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Designing Optical Traps from the Bottom Up

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Abstract
Optical trapping is a highly dexterous method of manipulating and interrogating nano- and micro-components. It has wide range of application, from fundamental biology and biomedical studies at the cellular and subcellular levels, to studies of colloid and surface chemistry as well as controlled studies of aerosol chemistry relevant to climate change models, to fundamental physics connected to our understanding of the statistical mechanics of small systems, with opportunities of working towards the macroscopic quantum limit. To allow greater flexibility of design we have supplemented our lab’s use of a commercial fluorescence microscope with a new, open-source hardware microscope, of our own design, incorporating x-, y-, and z-motion of the sample stage, piezoelectric fine-scale control of microfluidic chambers within the workstation, Köhler illumination, a CMOS camera, automated tracking of microparticles, and provisions for alignment and calibration (in three dimensions) of optical traps. Here we describe our analysis of the three-dimensional potential well created by a single-beam laser gradient trap, and discuss algorithms for compensating for any factors that might otherwise limit the quality of the optical trap.

Set-Up
Our setup also consisted of:
- Prosilica Camera DCAM 1.31
- LabVIEW Program:
  Communicates with camera and records pictures and video
- IDL Programs:
  For data collection and analysis

Microscope Construction
- Kohler Illumination
- CCD Camera
- Objective Lens
- Dichromic Mirror
- Piezo-Electric Stage
  - Used for calibration of potential in z-direction

Data

Results:
- The potential energy in the figure 3 and 4 is extracted by using Boltzmann’s formula:
- Figure 3 and 4 show that the stiffness in x- and y-direction is almost the same. This means that the strength of the trap in x- and y-direction is the same.
- The graph 2 show the relationship between the change in the z-direction and the change in the integrated brightness of the trapped particle. However, the relationship is subjected to the change in the illumination system, so we need more additional information about the particle (e.g. how its radius change when it move in z-direction) to study the z-potential energy of the trap

Conclusion
Improvements:
- Use the laser at a higher power
- Fix the aberration in the system
Further Research:
- Extract more information about the particle when it is moved in z-direction in order to establish a standard test that can help us study the z-potential energy of the trap