Optical Tweezers

(and a few selected applications)

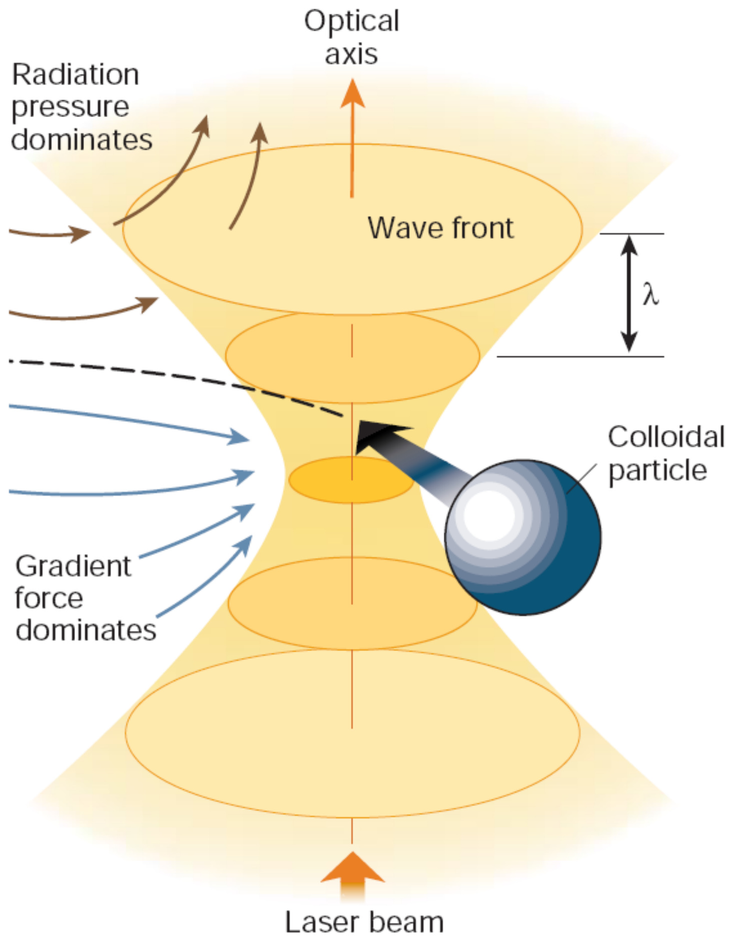
Seminar Talk

„Recent Progress in Nanooptics & Photonics“

Introduction to Optical Tweezers

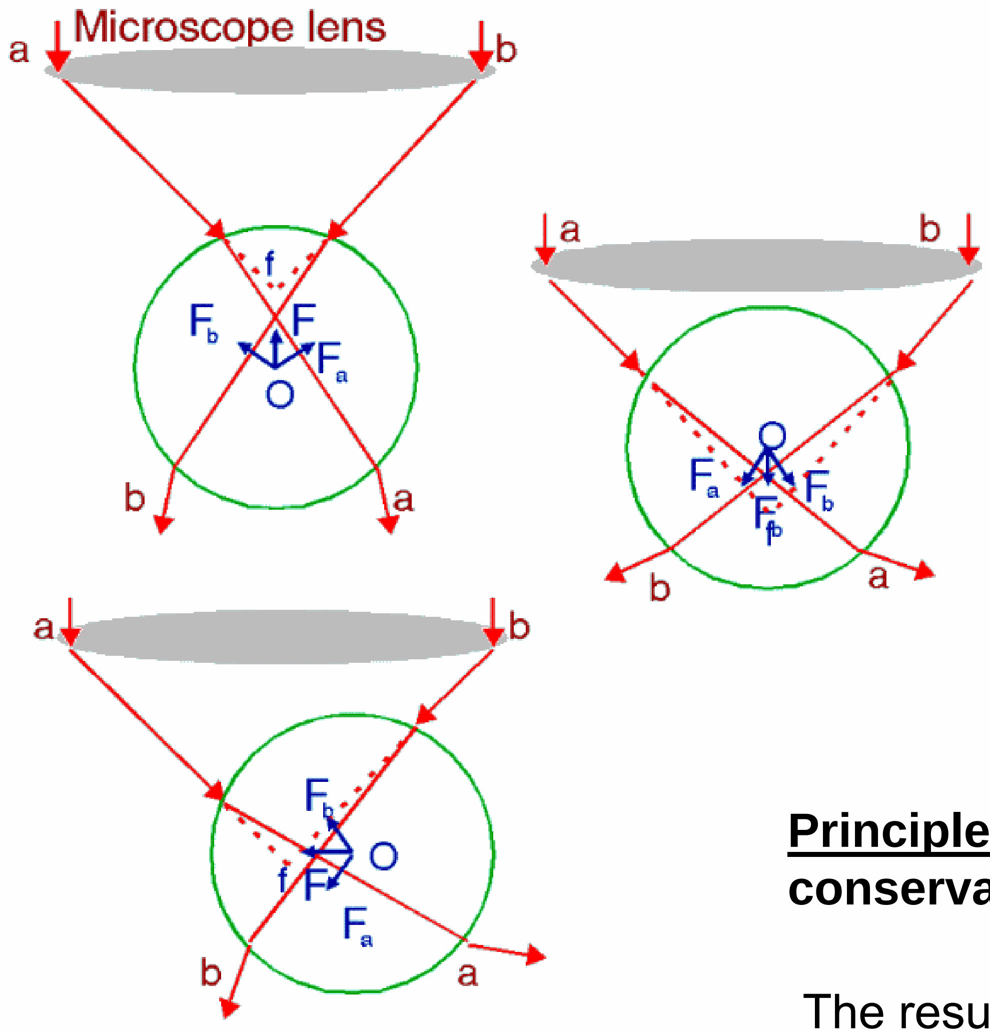
universität wien

- Introduced 1986 by Ashkin & Chu
- Today: Widely used tool in physics, chemistry & biology
- Applicable to objects from nm to µm size
- Simplest form of realization: A strongly focused laser beam
- Driven by two forces
  - Radiation pressure
  - Gradient force



Ashkin, A., Dziedzic, J. M., Bjorkholm, J. E. & Chu, S. Observation of a single-beam gradient force optical trap for dielectric particles. Opt. Lett. ***11****, 288–290 (1986)*

Principle of Operation



Mie-Regime

particle size >> λ

- Not suitable for all materials!
- Transperency is an issue!
- The shape of the particles matters! (usually spherical)

<u>Principle</u>: Refraction of light => momentum conservation

The resulting force is always pointing in the direction of the beam focus!

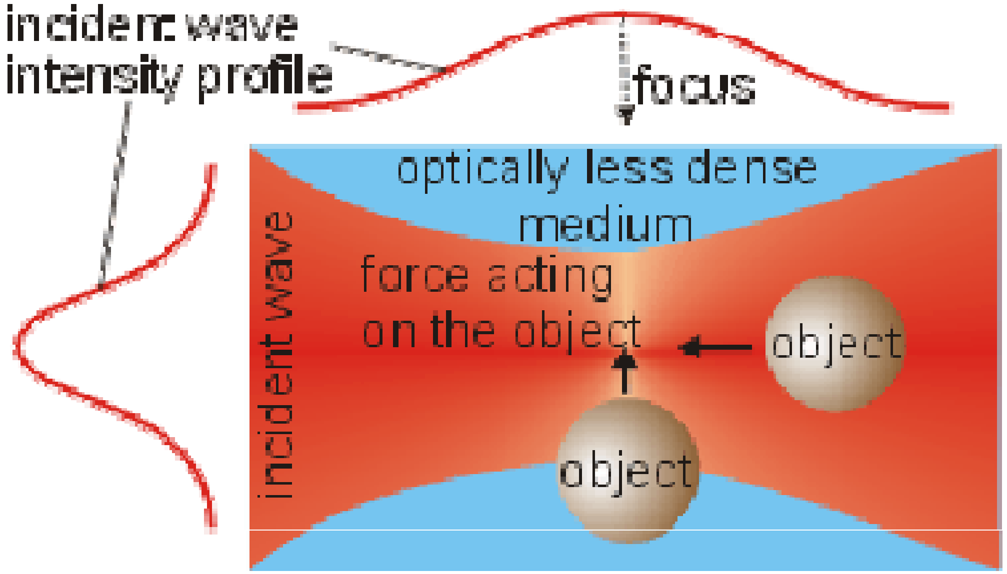
Principle of Operation

Rayleigh-Regime

particle size << λ

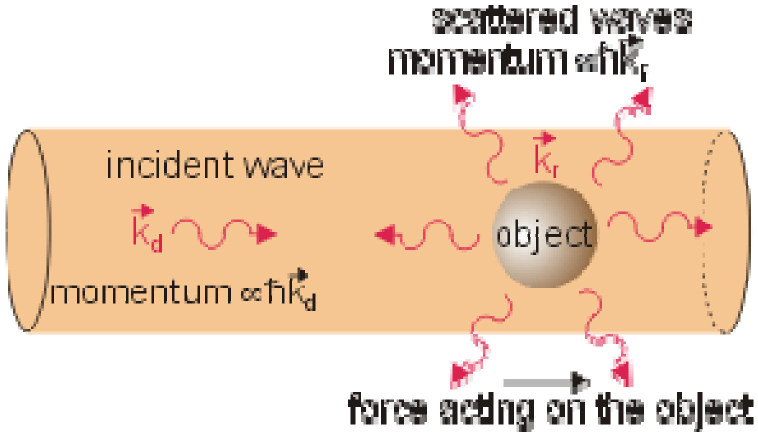
Gradient Force:

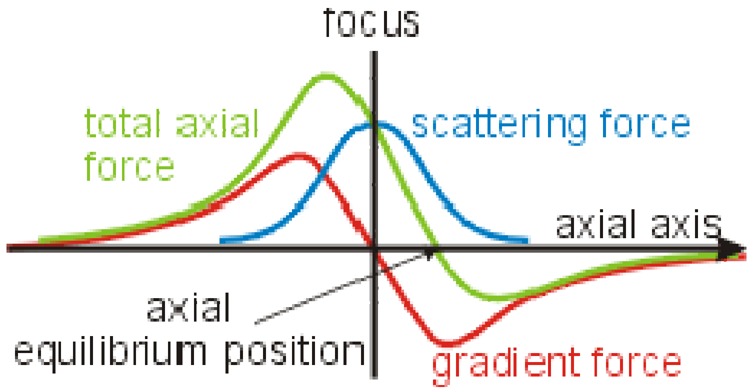
$$F_{grad} = -\tfrac{n}{2}\alpha\nabla E^2$$



Less restriced in particle shape

Scattering Force





- Balancing of scattering and gradient force required
- Equilibrium position exists only if gradient force dominates over the scattering force
- Possible, when the beam diverges rapidly enough from the focal point
- => Usually SBTs are built around optical microscopes

Applications

Manipulation of Nanowires

- Trapping of objects with high aspect ratio (>100)
- 2 dimensions => Rayleigh regime
- 1 dimension => Mie regime
- Used materials: GaN, SnO_2, ZnO, Si, Ag

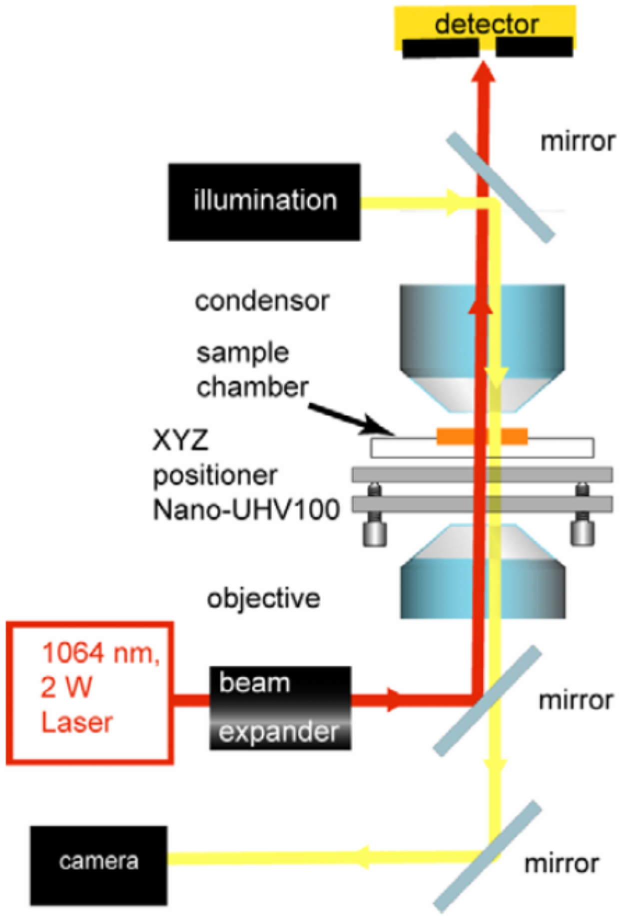
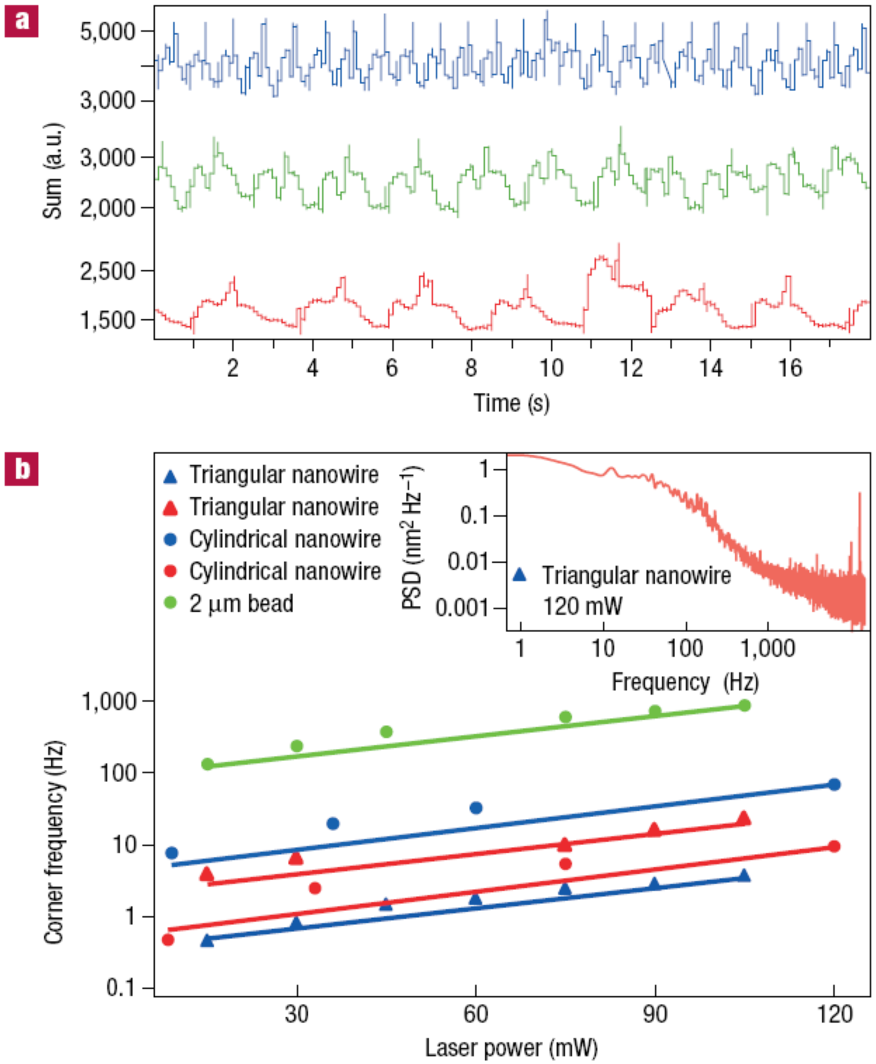


Figure 1. Schematic of the optical tweezers setup.

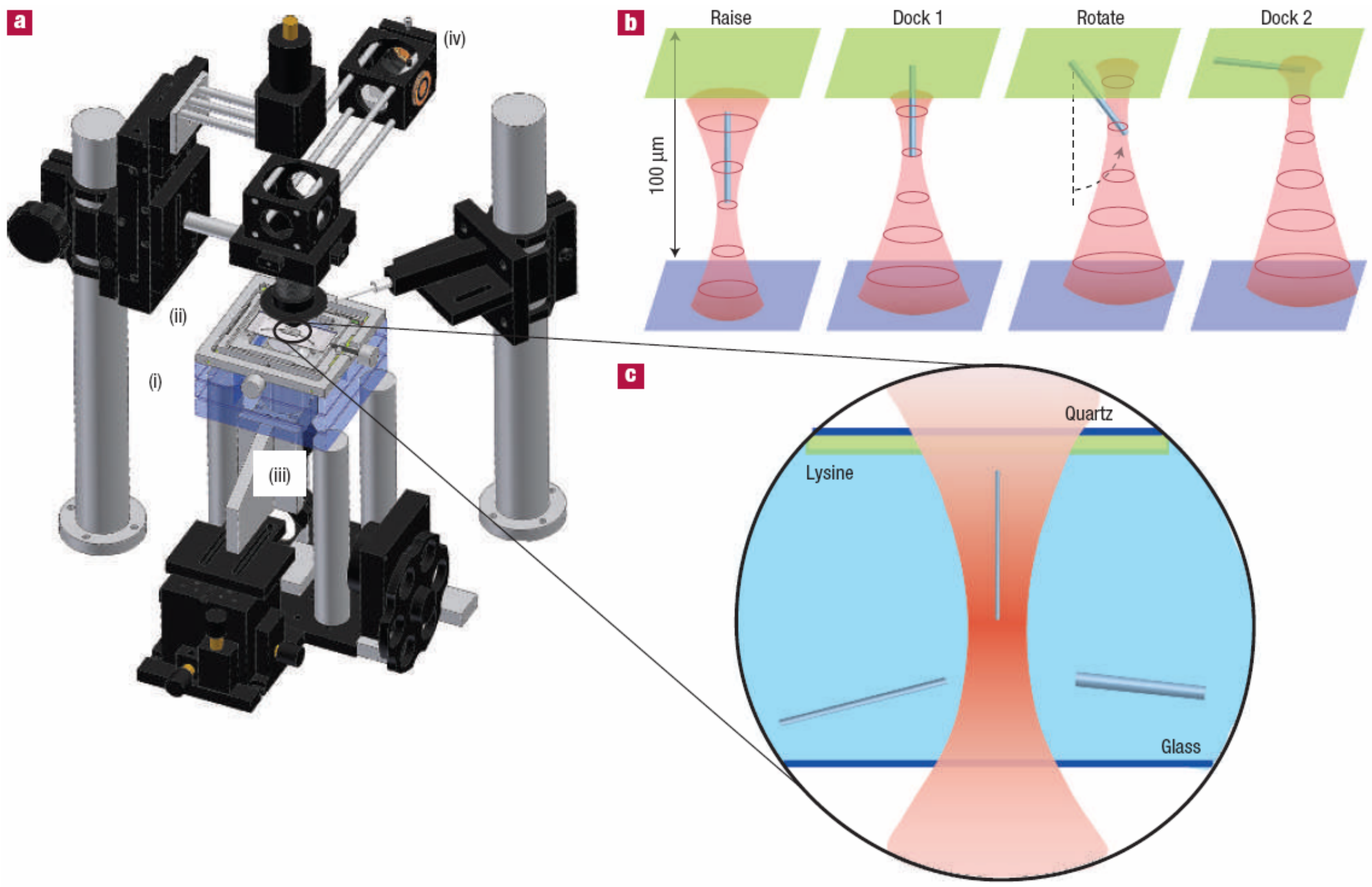
P. Pauzauskie et al., *Nature materials* **5**, 97 (2006)

Manipulation of Nanowires

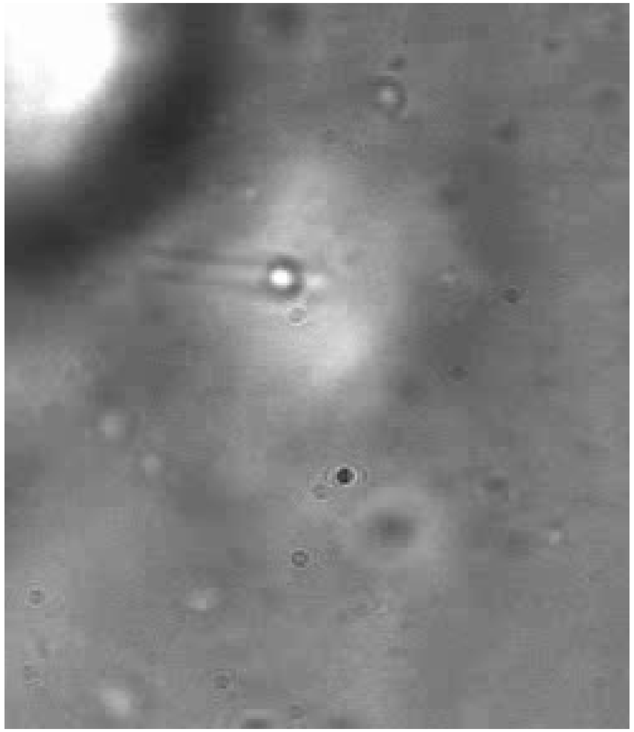


Non-trivial osciallations observed for SnO_2

Manipulation of Nanowires



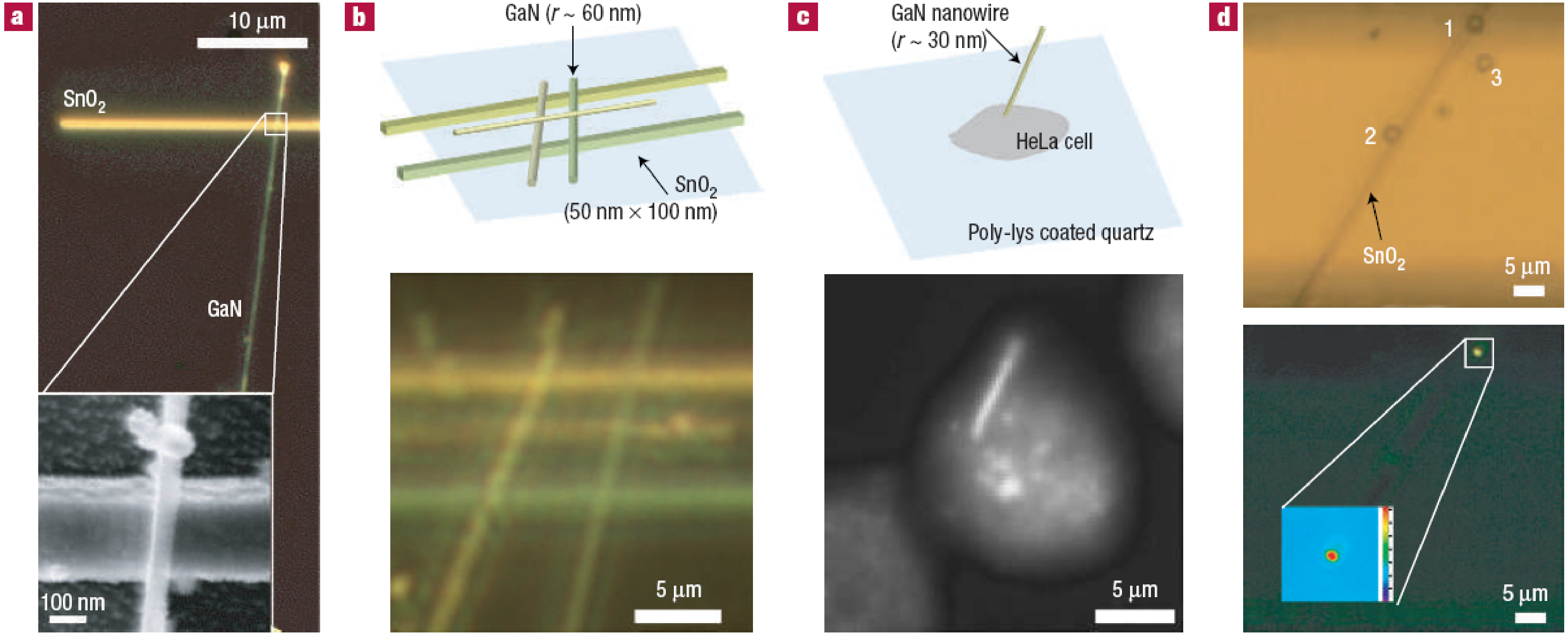
Manipulation of Nanowires



GaN nanowire being scanned across a HeLa cell

- Nanowires can be employed to deliver extremely localized chemical, electrical, mechanical and optical stimuli to living cells

A lab on a chip



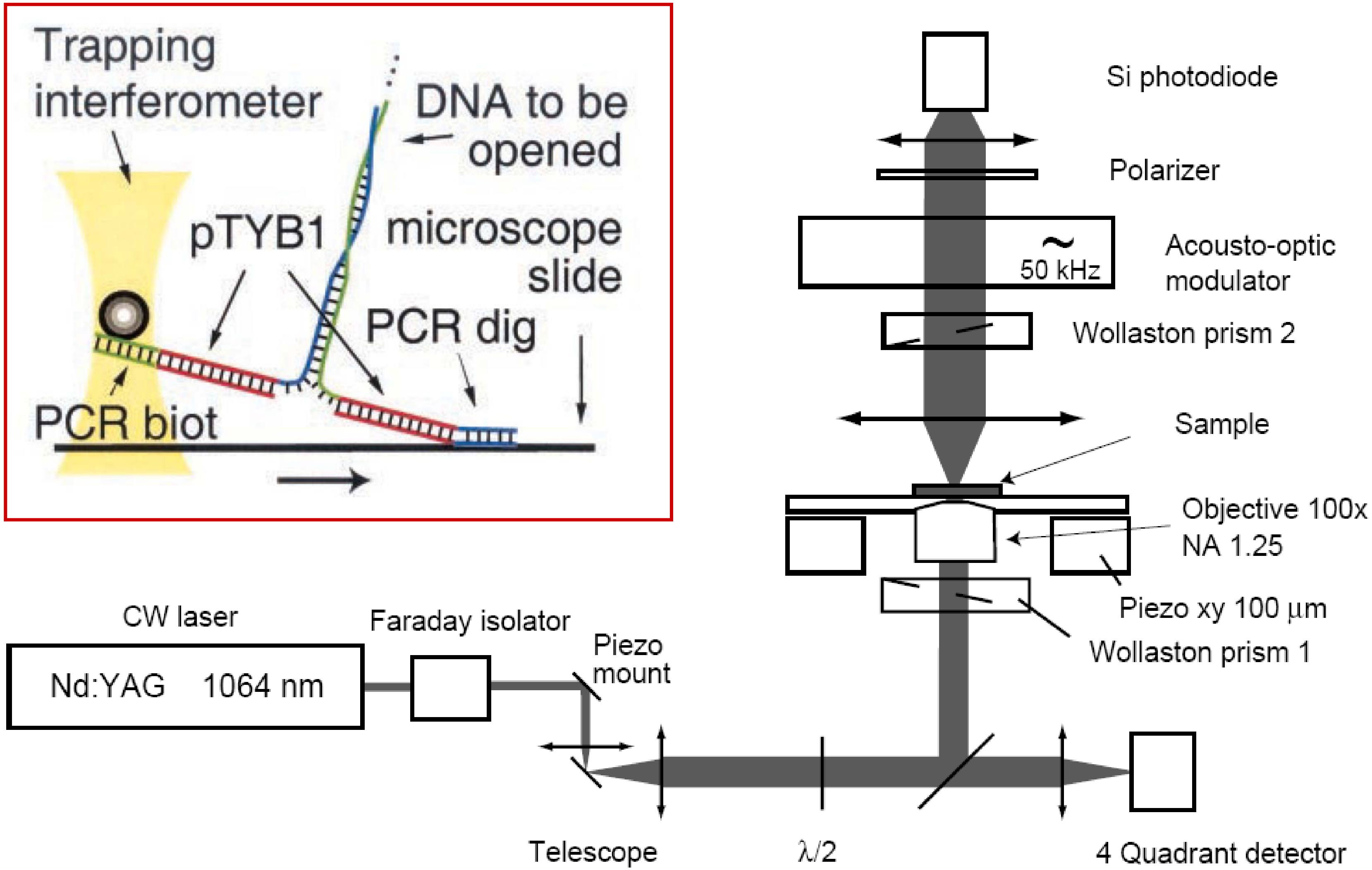
Welding

3D - Assembling

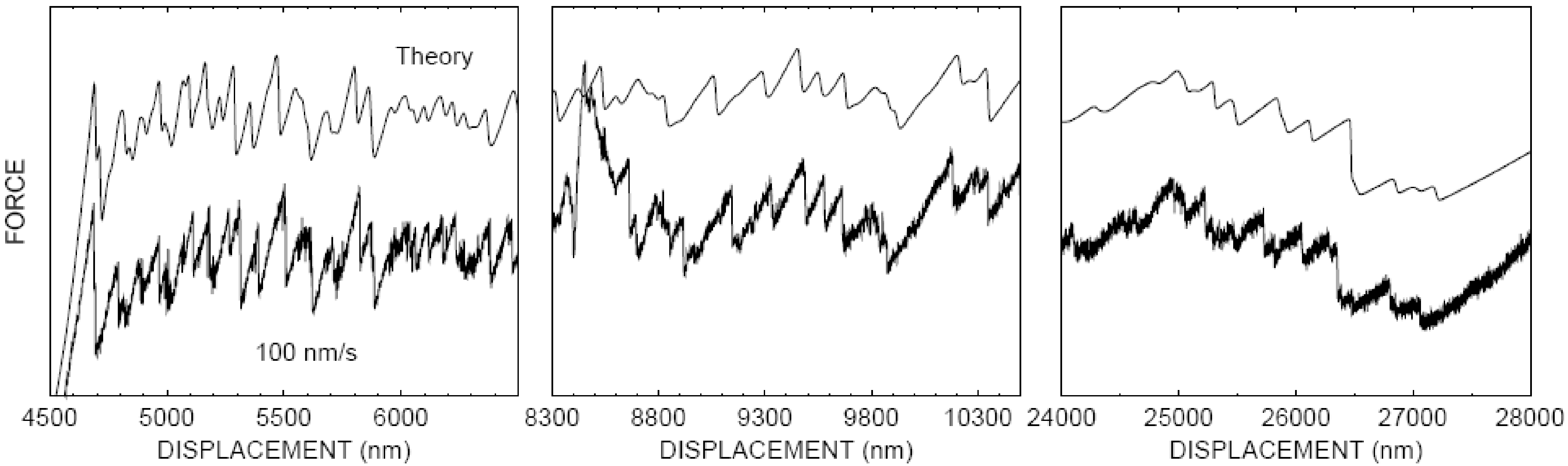
Probing

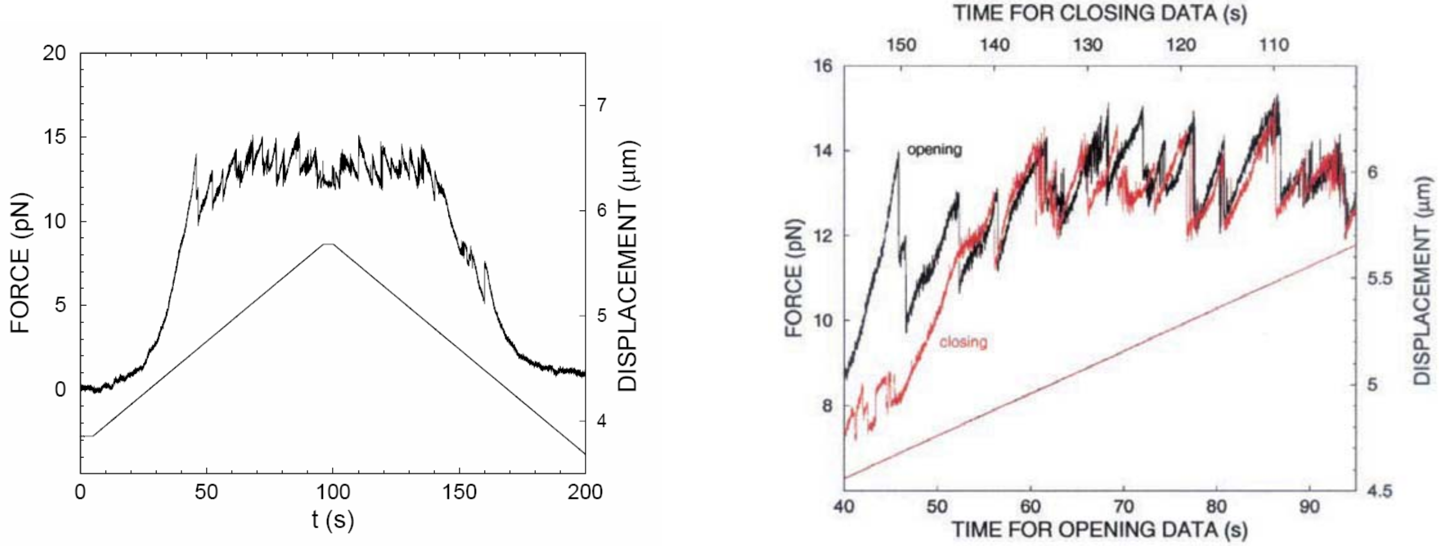
Transmitting light

Tweezers as precise balances

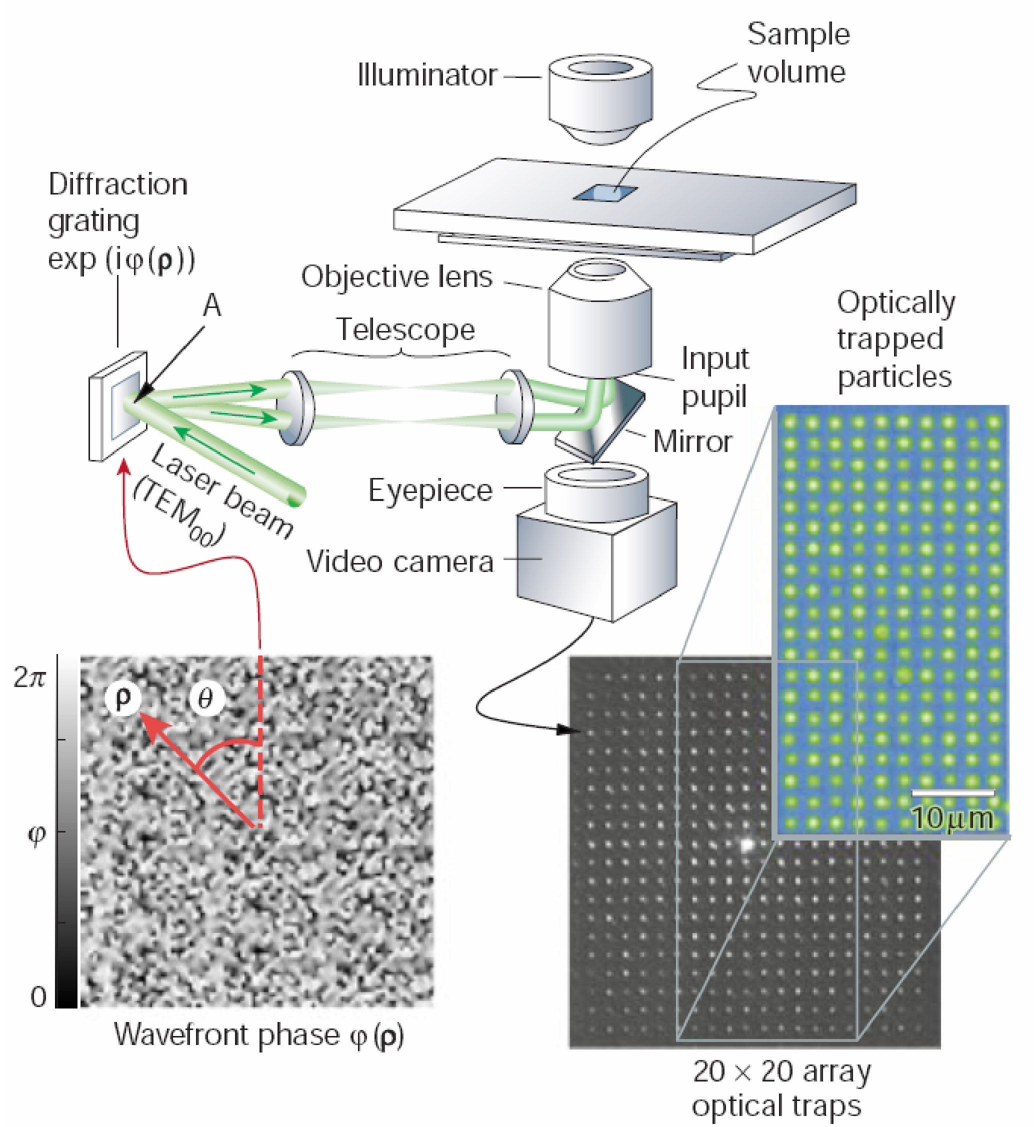


Force measurement





Optical Tweezers with a twist

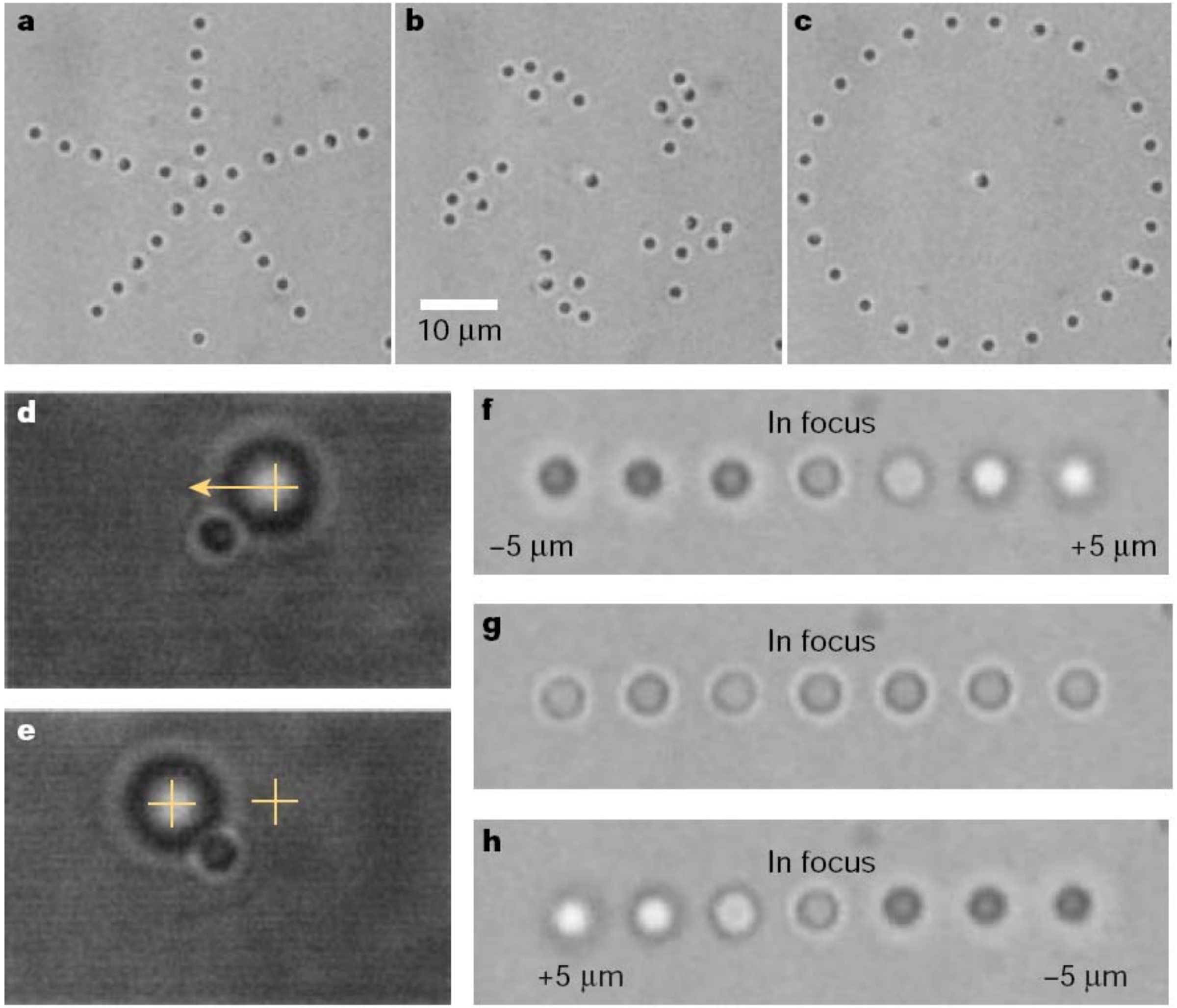


- Scanned tweezers
- Holographic tweezers
- => A multitude of traps out of a single laser beam
- => 2D, even 3D particle tracks can be realized
- => Sorting
- => Tailored energy landscape for colloidal particles (artificial crystals)

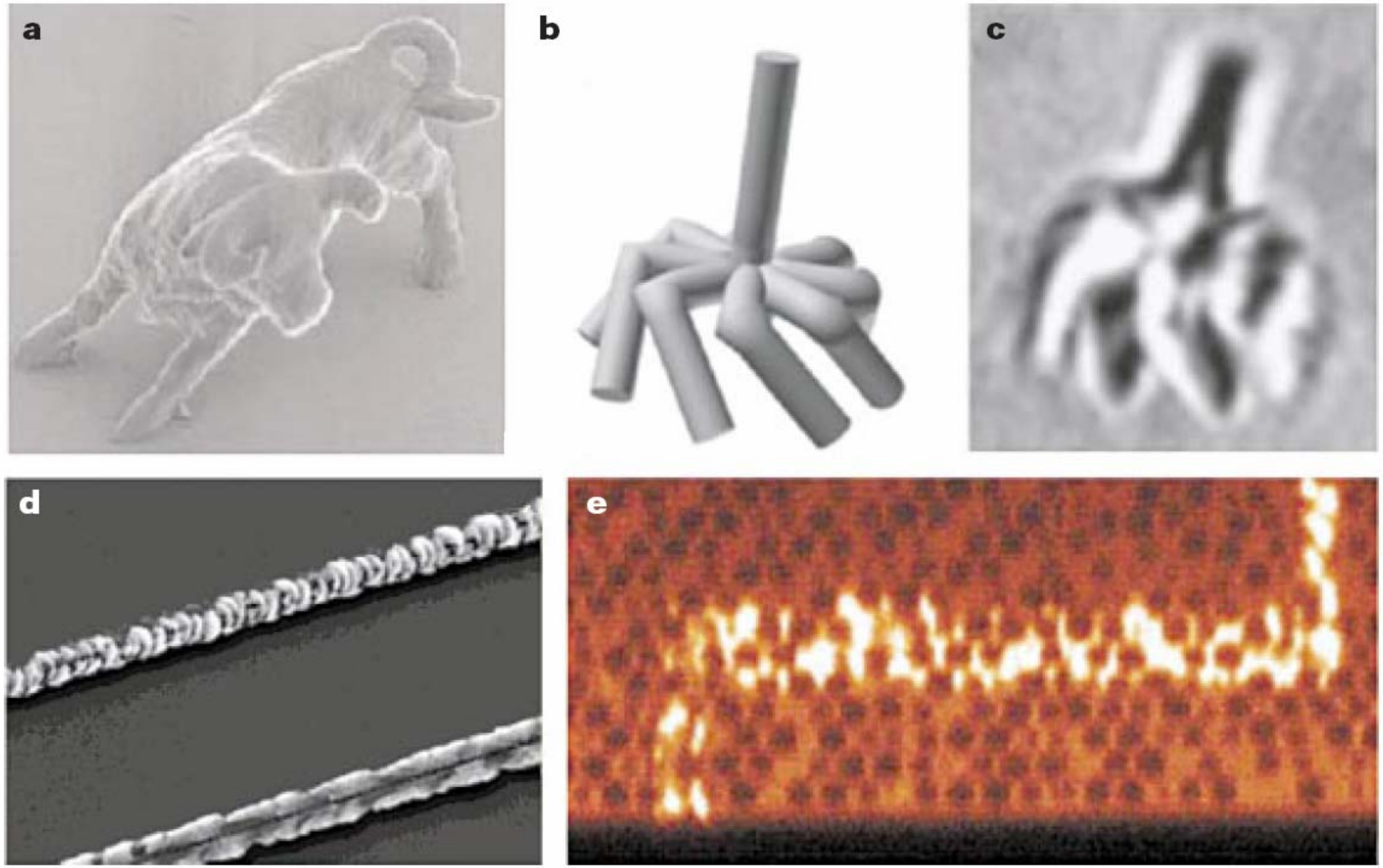
Optical Tweezers with a twist

800nm polysterene beads

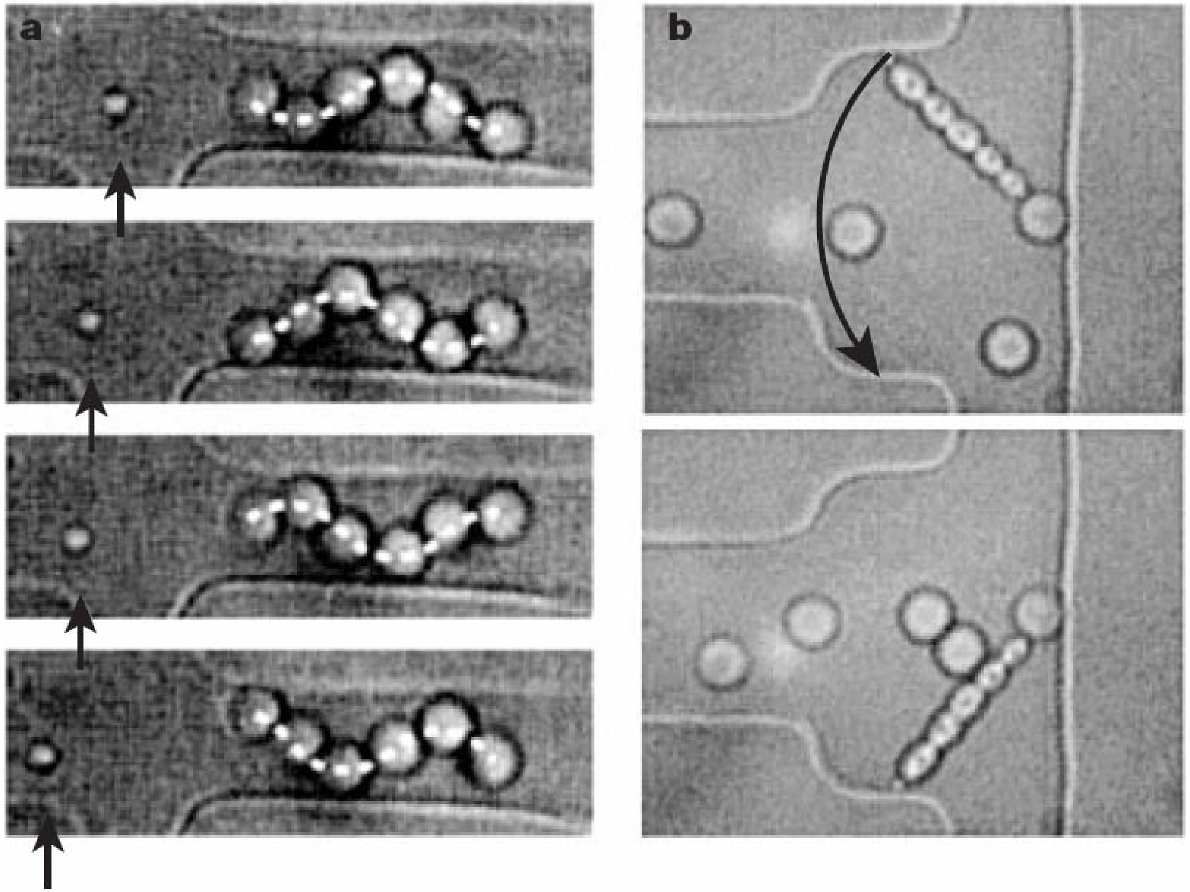
1µm silica beads



Photochemistry with Optical Tweezers



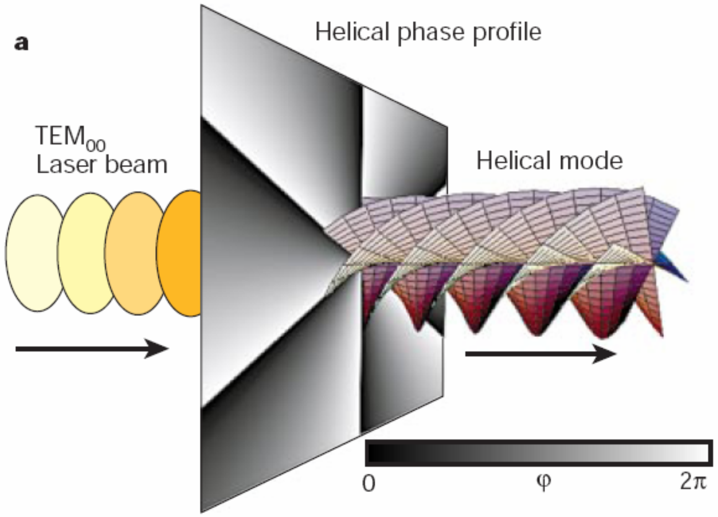
Optical Actuators

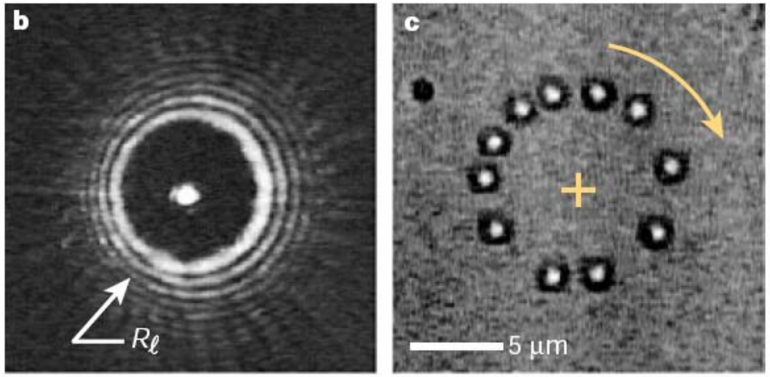


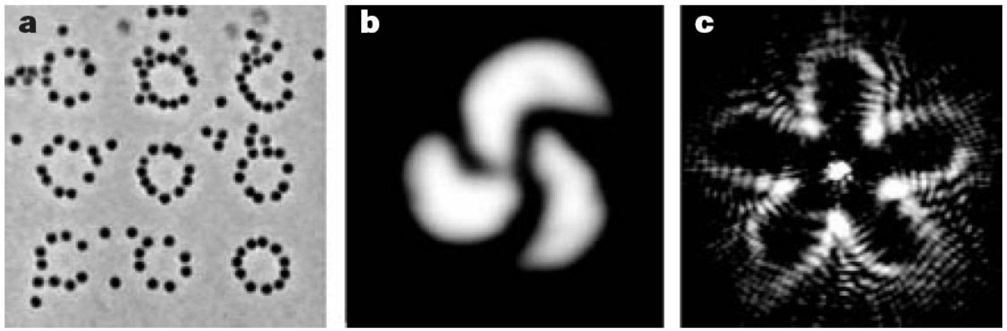
Advanced traps

Dark focus allows to trap new class of objects, not accessible with standard tweezers

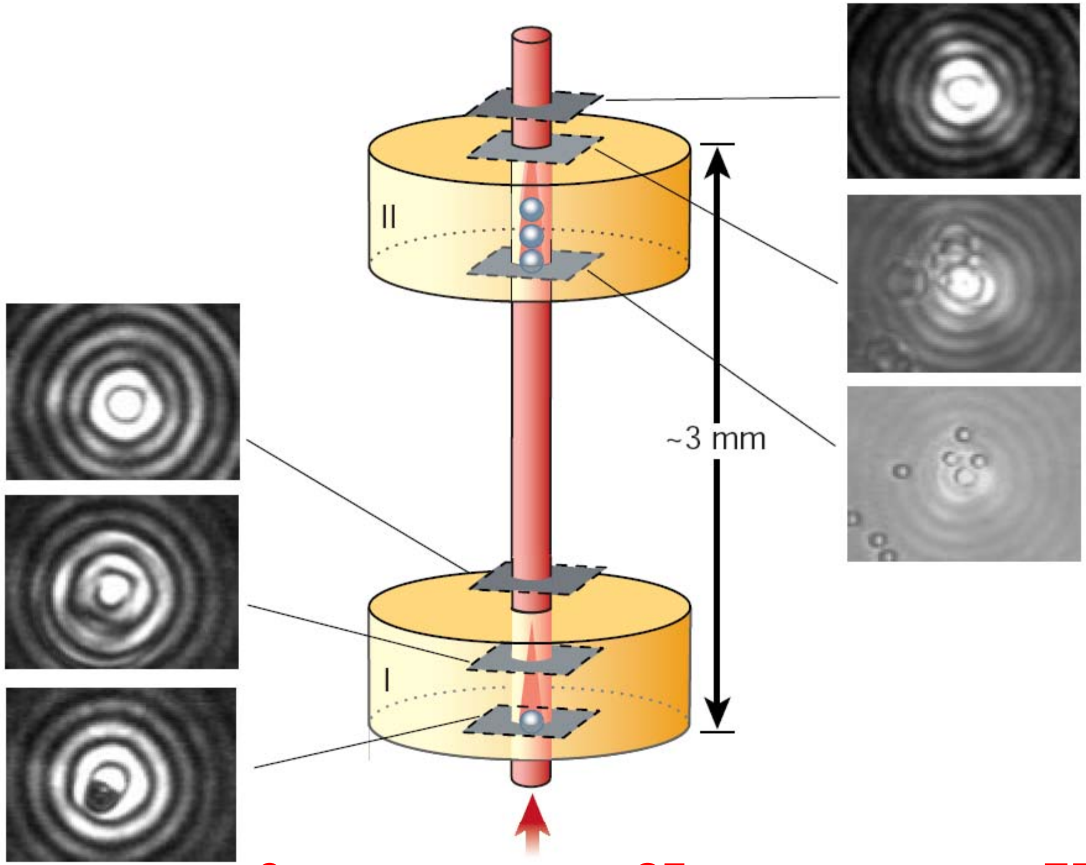
Helical modes exhibit the ability to exert tourques on objects





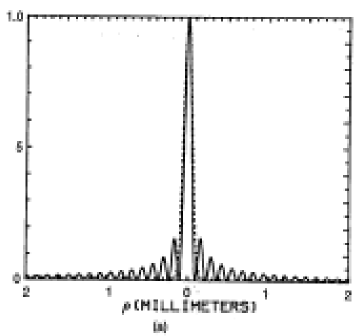


Bessel Beams

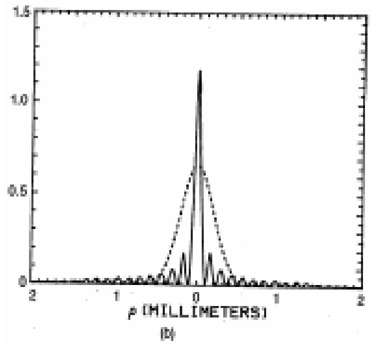


- Bessel beams allow to build traps that longitudinally extend over mm!
- Bessel beams exhibit „self healing“

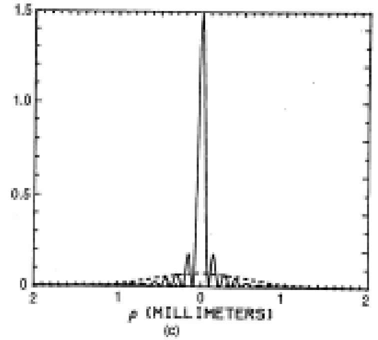
z = 0cm



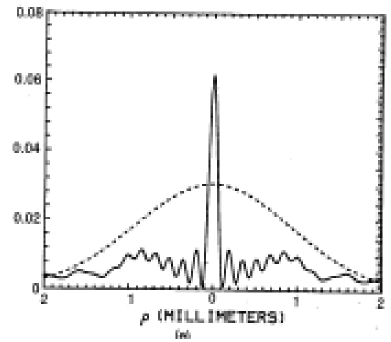
z = 25cm



z = 75cm



z = 120cm



Thank You