Nanostructured glass fibres for optical trapping of nanoparticles

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Summary

We introduce metal coated and nanostructured optical fibres for nanoparticle trapping. Information is provided on the probe manufacturing and design, with the distribution of the optical forces simulated with the finite element method.

Introduction

In order to trap smaller structures with optical tweezers and avoid laser damage of the object, strong gradient fields are necessary. Of particular relevance is the work by Juan et al., where a nanoaperture in a metal film enables trapping of a polystyrene sphere with 50nm diameter at only 1.9mW [1]. In order to further develop this technique, we have made and studied a gold coated and nanostructured optical fibre tip.

Discussion

As demonstrated previously, a focused ion beam (FIB) is able to manufacture nanoscopic slots on a metal coated fibre tip, enabling efficient light confinement beyond the diffraction limit [2]. Further developing this work, different slot geometries are studied in order to achieve efficient optical trapping of nanoparticles.
To produce the probes, tapered glass fibres were first horizontally cut with a FIB to obtain an apex of a few micrometres. After subsequent evaporation of a gold layer, apertures as in Fig 1a were milled through the metal into the glass fibre.
Fig 1b shows the simulated field distribution with a 200nm polystyrene particle in aqueous media, close to a probe similar to the one presented in Fig 1a (tip apex diameter: 3µm, gold layer thickness: 100nm, annular slot diameter: 500nm, slot depth: 500nm). For visibility and computing reasons, only a quarter of the symmetrical system is displayed. High optical intensity (displayed in $W \cdot m^{-2}$) is visible when the particle is close to the aperture, related to an influence of the object on the aperture´s transmission resonance based on a change of the local refractive index. This self-induced principle will drag an escaping particle back to the highest energy location (“back-action”) [1]. The dependency of the simulated optical forces on the particle position shows that stable trapping occurs inside the aperture. Currently, design parameters and other designs of the aperture are being studied for higher field localization.
A trapping set-up is currently being tested and first experimental results are expected later in 2013.

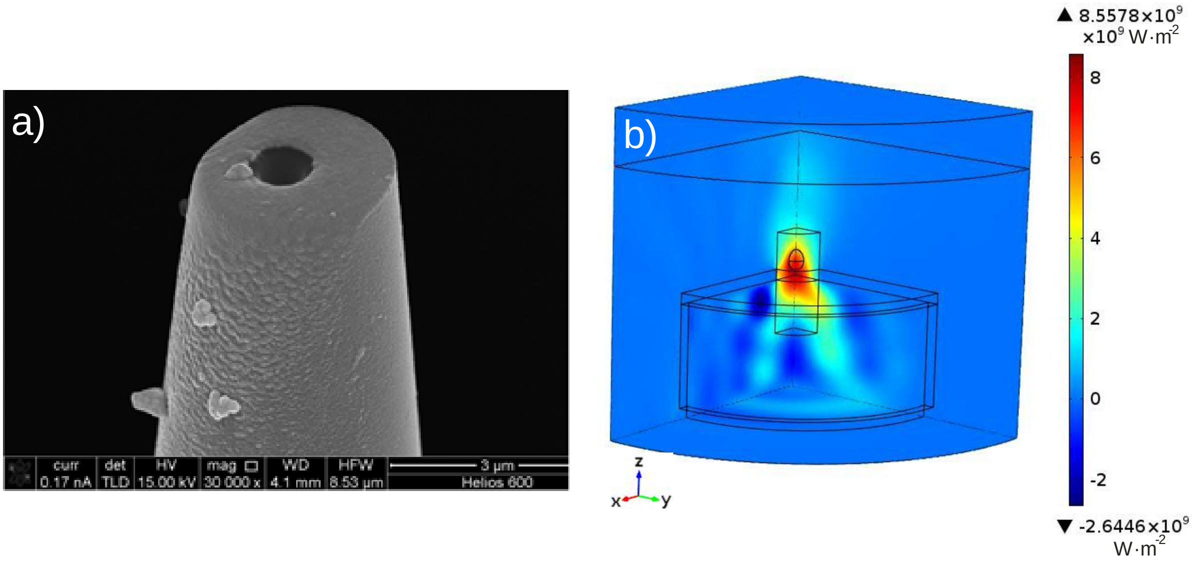

Fig 1: a) SEM image of a gold-coated, nanostructured glass fibre apex. The annular slot has a diameter of 500nm. b) Model of a system containing a 200nm spherical particle close to a probe with cylindrical opening. Only a quarter is simulated due to symmetry. It visualizes the high optical near field density that is induced by the aperture and the particle.

Conclusions

FIB manufacturing and modelling results demonstrate the viability of developing a back-action optical trapping system on fibre tips. The system is promising for, e.g., biomedical applications.

References

[1] M.L. Juan, R. Gordon, Z. Pang, F. Eftekhari, R. Quidant, Nature Physics, **5**, 915, 2009

[2] M. Ding, O. Fenwick, F. Di Stasio, J.Y. Ou, N. Sessions, Y. Jung, F. Cacialli, G. Brambilla, Optics Communications, **285**, 4688, 2012