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Anomalous hot electron generation from two-plasmon decay instability driven by broadband laser pulses with intensity modulations

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We present our investigations on the hot electrons generated from two-plasmon decay (TPD) instability driven by laser pulses with intensity modulated by a frequency $\Delta\omega_m$. Our primary focus lies on scenarios where $\Delta\omega_m$ is on the same order of the TPD growth rate γ_0 ($\Delta\omega_m \sim \gamma_0$), corresponding to moderate laser frequency bandwidths for TPD mitigation. With $\Delta\omega_m$ conveniently modeled by a basic two-color scheme of the laser wave fields in fully-kinetic particle-in-cell simulations, we demonstrate that the energies of TPD modes and hot electrons exhibit intermittent evolution at the frequency $\Delta\omega_m$, particularly when $\Delta\omega_m \sim \gamma_0$. With the dynamic TPD behavior, the overall ratio of hot electron energy to the incident laser energy, f_{hot}, changes significantly with $\Delta\omega_m$. While f_{hot} drops notably with increasing $\Delta\omega_m$ at large $\Delta\omega_m$ limit as expected, it goes anomalously beyond the hot electron energy ratio for a single-frequency incident laser pulse with the same average intensity when $\Delta\omega_m$ falls below a specific threshold frequency $\Delta\omega_c$, as shown in figure 1. We find this threshold frequency primarily depends on γ_0 and the collisional damping rate of plasma waves, with relatively lower sensitivity to the density scale length. We develop a scaling model characterizing the relation of $\Delta\omega_c$ and laser plasma conditions, as shown in figure 2, enabling the potential extension of our findings to more complex and realistic scenarios. Interestingly, the $3\omega_0/2$ scattering due to TPD can be lower for $\Delta\omega_m$ that corresponds to enhanced f_{hot}, qualitatively agreeing with the recent experiments on Kunwu broadband laser facility [1-2].

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References

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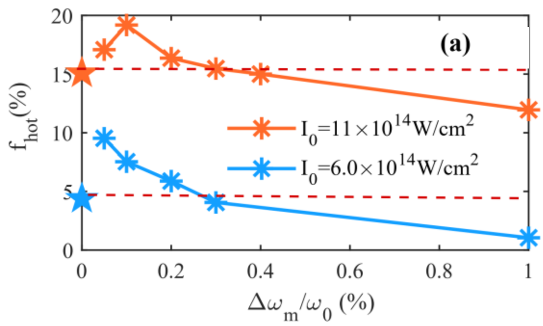

Figure 1. Time-averaged hot electron energy fraction of the incident two-color laser pulse, fhot , for different Δωm and average intensities I0 = 6 × 10^{14}W /cm^2 (blue) and 11 × 10^{14}W /cm^2 (orange). The two pentagram markers at Δωm = 0, in conjunction with the horizontal red dashed lines, indicate the steady-state f0 values for single-frequency drivers.

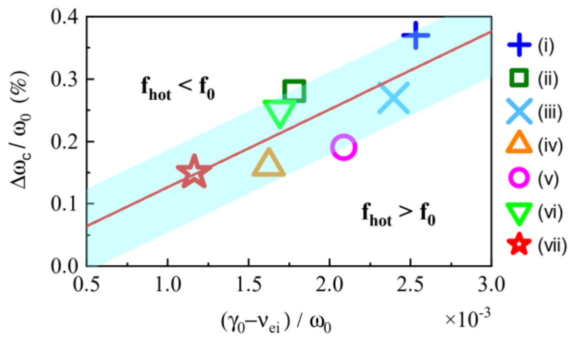

Figure 1. The threshold $\Delta\omega_c$ for γ0 − νei of different initial laser plasma conditions. The seven markers correspond to seven simulations with different physics parameters. The dark red straight line denotes the fitted results of the seven dots with the surrounding light blue region covering vertical variation ±0.05%. The upper-left and lower-right white areas stand for the parameters corresponding to fhot < f0 and fhot > f0, respectively.