*31st EPS Conference on Plasma Phys. London, 28 June - 2 July 2004 ECA Vol.**28G**, P-2.011 (2004)*

External Magneto-static Field Effects on Plasma Flows Arising from Primary Electron Acceleration in Two Crossed Laser Beams

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The study reported in this contribution is motivated by the need to model the planned Prague Asterix Laser System (PALS) experiments. In the acceleration configuration explored here, the plasma flow is driven by Coulomb forces arising when fast accelerated electrons escape from the acceleration region. The electrons are accelerated in a single plane laser beam that is in the presence of an additional (secondary) perpendicularly propagating plane laser beam with a randomized phase. The configuration is similar to that explored in a recent paper [1], where, however, the laser powers in both beams were above 1 TW, higher than the critical power for relativistic self-focusing. In contrast to the process described in [1], the electron acceleration in the present study is due to de-phasing of the electron motion by random kicks, as found in [2]. The "random kicks" are provided by the secondary randomized laser beam. The laser frequencies and laser beam electric field intensities chosen for the computations of the primary electron acceleration match the parameters available in PALS [3]. For numerical modeling, we used an advanced version of our 3-d two-fluid code [4], assuming the presence of an external magneto-static field ***B*** directed along the direction of the main laser beam propagation. By using test particle simulations of electron acceleration for parameters relevant to conditions available by the PALS laser, it is possible to determine an effective potential W, which expels and accelerates the ion fluid.

Initially, we explored the dependence of the outgoing plasma (ion) flow on an external magneto-static field B_z. It was assumed that the laser is focused to a line of about 30 mm length along the coordinate axis y, and that the dimensions of the accelerating region along the x and z coordinates are about 1 mm. The main laser beam was assumed to propagate along the axis z. The expelling potential W is due to the charge separation fields, and it is assumed to expel plasma along the coordinate z. In accordance with our previous computations of the average energy of the electron acceleration W [5], the magnitude of W was set to 0.5 MeV. In contrast to our preliminary estimates, we find that the magneto-static field B_z has to be rather strong, at least about 100 Tesla or higher, in order to influence significantly the plasma flow, as depicted in Fig. 1.

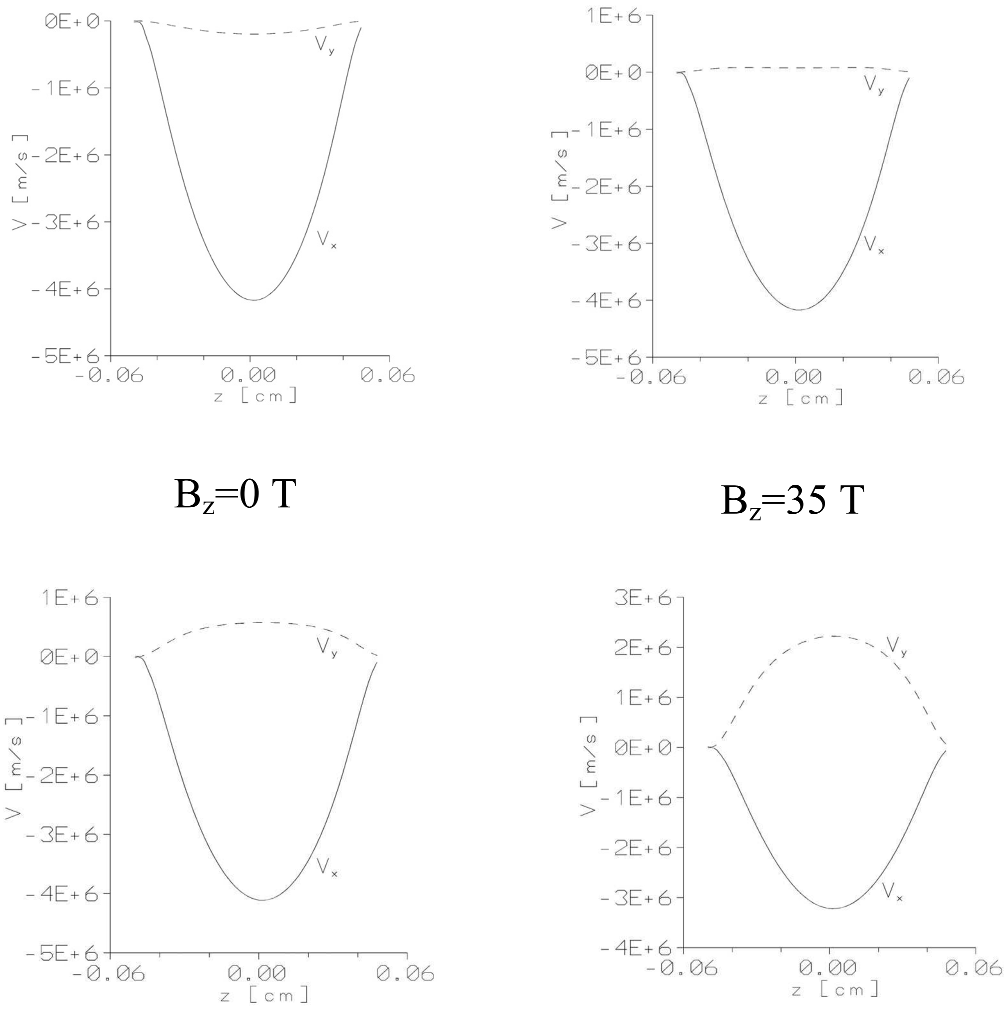


Fig. 1. Perpendicular plasma flows as a function of the external magneto-static field B_z.

Only the perpendicular plasma flow velocity is significantly influenced by B_z; the velocity and the power flux in the direction of B_z are influenced only marginally. On the other hand, a strong dependence of the plasma outflow was found on the transverse dimensions $2L_x$ and $2L_z$ of the interaction region, as Fig. 2 shows. For this case, it is assumed that B_z=0. When L_x and L_z grow, the plasma (ion) flow velocity V_z significantly decreases. This is because the gradient of the expelling potential, and in turn the expelling force, grows. The transverse ion flow velocities also decrease when L_x and L_z grow, their maximum being given by the case of the zero magneto-static field in Fig. 1.

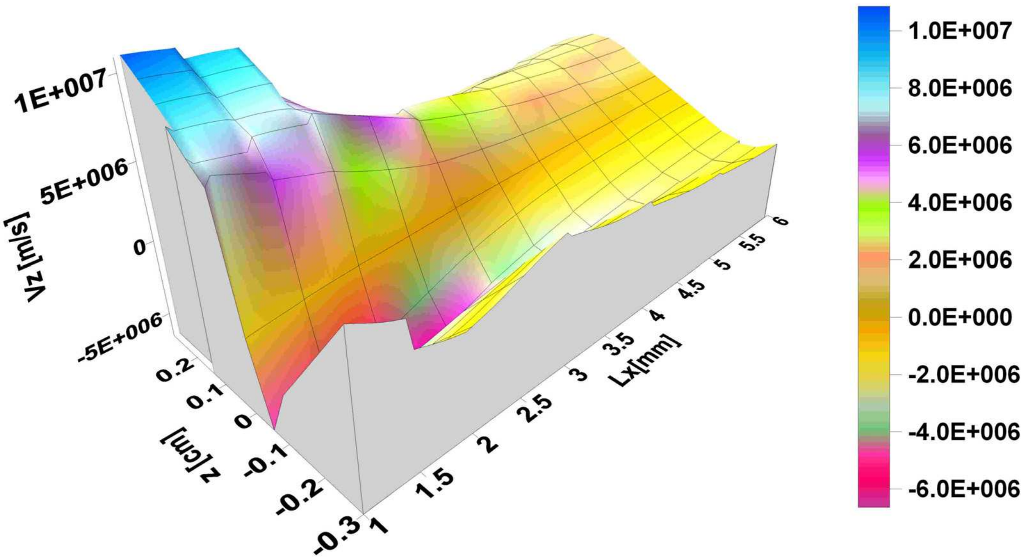
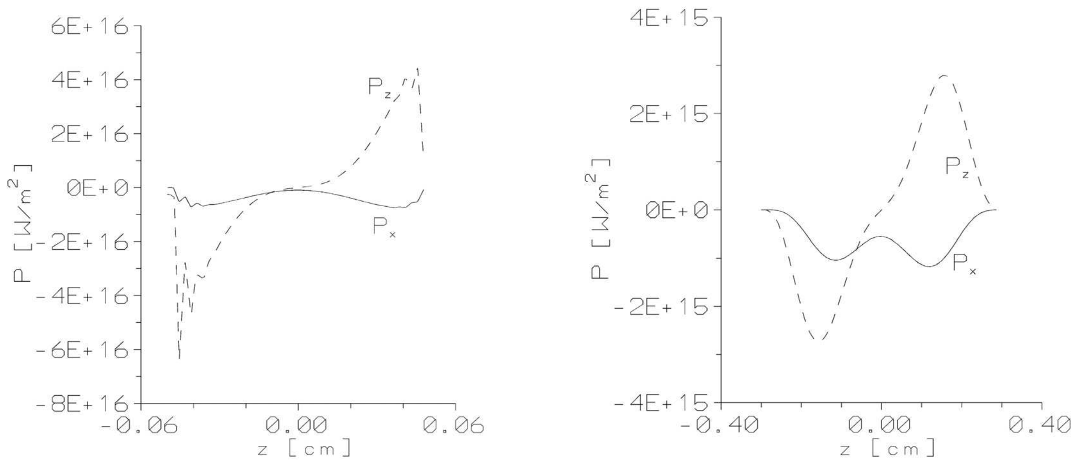


Fig. 2. Ion flow velocity V_z *as a function of dimensions of the acceleration domain.*

For this case, when $L_x = L_z$ =1 mm, the computed power densities in the ion flow are rather high, as Fig. 3 shows. They become comparable to the power flow in the main laser beam, which indicates that the approximation used here reaches its margins, and a self-consistent calculation would be more appropriate.

The above presented results of 3-d modeling demonstrate again [4] that the configuration of the two crossed laser beams can be efficient not only for electron acceleration, but also as an ion source. Since the electron acceleration in this crossed laser beam configuration concerns a large number of electrons in the target plasma [6], including thermal ones, the ion flux also has a high intensity.



$L_x = L_z = 1$ mm $\qquad$ $L_x = L_z = 6$ mm

Fig. 3. Power flux densities in the accelerated ion flow.

Our exploration of the ion flow dependence on the magneto-static field B_z, which is parallel to the main laser beam propagation, shows that the flow depends on B_z only marginally, unless B_z is of the order of 100 Tesla or higher. On the other hand, the intensity of the ion flow grows, when the transverse dimensions of the interaction region decrease. The ion energy can then reach the average energy W of the accelerated electrons, and the power flux in the ion flow can approach the power flux in the main laser beam. This indicates that a self-consistent approach would be needed for small dimensions of the interaction region.

Work partly supported by the Czech grant project GACR 202/04/0360.

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