Optical trapping and tweezing using a spatial light modulator

Y.Ismail[1,2], M. G. Mclaren[1,3], A. Forbes[1,2,4]

[1] CSIR National Laser Centre

[2] School of Physics, University of KwaZulu-Natal

[3] School of Physics, University of the Witwatersrand

[4] School of Physics, University of Stellenbosch

Presented at the

2009 South African Institute of Physics Annual Conference

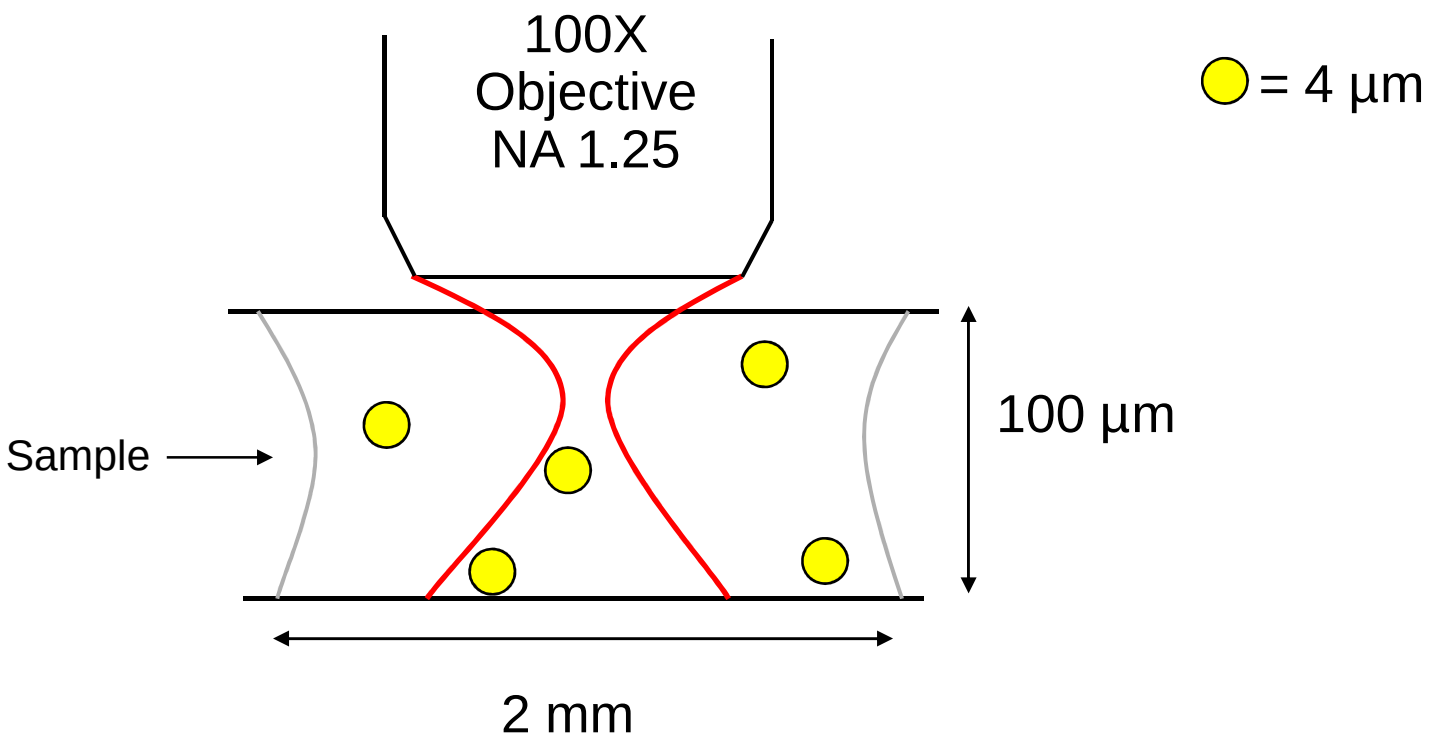
University of KwaZulu-Natal

Durban, South Africa

6-10 July 2009

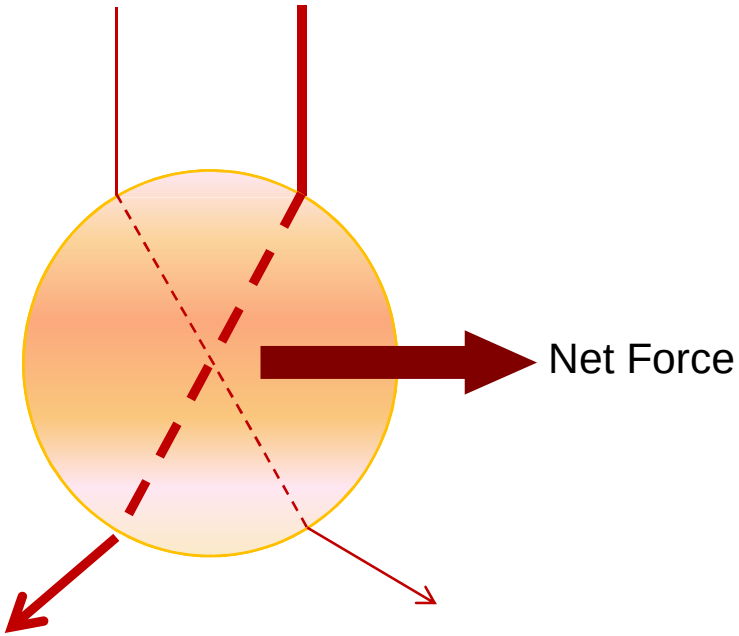
our future through science

Optical tweezing is based on the manipulation of micron sized particles in 3 dimensions



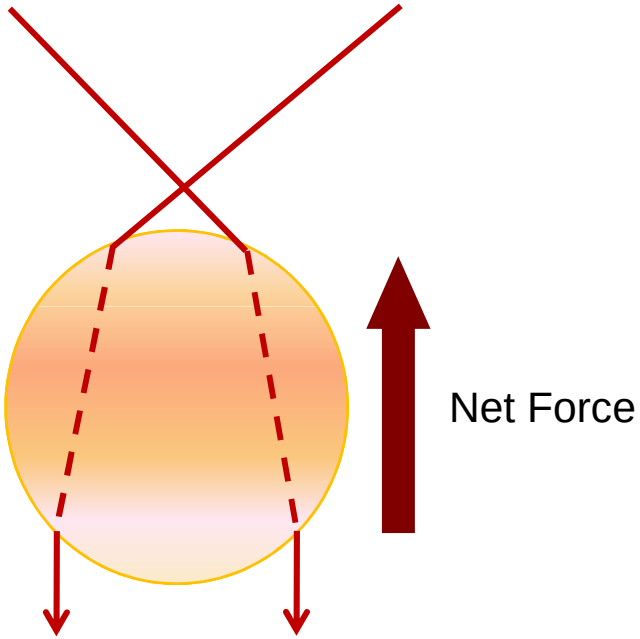
When light impinges onto a particle there is a transfer of linear momentum

Lateral trapping or
2-dimensional trapping



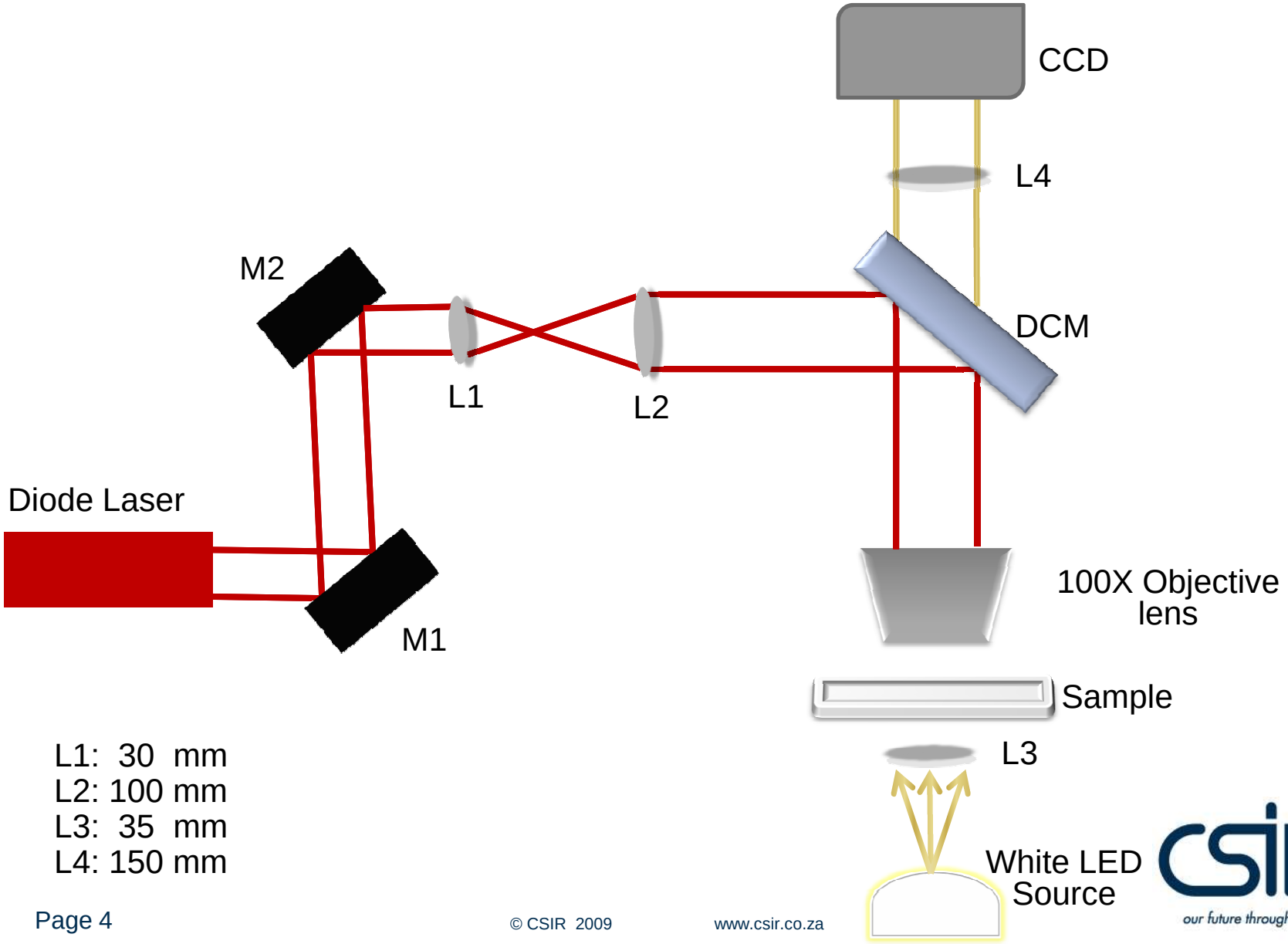
Lateral trapping

Axial trapping or
3-dimensional trapping

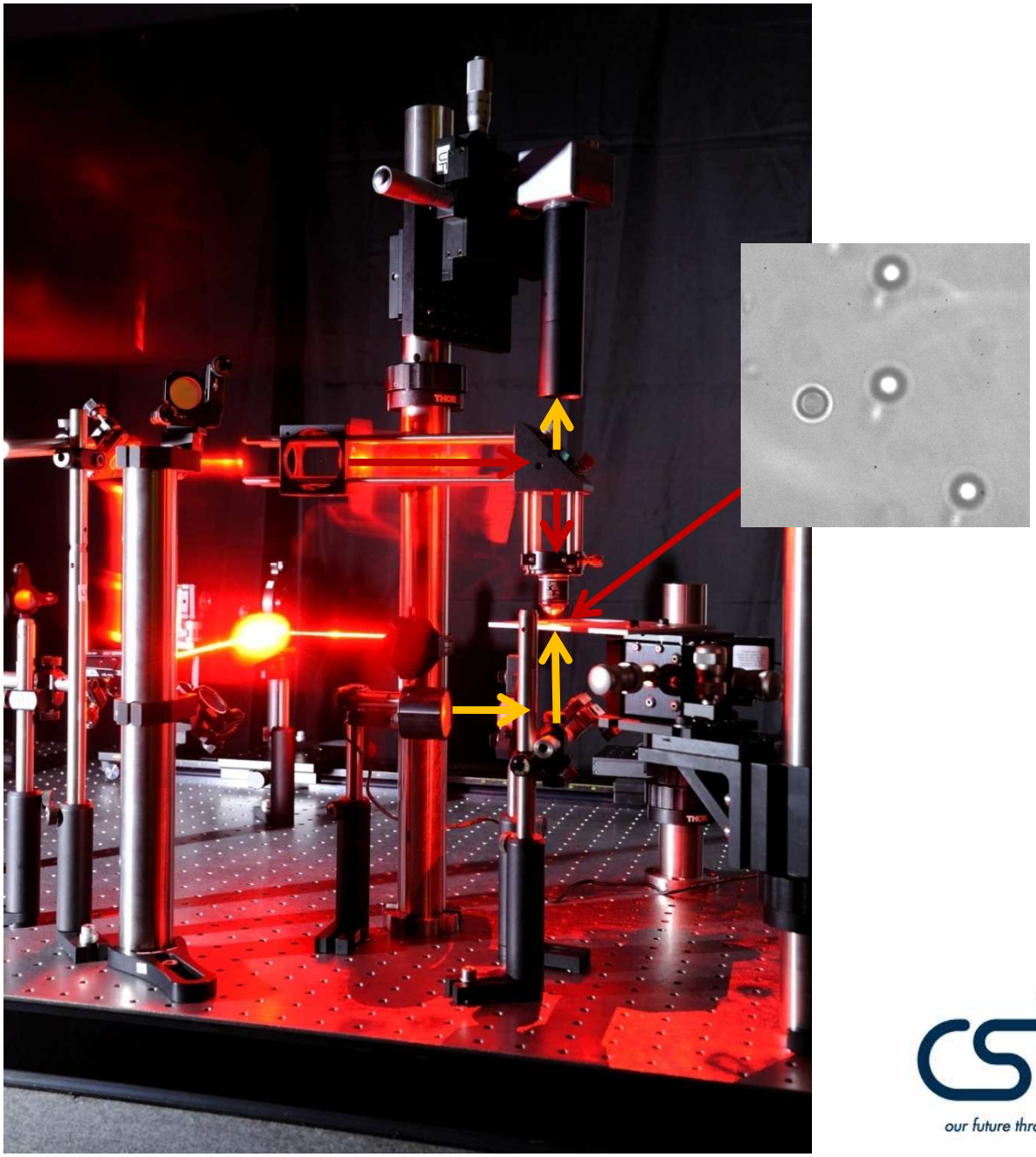


Axial trapping

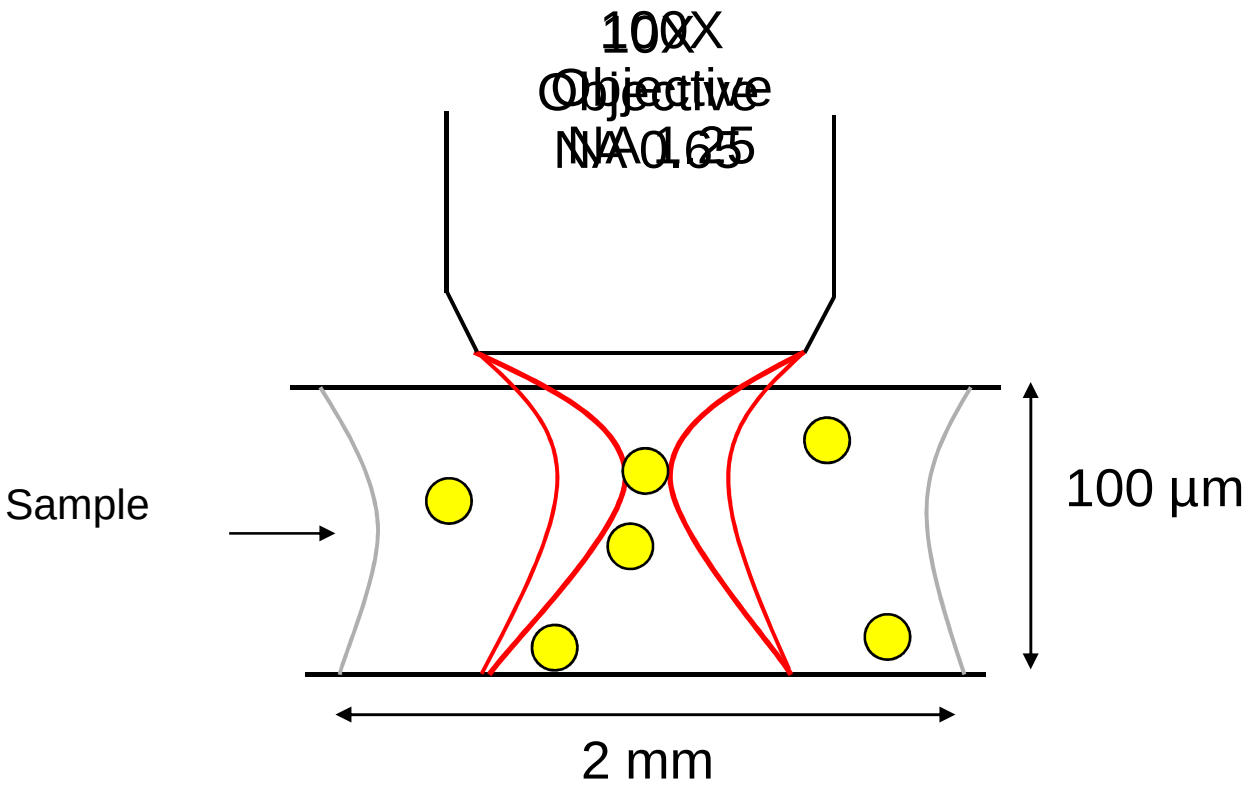
Experimental set-up of optical trap



L1: 30 mm
L2: 100 mm
L3: 35 mm
L4: 150 mm

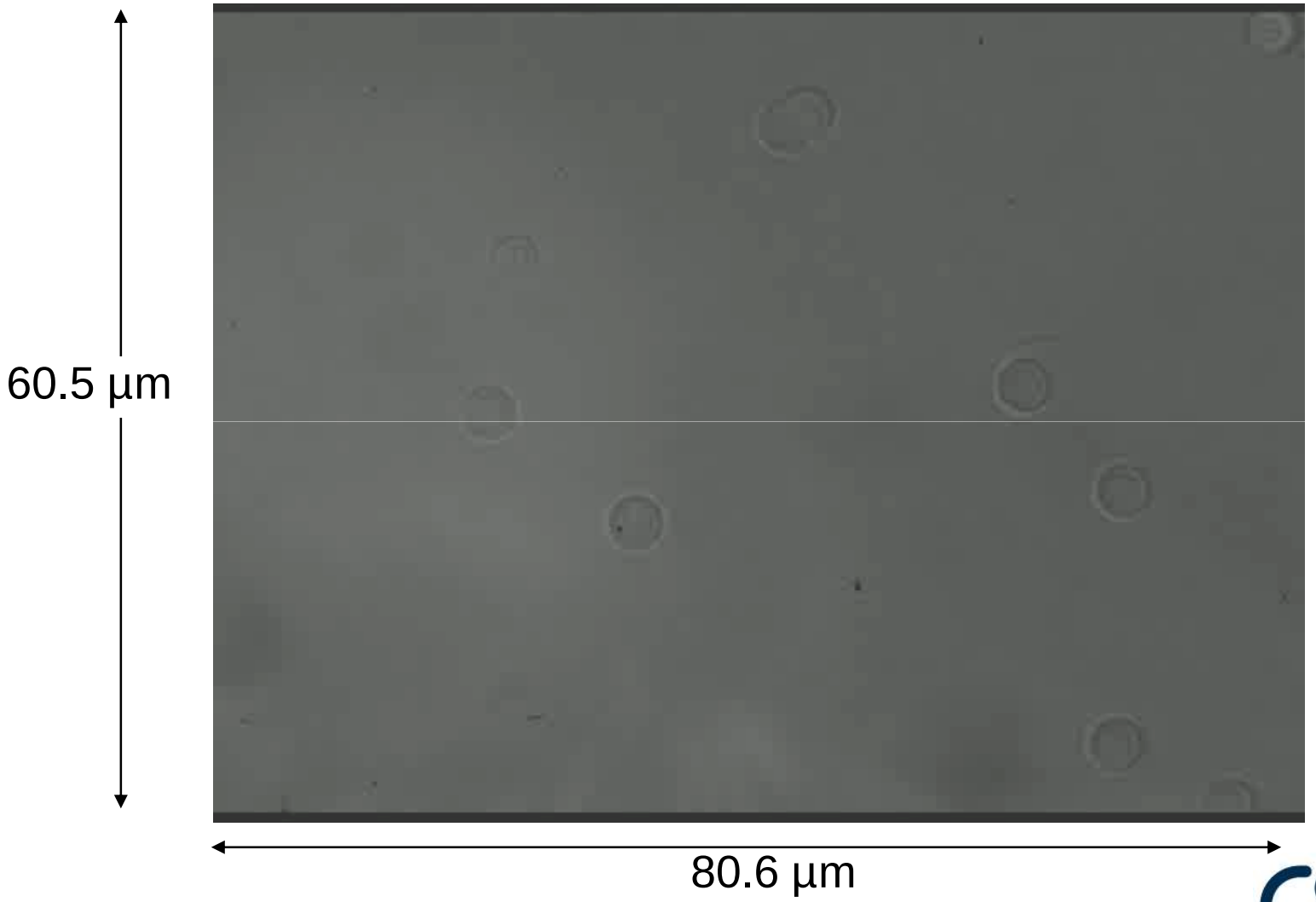


Schematic illustrating a silica bead of diameters, 4µm trapped within a Gaussian beam



= 4 µm

Trapping of 4 micron sized silica beads



The equi-partition method can be used to determine the strength of the trap

$$\frac{1}{2}\alpha\langle x^2\rangle = \frac{1}{2}k_B T$$

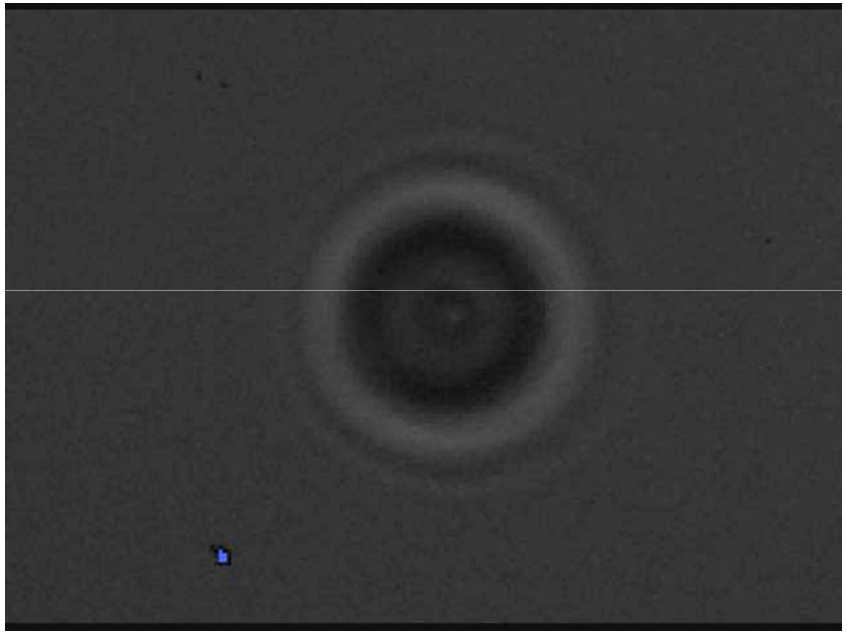
Trap stiffness

Variance of the bead

$$F = -\alpha x$$

Trapping force

Trap stiffness



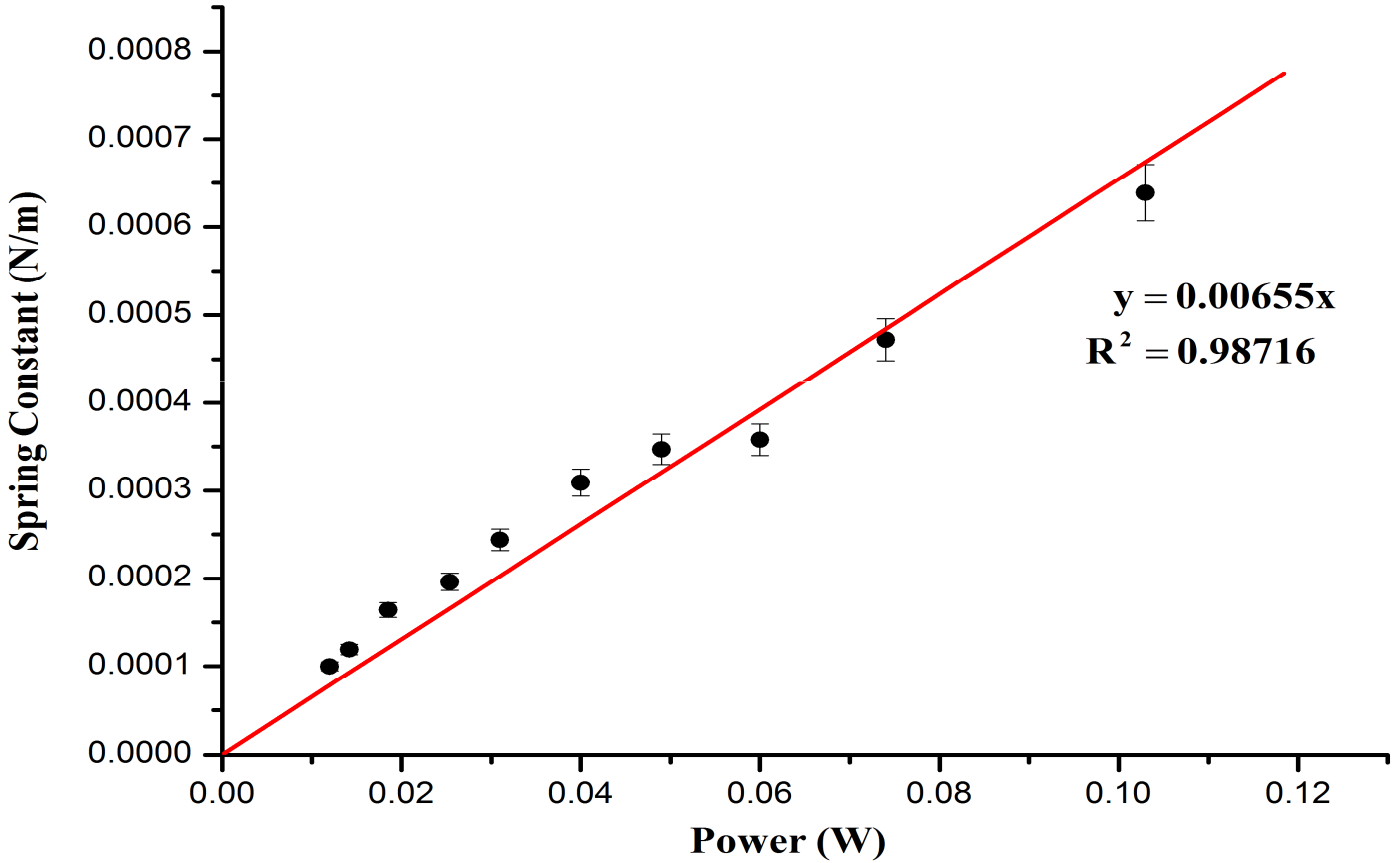
$$F_{trap} \propto I_{grad}$$

Trapping force

Intensity gradient

Calibrating the trap by the Equi-partition method

$$F = -\alpha x \qquad F_{trap} \propto I_{grad}$$



$$\alpha = 9.9\times10^{-5} \pm 5\times10^{-6}\ \text{N/m}$$

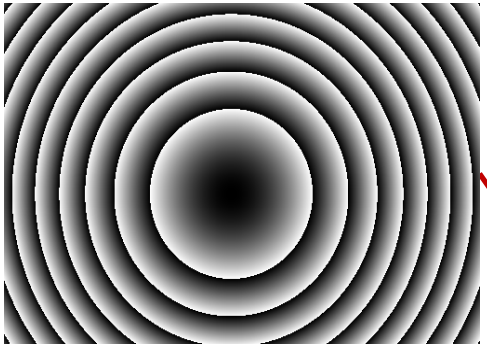
CSIR
our future through science

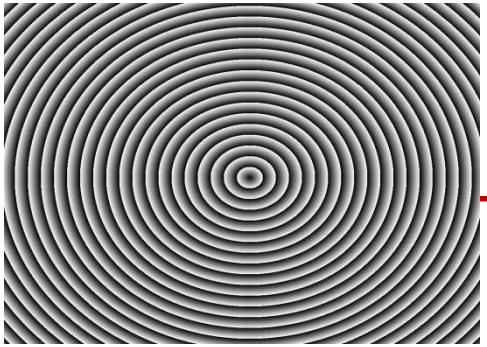
Novel beam trapping using a spatial light modulator

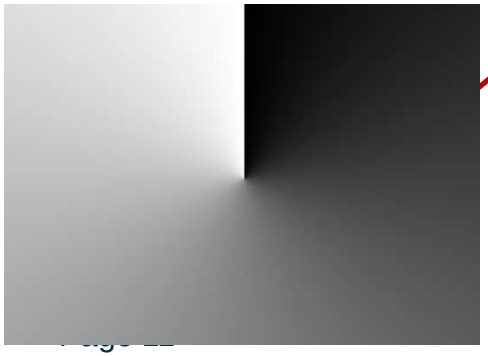
CSIR

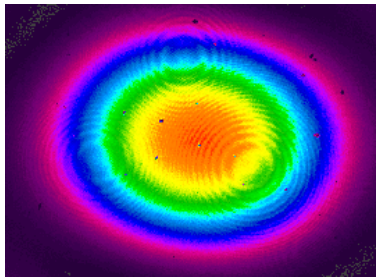
our future through science

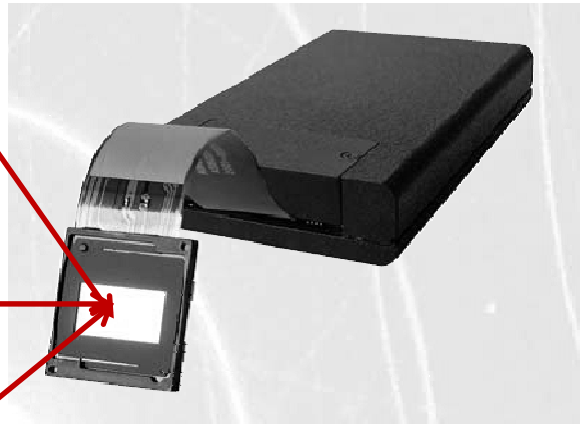
Digitally generating beams using a spatial light modulator (SLM)

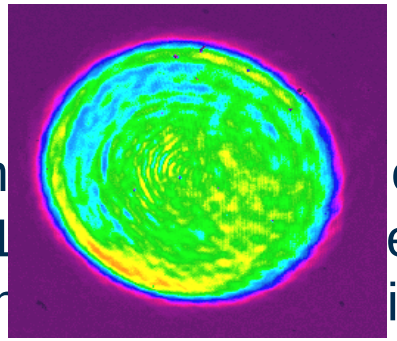




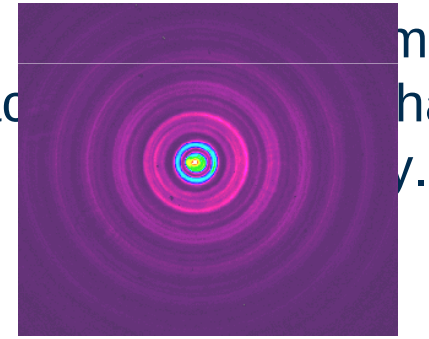


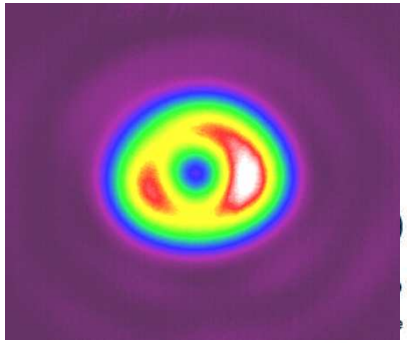


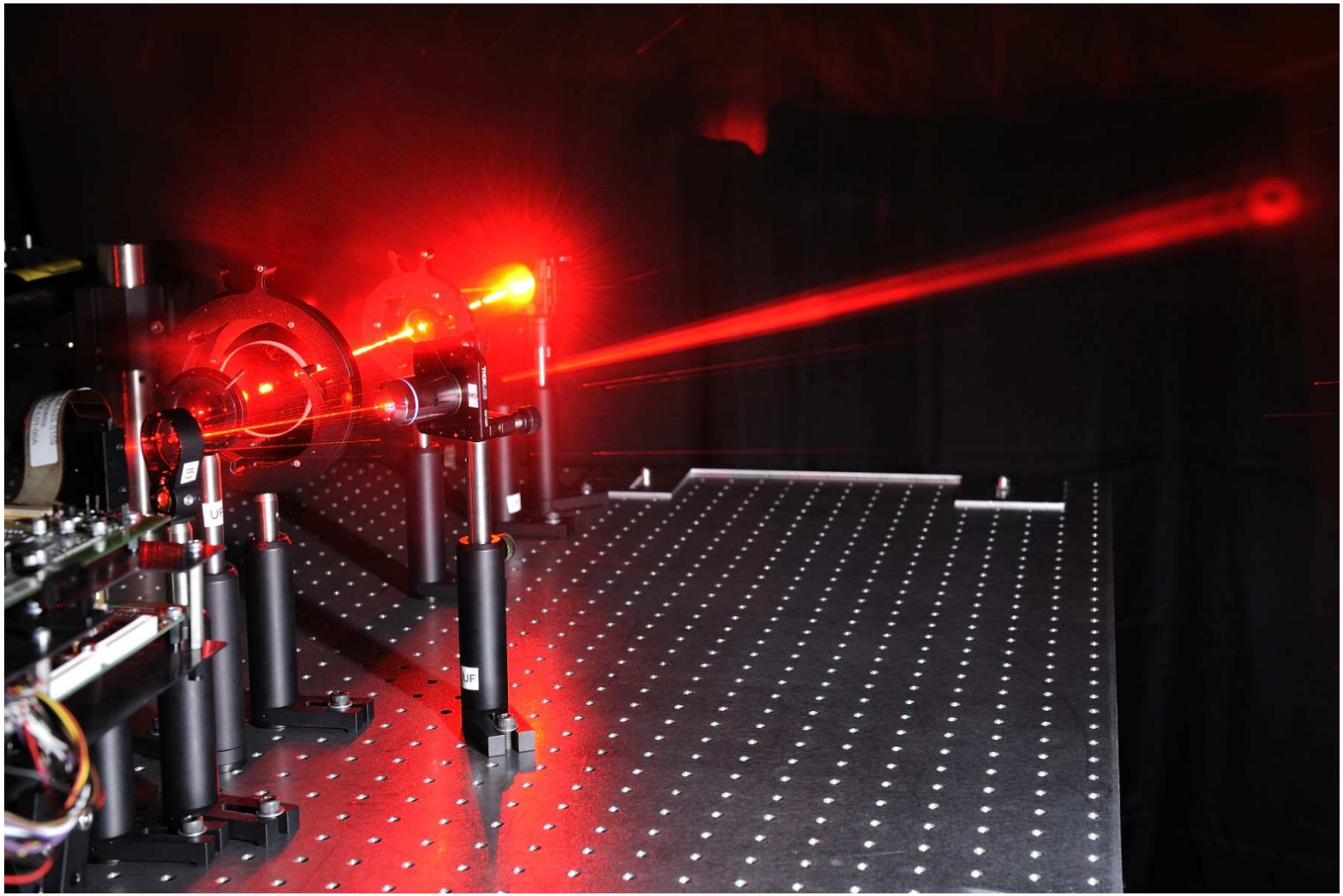




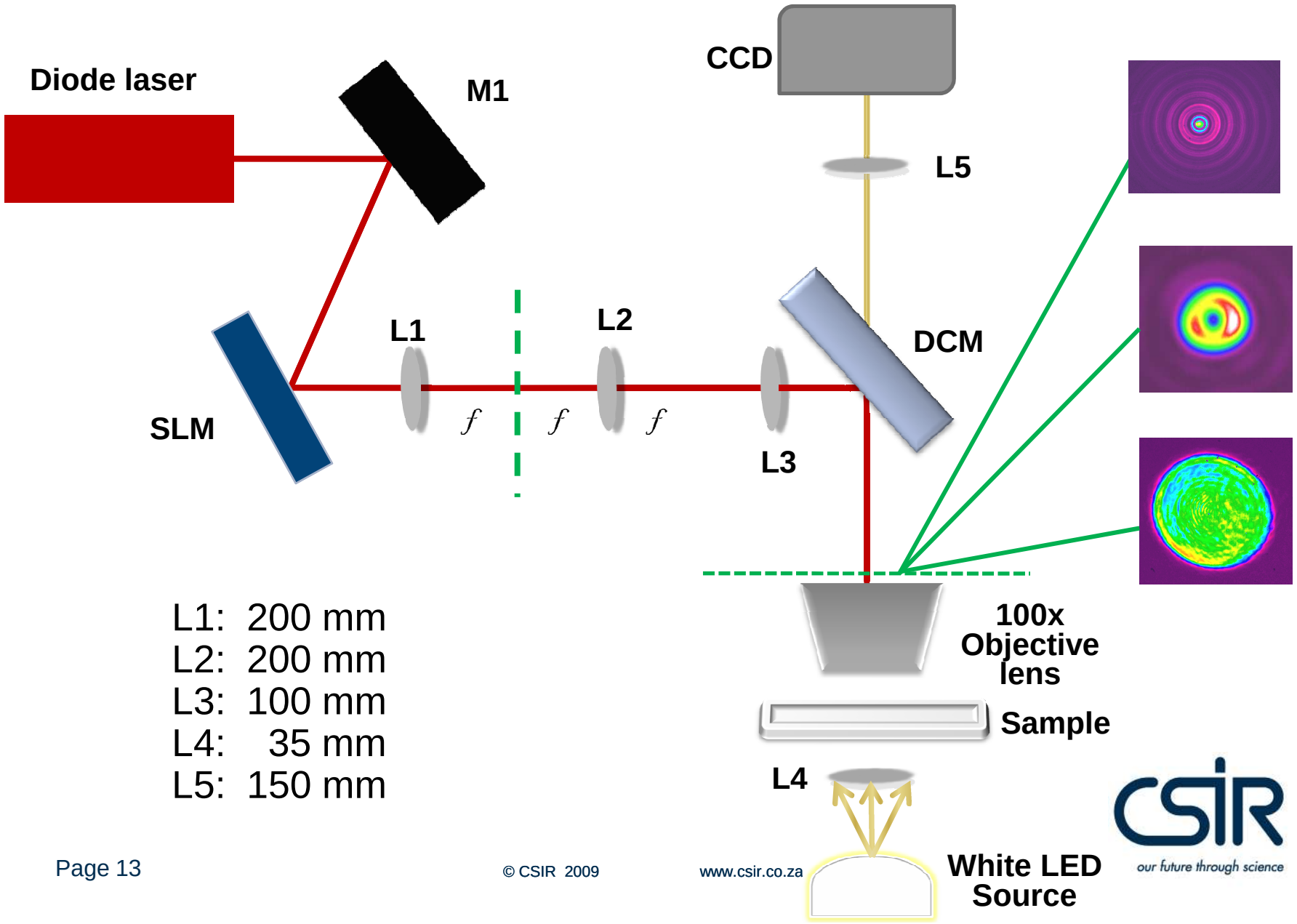
Th of an
SL e the
ph itude
of the incident
m
ac hase
y.





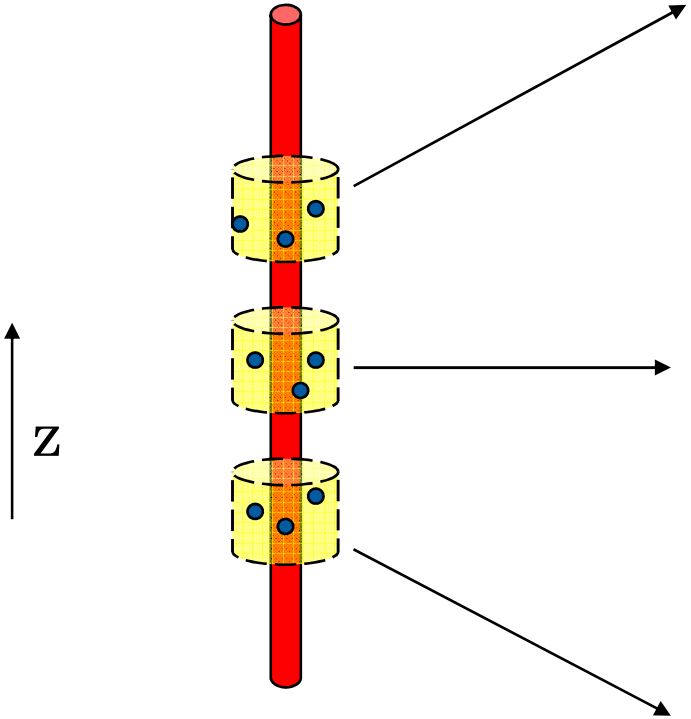


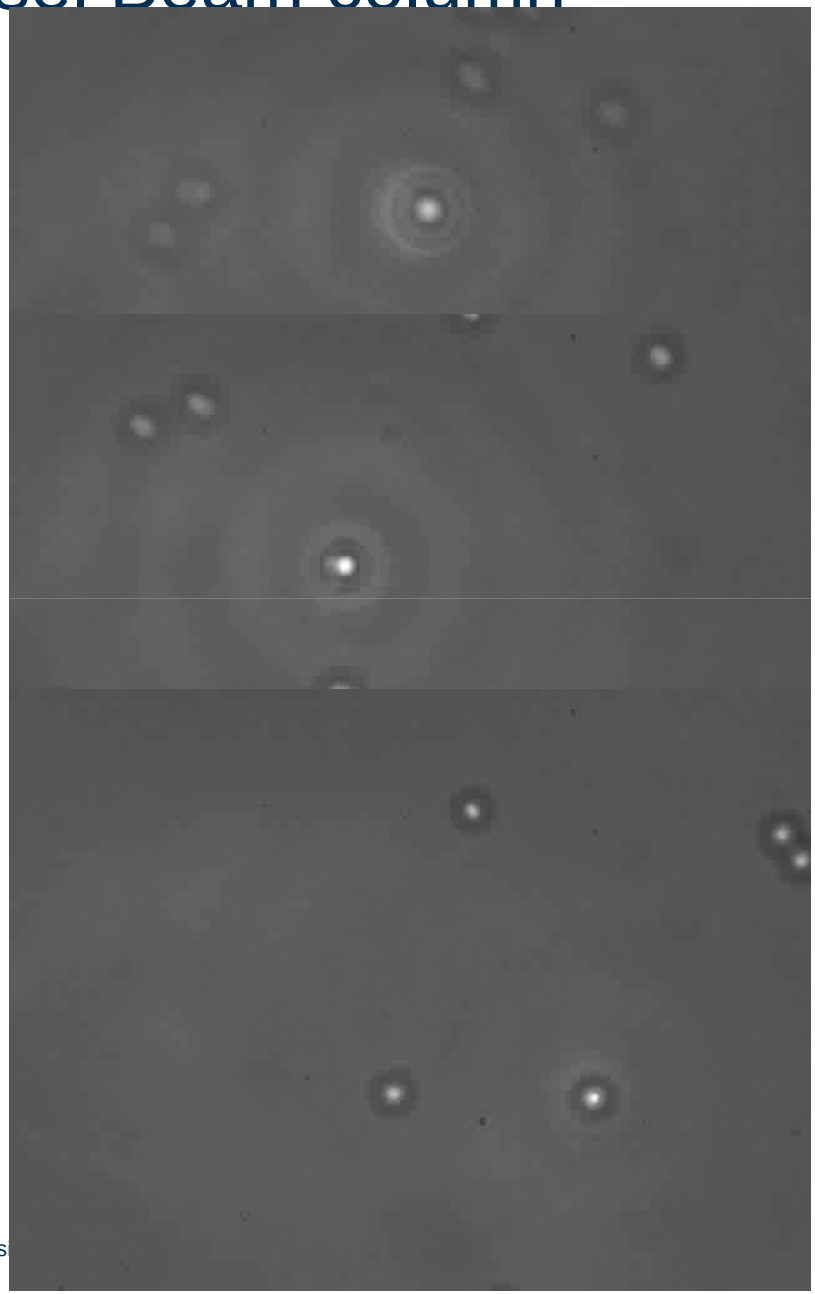
Optical set-up to achieve novel beam trapping



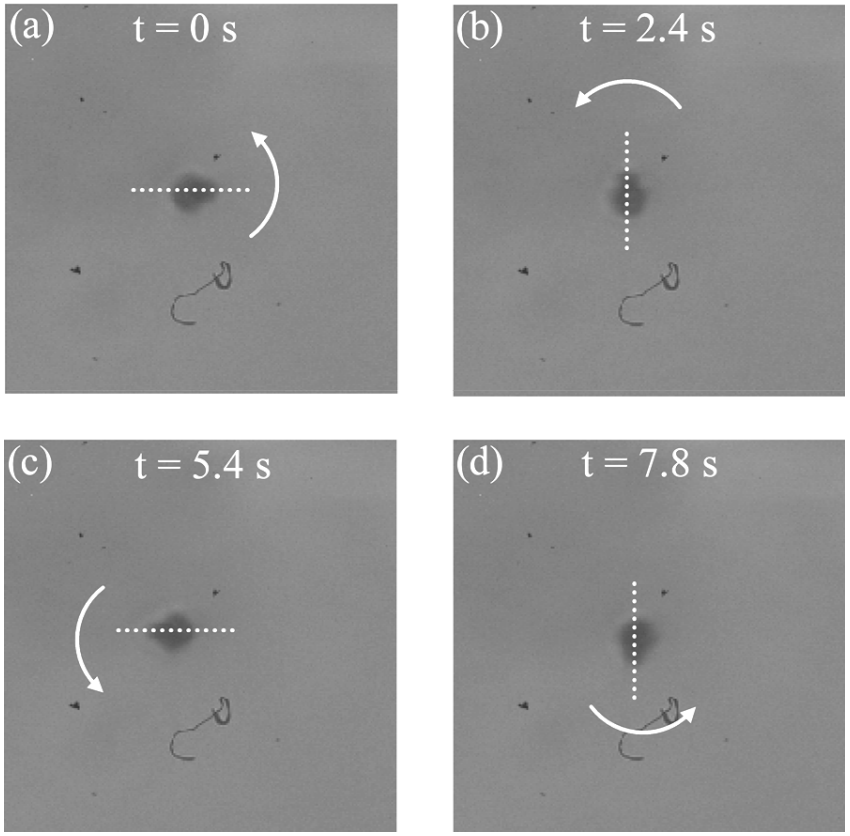
L1: 200 mm
L2: 200 mm
L3: 100 mm
L4: 35 mm
L5: 150 mm

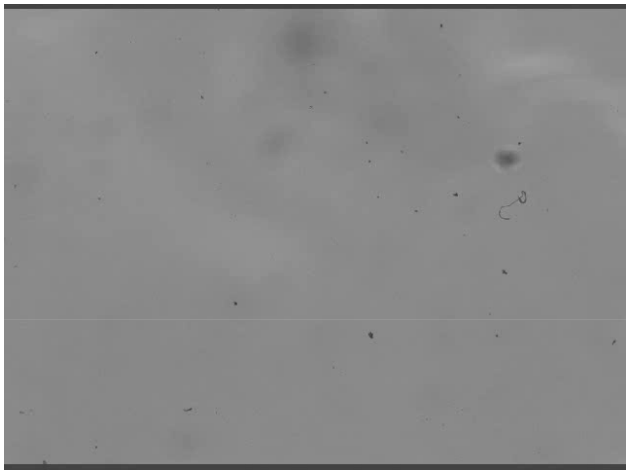
Trapping along a Bessel Beam column





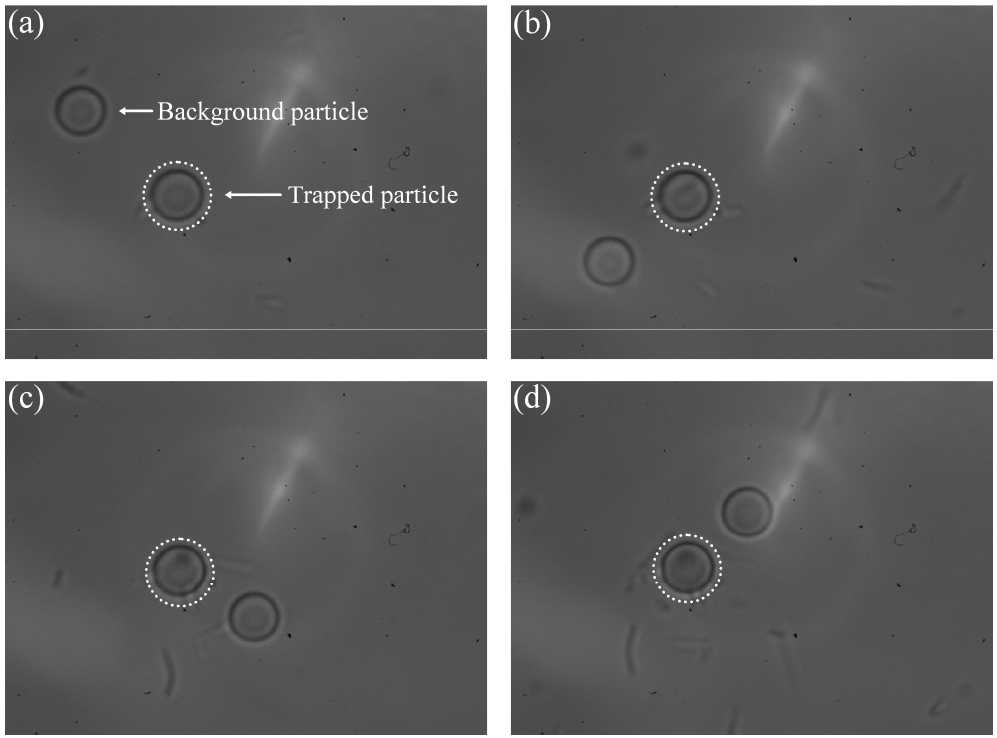
Vortex beam of order $\ell = 1$ rotated in the anti-clockwise direction

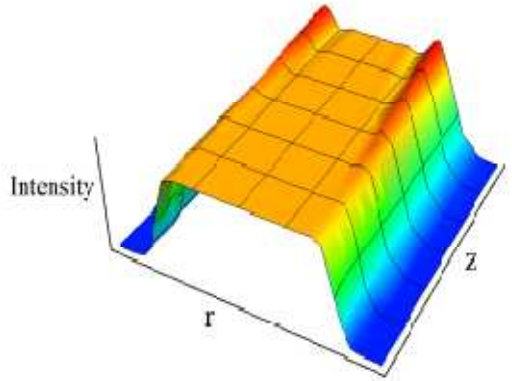


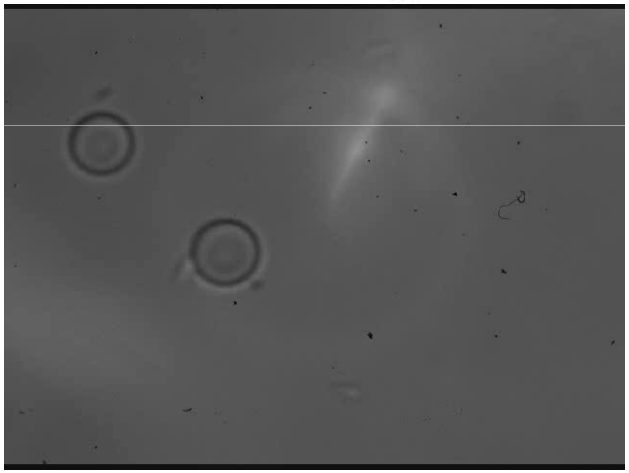


Video illustrating the rotation of iron fillings trapped within a vortex beam

Trapping of a silica bead using a Super Gaussian beam





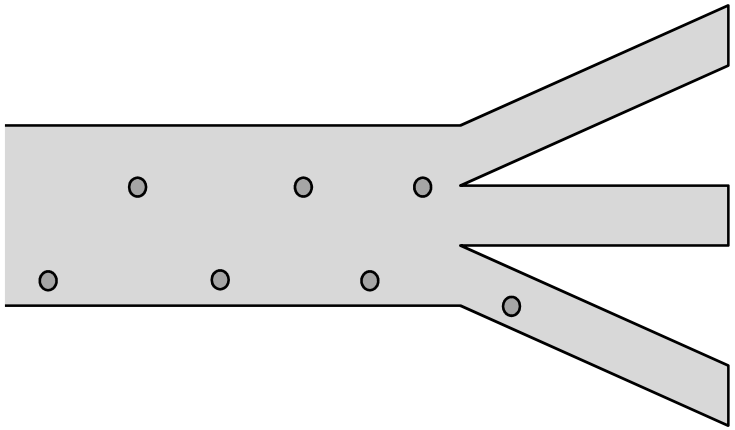


Video illustrating a SG trap

Future work

Venturing into the field of Micro-fluidic

An important aspect of Micro-fluidics is the study of fluid properties within a channel of dimensions of approximately tens to hundreds micrometers achieved by the use of optical tweezing. The basic micro-fluidic channel is made up of polydimethylsiloxane (PDMS).



Micro-fluidic channel

Applications in Micro-fluidics:

- Particle manipulation within a channel
- Measuring fluid properties
- Particle sorting

Measuring the drag force within a Micro-fluidic channel

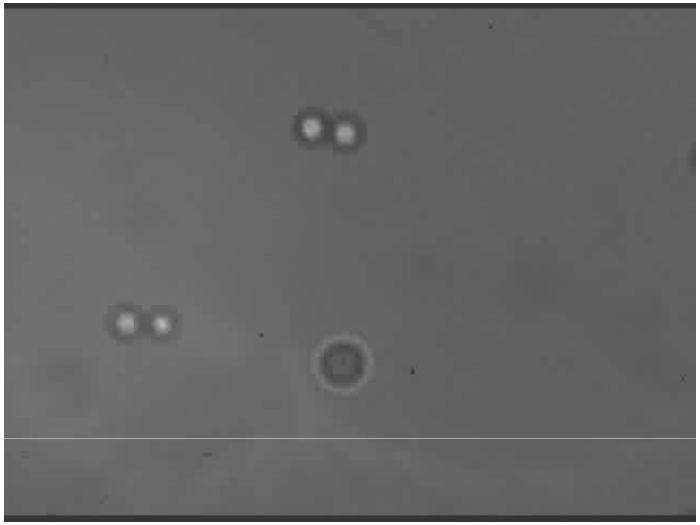
$$F_{trap} \propto I_{grad}$$

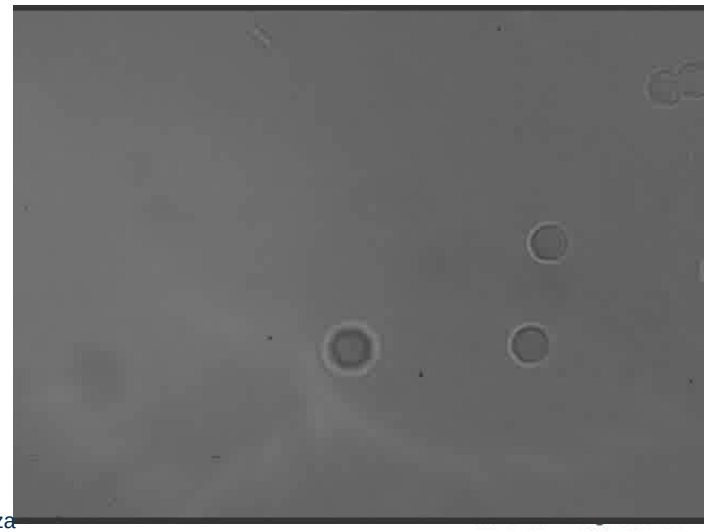
Intensity gradient

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

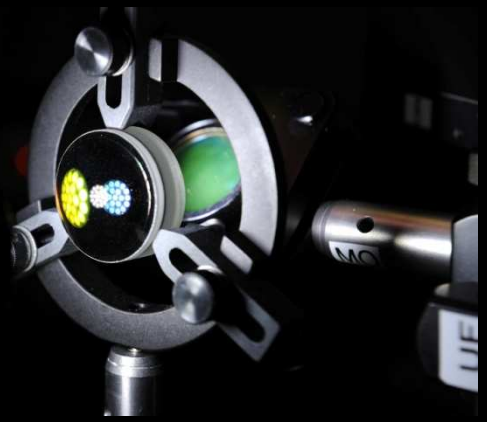
Viscosity of fluid

Velocity of fluid as bead escapes trap





Thank you



- **Join the Mathematical Optics**
- **research team!**

- **Opportunities: MSc and PhD studentships, Post docs and Sabbaticals**

- **Contact: Dr Andrew Forbes or Dr Stef Roux**

- **www.csir.co.za/lasers/index_mathematical_optics.html**

Thank you

our future through science