Measuring microscopic forces and torques using optical tweezers

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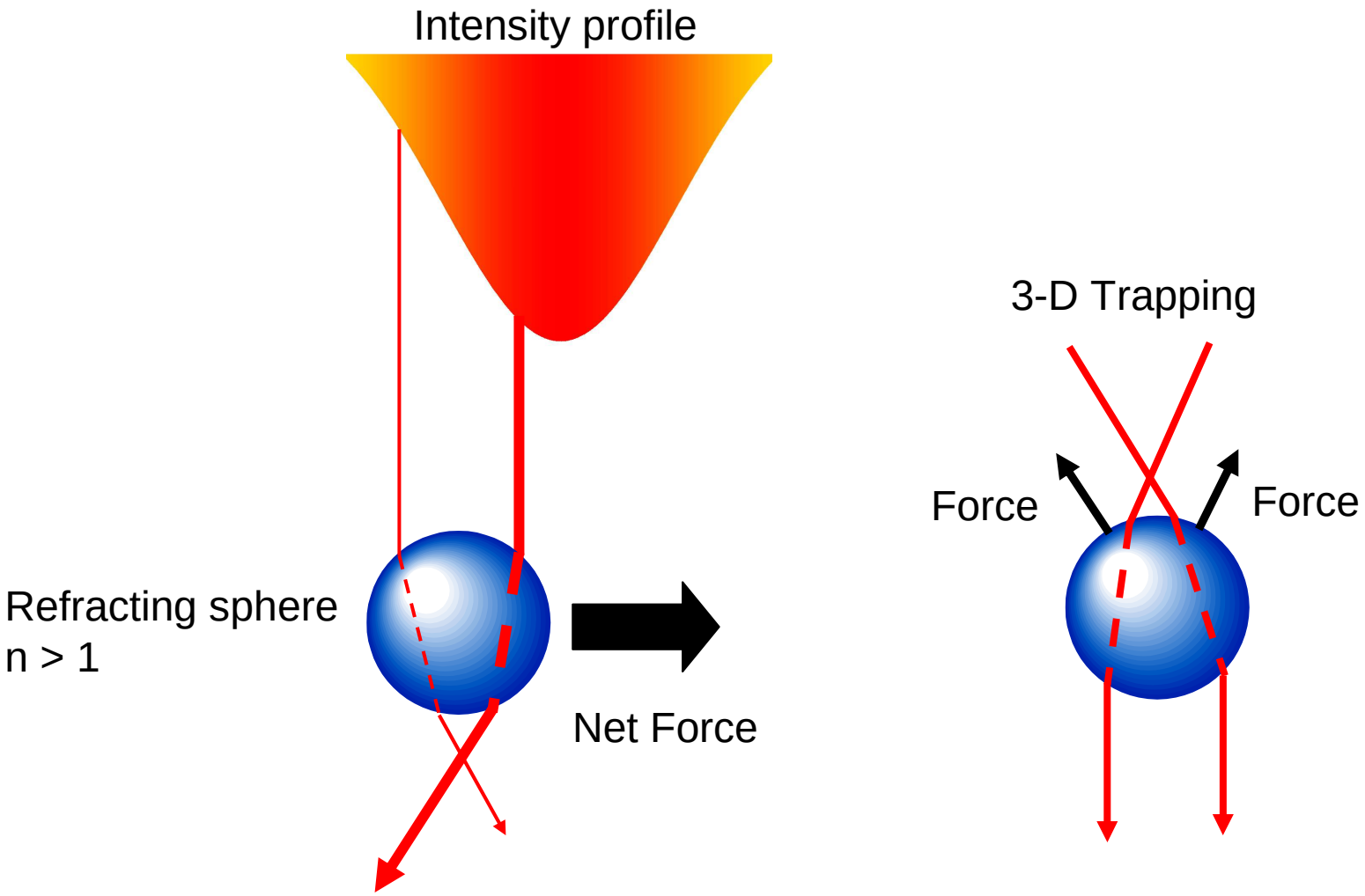
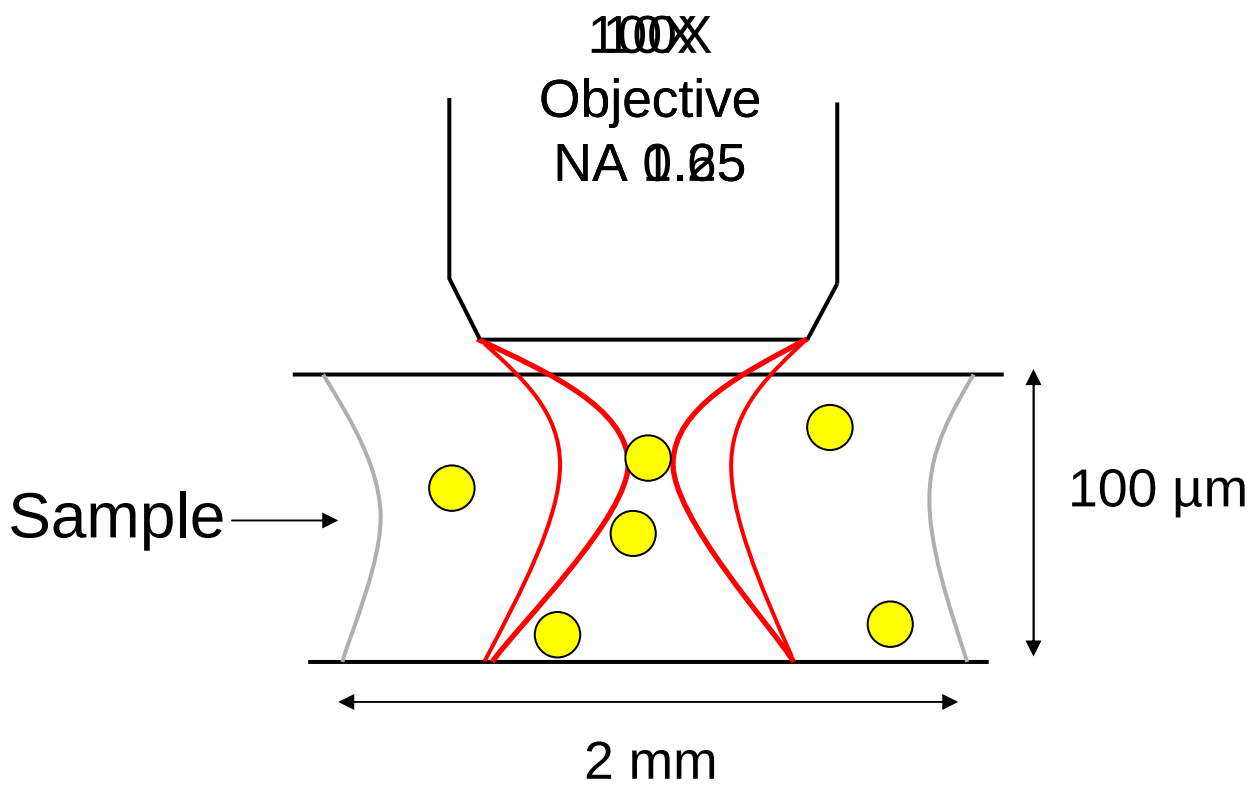
Linear Momentum

The transfer of linear momentum may be observed when photons propagate through a transparent micro-particle

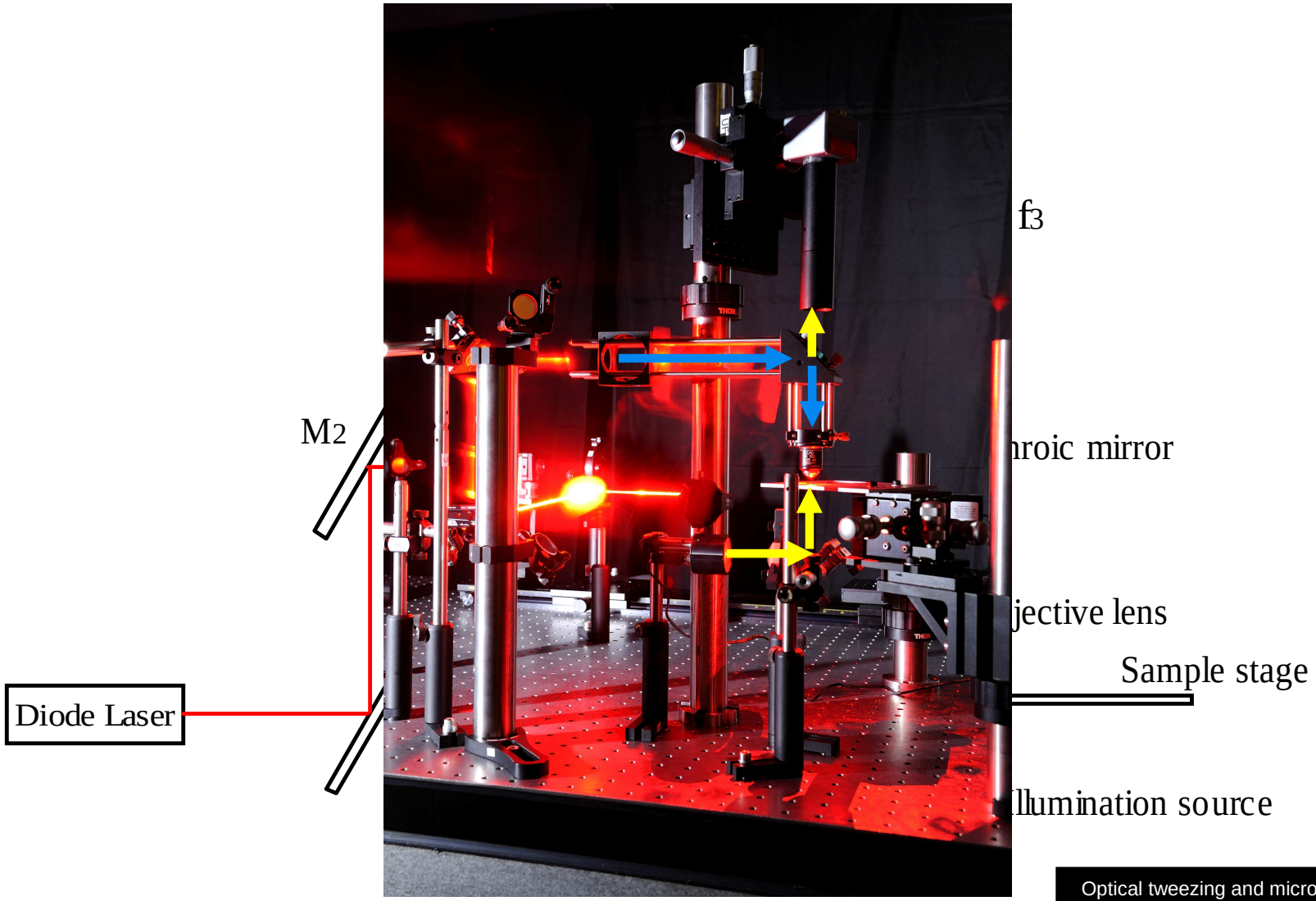


High numerical aperture produces a more tightly focused beam



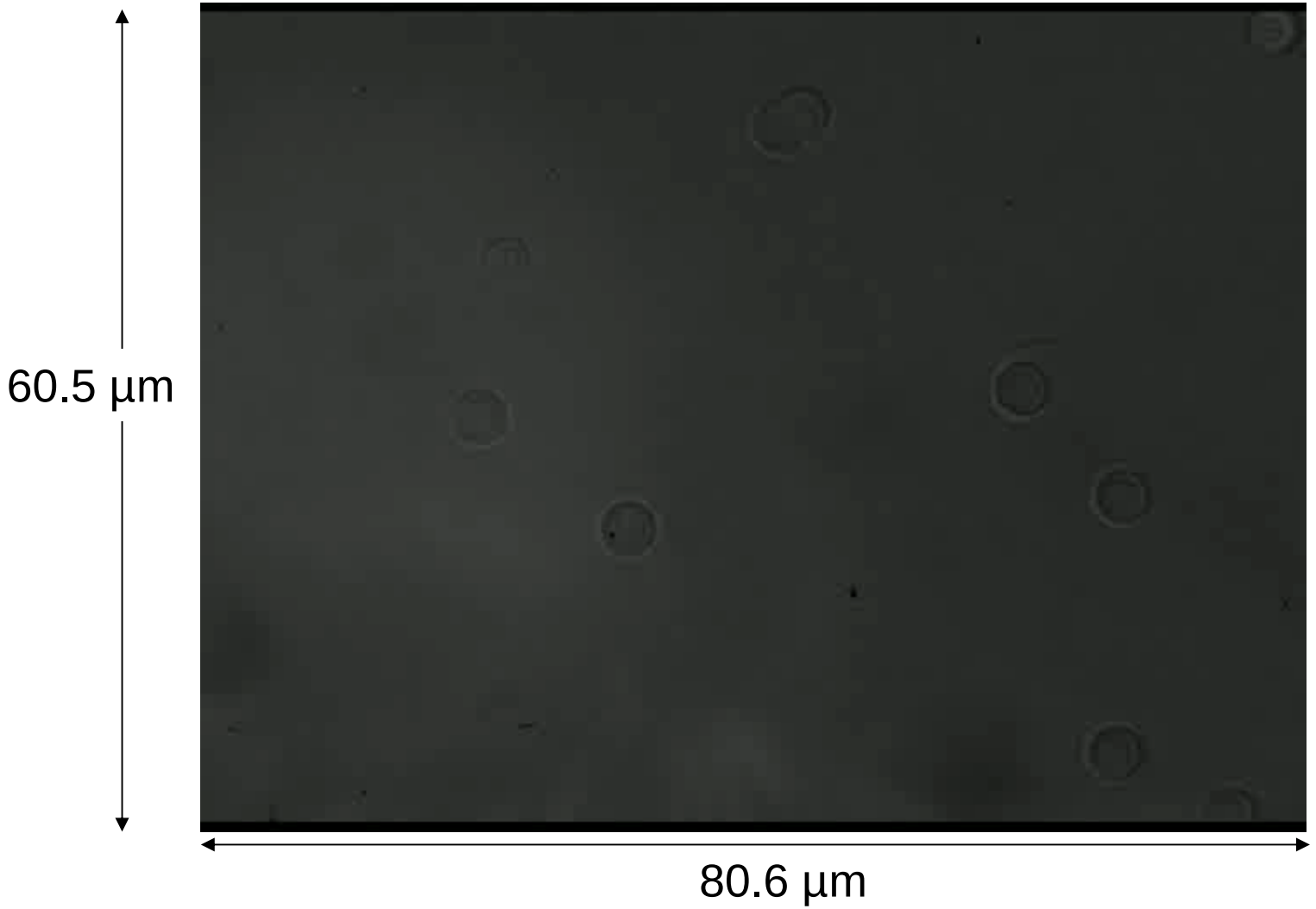
= 4 µm

Our home-built optical trapping and tweezing setup, complete with in-house microscope objective



Optical tweezing and micromanipulation, MSc (Wits), 2009

Optical micro-manipulation using 4 μm diameter silica beads



Trapping of 20 µm sized embryonic kidney cells

Determining the trap strength using 2 different methods

Drag Force Method

$$F_{trap} = 6\pi\eta R v_c$$

Viscosity of fluid

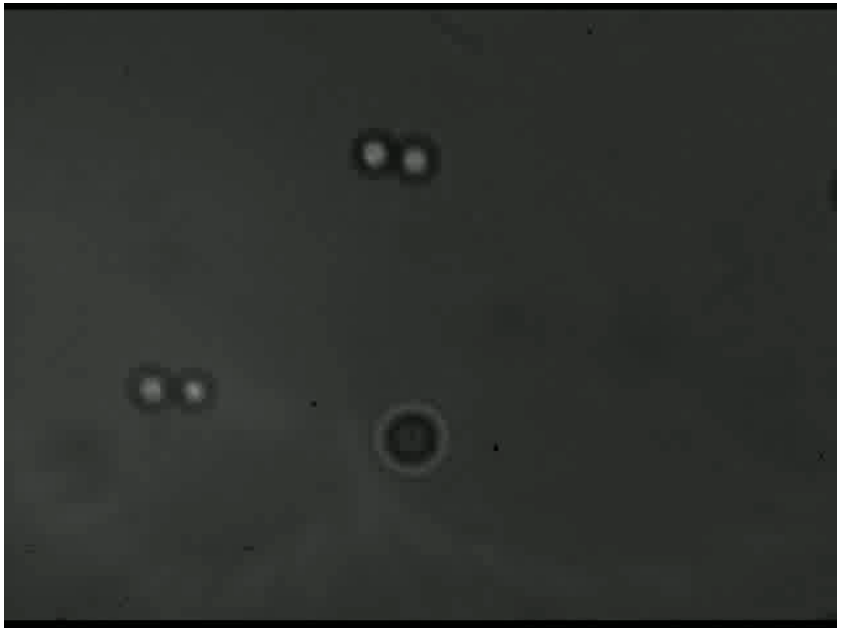
Velocity of fluid as bead escapes trap

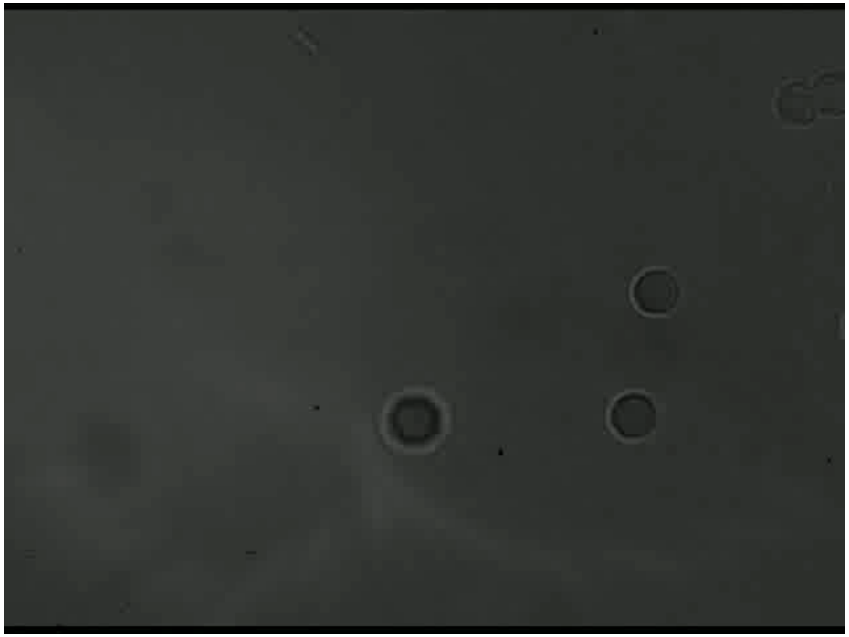
Equipartition Method

$$\vec{F} = -\alpha\vec{x}$$

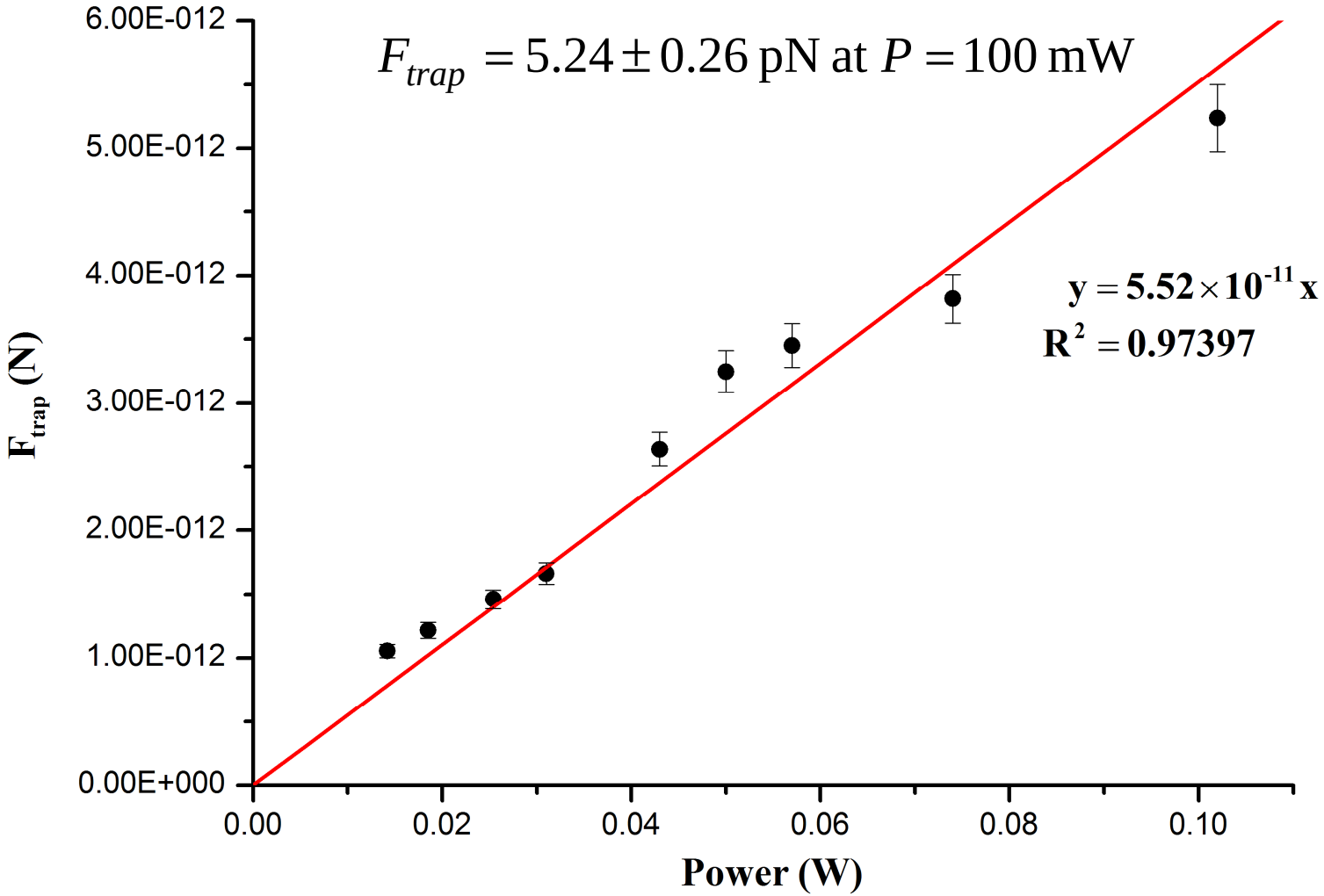
Trap stiffness

Drag force method

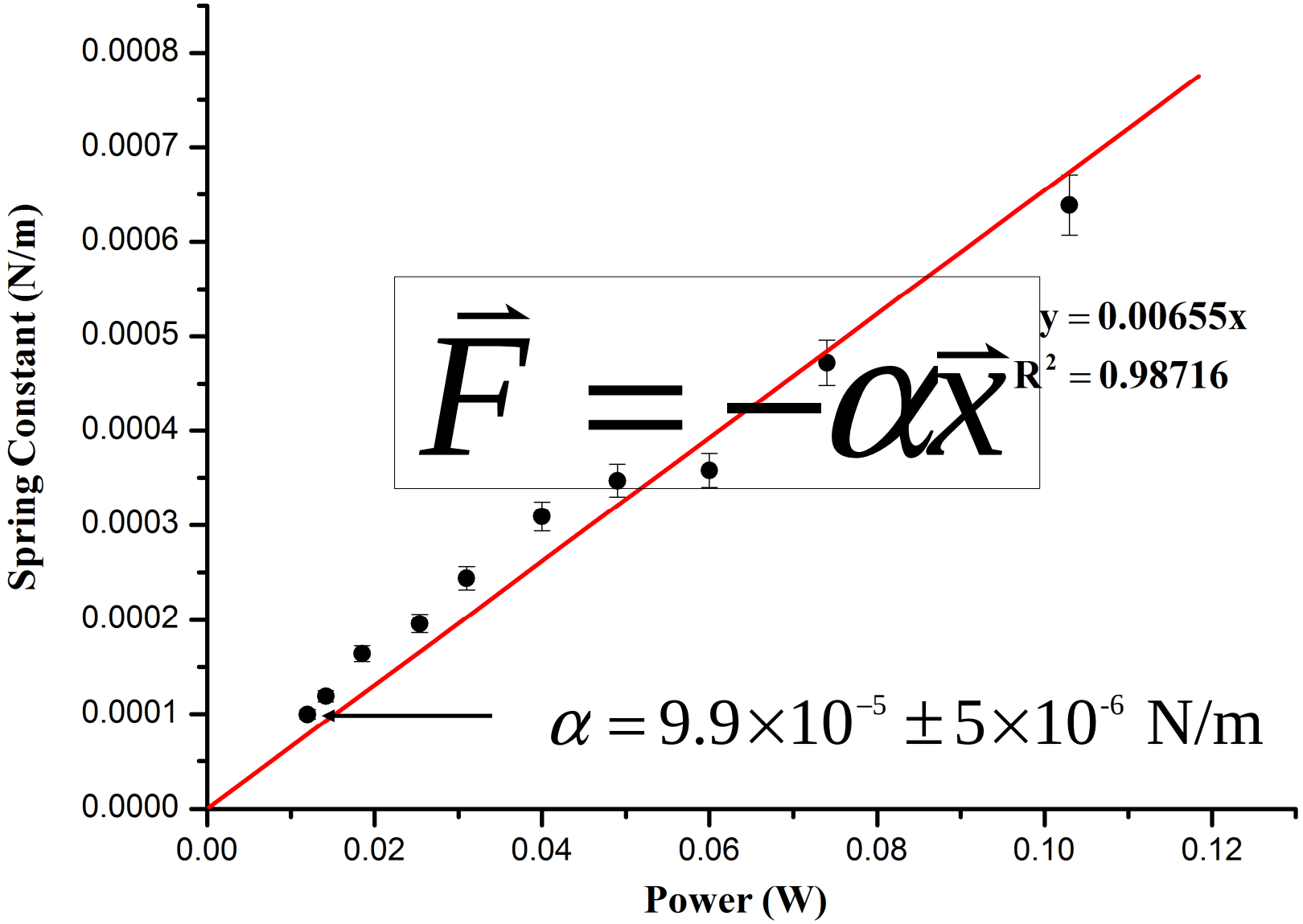




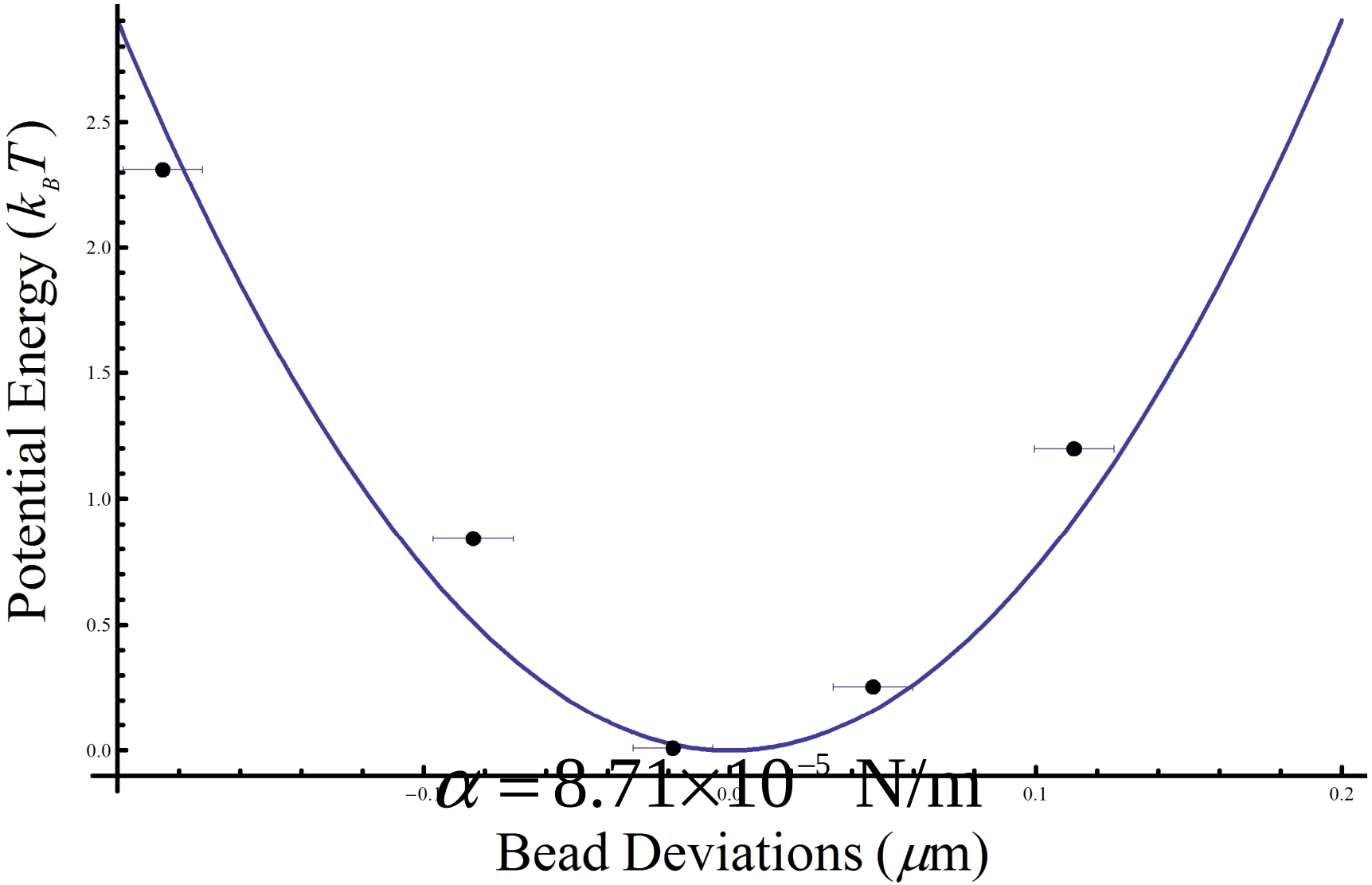
Drag force method



Equipartition Method



Equipartition Method



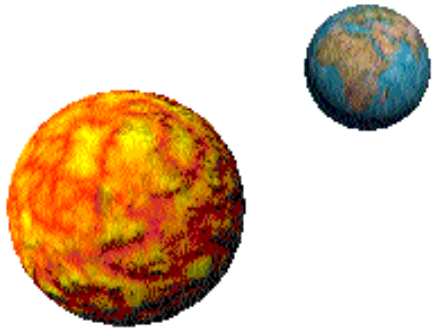
Angular Momentum

Angular momentum of light can be separated into two forms

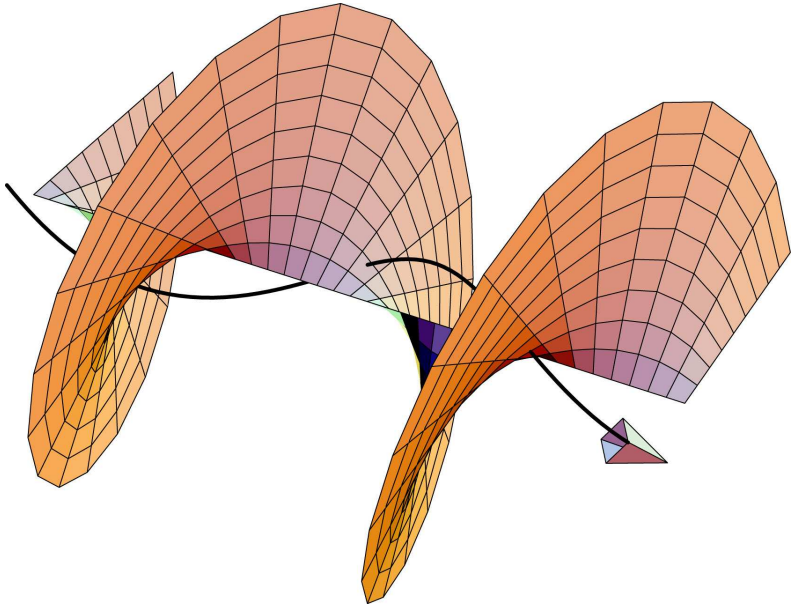
$$j = (l \pm \sigma)\hbar$$

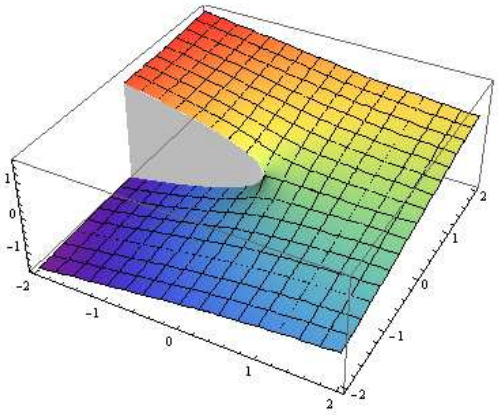
Spin Angular Momentum

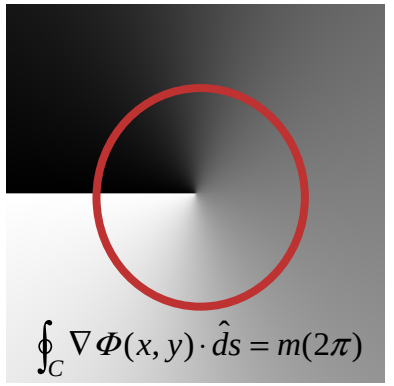
Orbital Angular Momentum

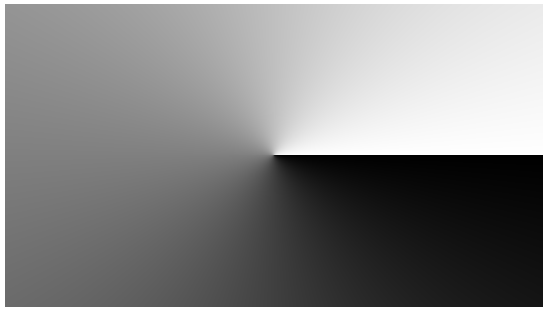


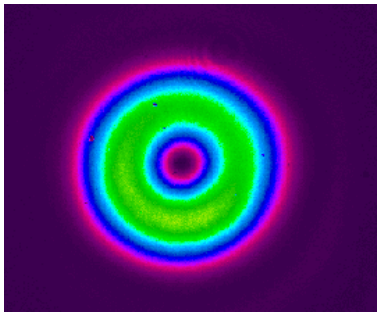
Creating ‘twisted light’

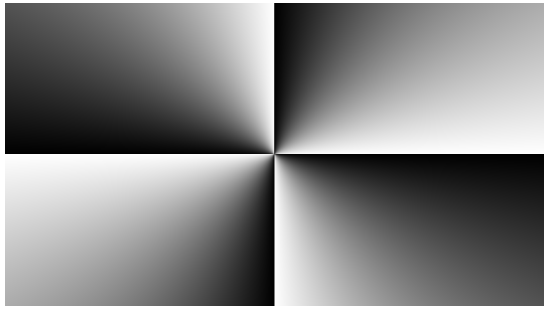


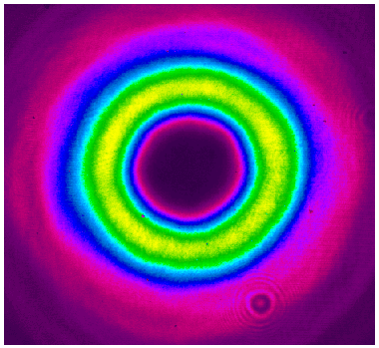




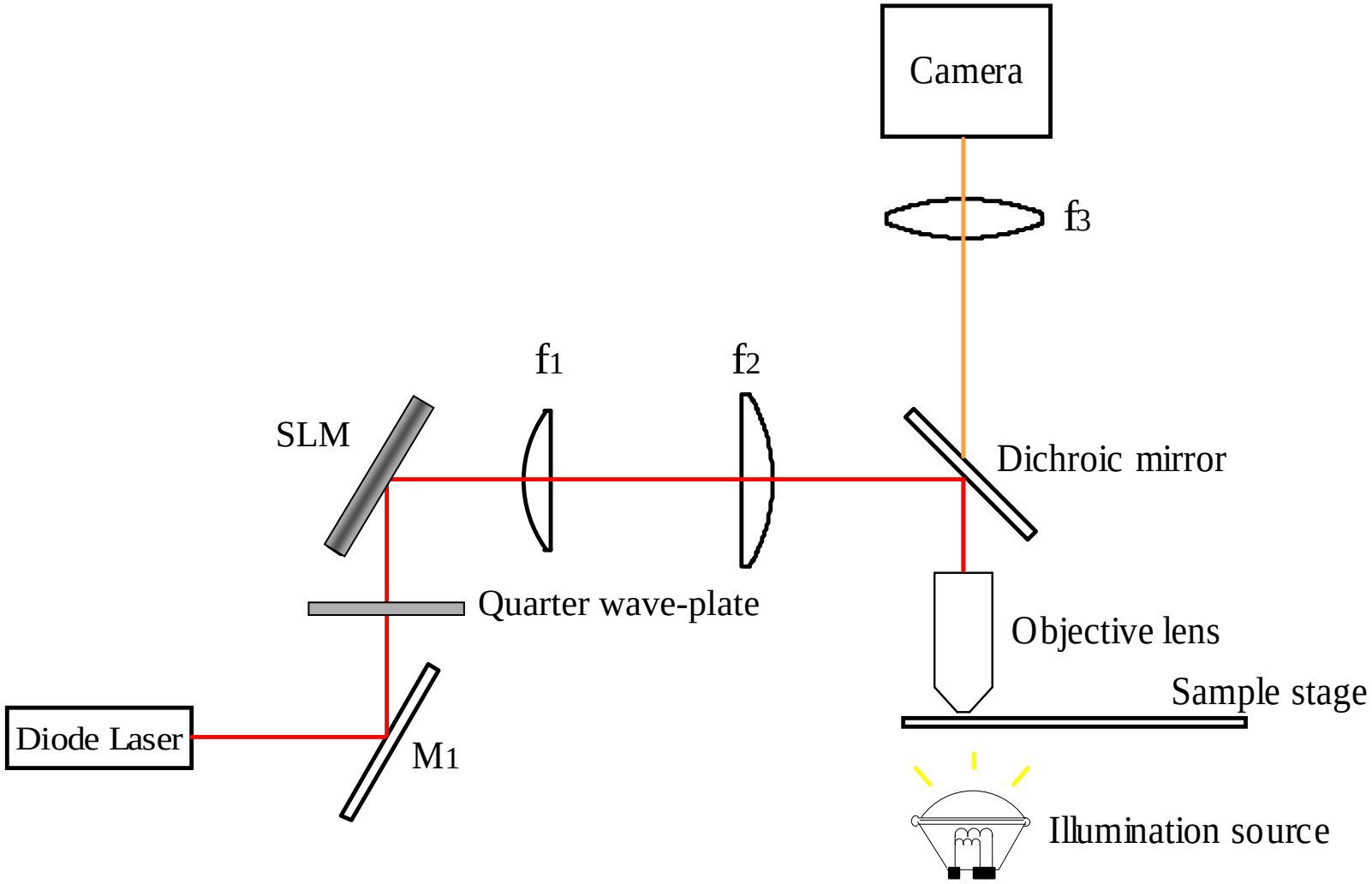




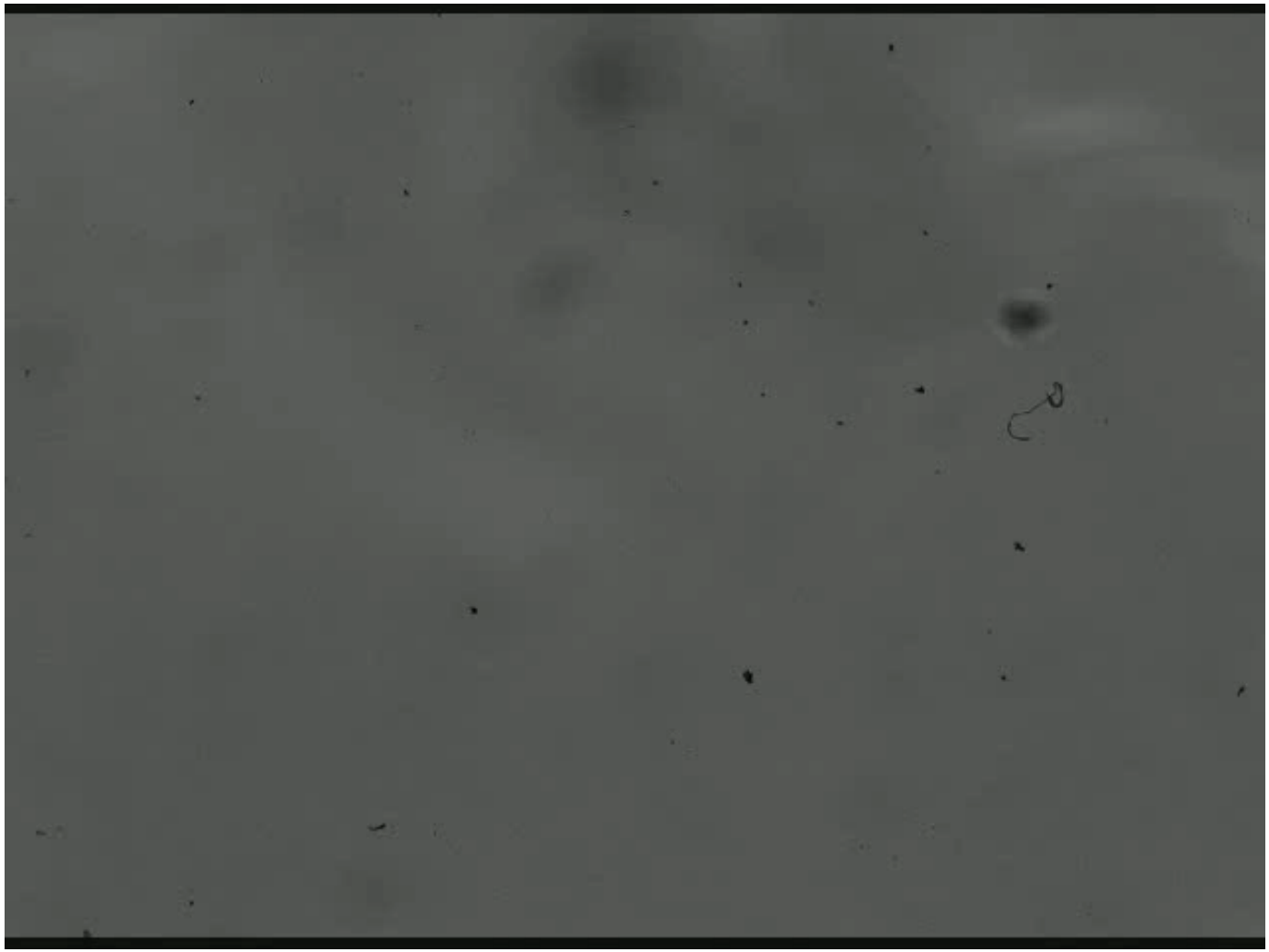




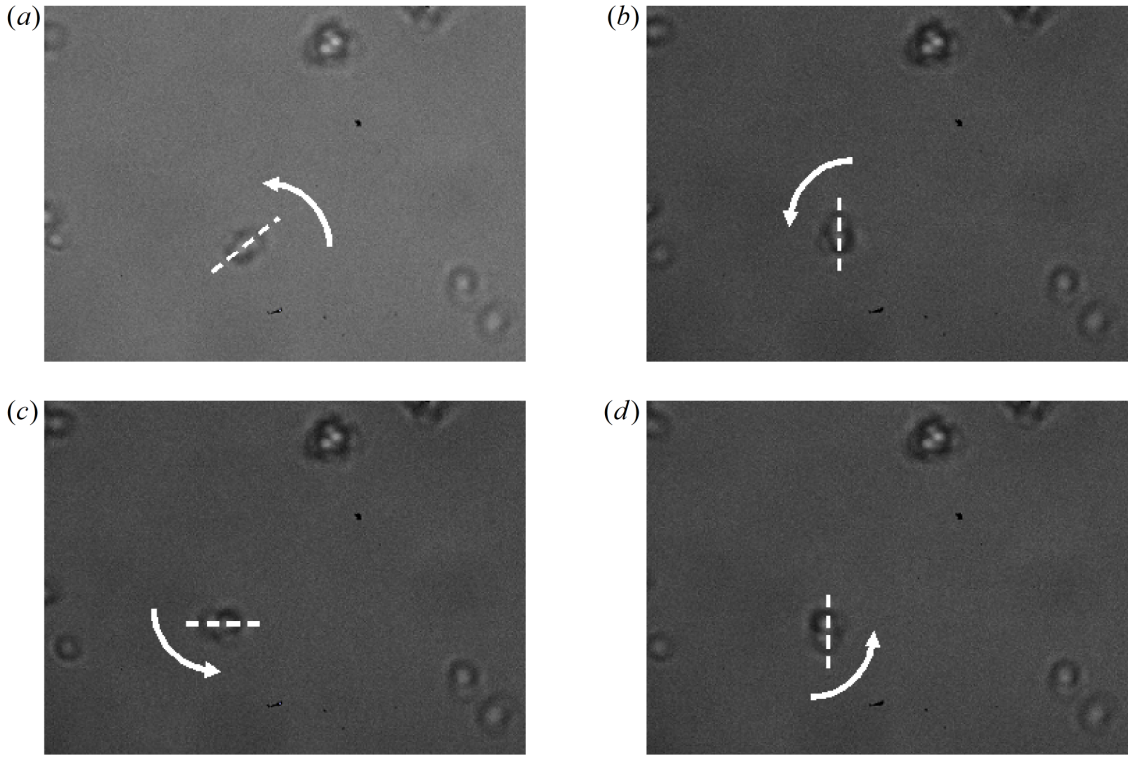
From linear momentum to angular momentum



The transfer of angular momentum can be observed directly in the laboratory



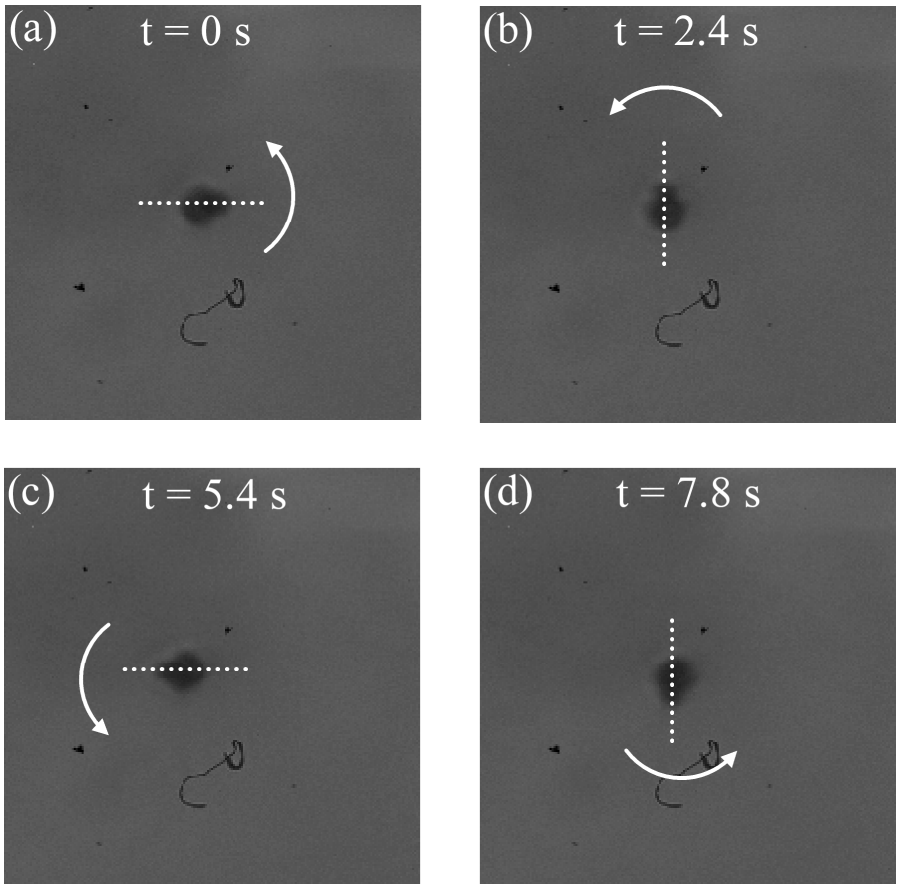
Rotation of birefringent calcite particles by the transfer of spin angular momentum



$$\omega = 1.57 \pm 0.09 \text{ rad/s}$$

$$\tau = 7.5 \times 10^{-21} \pm 0.4 \times 10^{-21} \text{ Nm}$$

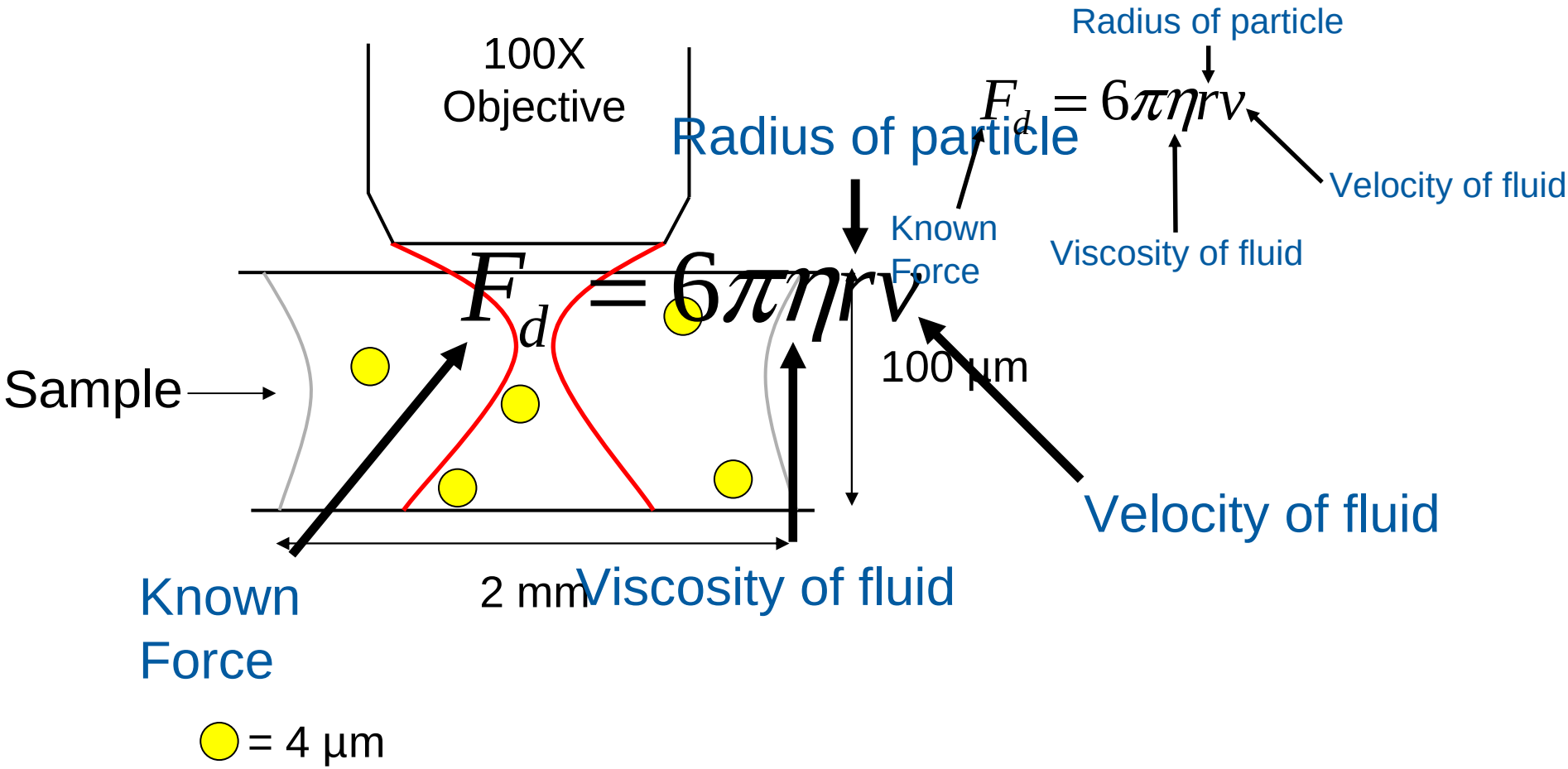
Transfer of orbital angular momentum with a vortex beam of order $\ell = 1$



$$\omega = 2.77 \pm 0.09 \text{ rad/s}$$

$$\tau = 1.2 \times 10^{-20} \pm 0.2 \times 10^{-20} \text{ Nm}$$

Technique can be used in microfluidics to precisely measure fluid parameters



Thank You

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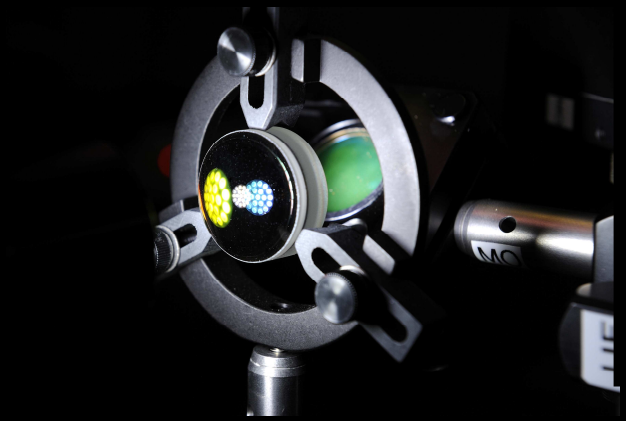

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