Annual Scientific Report

Continuation of the Application of Parallel PIC Simulations to Laser and Electron Transport Through Plasmas Under Conditions Relevant to ICF and SBSS

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P.I.: Warren B. Mori
UCLA Departments of Physics and Astronomy and of Electrical Engineering
mori@physics.ucla.edu

During the past year, significant progress has been Stimulated Raman Scattering, nonlinear plasma waves, and two-plasmon decay. We are on track to meet the project goals. Below we give a brief description of recent progress.

In 2006/2007 we continued to study several issues related to underdense laser-plasma interactions. We have been studying the onset and saturation of Raman backscatter for NIF conditions, nonlinear plasma oscillations, and the two-plasmon decay instability.

Stimulated Raman Scattering (This work is done was Mr. Ben Winjum):

Using the full-PIC code OSIRIS, we studied the onset, saturation, and recurrence of stimulated Raman scattering (SRS) over a wide range of parameters relevant to NIF. We investigated pump depletion of the incident laser light as a possible saturation mechanism. This was aided by our development of diagnostics to look at backward and forward traveling light. These diagnostics have also allowed us to look more closely at the evolution of the instability after initial saturation. Examples are shown in figure 1. In particular, we have studied nonlinear plasma wave convection and mechanisms by which convection can affect the recurrence of the SRS instability. We have also studied how varying the simulation length (the available length for gain) affects the instability onset. Through these studies, we have formulated a qualitative understanding of the onset and recurrence, as well as how these affect the reflectivity, particularly in cases where pump depletion is important.

We continued our study of several nonlinear effects that have previously been used to explain SRS behavior in NIF-relevant plasmas (nonlinear frequency shifts, sidebands due to the trapped particle instability, beam-acoustic modes). While the nonlinear frequency shift due to particle trapping has been suggested as a saturation mechanism, we also analyzed the frequency shift of an electron plasma wave due to fluid effects (harmonics of the wave) and compared this shift with the kinetic frequency shift due to particle trapping. This work will be published in Physics of Plasmas.

Time vs. Position of the Electric Field

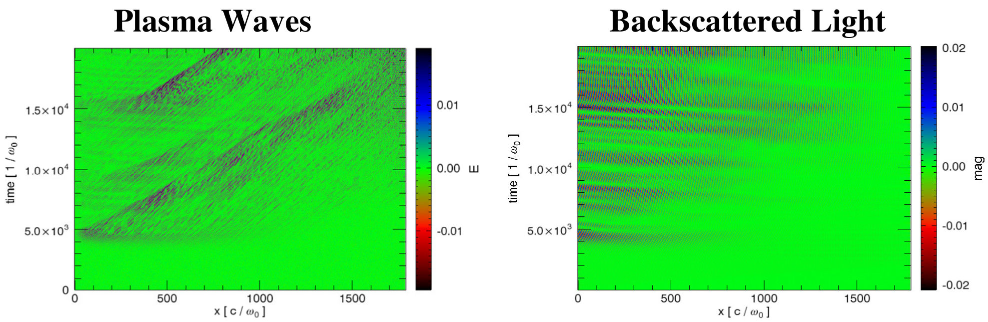

Figure 1. Time vs. position of the plasma wave and the backscattered light. Comparing these plots shows that the recurrence of the backscatter originates from the convecting packet of plasmons.

Papers:

B. J. Winjum, J. Fahlen, W. B. Mori, “The Relative Importance of Fluid and Kinetic Frequency Shifts of an Electron Plasma Wave.” Physics of Plasmas (accepted for publication).

Conference presentations:

B. J. Winjum, J. Fahlen, F. S. Tsung, W. B. Mori, D. E. Hinkel, A. B. Langdon, “Simulations of Stimulated Raman Scattering in One Dimension” SSAA Symposium 2007.

B. J. Winjum, J. Fahlen, F. S. Tsung, W. B. Mori, D. E. Hinkel, A. B. Langdon, “Simulations of Stimulated Raman Scattering in One Dimension” Annual Meeting of APS-DPP 2006.

B. J. Winjum, J. Fahlen, W. B. Mori, “Nonlinear Effects on the Saturation of Simulated Raman Scattering” Anomalous Absorption Conference 2006.
This work is being done by B.Winjum.

<u>Nonlinear plasma waves (This work was done by Mr. Jay Fahlen)</u>:

During this past year, we conducted many 1D electrostatic PIC simulations in which an external ponderomotive driver excites large amplitude plasma waves. These simulations examined frequency shifts due to particle trapping and fluid nonlinearities, sideband instabilities, and wavebreaking effects. Insight gained from these simulations was used in a paper comparing fluid and kinetic frequency shifts (Phys. Plasmas to be published). When the theory's approximations are satisfied, the simulations are in excellent agreement with results in this paper. For example, in figure 2, excellent agreement between the predicted and measured harmonic ratios is seen, especially for low values of

$k\lambda_d$ where the theory is most appropriate. These simulations have also demonstrated that existing theories for the kinetic frequency shift are inadequate in the regimes of interest for Raman scattering. The simulations can be used to better understand trapping nonlinearities and potentially lead the way to a kinetic theory that includes both trapping effects and wave harmonics.

To perform these simulations, several new features were added to the code, including filtering out certain parts of the wave spectrum to examine their effects and allowing several wave packets to be driven separately and independently. Many new diagnostics were also developed to accurately measure, among others, the simulated wave's frequency and amplitude.

IMAGE NOT AVAILABLE

Figure 2. Comparison between the theoretical prediction and the simulation results for the harmonic ratio in driven plasma waves.

Conference presentations:

J. Fahlen, B. Winjum, J. Tonge, F.S. Tsung, V. Decyk, W.B. Mori, "Driven Plasma Waves Relevant to Stimulated Raman Scattering", Conference Poster presented at APS DPP Meeting 2006.

This work is being done by J. Fahlen.

J. Fahlen, B. Winjum, J. Tonge, F.S. Tsung, V. Decyk, W.B. Mori, "Driven Plasma Waves Relevant to Stimulated Raman Scattering", Conference Poster presented at Anomalous Absorption Conference 2006.

J. Fahlen, W.B. Mori, J. Tonge, F.S. Tsung, B. Winjum, A.B. Langdon, D.E. Hinkel, "Cavity Formation and Collapse in Stimulated Brillouin Scattering", Conference Poster presented at Anomalous Absorption Conference 2006.

Two-plasmon decay (This work was done by Dr. Frank Tsung):

In the past year we have performed many additional simulations to study the behavior of the two plasmon instability in parameter regimes relevant to NIF direct drive experiments. The two plasmon decay is important in direct drive ICF because this instability has the lowest onset threshold of all the instabilities and it can cause pre-heating of the target, thus making compression more difficult. The most definitive (linear) theoretical work in this field were published by Dr. Bedros Afeyan and co-workers, using variational principles. We have performed a large number of simulations in the past to confirm the validity of the theory and to build confidence in our ability to capture the linear behavior of the instability. These simulations confirm the scaling of this instability to the dimensionless parameter $\left(k_\perp c / \omega_0\right)^2 \tilde{\beta}$ (where $\tilde{\beta}$ is a dimensionless parameter which measures the dispersion and convection of the plasma waves), and confirm the correctness of the linear theory for other density profiles which can only be treated theoretically by the variational principle. Furthermore, we have scanned over a wide range of parameters (both engineering parameters such as the electron temperature and laser intensity and dimensionless parameters like those introduced by Afeyan *et al*) to find regions in parameter space where other effects, such as Landau damping or mode-mode coupling which causes the simulation results to deviate from theory. We have also studied the nonlinear saturation and nonlinear final state of the instability. These simulations are currently being analyzed.

We are in the process of preparing several manuscripts of the simulation work to date.

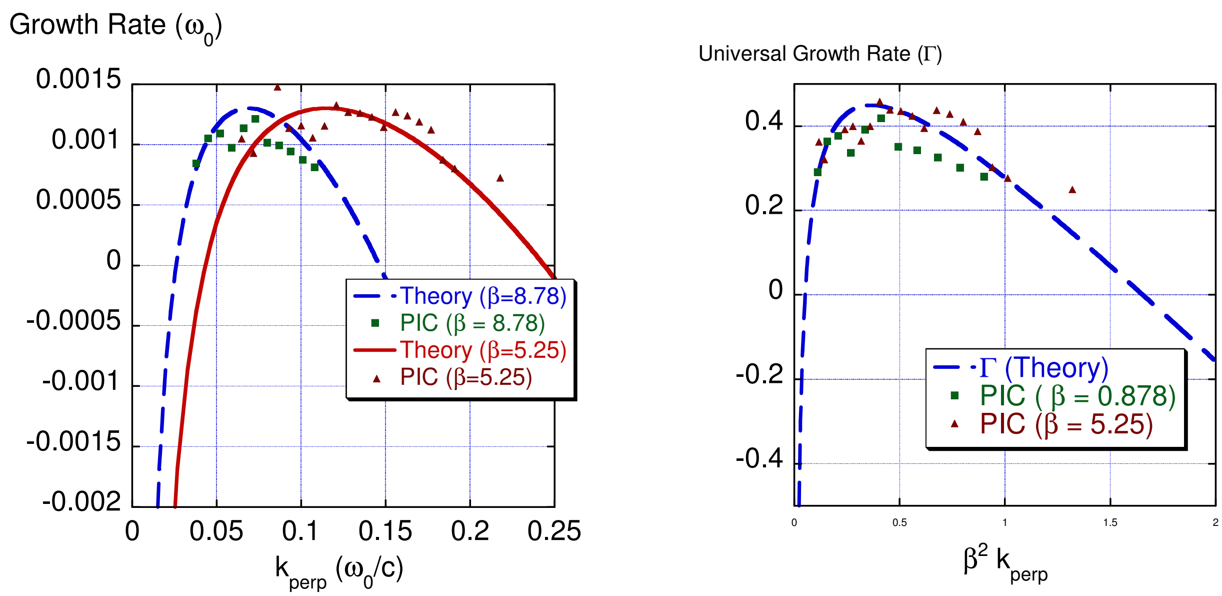

Figure 3: Two plasmon growth rate as a function of wave number in scaled parameters (right) and in unscaled parameters (left).

Conference Presentations in the Past 12 Months:

F. S. Tsung, B. B. Afeyan, W. B. Mori, Particle-in-Cell Simulations of the Two Plasmon Instability in a Density Gradient, presented at the 37th Anomalous Absorption Meeting (2007).

F. S. Tsung, B. B. Afeyan, and W. B. Mori, Particle-in-Cell Simulations of the Two Plasmon Decay Instability for Plane Waves in Inhomogeneous Plasmas, presented at the 48th Annual Meeting of the Division of Plasma Physics, Philadelphia, PA (2006).

F. S. Tsung, B. B. Afeyan, and W. B. Mori, Particle-in-Cell Simulations of the Two Plasmon Decay (TPD) Instability for Plane Waves in Inhomogeneous Plasmas, presented at the 36th Anomalous Absorption Meeting, Jackson Hole, WY (2006).