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Final Report of Investigation of the Acoustic Decay Instability in Laser Plasma Interaction

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Abstract

We have made extensive studies of the Ion Acoustic Decay Instability (IADI) in laser-produced plasmas using the Janus (Phoenix) laser at LLNL. We found that the threshold is quite low and that, in planar plasmas, it can be reduced to homogeneous-plasma, collisional values. These observations are consistent with the plasma-density profiles calculated by hydrodynamic simulations using the LASNEX computer code run with a flux limiter of $f = 0.1$. We have designed experiments to study the IADI in larger plasmas using the Nova laser.

Report

The Ion Acoustic Decay Instability (IADI) occurs when a laser-light wave decays, within a plasma, into an electron-plasma wave and an ion-acoustic wave. The IADI generally occurs near the critical density of the laser-light wave, so that the Landau damping of the electron-plasma wave is not too large. The IADI is not only of fundamental interest to plasma physics, it is also potentially important for laser fusion because the electron-plasma waves produced by the IADI generate hot electrons that can preheat the fusion fuel and degrade compression. In the Janus experiments we used long laser pulses ($t_L \sim 1$ nsec) to irradiate large (up to 900 mm) spots at low laser intensities ($I_L = 3 \times 10^{12} \sim 10^{14}$ W/cm²) with 1.06 μ m laser light.

We found the IADI threshold to be quite sensitive to the laser spot size. As we increase the spot size, the geometry of the plasma expansion becomes more planar and less spherical and the gradient scale length of

the plasma density increases. The observed threshold increased as the spot size decreased being 5×10^{12} , 2×10^{13} , and 6×10^{13} W/cm² for spot sizes of 600, 350, and 100 mm diameter, respectively. This threshold is quite low and reaches the collisional value expected in a homogeneous plasma for the experiments having the largest spot size. The experimental results are compared with theory in Fig. 1, in which λ_{De} is the electron Debye length and k is the wavenumber of the electron-plasma wave. Larger values of $k\lambda_{De}$ correspond to lower plasma densities. Both the threshold value and the instability peak value of $k\lambda_{De}$ agree well with the theory. The experimental results are also consistent with the plasma density profile calculated by a hydrodynamic simulation using a flux limiter of $f = 0.1$ in the LASNEX computer code (the inset of Fig. 1). The detailed results of our experiments are presented in Ref. 1 and 2.

The observed low threshold values indicate that the IADI is potentially important in large-scale-length plasmas, and should be evaluated for the conditions that apply to laser-fusion experiments. To this end, we have designed instrumentation to study the IADI in the hot, large-scale-length plasmas produced by the short-wavelength Nova laser.

References

1. K. Mizuno, P. E. Young, W. Seka, R. Bahr, J. S. De Groot, R. P. Drake, K. G. Estabrook, and S. Kawata "Ion Acoustic Decay Instabilities in Laser Pellet Interactions." SIXTEENTH IEEE INTERNATIONAL CONFERENCE ON PLASMA SCIENCE, Buffalo, New York, 1989.
2. K. Mizuno, P. E. Young, W. Seka, R. Bahr, J. S. De Groot, R. P. Drake, and K. G. Estabrook "Investigation of the Ion Acoustic Decay Thresholds in Laser-Plasma Interaction." UCD report PRG-M-176 (1989), submitted to Physical Review Letters.

Figure Captions

FIG. 1 The IADI threshold is shown as a function of $k\lambda_{De}$, with the solid circle showing the result from an experiment producing a relatively planar plasma. The curves show (a) the threshold values including collisional and Landau damping, (b) threshold values including convective losses as well, and (c) the calculated Stokes amplitude (see ref. 2) versus $k\lambda_{De}$. The inset shows plasma density profiles for $I_L = 5 \times 10^{12} \text{ W/cm}^2$, calculated using (a) flux limit $f = 0.1$, and (b) $f = 0.3$.

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