Seminar

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Institute for Plasma Research

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Title: Instabilities and Burn Analysis in context to Inertial Confinement Fusion

Speaker: Dr. Oriza Kamboj
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Date: 18th October 2022 (Tuesday)

Time: 03:30 PM

Venue: Join the talk online:
https://lobby.ipr.res.in/Dr.OrizaKamboz

Abstract

The community worldwide has been pursuing the aim of controlled fusion energy for decades. The bulk of inertial confinement fusion research, one area of fusion research in general, has concentrated on central hot spot ignition. Alternative methods, such as rapid ignition, provide the possibility of more extensive benefits with lower symmetry requirements, making them suitable for fusion energy generation. This presentation focuses on proposing solutions to significant challenges in ICF linked to instabilities and advanced fuels in ICF from an environmental standpoint.

One important component of the fast ignition scheme is the formation of pre-plasma in a cone-guided ICF scheme. When employing the conventional optical components of a chirped-pulse-amplified (CPA) laser-beam chain in a big laser system, the spot sizes generated are frequently much larger than would be ideal for fast ignition. This presentation aims to lower the focus spot size in the interior of the re-entrant cone's tip to the minimum size necessary for effective coupling to the densely imploded fuel core. The existence of pre-plasma in the cone is used in the method outlined. Due to the difficulties of reducing laser pre-pulse to below the threshold for plasma formation, such pre-plasma filling is difficult to eliminate completely when illuminating a cone with a high-energy CPA laser system. Paraxial theory in a WKB approximation was employed to derive the differential equation that regulates the progress of the laser beamwidth with propagation distance. A simulation is run assuming strong self-focusing in line with the laser parameters and plasma density profile specified.

Stimulated Raman scattering (SRS) is one of the mechanisms limiting the power scaling in inertial confinement fusion (ICF). In this work, we demonstrate effective suppression of SRS by the combined effects of static density fluctuations and an azimuthal magnetic field with a propagating chirped laser pulse. In the presence of an azimuthal magnetic field, chirped laser pulse propagates through a density rippled plasma and undergoes stimulated forward Raman scattering (SFRS), resulting in two radially localized electromagnetic sidebands waves and a lower-hybrid wave. Absolute and growing modes saturate due to ion density fluctuations, which then suppress instability growth through mode coupling. The modes modified by the combined effect of chirp and azimuthal magnetic field are effectively damped after saturation. As a result the overall growth rate of the instability reduces. The comparison of positive and negative chirp demonstrated that when positive chirp is being used,

instability is more effectively suppressed. Based on non-local theory, we have analyzed the growth of the SFRS for positive and negative chirp and estimate it for ICF relevant parameters and observed the effect of the growth rate another approach is considered to suppress SRS. A five-wave theory is developed, connecting stimulated Raman backscattering and decay instability produced in plasma with static magnetic field containing hot drifting electrons. A downward shifting electro-magnetic wave (EMW) and a forward-moving plasma wave are created by a Gaussian laser beam propagating in a static magnetic field. The plasma wave degrades into an ion acoustic wave (IAW) and a backward propagating secondary Langmuir wave with a larger wavelength. This energy diversion and linear Landau dampening of Langmuir wave by hot electrons suppresses SRS process. The plasma wave and the sideband EMW amplitudes fluctuate with time. The EPW amplitude has a similar effect.

We used third apporach in which we tried to study the Suppression of stimulated backward Raman scattering (SBRS) in presence of magnetic field and density rippled plasma is observed. The density perturbation due to the lower hybrid wave combines with the oscillatory velocity of the electron, given by the pump wave, to create a nonlinear current that drives the sideband waves. It was analyzed that for different modes of the growth rate, the SBRS is decreased significantly due to the ripple and local effects. For radial eigenmode number, the magnetized density ripple has a significant localization impact on the Raman process. The growth rate is at its maximum with the magnetic field, peaks at some optimal value, and then suppresses with the increase in the magnetic field.

Finally, our last objective looks at the burn-up of non-equimolar DT under inertial confinement fusion conditions (ICF). Deuterium: Tritium burnup calculations analytical tests are carried out on the ratios of 60:40 DT, 70:30 DT, 80:20 DT, and 90:10 DT, as well as the 50:50 DT case. The analytical work is then compared to 1-D hydrodynamic simulations. Based on this research, we can calculate the proportion of available fuel that will be used vs. the fuel's areal density in each instance. Non-equimolar DT has the potential to be used in ICF fuel capsules that achieve equimolar DT ignition and then propagate the burn into tritium sparse fuel to reduce the demands on the tritium breeding cycle.