

Methodology Article

The Laser-drop-method: Making Microorganisms Visible Without a Microscope Using a Simple Laser Pointer

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Abstract

In order to get students and the general public excited about physics and biology, you need experiments that are as simple and exciting as possible. They should be interesting but also inexpensive to promote interest in scientific experimentation. A drop of water acts like a magnifying glass, allowing you to see particles trapped inside it. All you need is a usual red or green laser pointer and a plastic syringe. Simply draw the water to be examined into the syringe and squeeze out a drop that just hangs from the tip of the syringe. By simply shining a laser beam through a drop of water hanging from the tip of the syringe, the particles are cast as magnified shadows on any wall (screen). This ‘laser drop method’ can be used to examine, view and measure microorganisms and green algae from ponds, pools and lakes. Even oral mucosa cells from the mouth and hairs can be magnified and made visible using the ‘laser drop method’. In addition, all zooplankton can be observed in the water droplets as very agile and free-swimming organisms. This method is very simple and a low-cost science activity, and is suitable for outdoor excursions, in lecture halls for students and in the classroom of higher grades as well as for demonstrations to the general public, as a tool of applied physics and biology. Home experimentation is also possible with the ‘laser drop method’.

Keywords

Microscope, Magnification, Laser Pointer, Water Drop, Microorganisms, Biology

1. Introduction

Microscopy of microorganisms is an essential part of microbiology, biology studies and biology lessons. Light microscopes with 100, 400 and maximum 1,000x magnification are usually used to penetrate into the μm range [1]. An amazingly simple method is to use a red or green laser pointer and a hanging drop of water to create a DIY projection microscope that makes microscopically small organisms such as green algae, ciliates, rotifers, copepods, nauplii and others visible to our eyes: the “laser droplet method”. You just need is a laser pointer and a plastic syringe, each fixed to a standard stand. If you shoot a laser beam through a drop of water hanging from

the tip of the syringe, you can make the contents of the drop visible as an enlarged shadow image on any wall (darkening required). The volume of the drop also offers the great opportunity to see living microorganisms in motion, which is hardly possible on a planar slide with cover glass. The microorganisms can therefore be examined in their natural environment (water) and the species can even be roughly determined - ideal for outdoor expeditions and in biology studies or biology lessons. In addition, the laser droplet method can also be used to image individual cells or hairs.

The physical basis is provided by Snell’s law of refraction

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[2], where the droplet acts as a spherical refracting lens with an assumed radius $r = g = 1.5$ mm. With a distance of two meters from the drop to the image plane ($b = 2$ m), a magnification factor $V = 1,773$ is obtained (equation (1)). The refractive index n_1 for air is 1.0, the refractive index n_2 of water is

1.33, B is the height of the image and G is the object height. Figure 1 schematically illustrates the magnification effect.

$$V = \frac{B}{G} = \frac{n_2 b}{n_1 g} \quad (1)$$

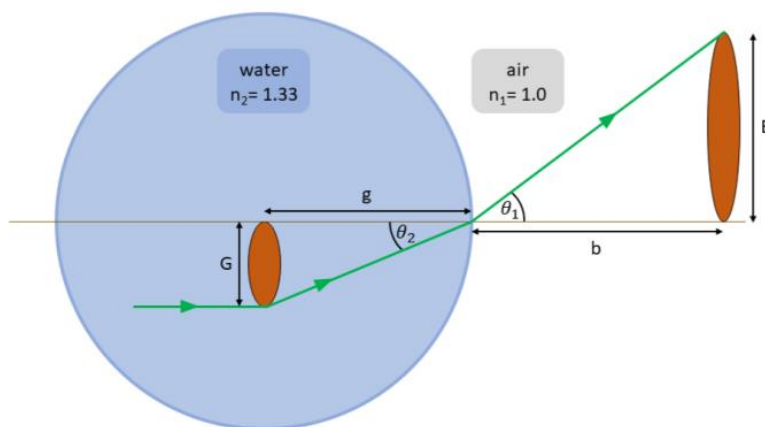


Figure 1. Scheme of magnification. Simplified illustration of the light path through drop of water and the resulting magnification of an object: g = radius of drop, b = distance drop - projection plane, B = image height, G = object height.

2. Materials and Methods

2.1. Basic Experimental Setup

Equipment and materials: green and red laser pointer (green: $\lambda = 532$ nm, red: $\lambda = 650$ nm, 1-10 mW), plastic syringe (10-20 mL volume), two stands with clamps.

Procedure: You draw about 10 mL of the water sample into the syringe. Fix the syringe in an upright position in the clamp on the first stand. The laser pointer is clamped horizontally to the second stand. The distance between the syringe and the laser pointer is not very important, about 20-30 cm has proven to be a good distance. The "screen" can be the wall of a room, a screen, a whiteboard or the outside wall of a building. The distance to the "screen" should be two meters so that the enlarged objects are within a centimeter range. To practise, a few drops were squeezed out of the syringe. A cup was placed under the syringe to catch the dripping water. It took some practice and patience before a drop stuck to the tip of the syringe. When the laser pointer was shone through the hanging drop, the shadows of the microorganisms or cells were measured with a (folding) ruler (one or two helpers required). Many microorganisms move very quickly across the screen, so it is best to perform the measurement in pairs. Video recordings have the advantage that still images can be used for measurement. Five to ten identical particles (oral mucosal cells, green algae, copepods, nauplii) were measured. Then a new drop was squeezed out of the syringe and the particles were measured

again. In each case, four drops per measurement were examined and the respective mean value and standard deviation (SD) were determined. Two hairs from two people were used for the hair measurement.

2.2. Examination of Water Samples from Ponds

Use the plastic syringe to draw water from the bank of a pond into the syringe (about 10-20 mL). The samples tested come from a park pond and a salt marsh pond.

2.3. Rotifers

Culture preparation in culture medium with green algae (*Chlorococcum*).

2.4. Hairs

A hair can be enlarged using the "laser drop method". To do this, thread as long a head of hair as possible (20-40 cm) from below through the syringe tip into the open syringe body, either with a fine sewing needle or with your fingers. The hair must protrude approx. 10 cm from both the tip and the upper opening. The plunger is then inserted and pushed all the way down without pulling the hair completely into the syringe body. Now about 10 mL of water is drawn into the syringe without the hair being completely sucked into the syringe. Then clamp the water-filled syringe into the clamp on the stand. The hair protruding from the bottom of the syringe tip often bends slightly so that it does not appear vertical in the

drop of water. The hair must therefore be weighted down with a small weight, for example a paper clip, a mini clothespin, a small screw or similar. Finally, squeeze a drop out of the syringe that completely surrounds the hair from all sides and send the laser beam through it.

3. Results

Figure 2 shows the experimental setup with a syringe drawn up with pure water. The green laser beam passes through the drop of water, but there are no shadows of particles on the "screen" (= negative sample).

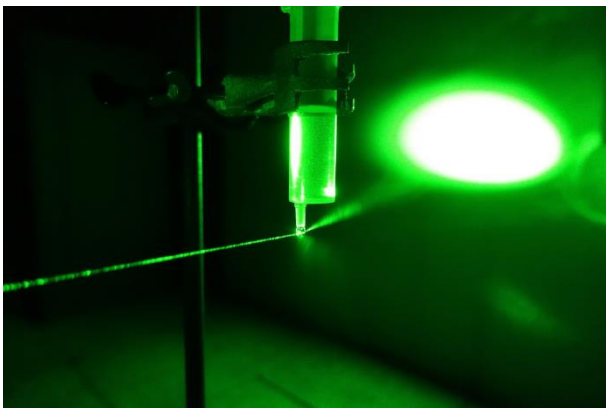


Figure 2. Experimental setup of the "laser drop method". The laser beam of a green laser pointer runs from left to right through a hanging drop of water.

3.1. Examination of Water Samples from Ponds

Figure 3 shows the typical result of a water sample taken in spring. Figure 3a probably shows a starlet alga (*Micrasterias*) [3] with an average original size of 40-300 μm and Figure 3b probably shows a *Coelastrum* [4] with an average original size of 20-120 μm . Both plankton species belong to the green algae (Chlorophytae).

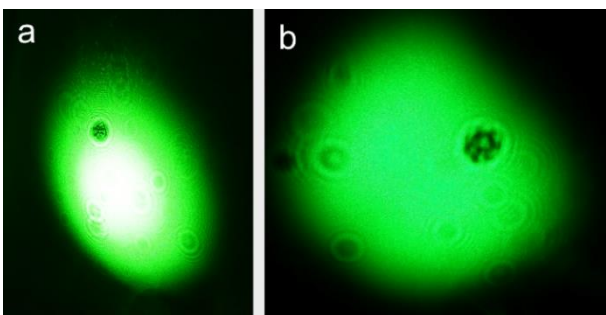


Figure 3. Shadow images of phytoplankton. Enlarged images of freshwater green algae in spring using a green laser pointer: a *Micrasterias*. b *Coelastrum*. Distance droplet to screen: 2 m, size of shadow: 7 cm $\pm$ 40 μm diameter.

Figure 4 shows the typical result of a water sample taken in summer and shows numerous microorganisms scurrying across the wall. These are the agile ciliates (*Ciliophora*) with an average original size of 20-300 μm , but they range from 10 μm to 3 mm in length [5]. Plankton proliferation had evidently increased dramatically during the warm period [6].

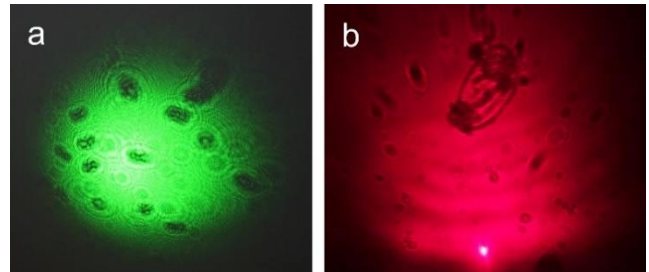


Figure 4. Shadow images of freshwater plankton in summer. The microorganisms look like tiny "balls of wool". (a) Illuminated with a green laser beam and (b) a red laser beam. Distance drop to screen: 2 m, size of shadow: 8-16 cm $\pm$ 45-90 μm diameter.

In Figure 5 (video screen shot) you can see the abdomen of a *Gastrotricha* with the typical two spine-like toe extensions at the end of the body, so-called adhesive tubes [7]. Original size: 70-500 μm [8].

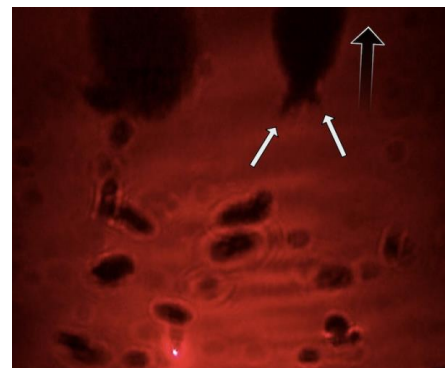


Figure 5. Shadow image of a *Gastrotricha* using a red laser pointer. Distance droplet to screen: 2 m, size of shadow: 20 cm $\pm$ 120 μm in length. The white arrows point to the two toe extensions. The black arrow indicates the direction of movement.

Two videos available online at Supplementary Material show various wild zooplankton species swimming around in summer pond as enlarged shadows created using the "laser drop method" with a laser pointer (red or green). Various microorganisms can be observed in different stages of development and forms which is not surprising as "young and old" and many different species live together in the water sample. In several samples of summer pond water, nimbly and hectically moving, sometimes rowing organisms flit through the picture, constantly changing direction. These include cope-

pods (original size 500-2,000 μm) [9] and their larvae (*Nauplius*, original size 60-120 μm) [10, 11] as well as ciliates and rotifers. A nematode can also be seen. Figure 6 a and b show a copepod with its two long antennules used in swimming. Figure 7 a and b show a copepod larva (*Nauplius*). Two videos with rowing copepods and nauplii can be viewed online under Supplementary Material.

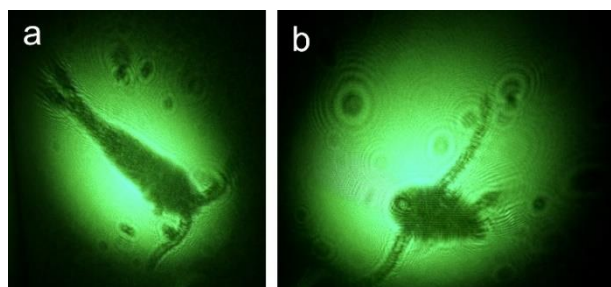


Figure 6. Shadow images of a Copepod using a green laser pointer. Distance droplet to screen: 2 m, size of shadow: 118 cm $\pm$ 670 μm long (video screen shots).

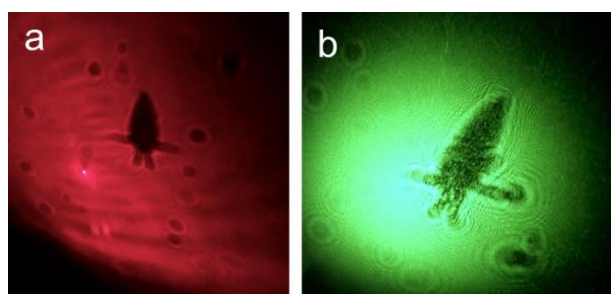


Figure 7. Shadow images of a Nauplius larva. (a) Illuminated with a red laser beam and (b) with green laser beam. Distance droplet to screen: 2 m, size of shadow: 12 cm $\pm$ 70 μm and 18 cm $\pm$ 100 μm long (video screen shots).

3.2. Rotifers in Culture Medium

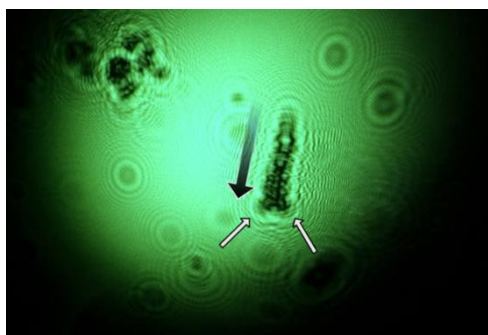


Figure 8. Shadow image of a rotifer (*Philodina citrina*) using a green laser pointer. Distance droplet to screen: 2 m, size of shadow: 40 cm $\pm$ 10 cm $\pm$ 230 μm $\pm$ 60 μm length. The white arrows point to the two-wheel organs. The black arrow indicates the direction of movement. *Chlorococcum*: 3.6 cm $\pm$ 1.25 cm $\pm$ 20 μm $\pm$ 7 μm diameter. The $\pm$ sign is a standard deviation (SD).

Figure 8 (video screen shot) shows a rotifer (*Philodina citrina*, original size 100-500 μm) in the culture medium, moving downwards in the direction of the arrow. You can clearly see the two-wheel organs (trochus/corona) on the head [12, 13]. The circular *Chlorococcum* green algae (original size 10-15 μm) serve as food.

3.3. Oral Mucosa Cells

As shown in Figure 9, the oral mucosa cells are visualized using red or green laser pointer. Their dimensions vary between 40 and 80 μm , displaying a range of shapes from irregular and diffuse to rectangular or round. Each cell contains a dark, round nucleus at its center [14]. Furthermore, the image reveals different cell sizes and occasional fragments caused by mechanical wear.

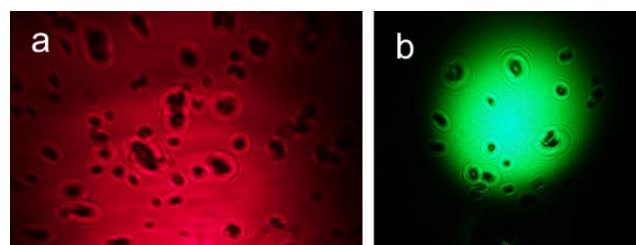


Figure 9. Shadow images of oral mucosa cells. (a) Using a red laser pointer (b) with the aid of a green laser beam. Distance droplet to screen: 2 m, size of shadow cells: 8-13 cm $\pm$ 45-75 μm diameter.

3.4. Hairs

A human hair threaded into the syringe tip can also be enlarged using the "laser drop method". Figure 10 shows a natural knot in a single human hair. The typical diameter of a normal human hair is approx. 60 μm [15].



Figure 10. Shadow image of a human hair with a natural knot using a green laser pointer. Distance drop to wall: 2 m, total diameter: 12 cm $\pm$ 70 μm (white bars). Medulla: 8 cm $\pm$ 46 μm , distance to the cuticula 2 cm $\pm$ 12 μm (red bars). The $\pm$ sign is a standard deviation (SD).

The measured data correlate closely with the theoretical predictions and remain within the calculated margins. Table 1

shows a summary of the results.

Table 1. Results of the “laser-drop-method” showing typical and measured size of microorganisms/cells on the screen. Distance drop to screen = 2 m; magnification factor = 1,773.

material	Typical diameter	expected size	measured size
Chlorococum	10-15µm	1.8-2.7 cm	3.6 cm ± 1.25 cm $\triangleq$ 20 µm ± 7 µm
Ciliophora	20-300 µm	3.6-53 cm	8-16 cm $\triangleq$ 45-90 µm
Rotifers (Philodina citrina)	100-500 µm	36-71 cm	40 cm ± 10 cm $\triangleq$ 230 µm ± 60 µm
Copepoda	200-2000 µm	36-355 cm	69 cm ± 30 cm $\triangleq$ 388 µm ± 171 µm
Nauplius	60-120 µm	11-21 cm	12 cm ± 2 cm $\triangleq$ 70 µm ± 12 µm 18 cm ± 0.9 cm $\triangleq$ 100 µm ± 5 µm
Oral mucosa cells	40-80 µm	7-14 cm	8-13 cm $\triangleq$ 45-75 µm
Hair	50-80 µm	9-14 cm	12 cm $\triangleq$ 70 µm

4. Discussion and Conclusions

The values measured correspond fairly well with the theoretical values and are within the calculated range. The results are summarized in Table 1. However, the measured values should only be regarded as a rough approximation, as this method takes several sources of error into account. Due to their own movement or flow forces, not all microorganisms or cells are located in the center of the hanging droplet, but are distributed throughout and move within the droplet. Depending on the size of the drop at the tip of the syringe, the radius of the droplet may vary. Depending on the alignment of the laser beam, this results in distorted or elongated wall images. Diffraction and interference patterns generated by the coherent laser light form the concentric rings around the microorganisms and cells. They distort the actual size and shape of the object somewhat. The measurement inaccuracy when measuring the shadows also plays a role. Therefore, the "laser drop method" is not an exact science, but it is perfectly adequate in the context of such a simple and yet so amazing experiment for easy imitation. It is remarkable that this simple method can actually be used to image living cells and microorganisms. If the screen or blackboard were teeming with green algae, copepods, nauplius larvae or oral mucosa cells (from students or teacher), it would certainly be a great experience for pupils and students in the lecture hall or classroom.

Abbreviations

SD Standard Deviation

Author Contributions

Andreas Korn-Mueller is the sole author. The author read and approved the final manuscript.

Data Availability Statement

The data supporting the outcome of this research work has been reported in this manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

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Biography



Andreas Korn-Mueller completed his PhD in Peptide Chemistry from Max-Planck-Institute of Biochemistry in Munich in 1994, and his diploma in chemistry from University in Tuebingen in 1991. He then spent two years conducting postdoctoral research in the high-security HIV laboratory at University in Munich. Since 1997, Dr. Korn-Mueller has been working as a freelance chemist, entertainer, author, and science communicator. So far, he has developed eight different science shows, which he successfully performs under the stage name “Magic Andy,” primarily at science festivals for young and old alike. Recognized for his exceptional contributions in fields of science education, Dr. Korn-Mueller has been honored with the “PUSH” award (public understanding of sciences and humanities), “Science On Stage” award as well as with the “University Award”. In addition, he has written five nonfiction books. In 2025 he worked as lecturer at the University of Applied Sciences Dresden for the experimental organic lectures.

Research Field

Andreas Korn-Mueller: creating new chemical and physical experiments, fluorescence and bioluminescence, chemiluminescent experiments using washing powder, “glow-in-the-dark” paint and foils, flames and fireworks.