A Remote Experiment for Optical Levitation of Charged Droplets

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Abstract. We present a remotely controlled experiment in which liquid droplets are levitated by a focused laser beam. The droplets levitate at the point where the photon pressure of the focused laser beam balances the gravitational force. The size and charge of a trapped droplet can be measured in this experiment, which allows studying many fundamental physics processes: photon pressure, diffraction of light and the motion of charged particles in electrical fields. The laser power required (~1 W) can easily harm the eye. High voltages are also used. Further, the cost of the equipment is relatively high. It thus constitutes an ideal experiment for remote control.

1 Introduction

In this work, we present a remote laboratory (RL) on optical levitation of charged droplets. In the experiment, optical levitation [1] is used to levitate droplets inside a small cell where an electric field can be used to move the droplet upwards and downwards in the laser beam. The RL presented in this work and in [2] offers access to an experiment where concepts of modern physics are introduced without being limited by costs, logistics or safety issues. The RL enhances formal learning by providing students with more laboratory time working with a spectacular experiment that is not accessible outside research laboratories.

2 Experimental setup

Optical levitation is a method for levitating micrometer-sized dielectric objects using laser light. In our experiment, various physical properties of the levitated droplet can be investigated. With the experimental setup, illustrated on the left side of Figure 1, users can measure the size and charge of the droplets and investigate how charged particles move in electric fields. A DPSS laser (diode pumped solid state), with a maximum power of 2 W is vertically aligned and focused into a glass cell. Droplets are generated using a piezo droplet dispenser and descend in the laser beam until they become trapped just above the focus of the laser.

Trapping occurs when the force of the radiation pressure directed upwards equals the gravitational force acting downwards. The interaction between the droplet and the laser field produces a diffraction pattern. The size of the droplet can be determined using the expression for Fraunhofer diffraction. The droplets are formed by 10% glycerol and 90% water. The water quickly evaporates leaving a glycerol droplet of radius 30 μm in the trap. Droplets normally become electrically charged. The top and the bottom of the trapping cell consist of two electrodes which can be used to apply a vertically directed DC or AC electric field. A DC field moves the droplet up or down in the laser beam until it finds a new stable position, while the AC field forces the droplet to oscillate around its equilibrium position. The magnitude of the oscillations depends on the size of the droplet, its charge, and the strength of the electric field. A position-sensitive detector (PSD) allows the user to track the vertical position of the droplet.

Fig. 1 Left: Sketch of the experimental setup. The droplet dispenser produces droplets which are trapped by a focused laser inside a cell. The motion of a trapped droplet is tracked by the PSD. Right: RL graphic user interface. To the left, a webcamera displays the cell in which the drop is trapped. To the right, a plot which represents the position of the droplet as a function of time is shown. The step in the graph of the droplet position is due to a user change in the electric field applied over the cell.

3 Remote Lab Application

We have created an intuitive application that allows the experimenter to perform the same tasks as if they were on site in the laboratory. The RL application for conducting experiments has been designed using EjsS [3]. It has been developed in JavaScript and can, therefore, be deployed in any standard web browser. The RL application is available online from an open course at the UNILabs (http://unilabs.dia.uned.es) web portal.

Figure 1 (right side) shows the RL application's graphical user interface (GUI). The interface is divided into two main areas. The left side is used for controlling and interacting with the laboratory devices to perform the experiments. In this part, buttons to turn the laser and the droplet dispenser on and off are provided, as are sliders to change the intensity of the laser and the strength of the electric field. The right side is used to give visual feedback to the users using videos and graphs. This part has four tabs presenting the following information: (i) *Trapping droplets* offers a close view of the cell (ii) *Sizing droplets* shows the diffraction pattern created by the droplet, (iii) *Tracking droplets* contains a graph plotting the vertical position of the droplet vs the time, and (iv) *General view* gives a general picture of the experimental setup.

4 Conclusion

An experimental set-up has been presented for carrying out modern physics experiments on an optically levitated droplet. The remote system allows access to the experimental setup to students and researchers all over the world and guarantees the safety of users, as they do not need to be in the presence of the high-power laser or the high voltages required for the experiment.

References

[1] A. Ashkin and J. Dziedzic, Optical levitation by radiation pressure, *Applied Physics Letters* **19** (1971) 283-285.
[2] D. Galan, O. Isaksson, M. Rostedt, J. Enger, D. Hanstorp and L. de la Torre, A remote laboratory for optical levitation of charged droplets, *European Journal of Physics* (accepted) (2018).
[3] W. Christian and F. Esquembre, Modeling physics with easy java simulations, *The Physics Teacher* **45** (2007) 475-480.