Plasmonic nanotweezers based on femtosecond-laser nanostructured substrates

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Optical tweezers are widely employed for various applications, however the efficiency of conventional optical tweezers is limited when trapping nanoparticles. Following recent advances in nanophotonics, optical manipulation by evanescent plasmonic fields instead of conventional propagating fields has been successfully demonstrated for nanoparticles with promising results. [1]

In this work, we report on the enhancement of optical trapping forces induced by the plasmonic field of femtosecond-laser nanostructured substrates. We employed a home-built optical trapping setup, using either a CW infrared (1070 nm) N-light fiber laser or a femtosecond Ti:sapphire laser system with a tunable emission wavelength of 750 nm – 1080 nm, followed by an optical parametric oscillator with an output wavelength of 1000 nm – 1300 nm. We trapped and measured the optical forces on polystyrene nanobeads (400 nm diameter), suspended on top of femtosecond-laser nanostructured silicon substrates with quasi-periodic sharp spikes (height ~200 nm), coated by thin metallic layers (Ag or Cu/Au), as shown in Fig. 1. Upon coating, the formation of metallic nanoparticles instead of a smooth metallic film is favoured on the substrates, due to the nanometric roughness of the surface of laser-structured silicon. The nanobead solution was imaged by fluorescence excitation with a blue laser diode that was focused on the solution through the trapping objective lens, forming an inverted fluorescence microscope.

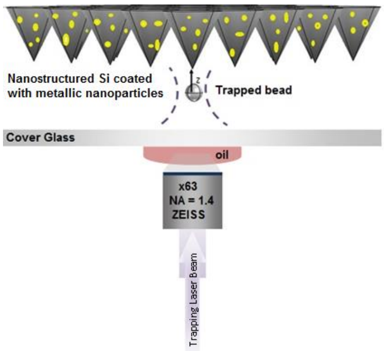

Figure 1: Optical trapping setup.

The optical trapping force is enhanced by a factor of 12 near the substrate surface and the quality factor of the trap presents an exponential decay with the distance from the substrate, which follows the decay of the near field of the coated nanospikes. The quality factor increases for wavelengths approaching the plasmon resonance of the substrate. The combination of quasi-periodic silicon nanostructures with metallic nanoparticles results in electromagnetic near-field enhancement of the trapping force, due to the excitation of localized surface plasmons on the substrate.

References

[1] M.L. Juan, M. Righini, and R. Quidant, Nature Photonics **5**, 349 (2011).

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