Experiments on the OMEGA EP laser to study the material dependence of the two-plasmon decay instability


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Overview

The two-plasmon decay (TPD) instability plays a major role in generating hot electrons (> 10 keV) in long-scale length plasmas. Understanding hot electron production is important to mitigate unwanted target preheat, and high-energy x-rays that interfere with diagnostics.

We performed experiments on the OMEGA EP laser to study Z-scaling of hot electron production from TPD. It is seen that hot electron fraction and temperature decrease with Z, thought to be a result of combined hydrodynamic and collisional effects.

Growth of TPD is limited by plasma hydrodynamics and collisionality, which depend on Z

Multiple laser beams can drive resonant, or “common” electron plasma waves (EPWs) with gains much larger than those for a single beam [1]. The EPWs’ energy is transferred to hot electrons via Landau damping.

\[ G = \int \frac{dI}{I} \int \frac{dI}{I} \int \frac{dI}{I} \]

TPD common-wave growth \( \sim e^G \)

Gain:

\[ I, I_z : \text{overlapped intensity} \]

Higher Z leads to:

- more collisional damping (\( \nu_c \)) of EPWs before their energy is transferred to hot electrons
- increased laser absorption, \( T_{\nu_c} \)
- slower expansion, shorter density scale length, \( L_n \) at \( N_{\nu_c} = n_r/4 \)

These decrease \( f_{\text{hot}} \) and \( T_{\text{hot}} \) through common-wave gain, \( G \) [2]

Hard x-ray measurements indicate that hot electron fraction and temperature decrease as the material Z increases

A bremsstrahlung x-ray spectrometer measures the hard x-rays produced by the interaction of TPD-generated hot electrons in the target [3].

\[ S(E, f_{\text{hot}} T_{\text{hot}}) = C f_{\text{hot}} Z E^{-E/kT_{\text{hot}}} \]

Hard x-ray spectrum, \( S(E) \) assumed to follow bremsstrahlung thick-target model, allowing for the estimation of parameters, hot electron fraction \( f_{\text{hot}} \), and temperature, \( T_{\text{hot}} \).

Conclusions and future work

Hot electron fraction and temperature systematically decrease as a function of Z, indicating that TPD growth decreases with Z.

Measured electron density scale-lengths generally decrease with material solid density (Z). This is consistent with the scaling of hot electron production through the common-wave gain model.

Multiple length-scales in electron density profiles indicates more detailed modeling of profiles is needed. Full reconstruction of profiles will provide more detailed info about hydrodynamics.

Hydro simulations will yield plasma temperatures, to calculate TPD gains. Disagreement with the TPD gain model may provide evidence of collisional damping and nonlinear saturation of TPD.