Numerical study of the electron velocity distribution under the influence of KrF- laser

By

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ABSTRACT

We focused on designing and constructing a two dimensional model to simulate the plasma under the action of KrF laser. The program is started with a uniform plasma in space and with Maxwellian distribution of velocity in both directions x and y as initial conditions. The electron velocity distributions are obtained at different values of electron density, where each electron density is investigated under the influence of KrF laser ($\lambda_o = 248\ nm)$ for 10^{15}w cm^{-2} power density.

We studied the temporal evolution of the velocity distribution in the x and y-directions.

INTRODUCTION

The roots of plasma simulation can be found in the methods used in designing vacuum tubes, oscillators and other first generation electronics devices. Numerical solutions to Poisson's equations were commonly used to the map the electric field distribution in a triode; trajectories of electron streaming in a magnetron were obtained by solving the equations of motion on a disk calculator. In a dynamic state represented by a collection of freely moving positive and negative charges subjected to external field [1].In order to simulate plasma one has to self-consistently obtain the force acting on particles ;i.e. to calculate particle and current densities and solve Maxwell's equations.

There are two basic models of plasma simulation, the particle model [2]and the fluid model[3]. In the fluid model the time evolution of the velocity distribution function is calculated by coupling the Boltzman or Vlasov transport equation with

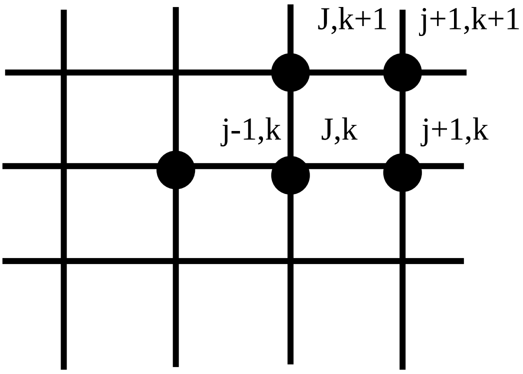
Maxwell equations, by the model the plasma at a point in the phase-space the simulation program can give the value of the distribution function at that point. The particle model is an extension of the technique of solving the equation of motion of a single particle. The particles are tracked in time as they move in their own as well as externally applied electromagnetic field ,which are determined by Maxwell equations. Forces on the particles are calculated using Lorentz equation. These forces determine the charge in position and velocity within a small time interval (dt)[ ].As they move , their redistribution in space modifies the fields which are recalculated periodically. The new fields are used in updating the particle positions and velocities. This is a self consistent technique[2].

The fluid models may leave out much of the physics that is important in understanding the behavior of plasma. By leaving out collisional kinetic effects, information about damping and nonlinear saturation of unstable modes is lost. In order to include these effects, the hydride approach, which suitably combines the particle and fluid models.

THE SIMULATION PROGRAM

To study the electron velocity distributions using particle simulation model, the algorithms for advancing the system one time step forward are divided into two parts; the calculation of the fields and the calculation of the particle force. The initial conditions of the system represent the positions and velocities of the charged particles. The most important consideration for particle models is particle collision[4].Just as in real plasma there are collisions between particles , which gives rise to collisional effects. The forces between model particles are much larger than in real plasma and the associated collisional effects are much greater [5]. To decrease these effects, there is a method called finite-size particle method which both speed up the force calculation and reduces the collisional effects[6].

The spatial grid, used for obtaining the fields from the particle charge density and current density, has grid points $x_j = j\Delta x$ and $y_K = k\Delta y$ as shown in fig.(1).



fig(1)

The field equations are solved on this grid ,and the forces acting on the particles are obtained by interpolating the fields back to the particles this is the "particle - in - cell " (PIC) technique. This procedure eliminates fluctuations at scales smaller than the grid spacing and also reduces the number of operations per time step .

The grid size is made small enough to resolve the details, and to avoid numerical troubles. The particle density is kept large enough to make density variations smooth. The particles themselves are treated as finite – size particles. This physics comes about automatically by weighting the particles to the grid. Zero – order weighting is again nearest – grid point weighting. First – order weighting is again linear interpolation called bilinear or area weighting.

The weights are given by:

$$\rho_{j,k} = \rho_c \frac{(\Delta x - x)(\Delta y - y)}{\Delta x \Delta y}$$

$$\rho_{j+1,k} = \rho_c \frac{x(\Delta y - y)}{\Delta x \Delta y}$$

$$\rho_{j+1,k+1} = \rho_c \frac{xy}{\Delta x \Delta y}$$

$$\rho_{j+1,k} = \rho_c \quad \frac{(\Delta x - x)y}{\Delta x \Delta y}$$

Where ρ_c ,is the charge density uniformly filling a cell (q/area).
In finite difference form ,Poisson's equation becomes[ ].

$$\frac{(\varphi_{j-1} - 2\varphi_j + 2\varphi_{j+1})_k}{\Delta x^2} + \frac{(\varphi_{k-1} - 2\varphi_k + 2\varphi_{k+1})}{\Delta y^2} = -\rho_{j,k}$$

The E 's are obtained from φ 's using

$$(\mathrm{E}_x)_{j,k} = \frac{(\varphi_{j-1} - \varphi_{j+1})_k}{2\Delta x}$$

RESULTS AND DICCUSION

In this work, electron velocity distribution for aluminum plasma under effect of KrF ($\lambda = 248nm$)using power density $10^{15} wcm^{-2}$. The laser light is normally incident on the plasma where the electric field is linearly polarized in the z-direction ,and the magnetic field of the laser light will rotate the velocity of the particle with out change in the magnitude.

The plasma properties is studied in three electron density regions below the critical density;

1- $n_e = 0.9 n_{cr}$

2- $n_e = 0.95 n_{cr}$

3- $n_e = 0.99 n_{cr}$

Figs(1,2,3) show the electron velocity distributions in the x- directions where the velocity scale is taken in terms of the thermal velocity at the time step 0.

The code ensure that the time is greater than $10^{-18}\sec$ in order to satisfy the simulation conditions. From the figs, the distribution at time step 0 are Maxwellian and it is obvious that the distributions in all cases are shifted toward the positive axis at time step 800 and it is obvious that at the time step 2500 the distributions becomes wider. From the figs, the distributions are seen to have energy tail. This is because energy transfer from laser to the plasma particles by inverse bremsstrahlang process where the absorbed energy of laser light causes an increase in the kinetic energy of the electrons ,i.e. an increase in the electron temperature [7].

Figs(4,5,6) illustrated the time history of the electron velocity distributions in the y-distributions. The results show that in all cases the curves at the time step 800 are shifted toward the direction of the negative – axes. It is clear that the distributions after time step 2500 indicate that more groups of high velocities are present.

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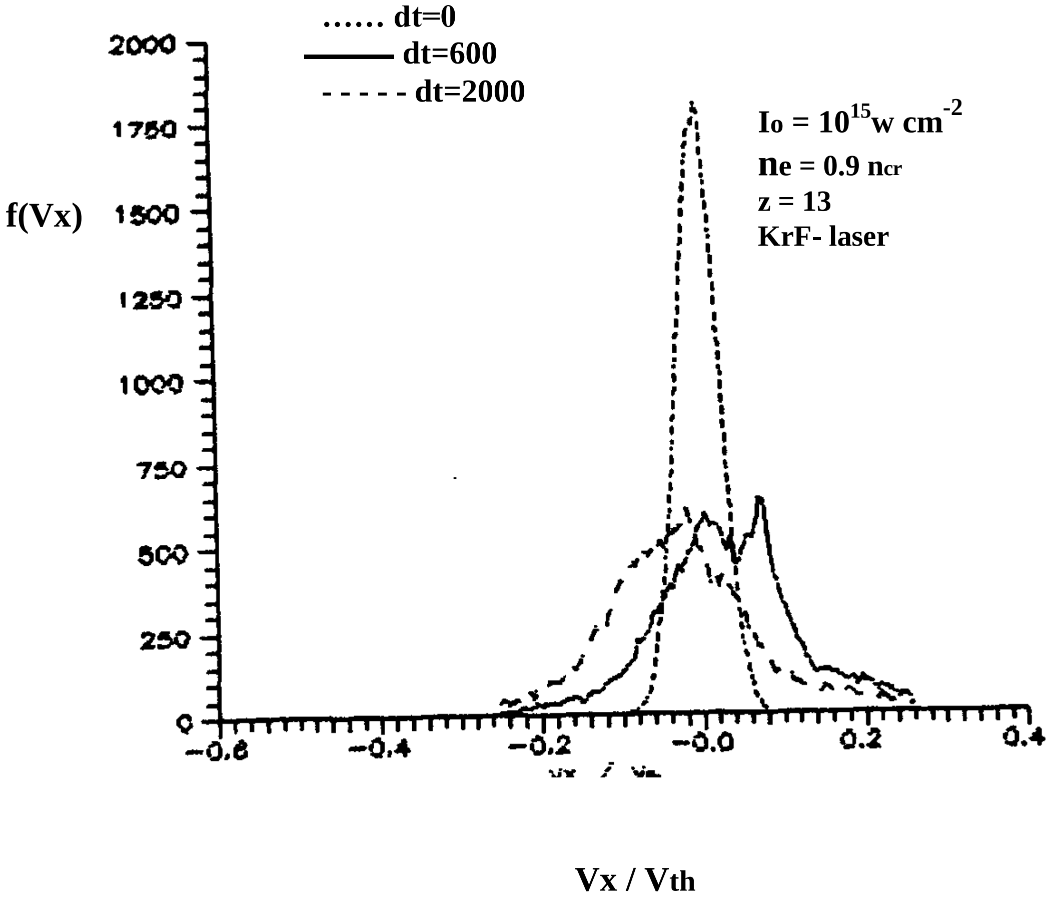

…… dt=0
dt=600
- - - - - dt=2000
Io = 10^15 w cm^-2
ne = 0.9 ncr
z = 13
KrF- laser
f(Vx)
2000
1750
1500
1250
1000
750
500
250
0
-0.6
-0.4
-0.2
-0.0
0.2
0.4
Vx / Vth

Fig (1)

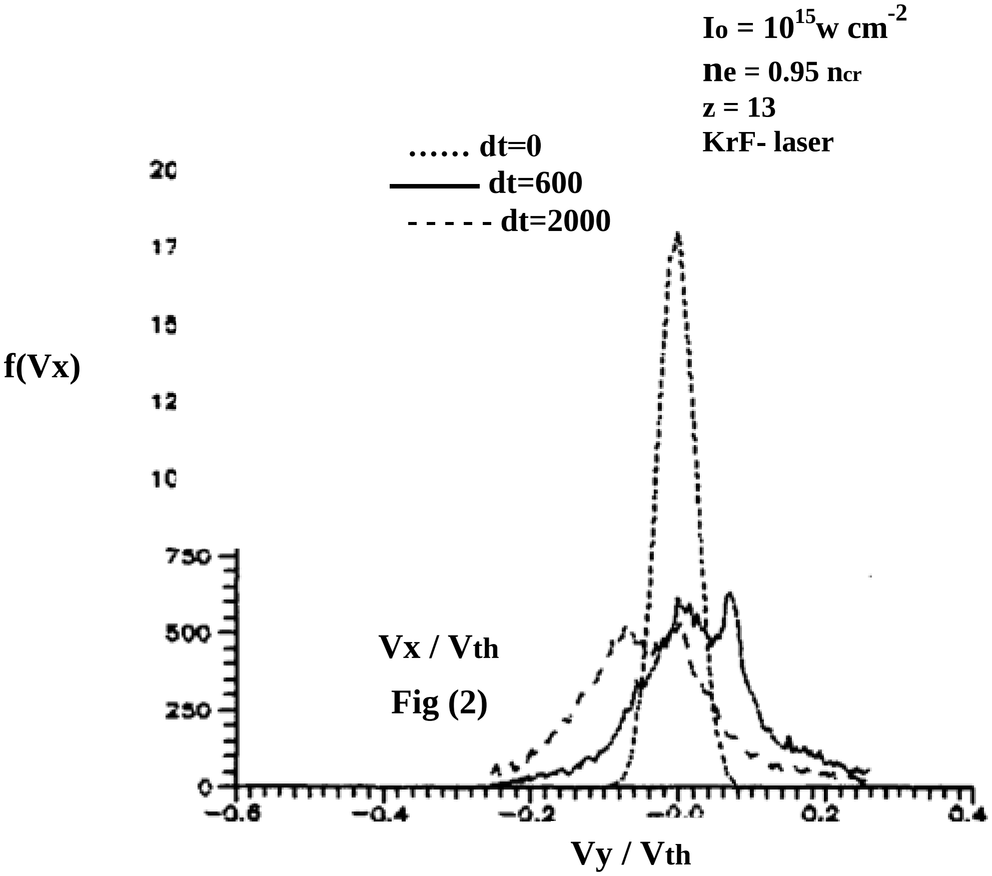
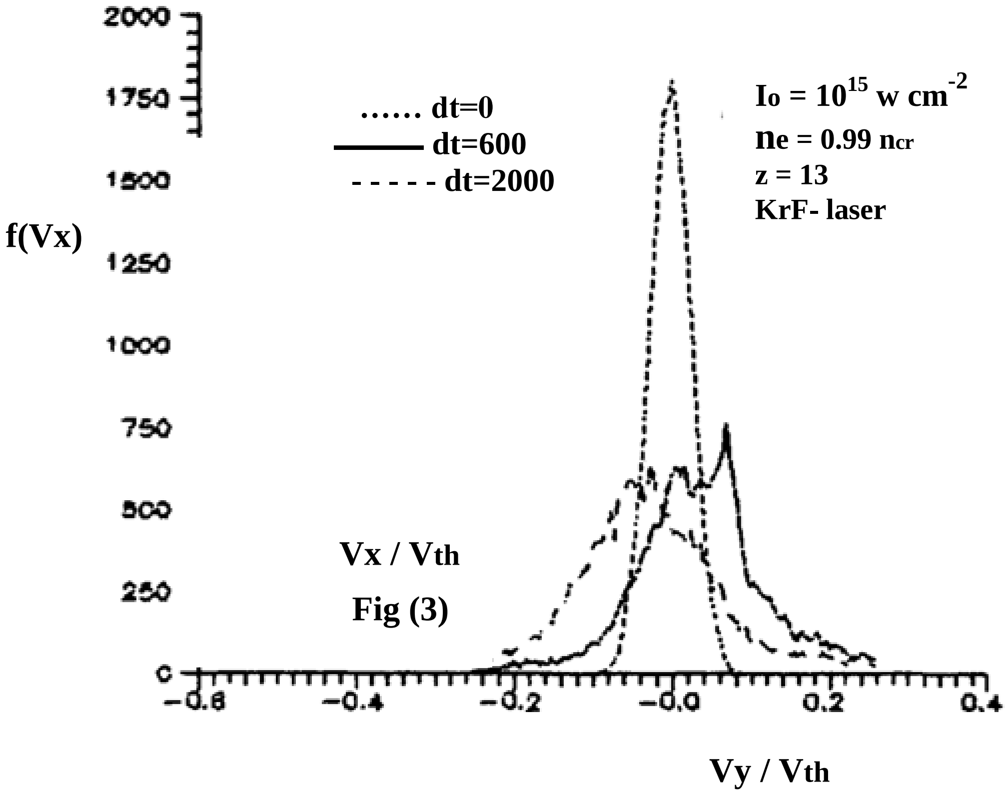

Io = 10^15 w cm^-2
ne = 0.95 ncr
z = 13
KrF- laser
…… dt=0
——— dt=600
- - - - - dt=2000
f(Vx)
20
17
15
12
10
750
500
250
0
Vx / Vth
Fig (2)
-0.6
-0.4
-0.2
-0.0
0.2
0.4
Vy / Vth

Fig (2)


2000
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1500
1250
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750
500
250
0
f(Vx)
…… dt=0
——— dt=600
- - - - - dt=2000
$I_o = 10^{15}$ w cm^{-2}
$n_e = 0.99\ n_{cr}$
z = 13
KrF- laser
Vx / Vth
Fig (3)
−0.6
−0.4
−0.2
−0.0
0.2
0.4
Vy / Vth

Fig (3)

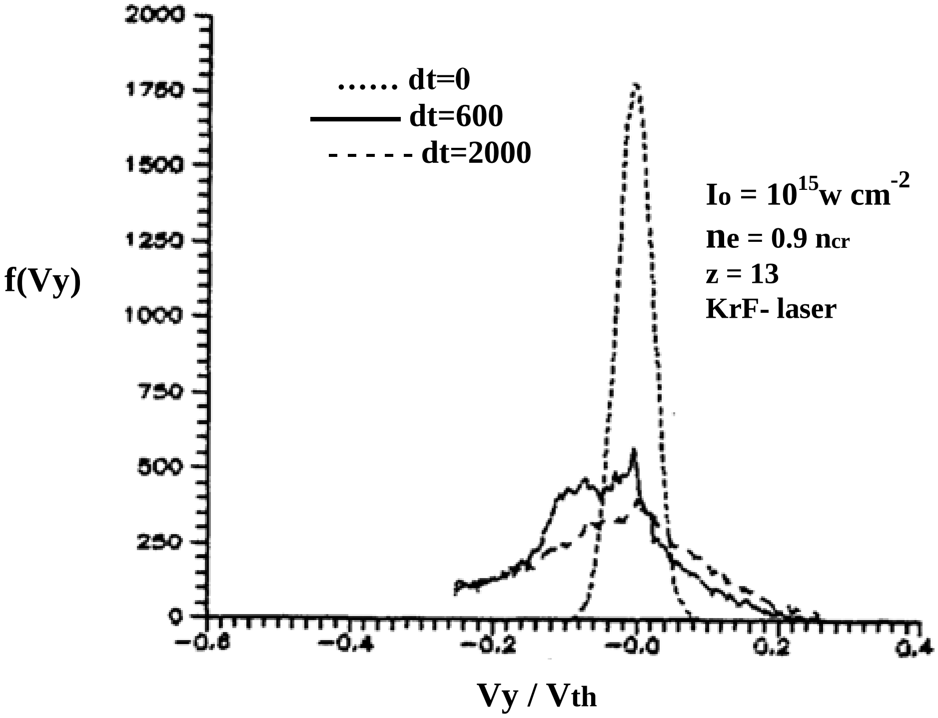
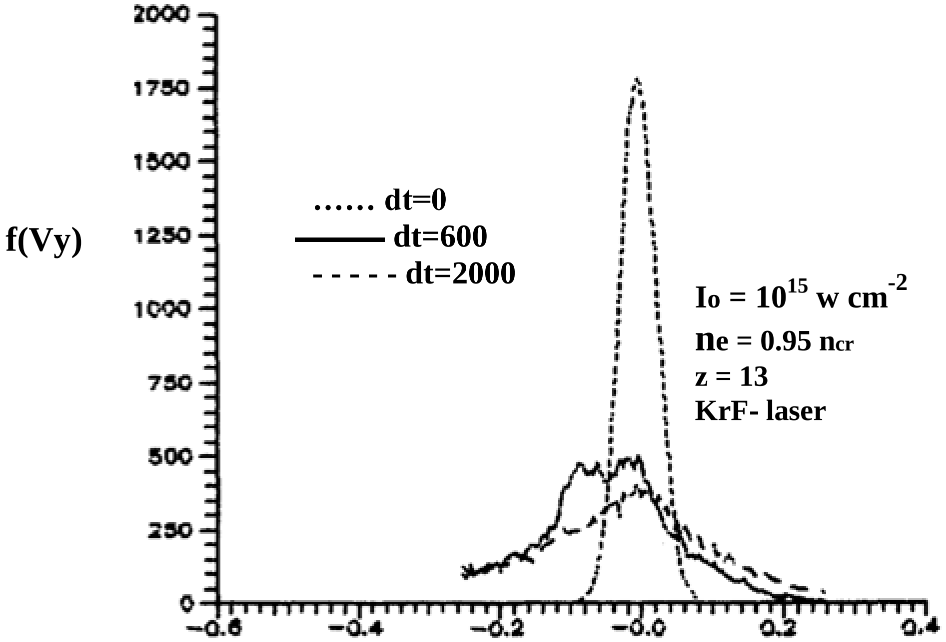

2000
1750
1500
1250
1000
750
500
250
0
-0.6
-0.4
-0.2
-0.0
0.2
0.4
f(Vy)
Vy / Vth
…… dt=0
—— dt=600
- - - - - dt=2000
$I_o = 10^{15}$ w cm^{-2}
$n_e = 0.9\ n_{cr}$
z = 13
KrF- laser

Fig (4)



Vy / Vth

Fig (5)

Vy / Vth

Fig (5)

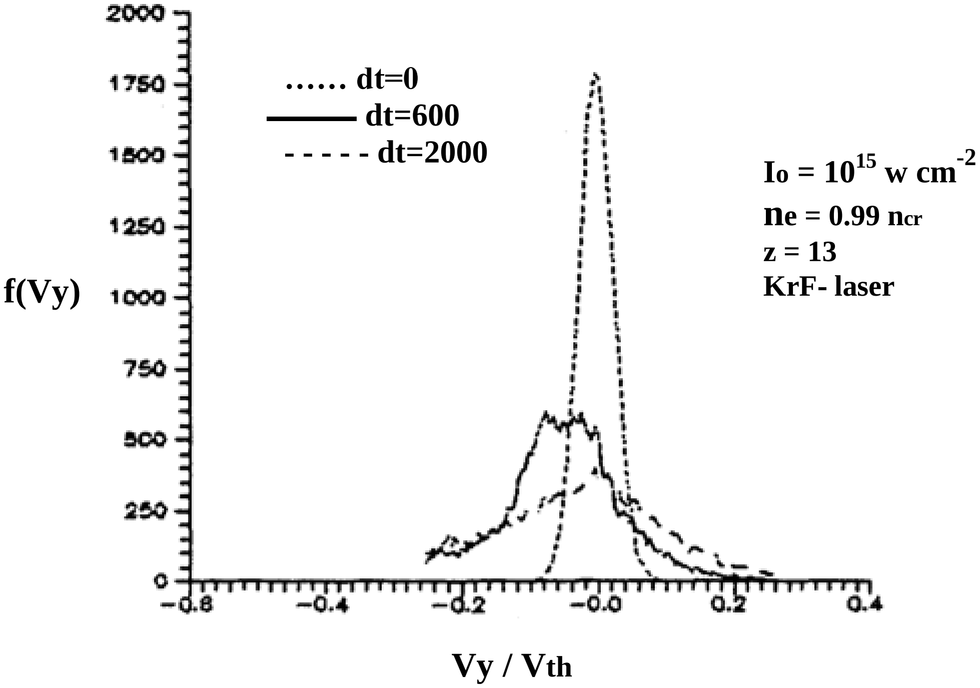

…… dt=0
dt=600
- - - - - dt=2000
Io = 10^15 w cm^-2
ne = 0.99 ncr
z = 13
KrF- laser
f(Vy)
2000
1750
1500
1250
1000
750
500
250
0
−0.6
−0.4
−0.2
−0.0
0.2
0.4
Vy / Vth

Fig (6)