Comparing Ray-Based and Wave-Based Models of Cross-Beam Energy Transfer

LPSE simulation of two crossing beams in a density and flow gradient

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Summary

A wave-based cross-beam energy transfer (CBET) model (LPSE-CBET) is used as a platform to test the accuracy of ray-based CBET models.

- Ray-based and wave-based CBET show good agreement when the assumptions made in the ray-based model are satisfied.
- Laser speckle can amplify CBET gains when the angle between the interacting beams is small.
- The CBET interaction between speckled beams generates larger density perturbations than the interaction between plane waves.
Collaborators

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Ray-based CBET models calculate CBET by considering pairwise interactions between rays.

\[ \frac{dI_i}{d\ell} = - \sum_j I_j \times L_{ij}^{-1} \]

\[ L_{ij}^{-1} = 5.88 \times 10^{-2} \frac{I_j \lambda}{T_e (1 + 3 T_i / Z T_e)} \frac{n_e}{n_c} \frac{\omega_s}{\nu_i} P(\eta_{ij}) \]

\[ P(\eta) = \frac{\nu_i^2 \eta}{(\eta^2 - 1)^2 + \nu_i^2 \eta^2} \]

\[ \eta_{ij} = \frac{\omega_j - \omega_i - (k_j - k_i) \cdot u}{\omega_s} \]

Assumptions:

- Small ion-acoustic waves (IAW’s) \((\delta n/n \ll 1)\)
- Plane-wave approximation
- Strong-damping limit (IAW’s do not propagate)
- Wentzel–Kramers Brillouin (WKB) approximation

LPSE solves for the enveloped electric-field vector and the ponderomotively driven ion-density perturbations using fewer approximations than ray-based CBET models.
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Ray- and wave-based CBET models show excellent agreement when the assumptions made in the ray-based model are satisfied.
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Laser-beam speckle can cause CBET gains to differ from predictions based on the plane-wave approximation.
The CBET gain is sensitive to beam speckle for gains $\gtrsim 1$ and relative beam angles of $\lesssim 15^\circ$.
Speckled beams can generate larger density perturbations than plane-wave beams even when the CBET gain is not modified.

Enhanced density perturbations could lead to earlier saturation of CBET than would be predicted using a plane-wave approximation.
Summary/Conclusions

A wave-based cross-beam energy transfer (CBET) model (LPSE-CBET) is used as a platform to test the accuracy of ray-based CBET models.

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Campaign SBS6, SBS21:SBS90, homogeneous at $n_e/n_e = 0.1$, nui = 0.01

- Speckled beam
- Plane wave

<table>
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<th>Angle</th>
<th>Gain</th>
<th>Intensity ($\times 10^{14}$ W/cm$^2$)</th>
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