Resonantly accelerated electrons from a tightly focused laser beam

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One of the most promising techniques to enhance focused laser intensities is to tightly focus the beam using an ellipsoidal plasma mirror. It has been successfully employed to obtain sub-μm spot size [1] resulting in an order of magnitude increase in focused intensity in comparison with a typical spot size of about 4 μm obtained with f/3 off axis parabolic mirror. The tightly focused laser beam has some important properties, which modify the laser target interaction process. First of all, it is associated with a large curvature of the wavefront of the laser beam out of focus, which has an influence on the propagation angle of accelerated particles. Secondly, the field is not purely transverse but it also includes non-negligible longitudinal field components.
In particular the longitudinal electric field is very important as its amplitude is $\sim 0.14\lambda_0/w_0$ of the transverse field at the periphery of the focal spot, where l0 is the laser wavelength and w_0 the Gaussian beam waist.

The electron acceleration process under tight focusing is studied using PIC simulations with the code EPOCH [2]. The electrons are first pulled from the target surface by the longitudinal component of the laser electric field. In the next phase, the electrons are accelerated by the transverse laser electric field component. Depending on their distance from the target surface, they are accelerated either towards the center of the focal spot (electrons close to the target surface) or in the opposite direction as the transverse component of the laser electric field has a different phase in these two regions. Finally, the v×B Lorentz force accelerates these electrons into the target or into the vacuum away from the target and they propagate further ballistically. As the longitudinal field has an opposite phase on both sides of the focal spot, the bunches originating from this process are phase shifted by half a laser period and they propagate in different directions because of the wavefront curvature. This opens the possibility to diagnose the absorption process with coherent transition radiation (CTR) at the rear side of the target, where the bunches arrive at a rate given by the laser frequency (ω_0) in contrast with the simple v×B heating process where the rate is given by $2\omega_0$.

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References

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