P9 – Towards Nanonewton Forces: Optical Trapping of Anti-Reflection-Coated Titania Microspheres

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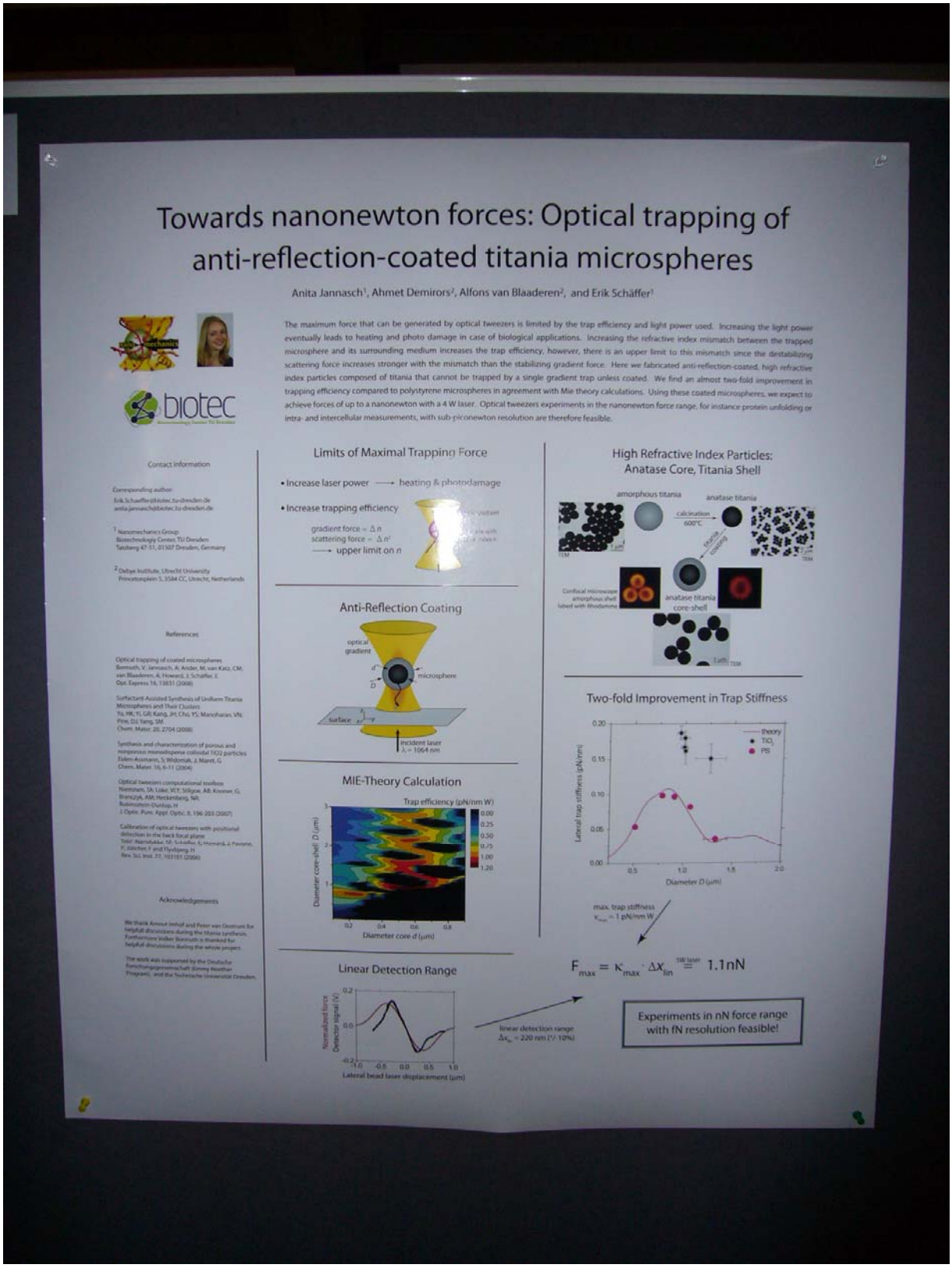
The maximum force that can be generated by optical tweezers is limited by the trap efficiency and light power used. Increasing the light power eventually leads to heating and photo damage in case of biological applications. Increasing the refractive index mismatch between the trapped microsphere and its surrounding medium increases the trap efficiency, however, there is an upper limit to this mismatch since the destabilizing scattering force increases stronger with the mismatch than the stabilizing gradient force. Here we fabricated anti-reflection-coated, high refractive index particles composed of titania that cannot be trapped by a single gradient trap unless coated. We find an almost two-fold improvement in trapping efficiency compared to polystyrene microspheres in agreement with Mie theory calculations. Using these coated microspheres, we expect to achieve forces of up to a nanonewton with a 4 W laser. Optical tweezers experiments in the nanonewton force range, for instance protein unfolding or intra- and intercellular measurements, with sub-piconewton resolution are therefore feasible.


Towards nanonewton forces: Optical trapping of anti-reflection-coated titania microspheres
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Limits of Maximal Trapping Force
• Increase laser power ⟶ heating & photodamage
• Increase trapping efficiency
gradient force ∝ Δ n
scattering force ∝ Δ n²
⟶ upper limit on n
Anti-Reflection Coating
optical gradient
microsphere
surface
incident laser
λ = 1064 nm
MIE-Theory Calculation
Trap efficiency (pN/nm W)
Diameter core-shell D (μm)
Diameter core d (μm)
Linear Detection Range
Normalized force Detector signal (V)
Lateral bead laser displacement (μm)
linear detection range
Δx_lin = 220 nm (+/- 10%)
High Refractive Index Particles: Anatase Core, Titania Shell
amorphous titania
anatase titania
calcination 600°C
TEM
Confocal microscope amorphous shell labed with Rhodamine
anatase titania core-shell
Two-fold Improvement in Trap Stiffness
theory
TiO2
PS
Lateral trap stiffness (pN/nm)
Diameter D (μm)
max. trap stiffness
κ_max = 1 pN/nm W
F_max = κ_max · Δx_lin (SW laser) = 1.1nN
Experiments in nN force range with fN resolution feasible!