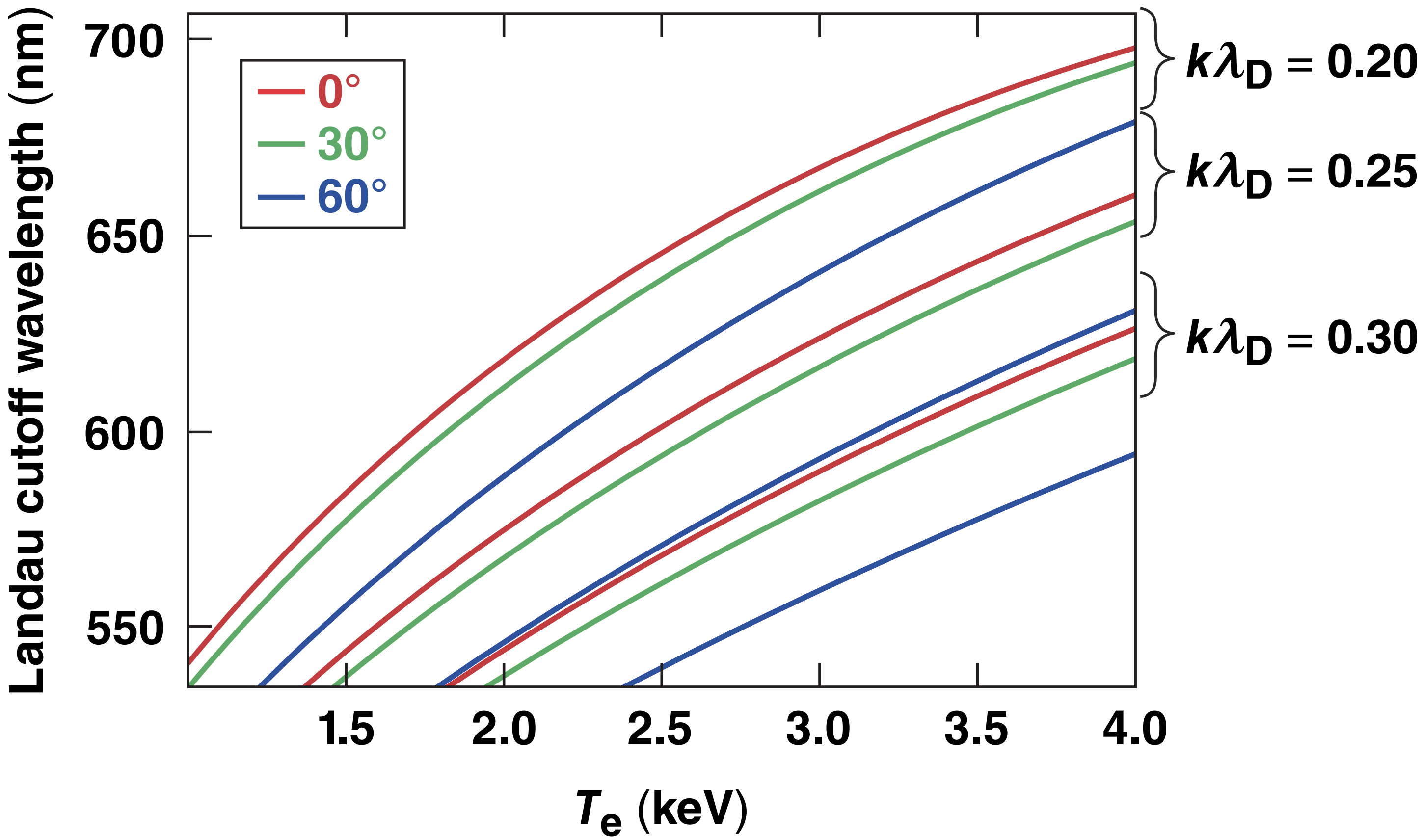
Landau cutoff assuming 50° sidescattering only



1-D *DRACO* simulations predict T_e to vary over a PDD target by ~10%

E24677a

The temperature inferred from the Landau cutoff is sensitive to the assumed maximum of $k\lambda_D$



TC12810

The SRS gain curve may provide a more-accurate estimate of temperature than the Landau cutoff

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- While the "cutoff" provides a rough estimate of temperature, it is vaguely defined, both theoretically and observationally; a more-precise diagnostic is desirable
- In 1984, W. Seka *et al.*,* attempted to use kinetic calculations of SRS gains as a temperature diagnostic; results were mixed, probably because of filamentation
- Currently, filamentation is suppressed by smoothing by spectral dispersion (SSD), and improved spectral resolution is available
- The maximum of the observed spectrum and the maximum of the gain curve are more readily identified and may provide a more-reliable temperature diagnostic

TC12811

*W. Seka *et al.*, Phys. Fluids 27, 2181 (1984).

The gain is calculated using a three-wave model of SRS combined with a kinetic electron susceptibility

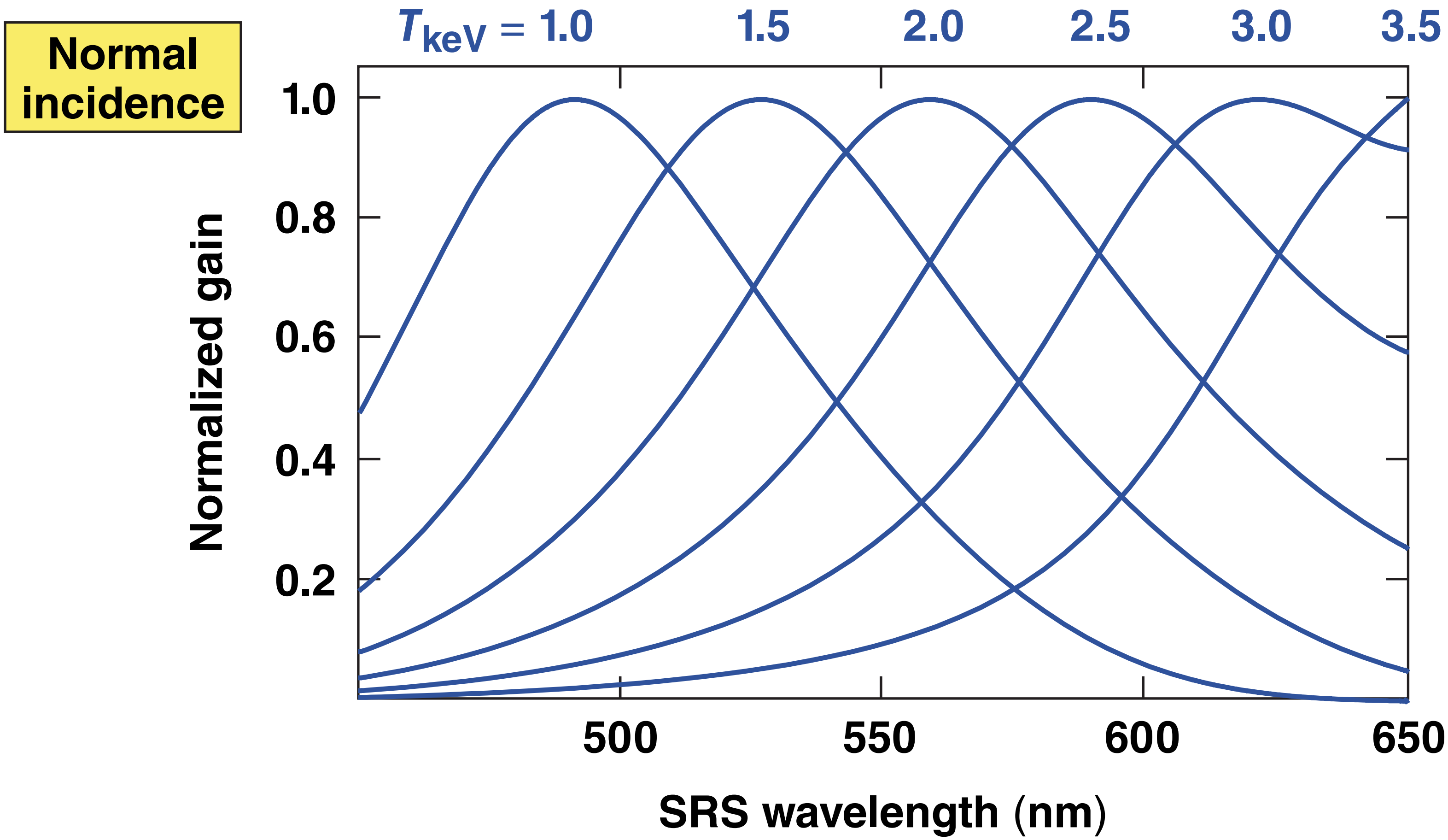
- This approach was first used by W. Seka *et al.*,* for backscatter; here it is generalized to allow for sidescatter
- The SRS gain is given by $G_{SRS} = \int \left(\frac{v_0}{c}\right)^2 \left(\frac{k_p^2}{k_s}\right) \mathrm{Im}\left[\frac{1}{1-\chi_e(k_p,\omega_p)}\right] dx'$

  with $\chi_e(k_p,\omega_p) = -\frac{\omega_{pe}^2}{2k_p^2 v_T^2} Z'\left(\frac{\omega_p}{\sqrt{2}\,k_p v_T}\right)$
- The gain is limited at long wavelengths by smaller resonance lengths and higher absorption and at short wavelengths by Landau damping
- This results in a single-peaked gain curve for SRS as a function of scattered wavelength
- Direct-drive SRS levels are low; linear theory suffices for spectral modeling

TC12812

*W. Seka *et al.*, Phys. Fluids 27, 2181 (1984).

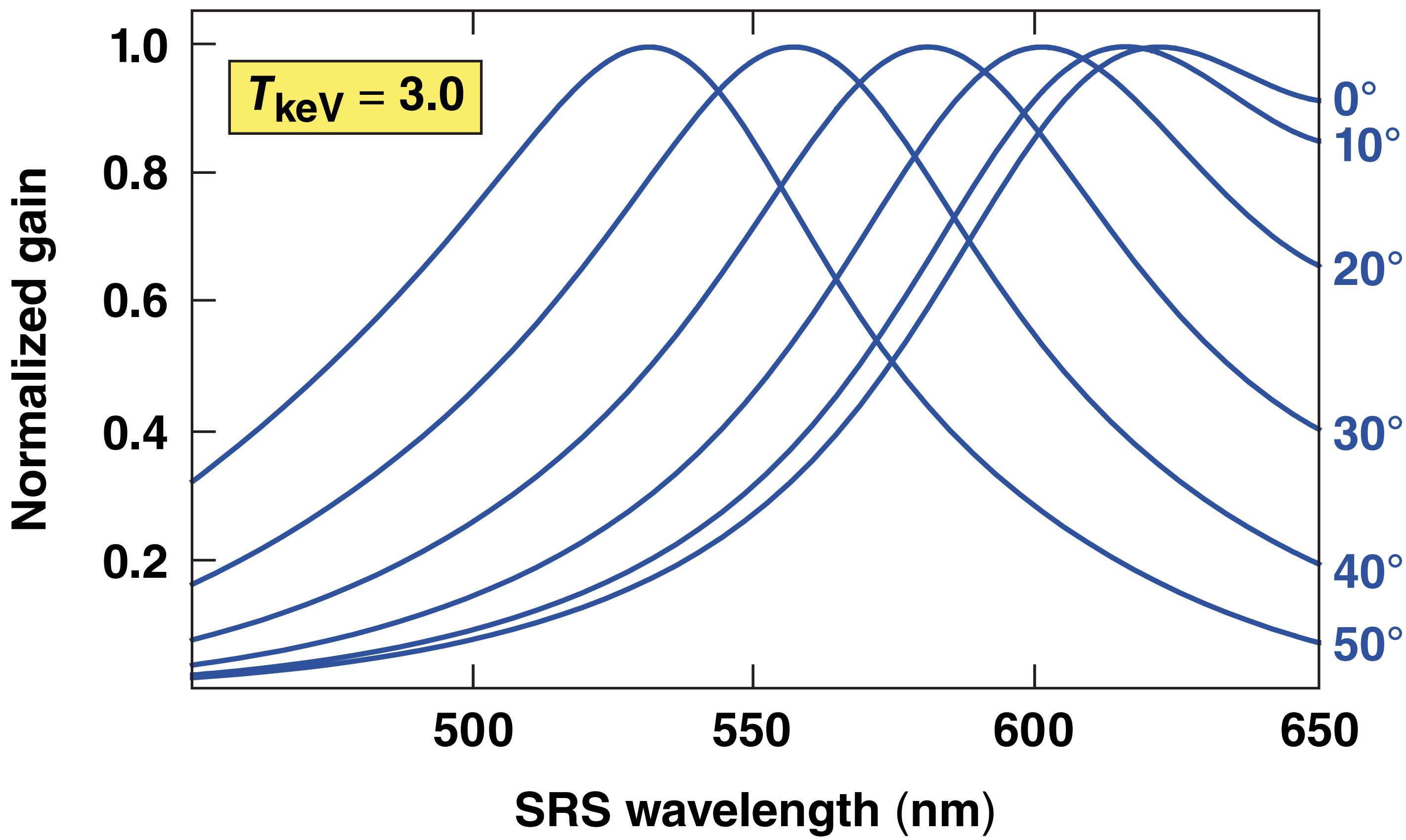
The peak of the gain curve shifts to longer wavelengths as the electron temperature increases



- The location of the peak is relatively insensitive to the magnitude of the gain

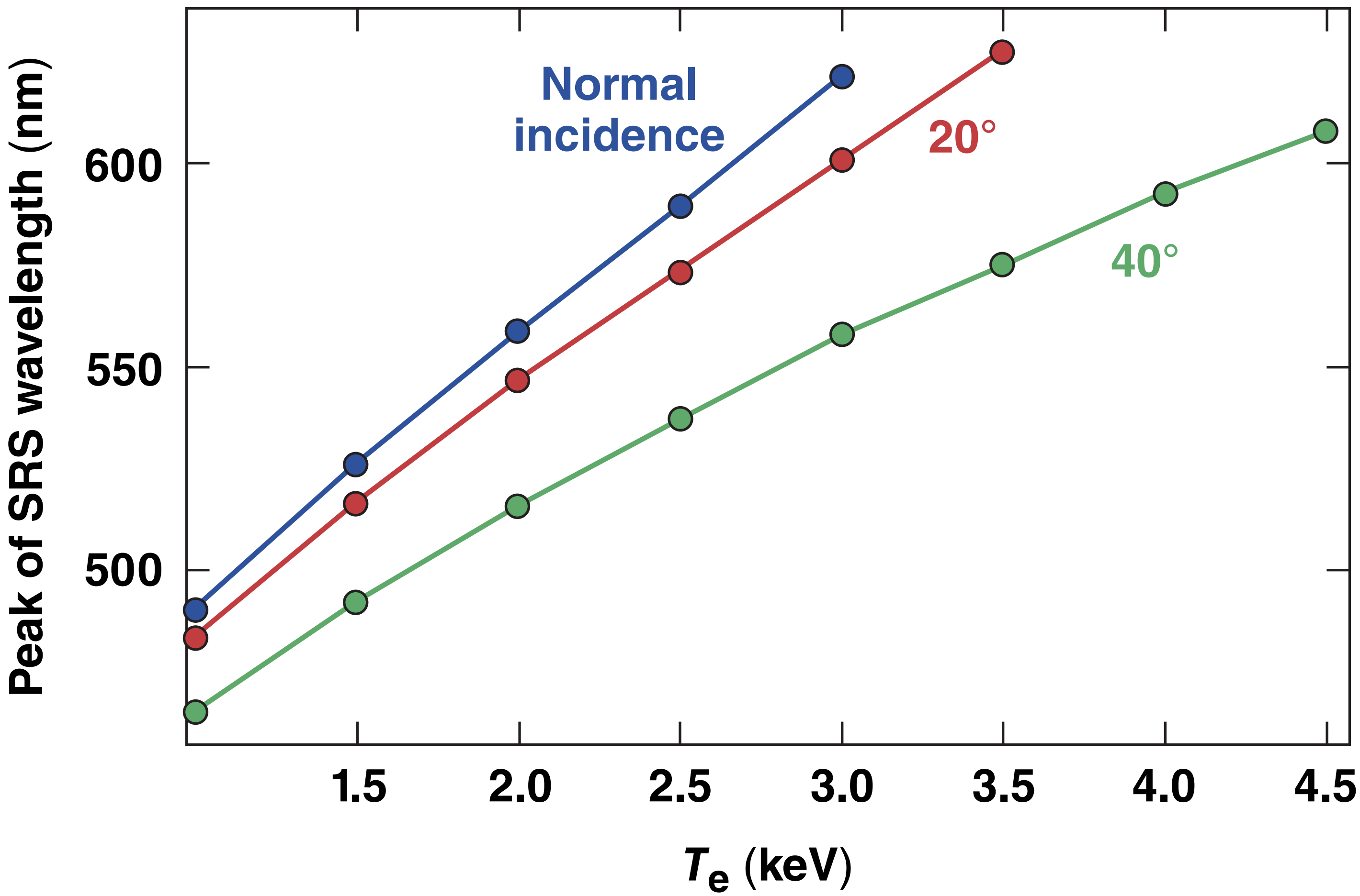
TC12813

The gain peak shifts to shorter wavelengths at larger angles of incidence



TC12814

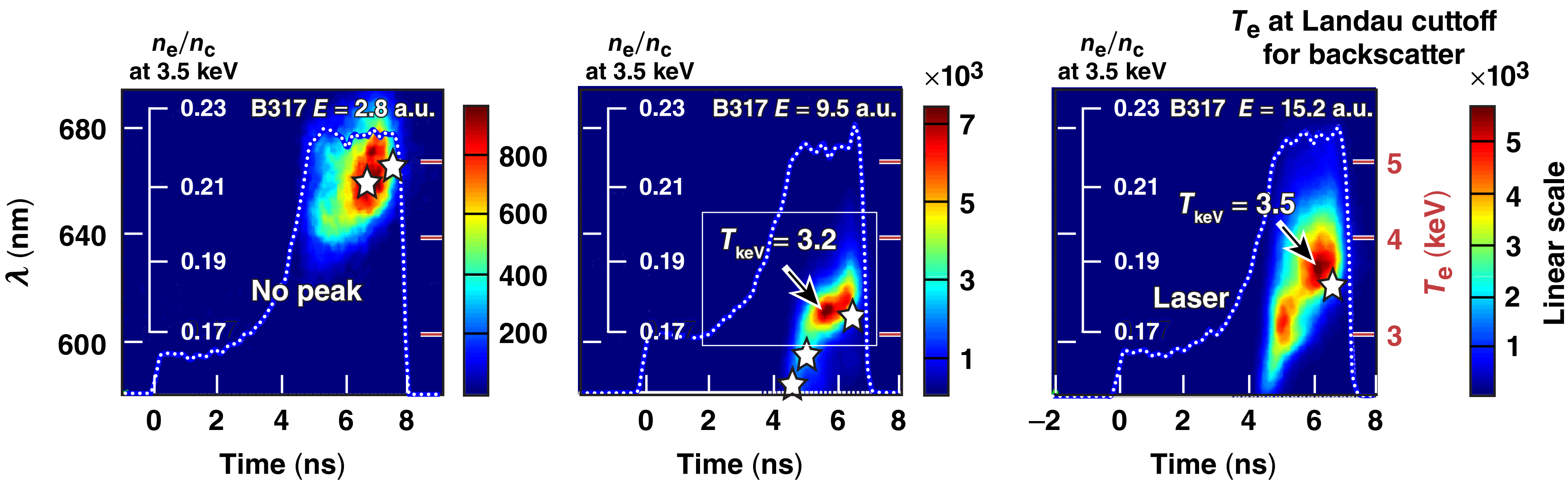
The SRS gain peak location is a nearly linear function of temperature



The peak is not well-defined for temperatures above ~4 keV.

TC12815

Temperatures obtained from spectral peaks agree well with simulation results



I_{14} (cold target) = 11.3	I_{14} (cold target) = 7.1 I_{14SB} $n_c/4$ ~ 0.3 to 0.4	I_{14} (cold target) = 11.2

$G_{SRS,SB^*} < 1$ for L_n ~ 300 μm, T_e ~ 3 keV (backscatter) (even for 5× enhancement for speckle intensity)

*single beam

TC12816

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TC12807