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**Dr. Vineeta Bajaj,**

JOVE

Review Editor

Dear Dr. Vineeta Bajaj,

First, we would like to thank the editor and the reviewers for their valuable input on our manuscript “Safe experimentation in optical levitation of charged droplets using remote labs”.

Two of the referees find the manuscript of great value and support its publication. The third referee states "Although the technique of optical levitation is of great importance, it is hard to find the novelty and sufficient scientific achievements in the manuscript. I therefore could not recommend it for publication. “We find it impossible to respond on such a vague and general statement without any specific criticism or references to others work. Further, the statement of reviewer #3 completely contradicts the statements of reviewers #1 and #2. We therefore choose to only comment and act on the very valuable statements of reviewers #1 and #2.

Reviewer #1 and #2 and the editor have made long lists if minor things that should be corrected, changed or added. We have carefully worked through the lists and made the appropriate changes. There are only a few points where we have chosen not to change the manuscript. In these cases, we have clearly described why we have left the comment without any action. Only one case is stated as a major concern, when Reviewer #1 writes:

"*Major Concerns:*

*Provide info on availability of the lab for general audience, in other words who is eligible to work with it? Are there any restrictions? Now, after registration I was not authorized to book a lab time. Hence, following concern: When the lab will be available to work with? Is there specific starting date? Is it only available during the semesters? Etc*."

Our answer to this concern is the following: The main point with our paper is to present the concept of a remote lab on optical levitation. Our concept can be copied and applied by other institutions to allow their students to access such an experiment. Very few remote labs offer free access to users, due to their possible supervising necessities and/or maintenance costs. Our system will be allowed for use after agreement between the consumer university and our university. Also, users first need to get enrolled to the proper course in UNILabs and then make a reservation to work with the remote lab through the booking system which, in turns, alerts us about potential uses of the equipment. Please note that since the remote lab uses a high-power laser, it is of extreme importance to control and schedule accesses to the equipment, for other people working in the same lab room would need to be aware when the laser could be turn on. Information about this is now given in the paper. It would, of course, be ideal if we could have the system open for use for any person connect to the internet and we are applying for financial support to set up a parallel system for such open access system.

To summarize, we have adjusted our manuscript by taking care of most of the suggestions by reviewers #1 and #2 and the editor. We believe this has substantially improved the quality and readability of our paper which we now hope meets the standards of JOVE.

With best regards

**The authors**

# Editorial comments

1. Please take this opportunity to thoroughly proofread the manuscript to ensure that there are no spelling or grammar issues. The JoVE editor will not copy-edit your manuscript and any errors in the submitted revision may be present in the published version.

In section 1.3.2 on page 4, the space between lines around the formula don't look correct in either Word or LibreOffice. Be sure to check the final version.

Introduction, paragraph 2, row 3: However, there are certain limiting factors when reproducing the experiment at schools or universities. (error in referencing)

**Changes made to the paper: All changes have been accomplished.**

2. Please revise lines 41-43, 96-97, and 115-117 to avoid previously published text.

**Changes made to the paper: Lines 41-43 have been changed to:**

***The experiment requires a laser power that is three orders of magnitude larger than levels that can be hazardous 2) the experiment uses voltages that are harmful and 3) the investments required for the setup exceeds the amount normally available in undergraduate teaching laboratories.***

**For lines 96-97, the whole paragraph has been changed. See point 15 of reviewer#2**

**Lines 115-117** **have been changed to:**

***By using the concept of a remote laboratory, experimental work in modern physics that require costly and dangerous equipment can be made available to new groups of students.***

3. Please spell out each abbreviation the first time it is used.

Page 3, 2nd paragraph, line 1. The abbreviation ICT (technologies) is only used once in the article without explanation. Exchange it with "information and communication technologies" if that is what is meant.

**Changes made to the paper: ICT has been explained. Direct current (DC), alternating current (AC), University Network of Interactive Laboratories (UNILabs), Watt (W) and volts (V) were also include.**

4. Please revise the protocol text to avoid the use of any personal pronouns (e.g., "we", "you", "our" etc.).

Short abstract, line 4: We here present a … This article presents a …

Long abstract, line 1: We present an experiment that allows … An experiment is presented that allows ...

**Changes made to the paper: We have rewritten all sentences with personal pronouns.**

5. Please revise the protocol to contain only action items that direct the reader to do something (e.g., “Do this,” “Ensure that,” etc.). The actions should be described in the imperative tense in complete sentences wherever possible. Avoid usage of phrases such as “could be,” “should be,” and “would be” throughout the Protocol. Any text that cannot be written in the imperative tense may be added as a “Note.” Please include all safety procedures and use of hoods, etc.

**Changes made to the paper: All protocols have been checked and modify to fulfill this suggestion**

6. Please note that your protocol will be used to generate the script for the video and must contain everything that you would like shown in the video. Software must have a GUI (graphical user interface) and software steps must be more explicitly explained ('click', 'select', etc.). Please add more specific details (e.g. button clicks for software actions, numerical values for settings, etc.) to your protocol steps. There should be enough detail in each step to supplement the actions seen in the video so that viewers can easily replicate the protocol. Some examples:

1.2.3: Where is translation stage A? How to adjust the stage? A schematic showing different translation stages may be helpful or label/mark these stages in Figure 1. What type of paper is used?

**Changes made to the paper: A new image, Figure 4 has been included to clearly identify translation stage A. Also, explanations in point 1.2.4 have been included: “*Do this by adjusting the translation stage marked with letter A in Figure 4. For that purpose, gently turn the driving screws at the base of the translation stage until the desired position is reached.”.***

1.2.4: How to raise the laser power?

**Changes made to the paper: An instruction for this has been added.**

1.3.1: Please reference Figure 1 here so the readers/viewers know where the screen is.

**Changes made to the paper: Reference “E” for the screen has been replaced by a reference to Figure 1.**

1.3.2: Where is the line marked 1? It is hard to follow without showing a picture.

**Changes made to the paper: A picture with the diffraction pattern and a clearly visible red line, marked with the text “1”, can be seen in Fig. 7. A reference to the figure has been also added when Line 1 is mentioned.**

1.2.2) Under “EJS variables” check the box named … select the (check) box named … and set “laser current2” to 25

**Changes made to the paper: Many sentences in the protocol have been changed to better explain how to follow the experimentation procedure.**

7. Please include single-line spaces between all paragraphs, headings, steps, etc.

**Changes made to the paper: Single-line spaces have been included between headings, paragraphs, steps, formulas…**

8. After you have made all the recommended changes to your protocol (listed above), please highlight 2.75 pages or less of the Protocol (including headings and spacing) that identifies the essential steps of the protocol for the video, i.e., the steps that should be visualized to tell the most cohesive story of the Protocol.

**Changes made to the paper: The essential steps for the video have been highlighted in bold respecting the 2.75 pages limit.**

9. Please highlight complete sentences (not parts of sentences). Please ensure that the highlighted part of the step includes at least one action that is written in imperative tense.

**Changes made to the paper: All highlighted parts include at least one action in imperative tense.**

10. Please include all relevant details that are required to perform the step in the highlighting. For example: If step 2.5 is highlighted for filming and the details of how to perform the step are given in steps 2.5.1 and 2.5.2, then the sub-steps where the details are provided must be highlighted.

**Changes made to the paper: All highlighted steps include all relevant details.**

11. Please include a figure or a table in the Representative Results showing the effectiveness of your technique backed up with data.

**Changes made to the paper: The following paragraph has been included in this section: “****When the laser beam is well aligned, and the bottom plate is clean, the drops are almost immediately trapped. When a droplet is trapped it can stay in the trap for several hours, giving plenty of time for investigations. The radius r of the droplets is in the range of 25 ≤ r ≤ 35 µm and the charge has been measured between 1.1⋅10-17 ±1.1⋅10-18 C and 5,5⋅10-16 ±5,5⋅10-17 C.”**

12. As we are a methods journal, please revise the Discussion to explicitly cover the following in detail in 3-6 paragraphs with citations:

a) Critical steps within the protocol

b) Any modifications and troubleshooting of the technique

c) Any limitations of the technique

d) The significance with respect to existing methods

e) Any future applications of the technique

**Changes made to the paper:** **The Discussion section has been modified to include the following considerations:**

**1. Our method is used to investigate the charge and size of droplets, one by one. When the measurements are made the droplet is released and descends onto the bottom of the cell, unfortunately making the bottom glass dirty. This will after some time cause the laser light to scatter, making it harder to trap the next droplet, meaning some cleaning is needed.**

**2. The measurements take quite some time to perform, so the method is mainly a tool to work with single droplets. If statistics for a large amount is the goal, other methods are better. For example: Electrostatic Charge on Spray Droplets of Aqueous Surfactant Solutions, Polat, M. Polat, H. Chander, S..**

**3. The size of the droplets are of large importance to the experiment, since it has a big influence on the calculations of the absolute charge. We have used three different methods to determine the size, and they all agree very well. The method described above (using the diffraction pattern) is one, the second one is to oscillate the droplet with a vertical electric field and use the phase difference between the electric field and the position and the last one is to image the shadow of the droplet on a screen, and with a camera determine the size.**

**4. Our experimental set-up is to be used as a RCL for students, to experience laboratory work with powerful lasers. The set-up is also being prepared for investigations of trapped droplets in vacuum. First the droplet is trapped in air, and the cell is enclosed, and the air is removed. Hopefully we can investigate the properties of a trapped droplet in vacuum.**

13. For in-text references, the corresponding reference numbers should appear as superscripts after the appropriate statement(s) in the text (before punctuation but after closed parenthesis). The references should be numbered in order of appearance.

**Changes made to the paper: It has been checked that all references are in the correct order and are formatted as superscripts.**

14. Please remove the embedded figure(s) from the manuscript. All figures should be uploaded separately to your Editorial Manager account.

**Changes made to the paper: All figures have been removed from the manuscript.**

Please submit each figure as a vector image file to ensure high resolution throughout production: (.svg, .eps, .ai). If submitting as a .tif or .psd, please ensure that the image is 1920 pixels x 1080 pixels or 300 dpi.

**Changes made to the paper: All images are now provided in .eps format.**

# Reviewers' comments

## Reviewer #1

### Major Concerns

Provide info on availability of the lab for general audience, in other words who is eligible to work with it? Are there any restrictions? At the moment, after registration I was not authorized to book a lab time. Hence, following concern: When the lab will be available to work with? Is there specific starting date? Is it only available during the semesters? Etc.

**Comments to this concern are included in the cover letter at the beginning of this document.**

### Minor Concerns

1) Line 86: Please, specify laser type and wavelength; How tight is the focusing? Provide focal length or NA of the trapping lens.

**Changes made to the paper: The following sentence has been included: “The laser is a 2 W 532 nm diode-pumped solid-state laser (CW), where usually about 1 Watt (W) is used. The focal length of the trapping lens is 3.0 cm.”.**

2) Lines 101-102: The magnitude of oscillations also depends on stiffness of the laser trap.

**Changes made to the paper: Suggestion has been considered and it has been included in the manuscript.**

3) Line 105: Abbreviation ICT is mentioned for the first time, please, explain it.

**Changes made to the paper: All abbreviations have been explained.**

4) Line 161: Value, x, should be adjusted according to the size/weight of the droplet. Or error (in the determination of size of the droplet) interval should be specified.

**Changes made to the paper: We have included a previous step in other to center the droplet image in the PSD. The error interval has been included in the calculations step.**

5) Line 183: It could be suggested that gradual and slow adjustment of laser power could prevent droplet lost from the trap.

**Changes made to the paper: This sentence has been changed to:**

***Slowly reduce the laser power until the droplet is back in its original position as noted in 1.5.1.2.***

6) Lines 235-237: Wouldn't it be better to set a target (e.g. a beam dump) for laser beam to hit to check the alignment of the system? Please, also describe how maintenance service can be contacted.

**Comment to reviewer:**

**Because the number of webcams limits the user's vision of the setup, and because, for security reasons, we have made the decision not to allow him or her to adjust the laser position remotely, we had not considered the possibility of the target. However, a non-alignment of the laser is highly unlikely as the maintenance team checks the operation every day and we have not observed any misalignment that is not due to prior manipulation.**

**However, we will consider this comment for future versions of the environment, in which we will certainly consider including the beam dump.**

**Changes made to the paper: The following text has been added:**

***To contact the maintenance services, click on the icon that represents a dialogue bubble, located in the upper left corner of UNILabs. Then click on the "Admin user" message, write the message at the bottom describing the problem and press "Send”. To contact the maintenance services, click on the icon that represents a dialogue bubble, located in the upper left corner of UNILabs. Then click on the "Admin user" message, write the message at the bottom describing the problem and press "Send".***

7) Line 289: Please, check if the Ref. [7] is correct.

**Comment to reviewer: It is correct.**

8) Line 291: Please, check if the Ref. [8] is correct.

**Changes made to the paper: There was an error in the text referencing the main author of the work, but the reference was correct.**

9) Line 322: IB-Diploma program is not known to the worldwide/non-Swedish readers.

**Changes made to the paper: It has been changed to**

***International Baccalaureate (IB) Diploma Programme (www.ibo.org)***

## Reviewer #2

Major / Minor Concerns:

1) Line 73. I strongly believe that the tool developed is wonderful for student to be introduced into experimental methods. Moreover, this is a great simulator/training tool for experiment rehearsal (e.g., like those required for experiments in the Intl Space Station). However, I do not agree with the authors that claim this to ''allow more time working with laboratory equipment''. The ''hands-on'' experience is by no way fulfilled for the operators. The author shall spin their sentence in a different way.

**Comment to reviewer: Here we disagree with the reviewer. A remote laboratory does indeed allow more time for student to be trained in experimental work. This is obvious in the case of student on remote study programs but also for on-campus students since remote labs do not require to pay the cost for laboratory assistants. Hence, lab session can be made (much) longer.**

**We do agree that remote lab do not give “hands-on” in the sense of “mounting and turning knobs”. But we have not used the expression “hands-on” experience in our description of the RL.**

2) Lines 79-80. I do not understand what the authors want to say with ''limitations''. Please expand and explain.

**Changes made to the paper: The sentence has been changed to:**

***Therefore, RLs can not only offer a solution to both the financial and safety issues that traditional labs present, but also provide more interesting opportunities.***

3) Lines 82-84. The authors shall provide a short explanation as well as a reference for the technique.

**Changes made to the paper: Reference 4 has been included in the sentence, it explains well those techniques.**

4) Line 90. Why is trapping time limited to 9 hours? Droplet evaporation? Laser power drift? Please explain.

**Changes made to the paper: It has been changed to:**

***There is no upper time limit observed for trapping. The longest time a droplet has been trapped is nine hours, where after the trap was turned off.***

5) Throughout the text, ALL acronyms shall be defined when first encountered.

**Changes made to the paper: All abbreviations and acronyms have been defined correctly.**

6) Line 107. It is claimed that the lasers used are potentially hazardous. The authors shall minimally describe the laser types and Classes and explicitly explain where and how they are used in the set up.

**Changes made to the paper: Now line 107 reads:**

***Table 1 shows the possible injuries that lasers can cause according to their class; in this setup a Class IV laser has been used, the most dangerous one. It can operate with a 1 Watt (W) of visible laser radiation, so the safety provided by the remote operation is clearly suitable for this experiment.***

7) Line 123. I hope a Laser Safety Officer did an analysis of the set up and the surrounding lab environment. I would strongly suggest that the authors write that the users shall have a minimal training with regards to laser safety (eye, skin) prior to do any manipulation with at least laser class 3 or above.

**Changes made to the paper: Added after line 120 “Protocol”:**

***The laser used in this experiment is a class IV laser delivering up to 1 W of visible laser radiation. All personnel present in the laser laboratory must have conducted adequate laser safety training.***

8) Line 127. Please add/describe A, B, C, and D on Figure 1.

**Changes made to the paper: It has been clarified that the user should check that four light absorbing boards are surrounding the experiment. The A, B, C and D marking on the boards are removed.**

9) Line 131 or somewhere else in the text, add something like ''Power ON all systems'' and ''wait xx minutes for electronic stabilization, etc''.

**Changes made to the paper: The suggestion has been added to the sentence.**

10) I suppose that the experimental cell is in the open atmosphere (air). Please specify. Any chemical reactions noticed at the droplet interface? Any photoinduced effects?

**Changes made to the paper: The observed effects on the charge and the size on the droplets, from air and laser, are now discussed under the Representative results section.**

11) Line 139. How this can be known? Please explain.

**Changes made to the paper: The sentence has been changed to:**

***Observe the laser beam using alignment laser goggles to make sure that the beam ends up in the beam dump. If not, adjust position of beam dump.***

12) Lines 146, 147, 151. Add/describe A, B, and E on Figure.

**Changes made to the paper: It has been clarified how to use the translation stage (and which one). A new figure of the discussed stages has been enclosed.**

13) Line 152. With the info that I have, taking a photograph with a mobile could be a real laser hazard if the beam hits the screen and is reflected back to the eye... I would not recommend this…

**Changes made to the paper: Now it reads:**

***Take a picture with the web-camera that is placed to observe the screen from underneath.***

**Comment to reviewer:**

**We agree that it could be a potential hazard as it was written. The picture should be taken with a web-camera placed in a position where there are no reflections. This is accordance with standard laser safety procedures that should be applied when the system is mounted.**

14) Line 154. Explain in more details or add a reference.

**Changes made to the paper: The following text has been added to the sentence:**

***A more detailed explanation of the process can be found in the work of J. Swithenbank et al6.***

15) Line 166. What shall we expect depending upon charge in terms of drift? By the way, how is the droplet charged? Capacitive, tribological, photoelectric effects?? Please explain.

**Changes made to the paper: We have changed lines 94-99 in order to answer this concern to:**

***The droplets emitted from the dispenser consist of 10 % glycerol and 90 % water. The water part quickly evaporates, leaving a 20 to 30 µm sized glycerol droplet in the trap. The maximum size of a droplet that can be trapped is about 40 µm. There is no evaporation observed after about 10 s. At this point, all water is expected to have evaporated. The long trapping time without any observable evaporation indicates that there is minimal absorption and that the droplet essentially is at room temperature. The surface tension of the droplets makes them spherical. The charge of the droplets generated by the droplet dispenser depends on the environmental conditions in the laboratory, where they most commonly become negatively charged. The top and the bottom of the trapping cell consists of two electrodes placed 25 mm apart. This can be used to apply a vertical electric DC or AC field over the droplet. The electric field is not strong enough to create any arcs even if 1000 V is applied over the electrodes.***

Lines 16) Line 174. I guess that the authors want to say ''measurement of the mass of the droplet''. Please check this as there are so many measurements that can be taken on and in the droplet.

**Changes made to the paper: Now it reads:**

***To calculate the charge of the droplet it is necessary to first measure size of the droplet. The weight (Fmg represented in the Fe equation of step 1.5.1.5) of the droplet can then be determined since the density of the liquid is known.***

17) Line 179. How stable is the laser power in time? This could affect position as well as droplet evaporation and thus concentration (index of refraction).

**Comment to the reviewer:**

**We have studied the variation in time of the laser and it is minimal. It can vary 3 mW per second in the worst case, so it does not make a difference in the measure of the position of the droplet.**

18) Line 213. Any safety interlock button/signal to tell potential users in the vicinity of the lasers to move out?

**Changes made to the paper: We have added the following text in 2.2.1:**

***Note: When a user connects to the remote laboratory, it emits an acoustic signal that warns other people in the surrounding area for a few moments that someone will power on and manipulate the laser remotely.***

19) Line 249. What is the maximum size of the droplet achieved? Any deformation from a sphere or ellipsoid? Any noticeable evaporation or photoinduced gradients? What is the temperature of the levitated droplet? Please discuss these effects.

**Comment to the reviewer: Please see comment 15**

20) Line 281. What is the spacing between the electrodes? Are there any risks or arcing with your given spacing, voltage (1 KV), atmosphere, and potential evaporation?

**Comment to the reviewer: Please see comment 15**