DOI 10.25205/978-5-4437-1667-1-4

Electromagnetic phenomena in laser processing of materials

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The nanoscale pattering of materials and surfaces is extremely important for a broad range of practical applications. Nanopatterning techniques that are fast, efficient, and do not require a mask are particularly attractive. Here, I will discuss two such examples. The first concerns the formation of Laser Induced Periodic Surface Structures (LIPPS) upon irradiation with high-energy fs pulses [1, 2]. I will focus on metals and I will discuss the case of thin films [3]. In such cases, both symmetric and antisymmetric surface plasmon waves can be excited. Their interference shapes the distribution of energy deposition (absorption) and can thus largely dictate the resulting surface topology. I will show that it can be tailored through the film thickness and the sub-/super-strate properties. The second concerns the utilization of nanoparticles to produce locally-enhanced fields (photonic nanojets) [4]. This field enhancement can improve the structuring capabilities of a laser beam, reducing the power requirements and enhancing the resolution. By varying the characteristics of the particle (diameter, material), one can tailor the properties of the formed nanojet, namely, maximum achieved field enhancement, “focal distance”, and spot size.

In both cases, we numerically calculate the electromagnetic fields by rigorously solving Maxwell’s equations with the Finite Element Method (FEM) [5]. Following energy deposition (absorption) on the surface, a complex physical process initiates that involves heat transfer and mass transfer (material melting and resolidification) or removal (ablation) and ultimately leads to the formation of the resulting surface topology. Tracing the connection between the distribution of the energy deposition and the resulting surface topology is a standing open issue [6].

The author acknowledges collaborators Dr. G. Perrakis, Dr. G. Tsibidis, Dr. E. Stratakis, Dr. P. Lingos and Dr. M. Kandyla, Dr. S. Starinskiy, N. Chouchoumi.

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