How the size of a particle approaching dielectric interface influences its behavior

Equilibrium position of particle trapped in common single beam trap (SBT) is slightly beyond the trapping laser beam waist. However, the weak Gaussian standing wave (GSW) component of the resulting field is generated, when the beam is reflected on the bottom slide of the sample chamber. Even the common glass-water interface (reflectivity R=0.4%) generates GSW strong enough to influence the axial position of trapped particle up to the distance several μm from the interface. Particles of different sizes are influenced by the GSW differently.

In the plots on left, there is a comparison between z -z  value and TPF signals – the TPF signal is higher for larger particles.

The measurement series are divided into three groups:
- particles highly sensitive to the GSW – represented by spheres of radius 0.345 μm
- particles moderately sensitive to the GSW – spheres of radii 0.3 μm and 0.465 μm
- particles least sensitive to the GSW – spheres of radii 0.245 μm and 0.41 μm

To find out the behaviour of particles of different sizes quantitatively, we acquired large number of z -z  values for each of the particle sizes. Their average values and standard deviations are put in the plot (right figure) together with theoretical sensitivity.

The examples of measurement results can be found in following plots. Each plot consists of QPD (blue) and TPF (red) signals in region of interest, which are already processed and calibrated. Saw-tooth profile of the QPD signal is well-defined and it is shown, that each maximum of z -z  corresponds to minimum of TPF signal. Each plot contains also inset with several peaks following the 4 μm range – signals in insets are already smoothed and unbent. All insets have the same scale, so the differnce between modulation depths can be roughly compared with naked eye.

CONCLUSIONS

In this work we demonstrated experimental research on behaviour of optically trapped particles approaching the dielectric interface. It was shown that even common glass bottom slide with reflectivity R=0.4% creates GSW strong enough to deflect particle from its SBT equilibrium position. We measured this behaviour on particles of radii 0.245 μm, 0.3 μm, 0.345 μm, 0.41 μm and 0.465 μm. The experimentally obtained data were compared to theoretical prediction of the effect. We have proven that for particle sizes 0.245 μm and 0.41 μm in radius, the unwanted jumps in weak GSW are minimized, whereas when using particle of 0.345 μm radius as SBT probes, the movement exhibits larger jumps when approaching the surface.

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