Optical Micro-manipulation: A primer

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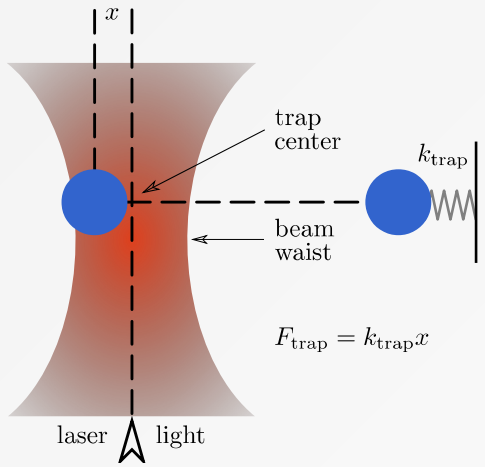

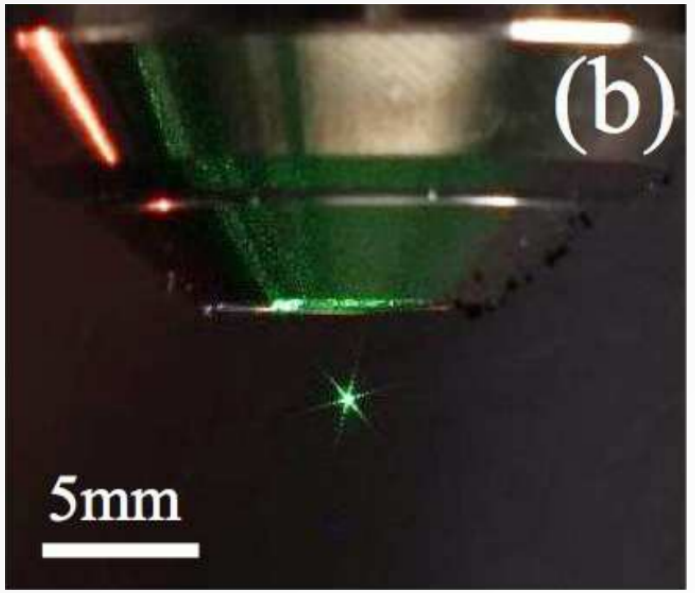

VCQ Vienna Center for Quantum Science and Technology

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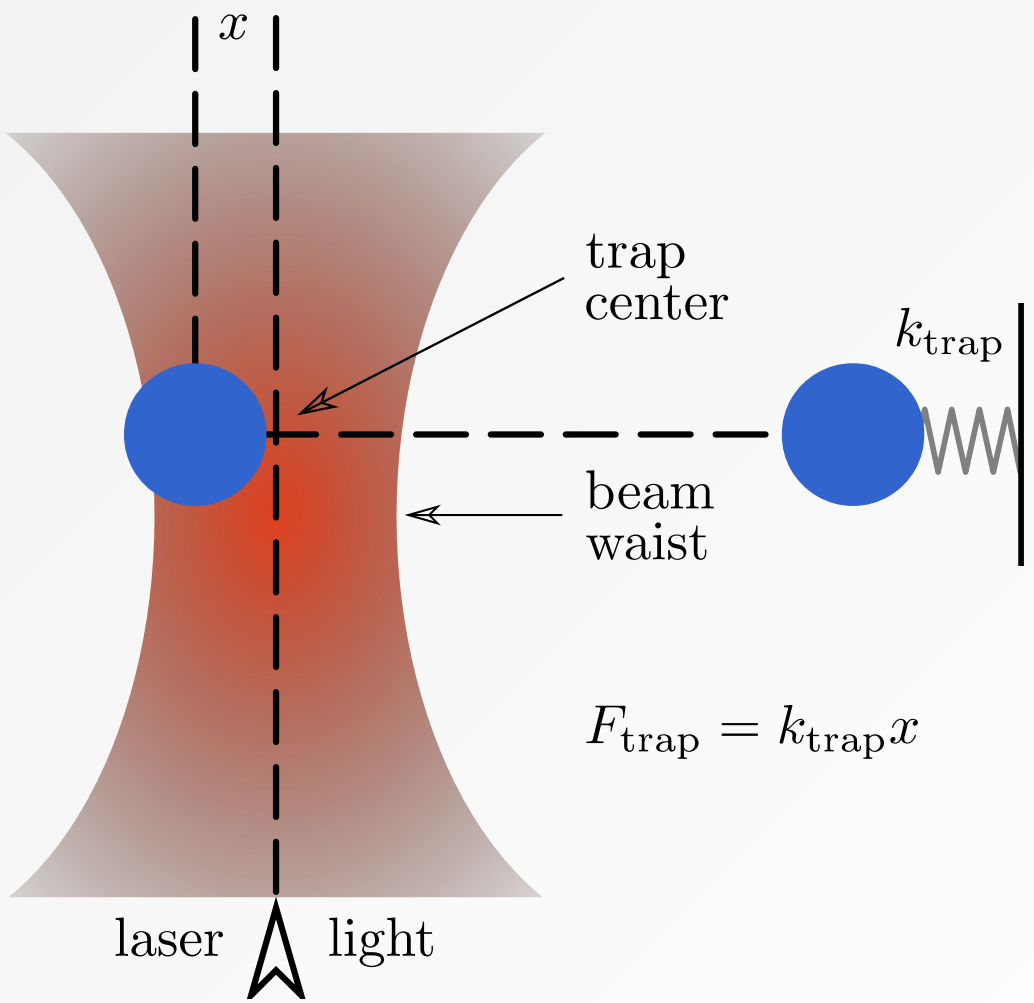
esa

Theory

Dielectric medium

Dipoles form due to electric field of light

Attracted to strongest field (focus)



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What are they good for?

Moving particles **Atoms to ≈ 100 μm**

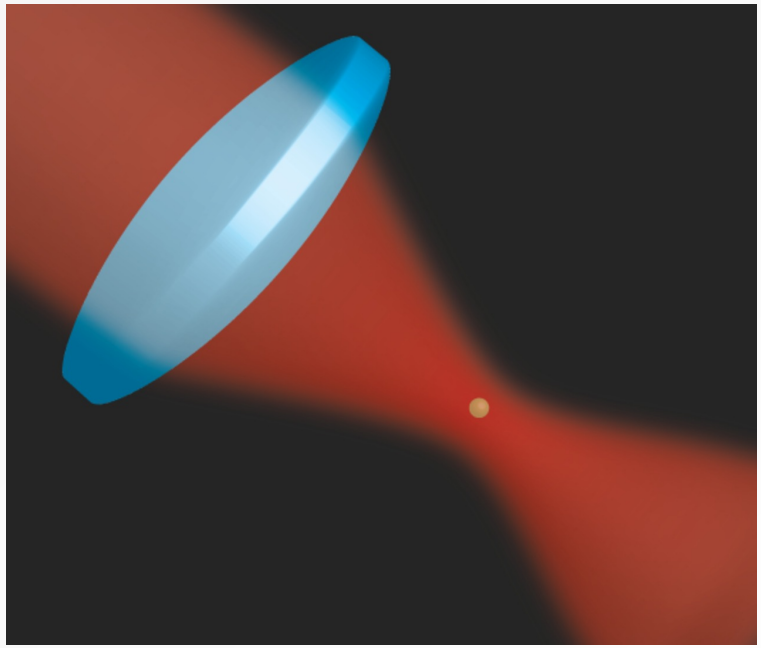
Rotating particles

Force measurements **pN**
Weight of particles

Interactions between particles

Isolating particles
Spectroscopic studies
Imaging studies

Biological samples



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Advantages

Cheap 50 K – 100 K €

Can perform studies without contamination

Can sort particles by material, size, weight, etc.

Can safely handle several types of biological samples without harm

Increase laser power to vaporize sample if needed.

Limitations

Material dependent:

Wont trap good electric conductors (e.g pure metals)

Heavy particles need more laser power

Temperature can increase

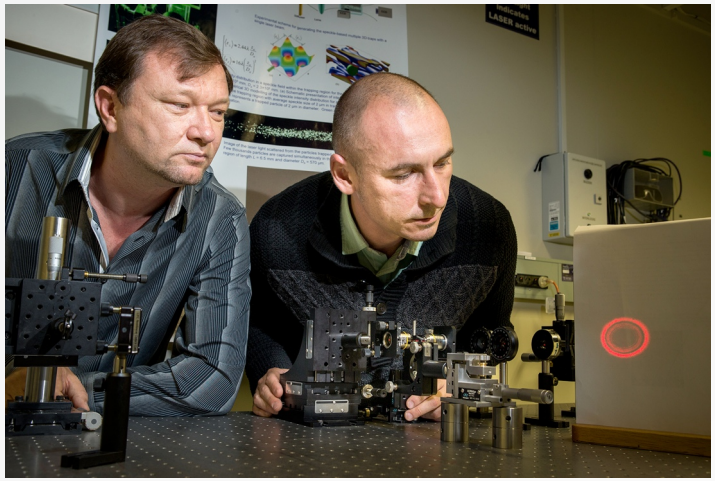
Harder to trap in air (need more power)

Trapped 5 – 20 mm from lens

Tractor beams

Back hotter than the front.

Air pushes the particle.



Larger objects (upto mm)

No direct heating

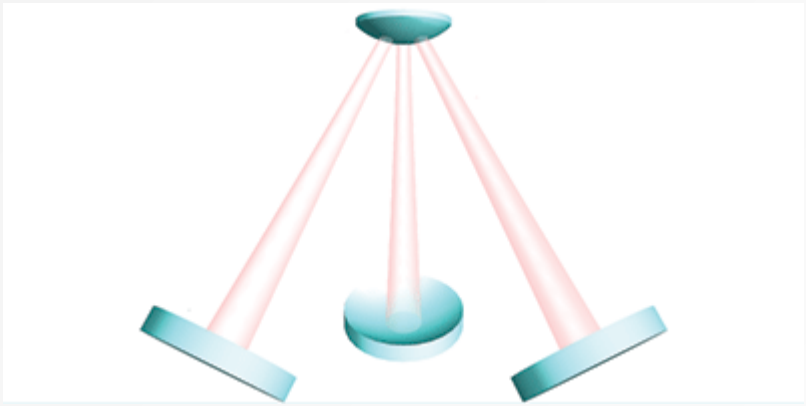
Needs dense atmosphere

Limited motion

Optical levitation

Beam from bottom

Pushes object up



Any opaque object
Large objects (upto Kg)

Unstable
Very high power
Several view ports
Limited motion
Only traps in one direction per beam

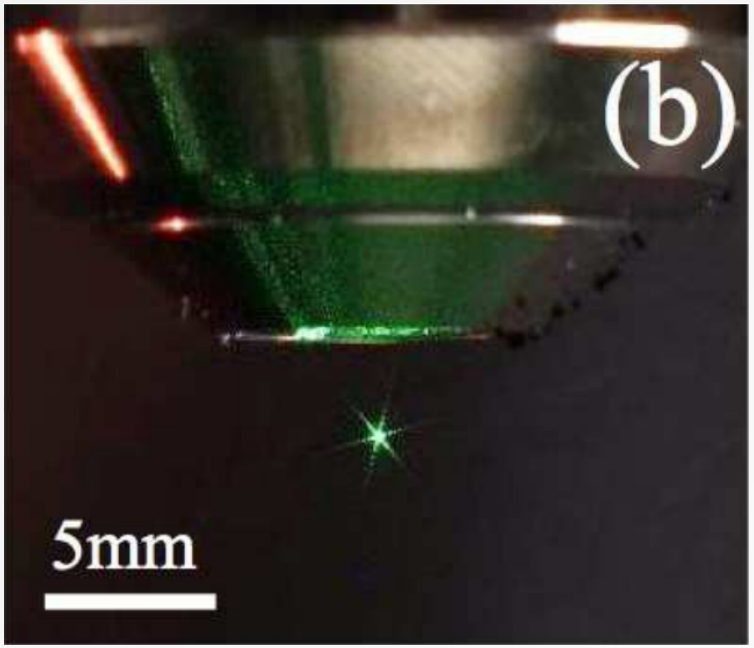
Guccione, Giovanni, et al. "Scattering-free optical levitation of a cavity mirror." Physical review letters 111.18 (2013): 183001.

Case study: a silica bead

25μm silica bead

Trapped in air

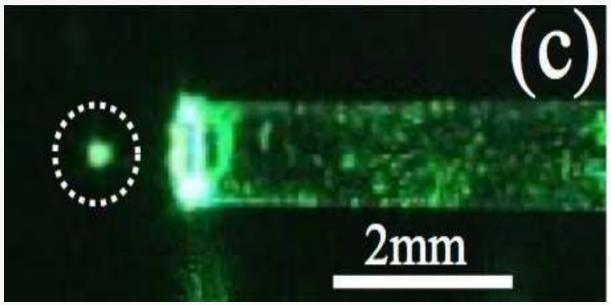
25 mW laser power



5μm silica bead

Inserted into glass capillary

5 mW laser power



Shvedov, Vladlen G., et al. "Robust trapping and manipulation of airborne particles with a bottle beam." Optics express 19.18 (2011): 17350-17356.

Case study: heating

Heating depends on:

- Absorption of material
- Wavelength
- Optical intensity
- Duration of trap
- Thermal capacity

Cooling depends on:

- Atmosphere
  - Composition and density
- Thermal radiation
- Ambient temperature
- Number and nature of objects trapped

In vacuum: Temperature incease 20 – 30°C/s of trapping

In 1mBar of He: Temp. increase < 5°C (continuous trapping)