Formation Mechanism of Periodic Nano-grating Structures on Metal Surface Induced by Short Pulse Laser

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It was found in many experiments that repeated irradiations of short pulse lasers could form periodic nanostructures on metal surfaces [1-3]. The formation mechanism of such structures was suggested [4,5], but it is not fully understood yet. Therefore we use two-dimensional relativistic electromagnetic PIC (Particle In Cell) code, in which relativistic equations of motion for charged particles and Maxwell equations for electromagnetic fields are simultaneously computed in two-dimensional space and three-dimensional velocity space, to simulate laser-plasma interactions and to investigate the formation mechanism.

When the laser intensity is relativistic ($I_L\lambda_L^2=10^{18}$ W/cm^2-μm^2), the periodic nano-grating structures are clearly self-organized at the boundary between performed plasma and dense plasma. According to time evolution of the magnetic field and the electron current density in the dense plasma, it was found that the Weibel instability plays a significant role to form the periodic nano-grating structures [6].

On the other hand, the periodic nano-grating structures are also formed at the boundary even no Weibel structure is developed in the case of non-relativistic laser intensity ($I_L\lambda_L^2=10^{16}$ W/cm^2-μm^2). As the interspace of the periodic nano-grating structures depends on the plasma density and it can be explained by the dispersion relation of surface plasma wave, the surface plasma wave could play an important role to form the periodic nano-grating structures. Thus in the forming region, bi-directional surface plasma waves are excited and they compose the standing wave, which forms small periodic perturbations by the Ponderomotive force. As the plasma irradiated by the laser is under unstable conditions for the oscillating two-stream instability, the perturbation can grow to form the periodic nanostructure [7].

References

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