NOTE

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Charged particle dynamics in the field of a gamma ray laser*

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Recently, physicists have become interested in producing short wavelength, high power coherent laser beams. Efforts are going on to develop gamma ray lasers (grasers) (Husain and Gupta 1990, Jones 1988 and Baldwin *et al* 1981) and these may yield a large number of applications (Baldwin *et al* 1981, Hecht 1987).

In this short note, we present a model calculation for the interaction of a charged particle with a gaussian graser beam. Our results indicate interesting physics in the form of either reflection or transmission or trapping of the particle for large times.

Let us assume a particle of charge q, mass m and initial velocity v_0 moving in x-direction interacts with the graser beam propagating in the z-direction (see Figure 1) described, at time t, by the electric field

$$E(x, t) = E_0 \sin \omega t \exp(-x^2/R^2)$$

where E_0 is the constant electric field of the graser beam along the z-axis, ω is its angular frequency, and R is a parameter representing the beam width. The magnetic and radiative reaction forces acting on the particle are negligible in comparison to the electric force provided the velocity v_0 is non-relativistic. Thus the equation of motion for the particle interacting with the graser beam is :

$$d^2x/dt^2 = (qE_0/m) \sin \omega t \exp(-x^2/R^2).$$

This equation was numerically solved for $m = 9.1 \times 10^{-31}$ kg, $q = -1.6 \times 10^{-19}$ Coulomb, $\omega = 2\pi \times 10^{19}$ rad/sec, $R = 5 \times 10^{-4}$ met and $E_0 = 1.7 \times 10^{16}$ volts/met. (the power of the graser beam is taken to be 3×10^{21} watts (Collins 1986 and Hecht 1987)) using the fourth order Runge-Kutta Method (Andrus 1983 and Dorn *et al* 1972).

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In order to see the behaviour of the particle in the graser field we first take v_0 as 10^5 met/sec and $x_0(=x$ at $t=0)$ to be -10^{-8} met. Then the particle first

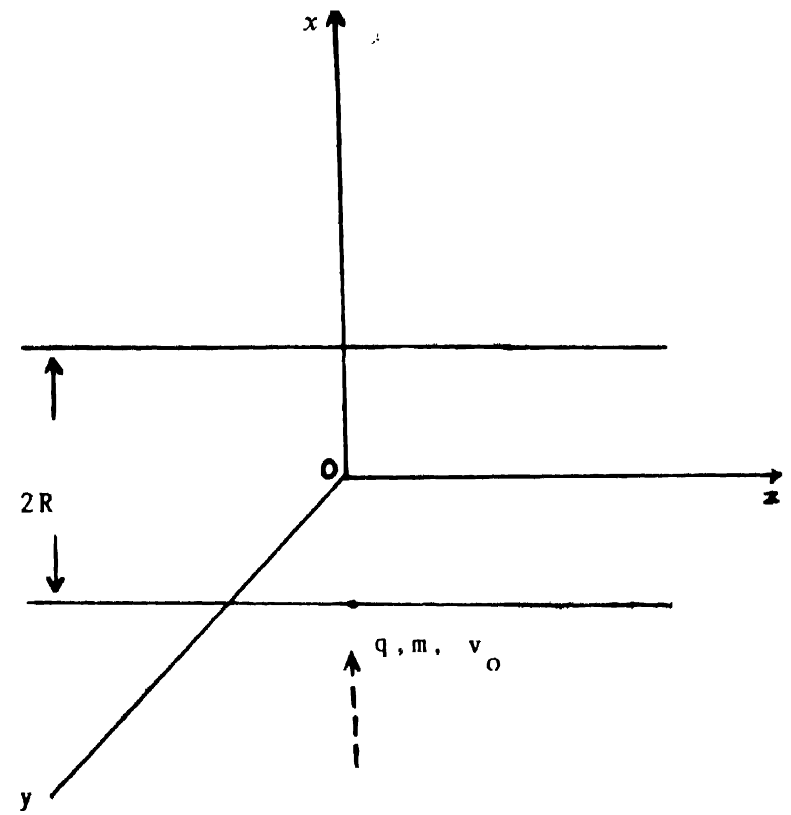
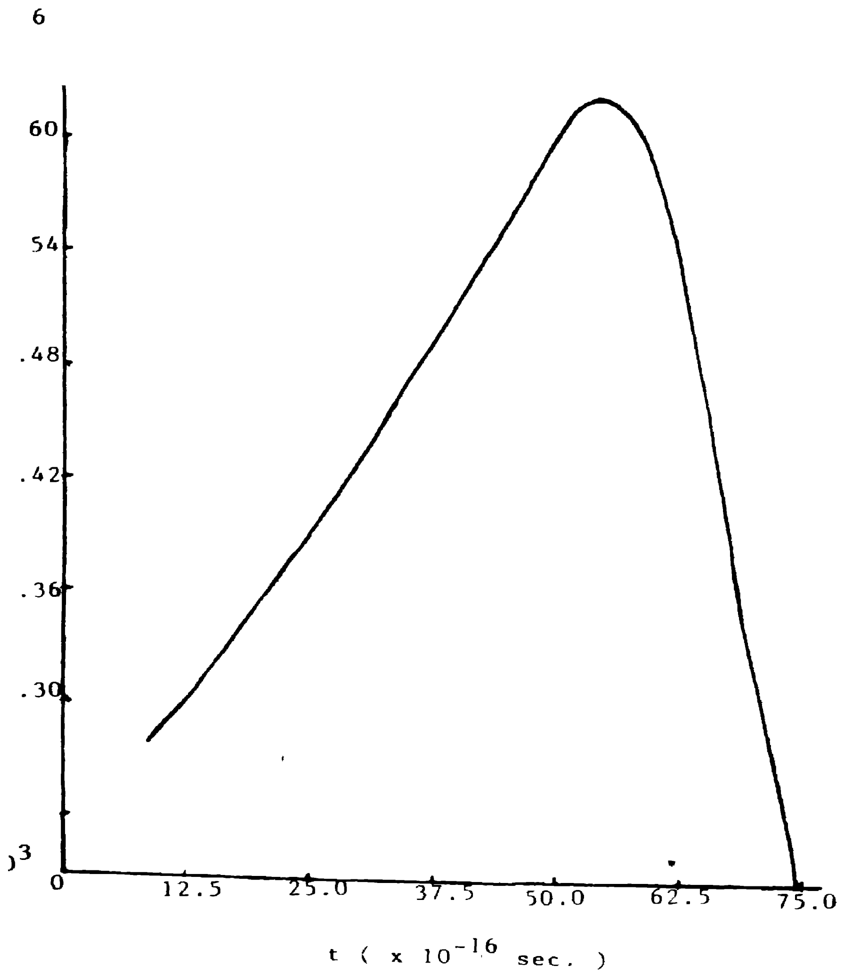


Figure 1. A graser beam and the incoming particle. v_0 is the initial particle velocity.

enters into the field with its own linear momentum but as soon as the graser field overcomes it the particle reflects in the backward direction (see Figure 2).

It is found that the reflectory nature of the particle into the graser field is exhibited until v_0 is raised upto 1.7556×10^6 met/sec. At this higher initial particle velocity the oscillatory motion of the particle into the graser beam is exhibited (see Figure 3). Figure 4 shows the different transit times T, in which the particle crosses the graser beam, at different initial velocities. We see that for higher initial velocities (above 3×10^6 met/sec) the transit time is approximately given by the simple kinematics $T=2R/v_0$, but for lower initial velocities the motion involves dynamics and the transit time abruptly increases as the initial velocity decreases. It also gives an idea of the trapping of a particle for a long time (at least 10^6 sec) inside the graser beam at initial velocities $\gtrsim 1.7556 \times 10^6$ met/sec.



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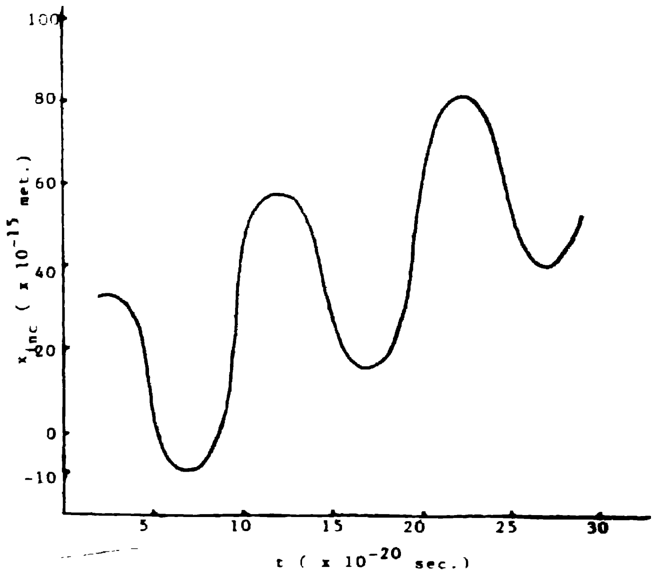

Figure 3 The oscillatory motion of the particle into the graser beam

Acceleration, deceleration and scattering of electrons from a 1064 nm Nd : YAG laser of about 10^{18} watts/cm^2 has been observed (Bucksbaum *et al* 1987). However, trapping of electrons by a laser beam has not been seen so far.

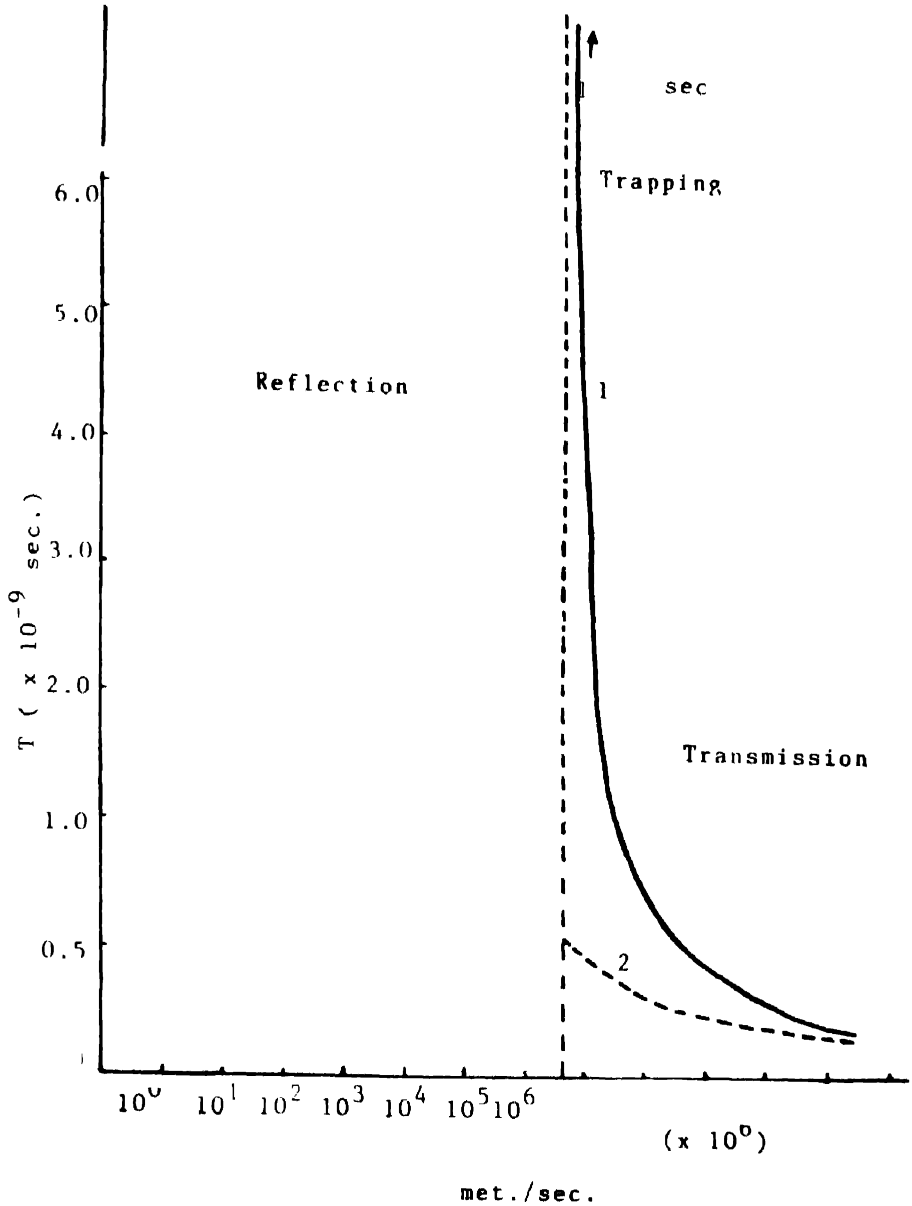

Figure 4. The transit time (T) vs initial velocity (v_0). Curve 1 is for the dynamical motion of the particle in the graser beam. Curve 2 is for purely kinematical motion ($T=2R/v_0$).

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