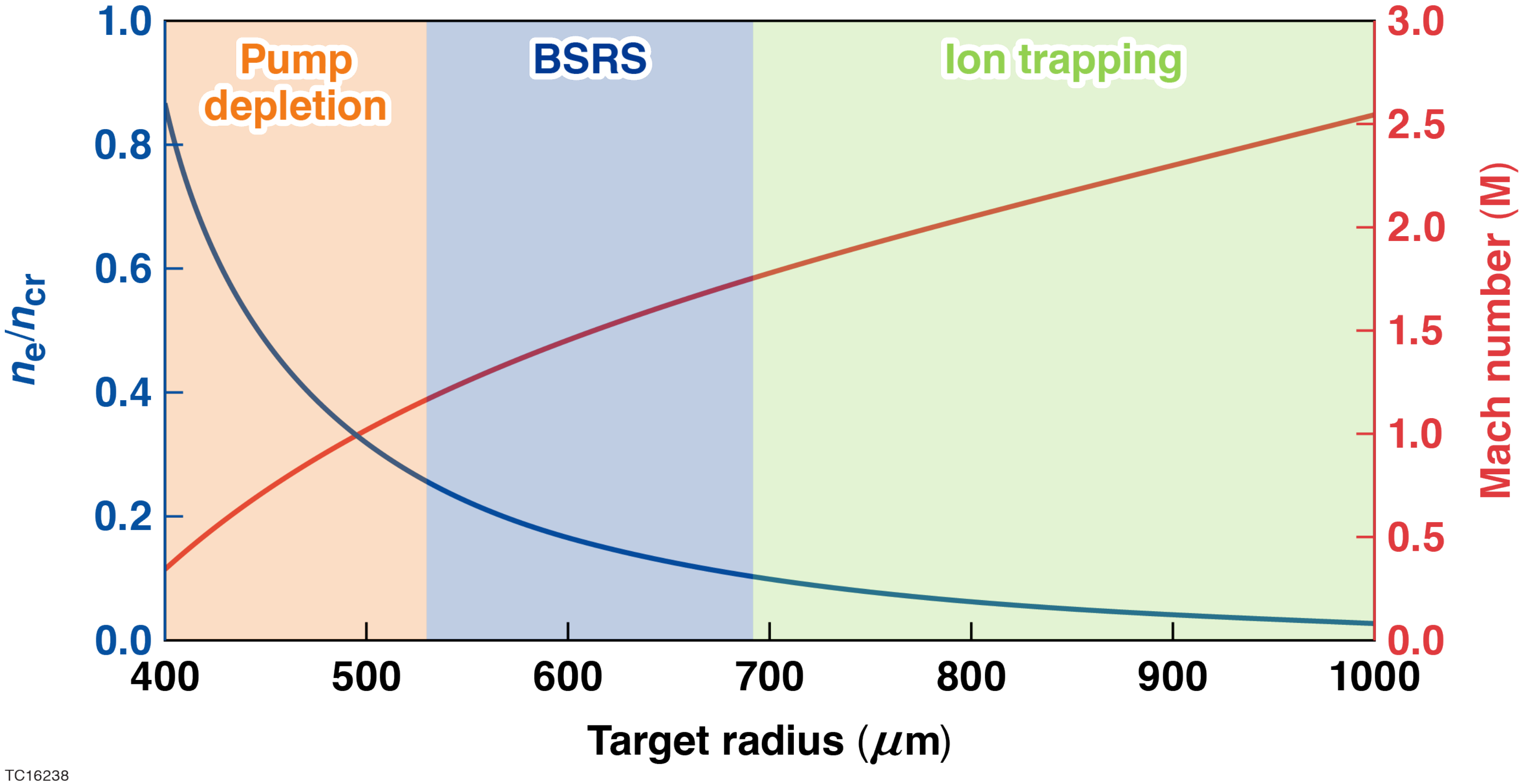
Nonlinear dynamics of cross-beam energy transfer in conditions relevant to OMEGA implosions



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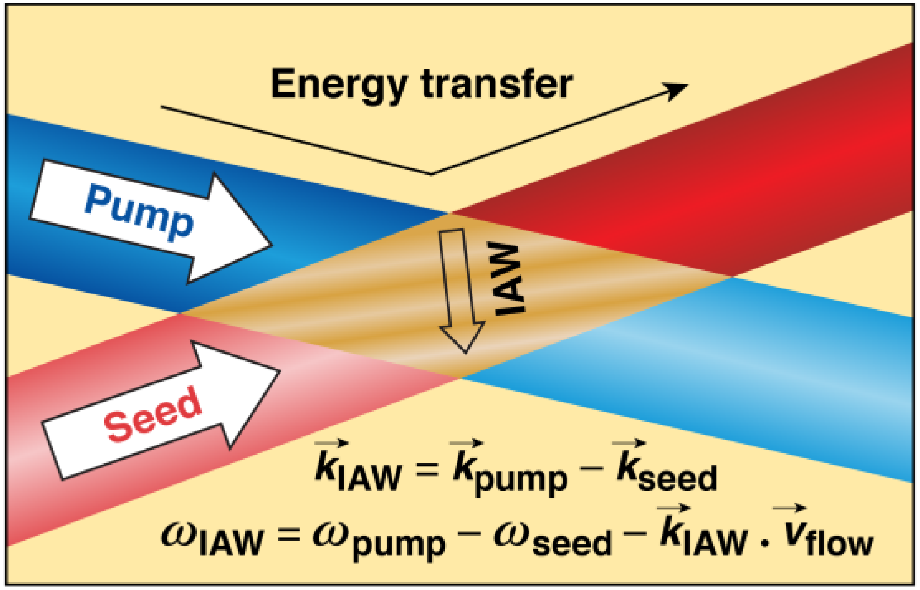
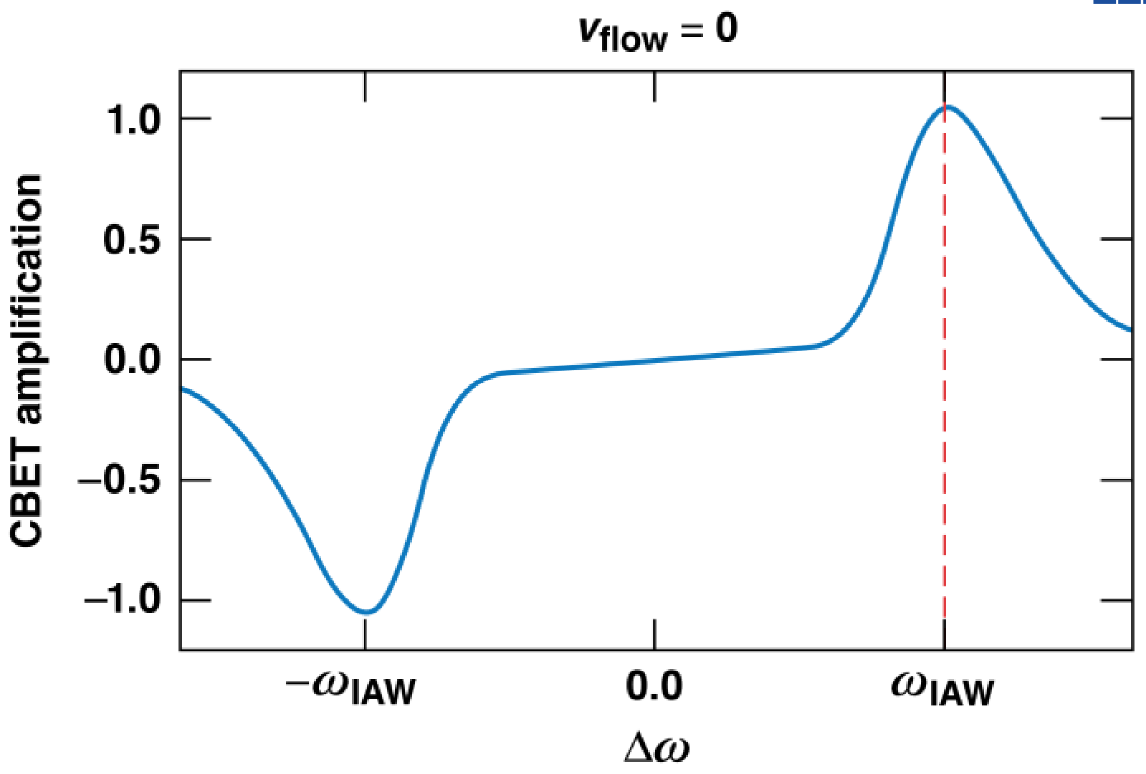
The nonlinear dynamics of CBET in plasma conditions relevant to OMEGA implosions depend on the plasma density (n_e)

- Collisional vector particle-in-cell (VPIC) simulations were performed to model CBET in plasma conditions relevant to OMEGA implosions
- For low plasma densities, $n_e = 0.10\ n_{cr}$, ion trapping can enhance CBET
- For intermediate plasma densities, $n_e = 0.20\ n_{cr}$, the seed beam can become unstable to stimulated Raman backscatter, which can reduce the apparent energy transfer
- For high plasma densities, $n_e = 0.30\ n_{cr}$, CBET can saturate due to pump depletion

Cross-beam energy transfer (CBET) is the exchange of energy between two laser beams mediated by their mutually driven ion acoustic wave (IAW)

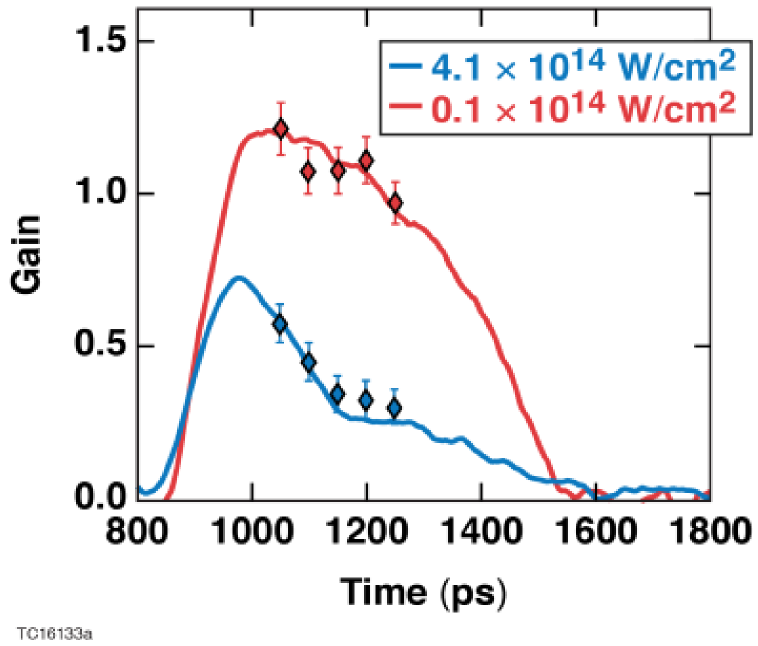




TC16129

Linear CBET theory predicts maximum energy transfer when the detuning frequency of the laser beams is equal to the Doppler-shifted frequency of the IAW

Previous studies on the OMEGA TOP9 platform revealed that CBET can saturate through ion-trapping induced detuning[1,2]



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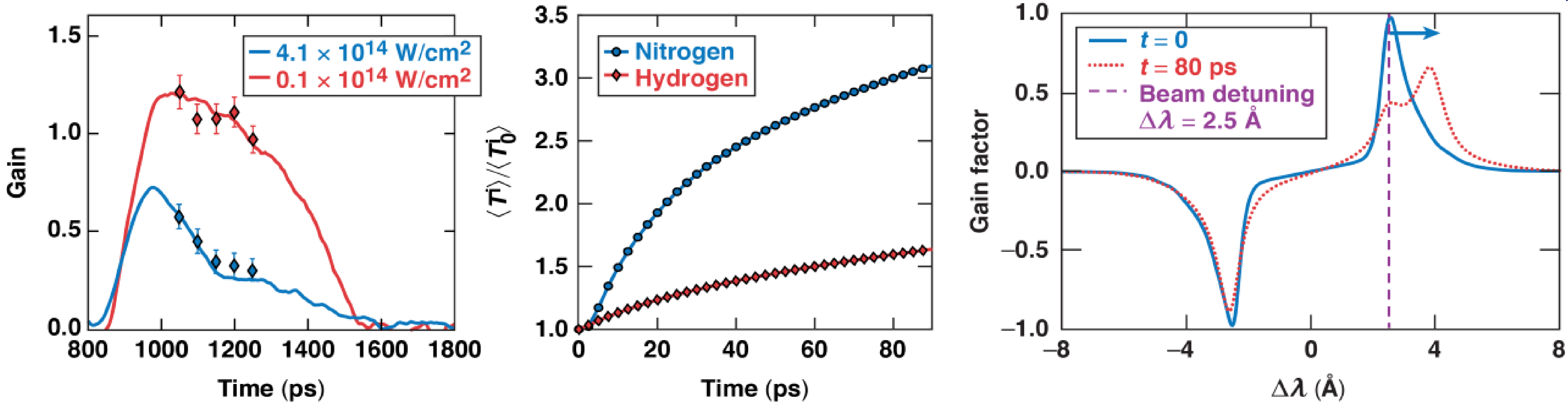

TC16133a

- Thermalization of trapped ions increased the ion temperature and detuned the resonant IAW frequency

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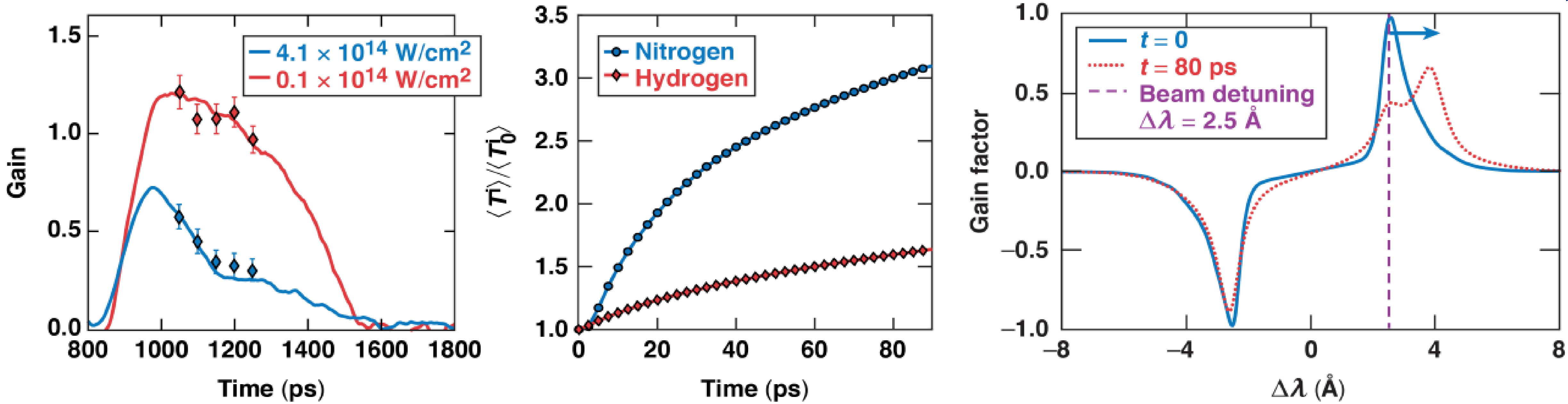

TC16133a

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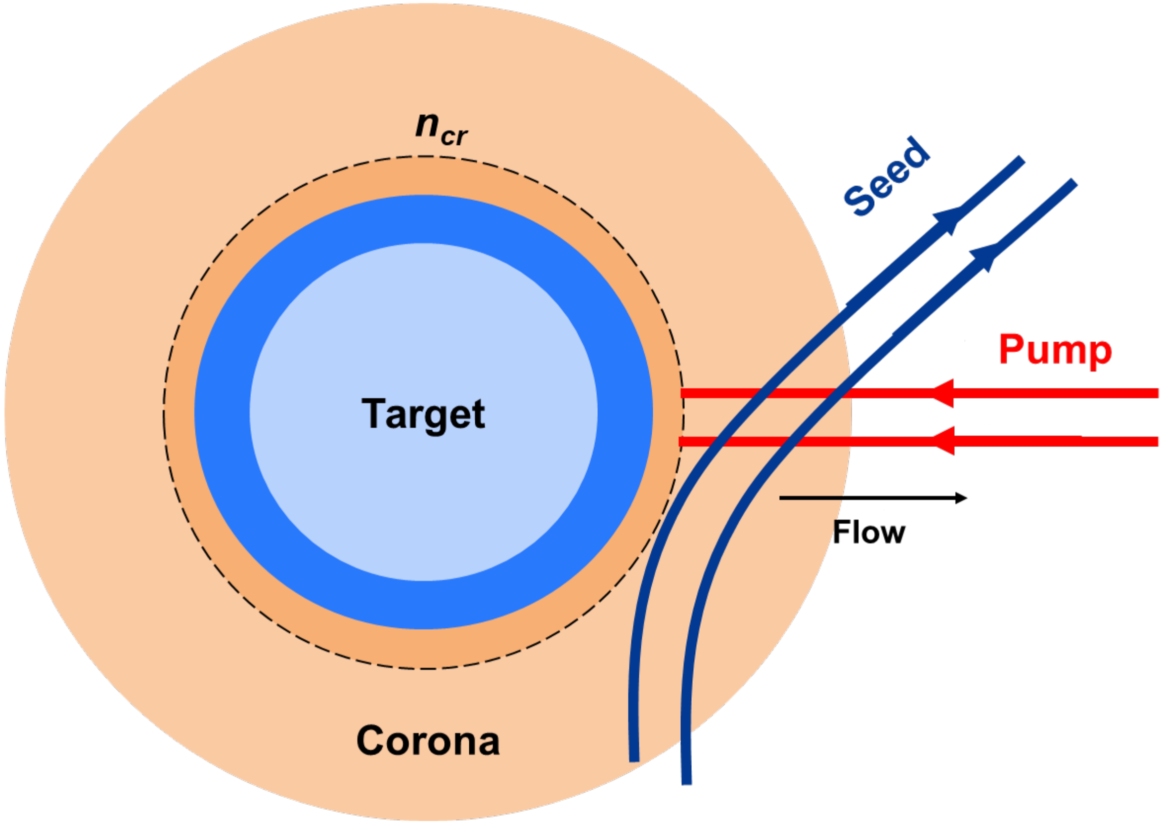
How does CBET saturate in conditions relevant to a direct-drive implosions where the plasma is hotter, denser, non-uniform, and flowing?

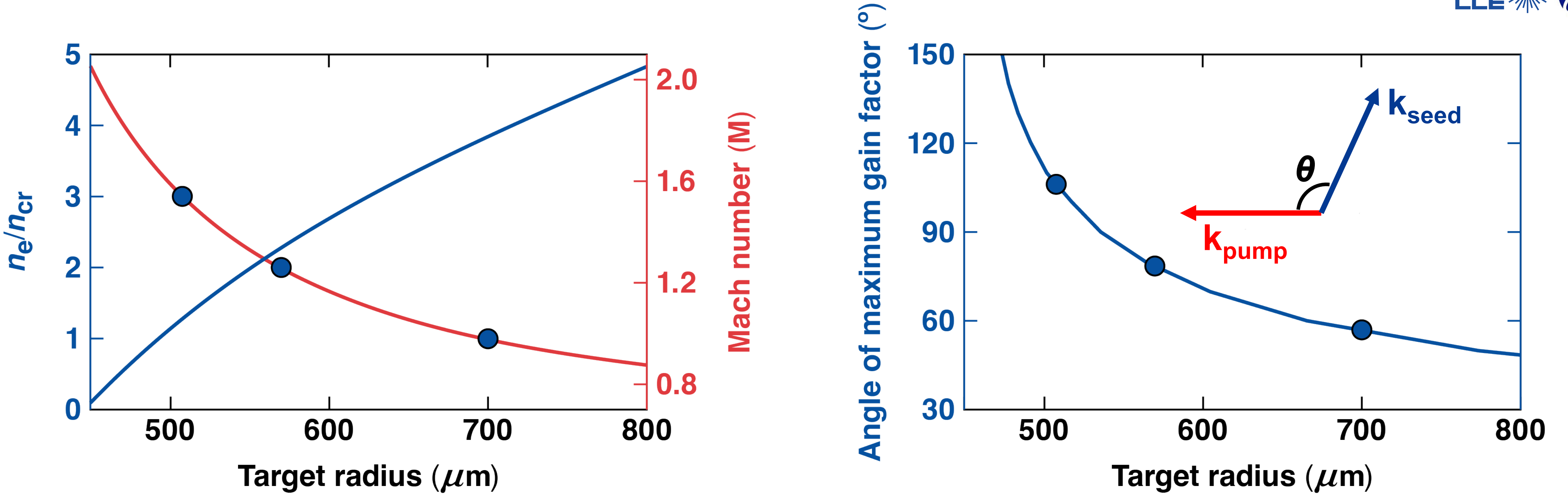
Collisional vector particle-in-cell (VPIC) simulations were conducted to explore CBET saturation in conditions relevant to an OMEGA implosion



Plasma parameters
n_{e0} = 10%, 20%, & 30% n_{cr}
H (50%) and C (50%)
T_e = 2.5 keV and T_i = 1.2 keV
Laser parameters
$\theta_{crossing}$ *varies*
λ = 351 nm (pump wavelength)
F# =6.7
Beam width = 20 μm

Plasma conditions were extracted from a LILAC simulation of an OMEGA implosion

At each density, CBET was simulated between a pump and seed with a relative angle that maximized the gain factor

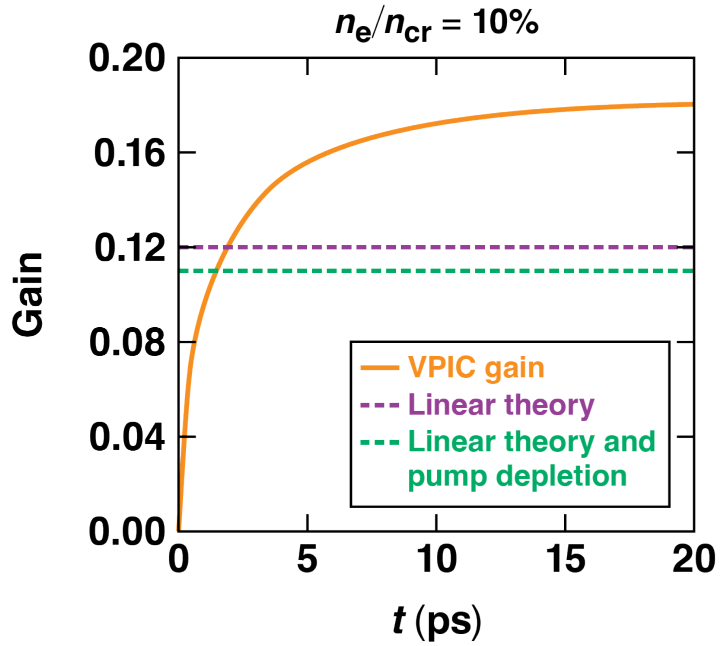


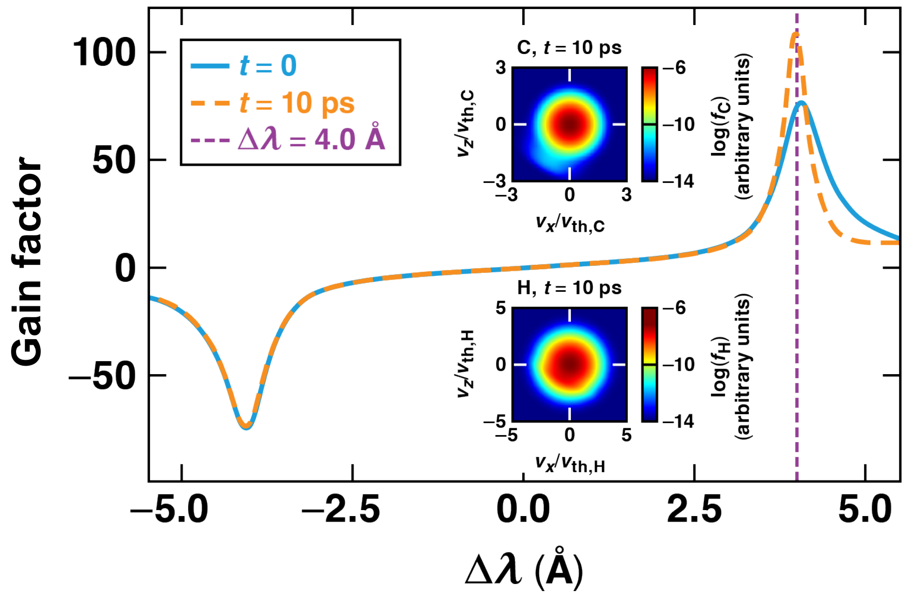
TC16239

- Density gradients were observed to impact the saturation mechanism and were included
- CBET resonance was achieved by shifting the seed wavelength, which was verified to give nearly identical results to using a constant flow

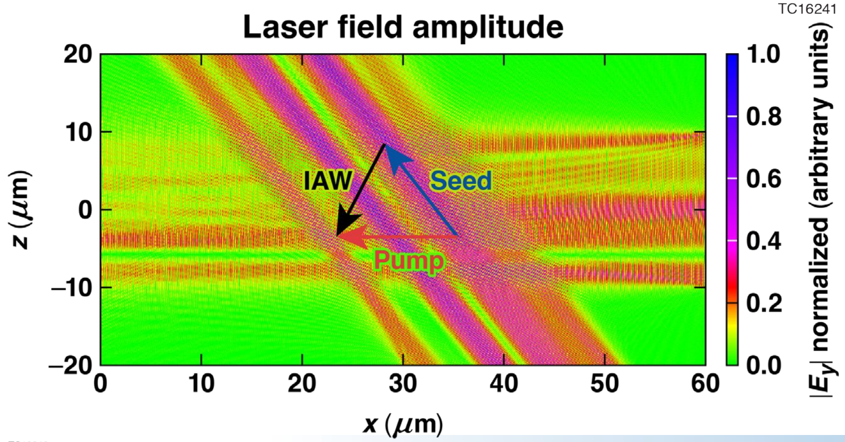
At low plasma densities, $n_e = 0.10\ n_{cr}$, ion trapping enhanced CBET by reducing Landau damping

Plasma parameters
$n_{e0} = 10\%\ n_{cr}\ (L_n \approx \infty)$
Laser parameters
$\theta_{crossing} = 60^{o}$
$\Delta\lambda = 4.0$ A
$I_{pump} = 2.0e14$ W/cm^2 $I_{seed} = 2.0e14$ W/cm^2





TC16241

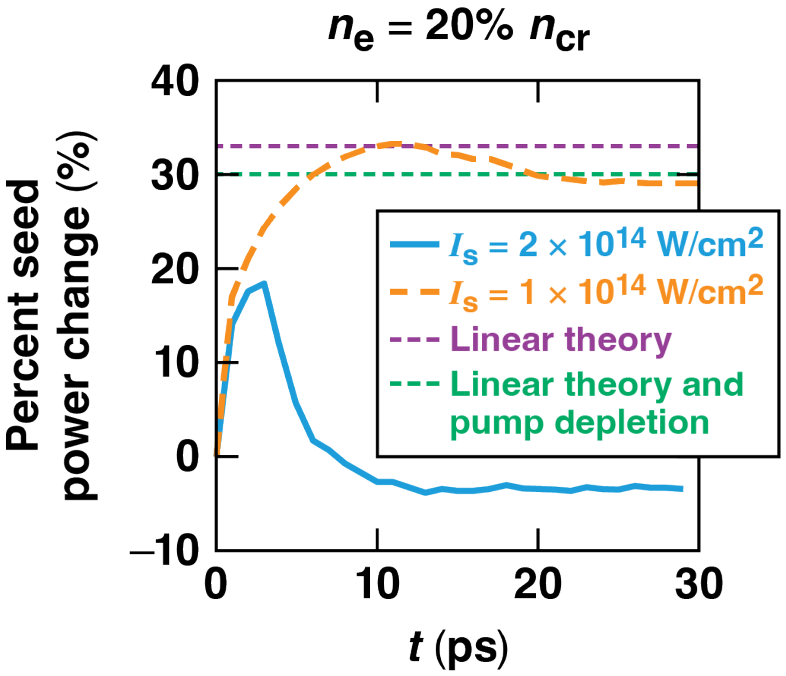


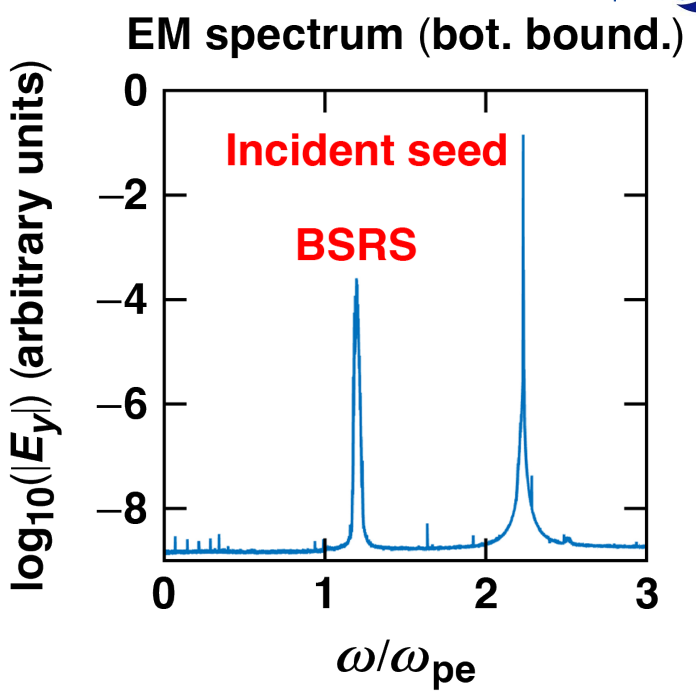
- At lower density, collisional de-trapping takes longer, leading to stronger and persistent ion-trapping

TC16240

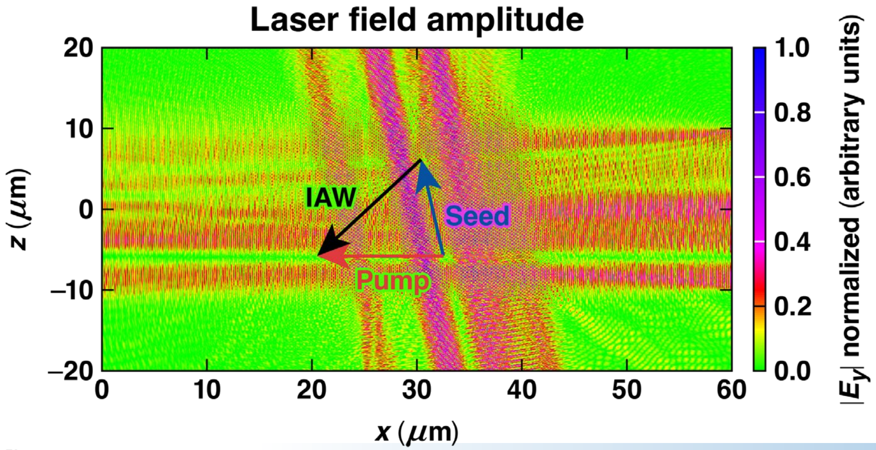
At intermediate densities, $n_e = 0.20\ n_{cr}$, the seed undergoes Raman backscattering, which reduces the apparent energy transfer

Plasma parameters
n_{e0} = 20% n_{cr} (L_n = 200 μm)
Laser parameters
$\theta_{crossing}$ = 80°
Δλ = 4.9 A
I_{pump} = 2.0e14 W/cm^2 I_{seed} = 1.0 & 2.0e14 W/cm^2





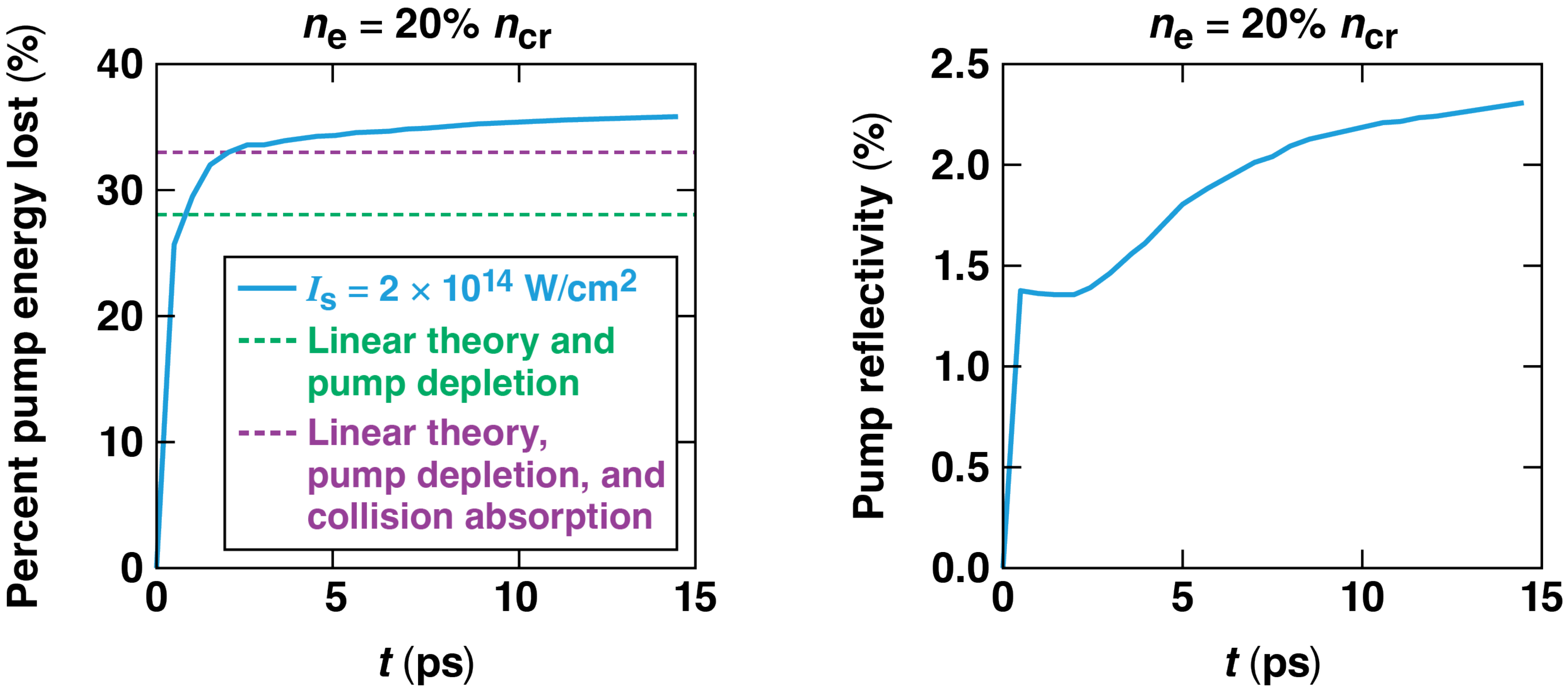
TC16243



- The seed beam propagates in a near-uniform plasma, tangential to the density gradient, exacerbating SRS

TC16242

Despite SRS backscattering of the seed, the energy lost from the pump beam is in good agreement with the linear theory

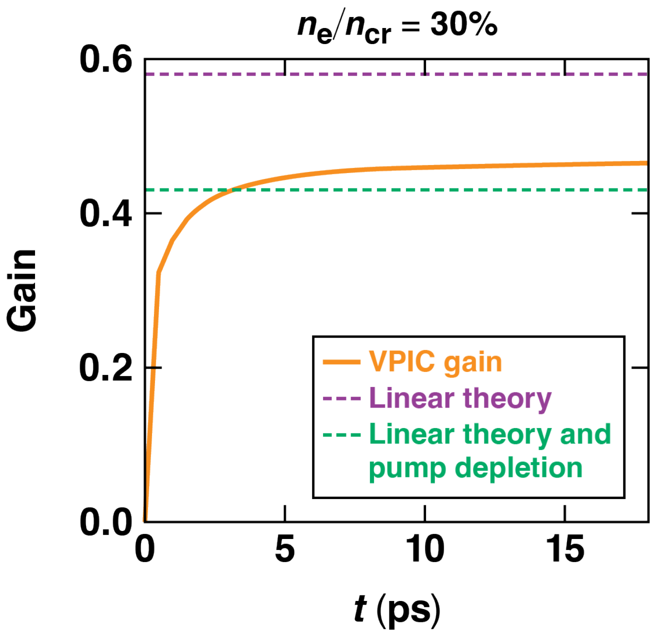


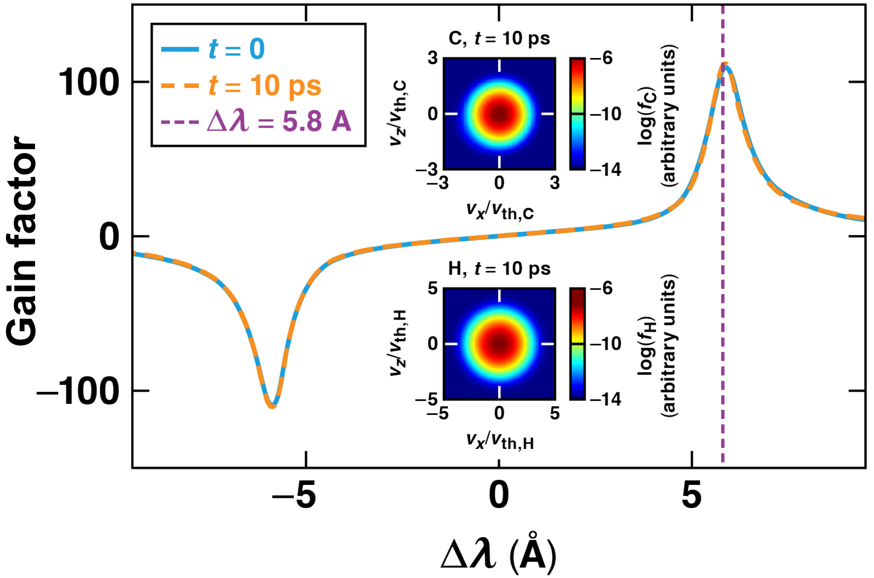
TC16244

- The density gradient and energy transfer to the seed suppress SRS backscatter of the pump beam

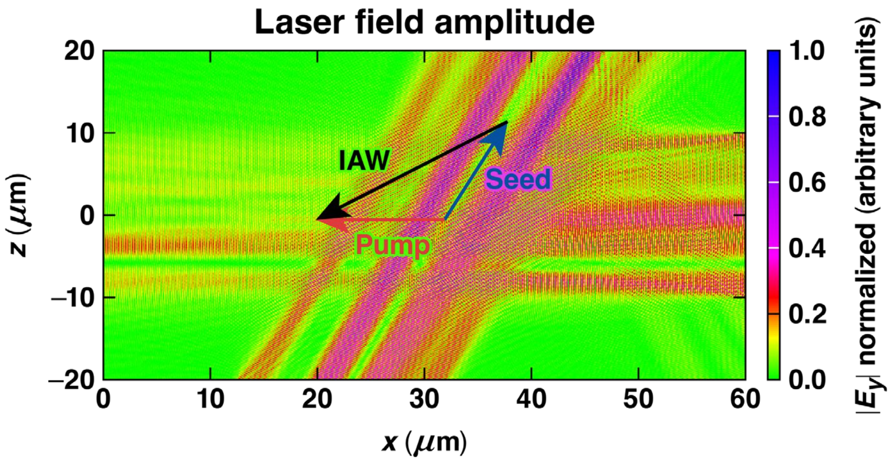
At high plasma density, $n_e = 0.30\ n_{cr}$, CBET saturates due to pump depletion

Plasma parameters
$n_{e0} = 30\%\ n_{cr}\ (L_n \approx 225\ \mu m)$
Laser parameters
$\theta_{crossing} = 110^o$
$\Delta\lambda$ = 5.8 A
I_{pump} = 2.0e14 W/cm^2 I_{seed} = 2.0e14 W/cm^2





TC16246



TC16245

- At higher density, SRS cannot be phase matched and collision frequencies are larger, resulting in weaker ion trapping

Summary

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