Standing wave optical trap for the investigation of nanoscopic aerosol particles

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INTRODUCTION

Optical trapping involves sending two powerful laser beams in opposite directions to trap a particle where they meet, and can be used to trap micrometer and nanometer sized particles which are otherwise difficult to isolate for study [2], [3].

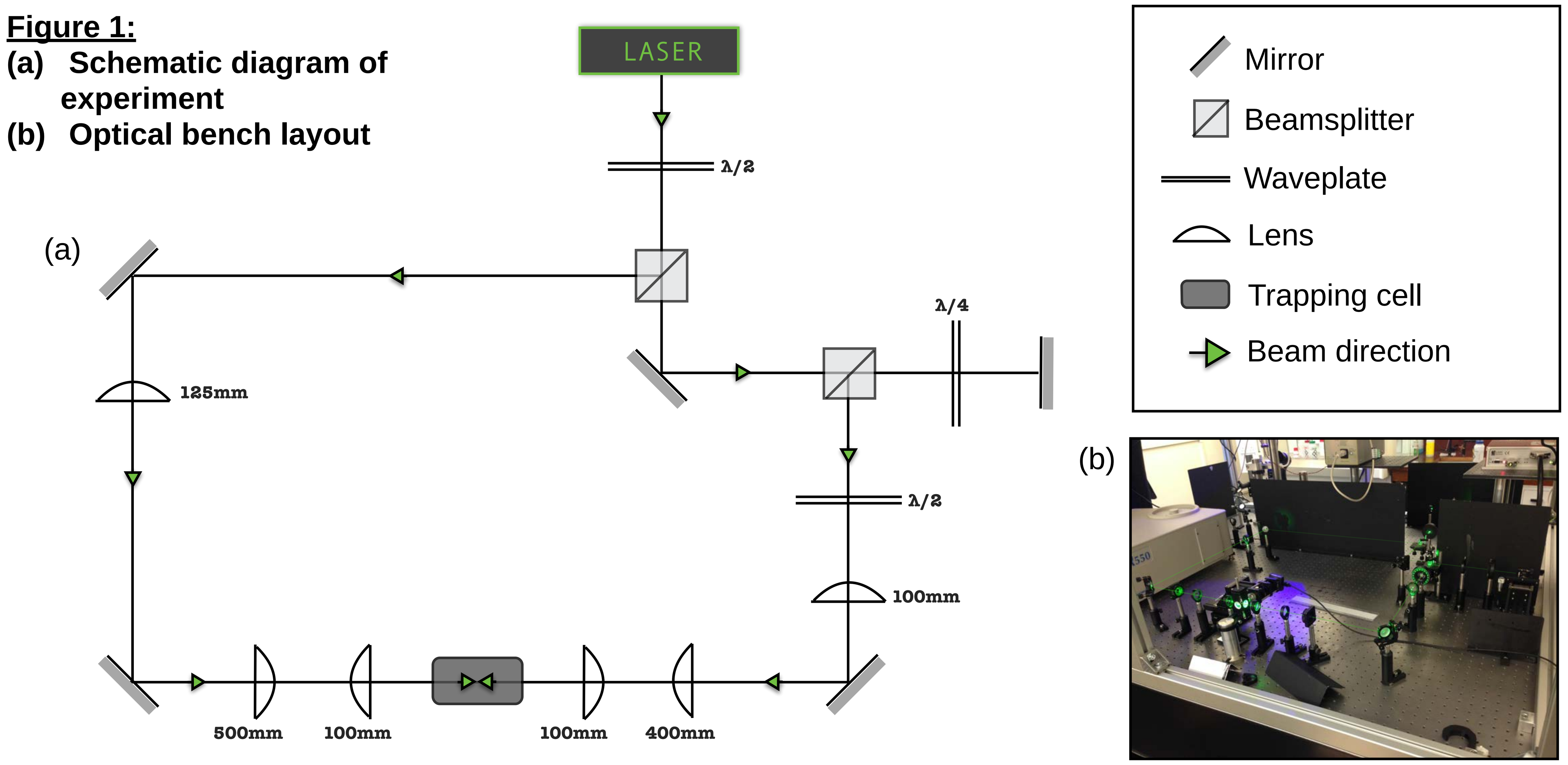
Light is an electromagnetic wave, and is therefore subject to wave effects like interference and diffraction. Recently, the interference of similarly polarised beams has been used to create a new type of trap, a so called '**standing wave**'. In this approach, multiple particles can be trapped at the same time and filtered according to their sizes. It is the approach which best allows investigation of aerosol particles, and therefore has applications in climate science and to drug inhalation technology. **The primary aim of this project was to build such a standing wave trap.**

Cloud formation processes are governed by **nucleation**, when wet air cools and many small water droplets form from the supersaturated air [1]. Processes such as these can be recreated and investigated in the laboratory, by trapping an aerosol particle and then altering the humidity in the air local to it. **The secondary aim of this project was therefore to control relative humidity and investigate the nucleation process.**

BUILDING THE EXPERIMENT

The bulk of the project consisted of building the experiment and setting up the imaging and data retrieval system. The trap itself (Fig 1) took a single laser beam from a Type-4 **539nm laser** and split it into two arms using a **polarising beamsplitter**. The main challenge was to align the two resultant beams so that they were perfectly head-on when meeting, while keeping the path lengths equal to within a tolerance (**coherence length)** of ~7mm. The right hand arm was kept static, with an inbuilt lens relay involving a **moveable mirror** to allow for incremental change in the path length of this arm so as to correct for any offset between the two arms.

Figure 1:
(a) Schematic diagram of experiment
(b) Optical bench layout



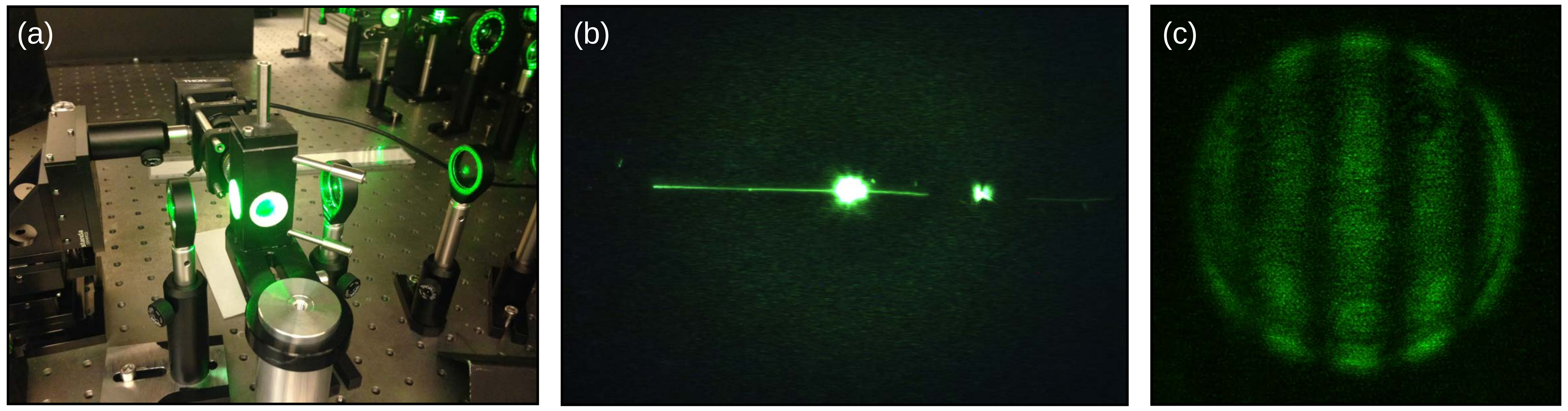
Half and quarter-wave plates were used to ensure that the two beams were of either parallel polarisation (for a standing wave trap) or orthogonal polarisation (for a **radiation pressure trap**), depending on the choice of settings. **Lens relays** in each arm provided the beam with 4x enlargement. The cell which would hold the aerosol was placed such that the beams from each arm focused at a point within it.

A **camera** with a 1.8mm focal length lens was set up to image the trapping cell, and a H2O **gas line** connected to the cell to control relative humidity. A 10% NaCl, 90% H2O solution was nebulised in to the cell.

MIE SCATTERING

Individual aerosol particles can be modelled as **dielectric spheres** with a particular (complex) **refractive index.** Electromagnetic wave scattering means that light rebounds off these particles in some directions more than others, creating a **fringe pattern** (Fig 2c). The necessary scattering regime for micrometer and nanometer sized particles is called **Mie scattering.** By imaging this pattern and fitting to the theoretical model of what the pattern ought to be, we can infer various characteristics of the aerosol particles.

Figure 2: (a) Trapping cell being imaged (b) Image of laser beams and two trapped particles (c) Focused image of a trapped particle, showing Mie scattering fringes

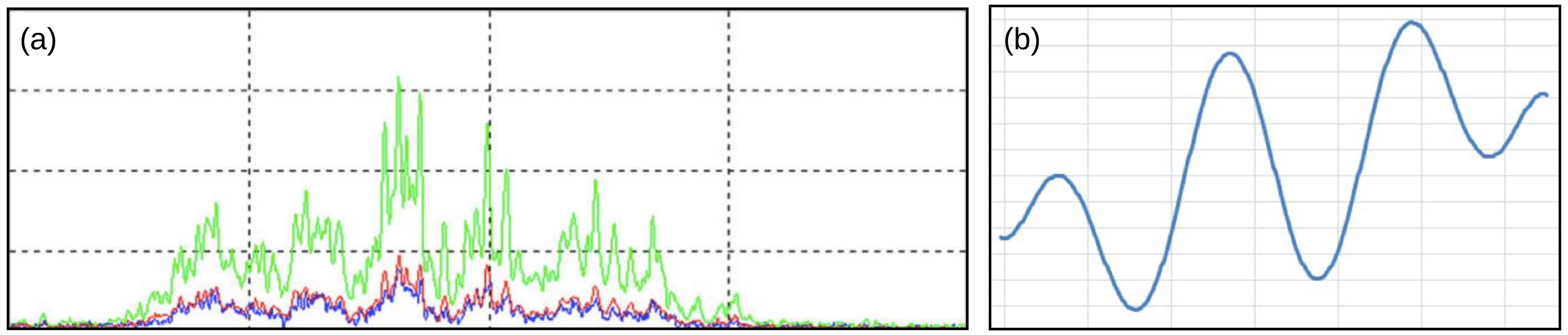


PRELIMINARY RESULTS

Individual particles and pairs of particles were successfully trapped (see Fig 2) but a fully-fledged standing wave trap was not achieved since it was not possible to stably trap three or more particles at the same time. Prioritising the improvement of the optical trap meant only preliminary results were taken using single particles.

The regime was as follows: a **relative humidity of 51.63%** was used; *E-AIM* gave a **molality** (concentration of salt) **of 515.7 g/dm^3**. Combined with a **temperature of 23.9C**, Millard and Seaver [4] gave a **refractive index of 1.409.** The beams had parallel polarisation. *MiePlot* produced theoretical values for various wavelengths; the first attempt at a fitting of 1000nm is shown in Fig 3b. The line profile from the *ThorCam* program is in Fig 3a.

Figure 3: Plots of intensity vs scattering angle (a) From imaging data (b) First theoretical output



CONCLUSIONS AND FUTURE WORK

I have gained an intuition as to the practical function of various optical instruments that I have learnt about in my degree course. Through reading various academic papers I have gained an appreciation of Mie scattering theory, and the phenomena of efflorescence and deliquescence in aerosols. I have met formally for the first time the concepts of optical guiding, aberration and relative humidity.

Although only preliminary results were taken, the time-consuming job of building the optical trap is now complete. With further small adjustments this apparatus could be used as a fully operating standing wave trap and more conclusive aerosol investigations undertaken as in [2], [3].

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