Detecting Gyroscopic Thrust

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This paper describes a simple experiment on detecting gyroscopic thrust demonstrated by Prof. Eric Laithwaite in 1974. In this experiment the gyroscope suspended on the line by one end of its rotation axis was deflecting from the pivot point during precession. In addition to the original setup the author has isolated the gyroscope from surrounding air and conducted a video recording of the experiment from two positions simultaneously. The recording of gyroscope position and orientation allowed author to determine the trajectory of the gyroscope and analyze deflection dependency on gyroscope orientation. The results of this analysis indicate the existence of the external force acting on the gyroscope and causing the increase or decrease in linear momentum. It is suggested that the force is a result of the difference in aether pressure in front and at the back of the gyroscope rotor.

1. Introduction

The experiment described in this article continues the one presented by Prof. Eric Laithwaite during his famous public lecture at Royal Institution of Great Britain in 1974 [1]. In this experiment a gyroscope suspended on the line by one end of its spin axle was deflecting from pivot point during precession. In addition to the original experimental setup, the author decided to isolate the gyroscope from surrounding air in order to eliminate aerodynamic factors. Moreover, the author recorded the gyroscope trajectory and measured its deflection from the resting position and the orientation of its spin axis relative to the trajectory. The results of the experiment provide strong evidence for a thrust that moves the load suspended on the line.

2. Experimental Setup

The experimental setup includes the following parts:

- Flat washer suspended on a line 224 cm long.
- Laser pointer suspended on the washer leaves a light spot on a grid paper placed on the floor. The grid paper has a mark corresponding to resting state.
- Manual gyroscope isolated from surrounding air by two conical paper screens. One of the screens has a slash for the pull-cord that spins the rotor.
- Arrow pointer mounted on one of the gyroscope ends to indicate the orientation of the spin axis.

The total mass of the load is 98g. From here on the "load" means the set of objects that includes the washer, the gyroscope and the laser pointer.

3. Principal Experiment

Prior to actual experiment the grid paper is placed in the position where the laser pointer aims at the mark. After starting the gyroscope one end of its spin axle gets inserted into the washer (See Fig. 1). The position of light spot and arrow pointer is traced by video footage made from top and side views. For illustration purposes the fragments of video footage are shown on Figs. 2 and 3.

The following observations were made during the experiment:

- The trajectory of the light spot had a spiral-like shape with the resting point in the center.
- The spiral was curved in the direction of precession.
- During first 30 seconds after releasing the load the spiral radius demonstrated wavelike increase.
- After the first 30 seconds the spiral radius revealed wavelike decrease which is related to the slowdown of gyroscope spinning.

After frame-by-frame processing of video footage, the author reconstructed the trajectory of the load in Cartesian and polar coordinates by measuring the position of the light spot on the grid paper. The polar angle was counted clockwise. The speed of video footage is 10 frames per second. The accuracy of measurements in Cartesian coordinates is 2-5 mm. The orientation of the spin axis relative to the chosen polar axis was measured manually on the video-frame printouts with the accuracy of 3-5°. The accuracy of synchronization of two video records is 0.02 seconds.

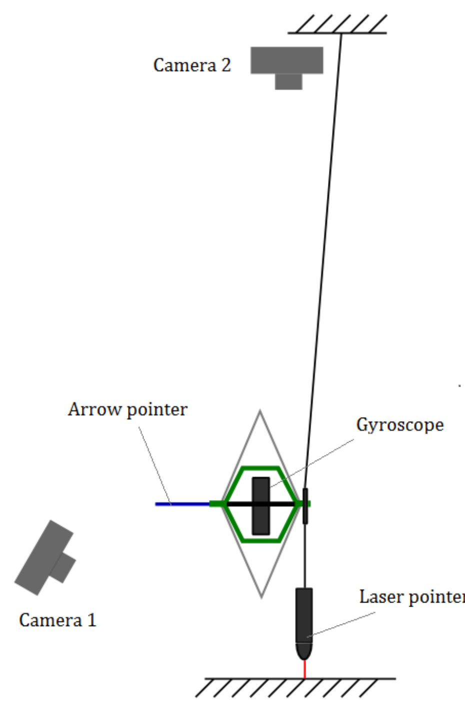

Fig. 1. Principle experiment setup

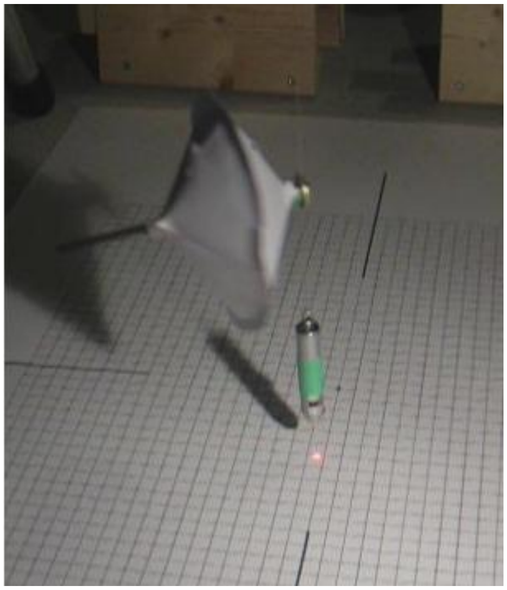

Fig. 2. Side view

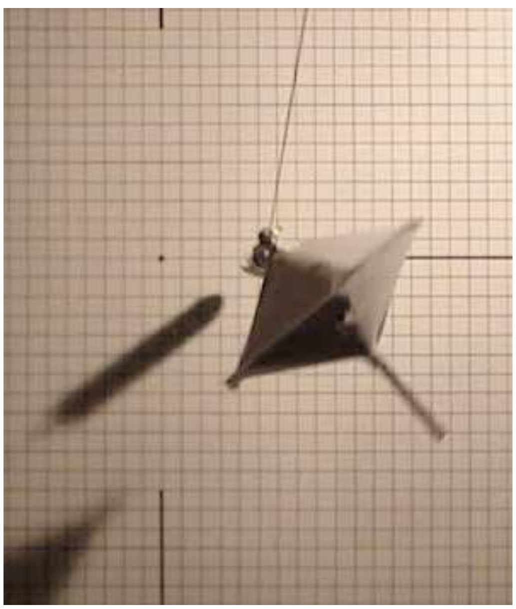

Fig. 3. Top view

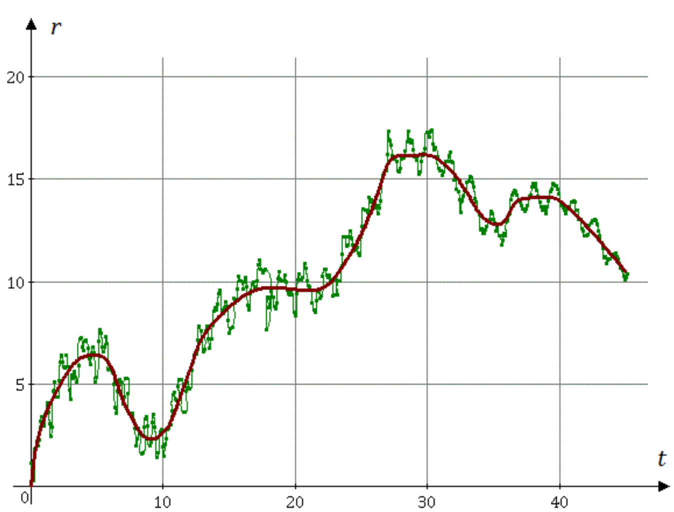

Fig. 4. Dependency of polar radius r (spiral radius) on time

Fig. 4 illustrates the dependency of polar radius r (deflection from the resting position) on time. The pole is the mark on the grid paper corresponding to the resting position.

Fig. 5 illustrates the dependence of polar angle φ on time.

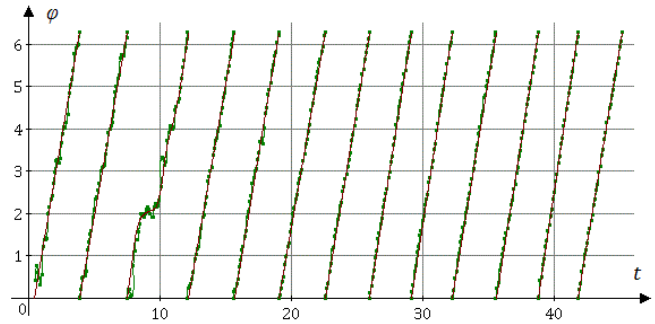

Fig. 5. Dependency of polar angle φ on time

Fig. 6 illustrates the dependence of the angle α between spin axis of the gyroscope and the polar axis.

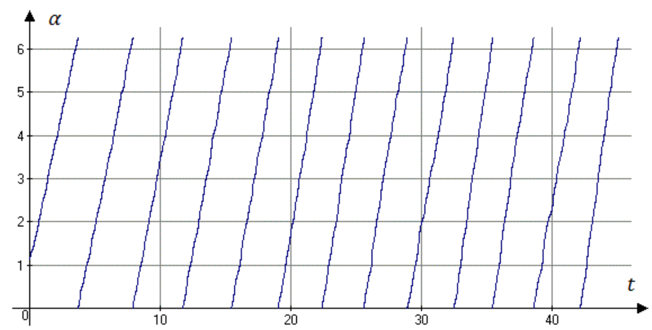

Fig. 6. Dependency of the angle α between spin axis of the gyroscope and the polar axis

Fig. 7 illustrates the way of calculating angle θ between the spin axis and the normal line to the trajectory. (The spiral on Fig. 7 has an arbitrary shape and does not reflect the actual trajectory of the light spot.)

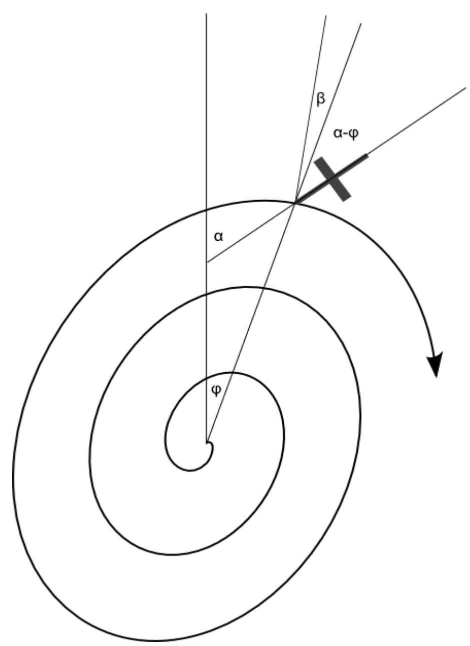

Fig. 7. Angle θ between the spin axis and the normal line to the trajectory

Angle β between radius-vector $\vec{r}$ and normal line to a spiral is calculated using Eq. (1)

$$b_{k+1} = -\frac{b_k}{(k+1)(k+2)} .$$

$$\beta = \arctan \frac{dr}{r\,d\phi} \tag{1}$$

As long as the values of $\frac{dr}{dt}$ and $\frac{d\phi}{dt}$ can be determined using graphs on Figs. 4 and 5, Eq. (1) can be rewritten as:

$$\beta = \arctan \left(\frac{\frac{dr}{dt}}{r \frac{d\phi}{dt}} \right) \tag{2}$$

Then angle θ between the gyroscope spin axis and the normal line to the trajectory can be found using Eq. (3).

$$\theta = \beta + \alpha - \phi \tag{3}$$

Fig. 8 shows values of $\frac{dr}{dt}$ and θ for some moments of time.

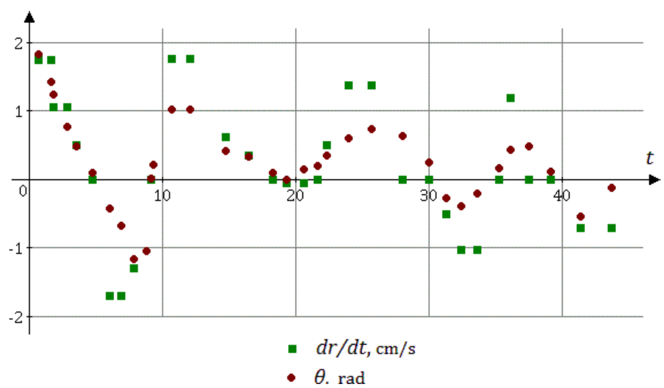

Fig. 8. Dependency of rate of change of polar radius, and the angle between spin axis and the normal line to the trajectory on time

Fig. 9 shows the periods of the light spot orbiting around the resting point and the gyroscope precession periods. The dots on the graph correspond to the ends of the respective periods. The light spot has the end of the orbiting period when it crosses the polar axis. The end of precession period happens when the spin axis is aligned with the polar axis.

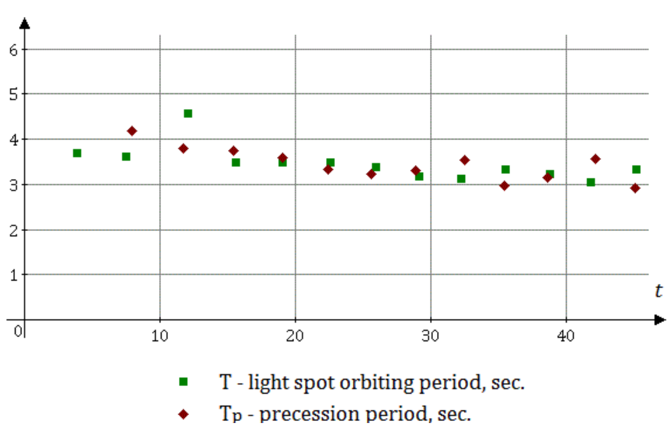

Fig. 9. Dependency of the light spot orbiting period and the gyroscope precession period on time

4. Additional Experiments

In two additional experiments the length of the line was 150 cm and 437 cm. In both cases the observed effects were the same as in the principal experiment.

5. Alternative Experiment

In the alternative experiment the gyroscope was suspended in a way that minimizes precession (See Fig. 10). After starting the gyroscope and releasing the load, the trajectory of the light spot had a chaotic nature that can be attributed to the initial pendular oscillations of the load. The deflection was up to 3 cm.

Fig. 10. The alternative experiment

6. Calculations

The calculations are based on the results of the principle experiment and use the following notations.

- L length of the suspension line, 2.24 m
- T period of the light spot orbiting around the mark
- w angular velocity of the light spot orbiting around the mark
- γ deflection angle of the suspension line
- v linear speed of the load
- r horizontal projection of deflection (polar radius)
- h height to which the load was lifted
- m mass of the load, 0.098 kg
- a acceleration of the load
- F accelerating force, projection of the thrust force on the trajectory
- E translational kinetic energy of the load
- A work done by lifting the load
- p linear momentum of the load

1. The period of the light spot orbiting around the mark at the moment of maximum deflection (28-30 seconds since the movement started) is 3.17 seconds. Then the angular velocity will be the following.

$$w = \frac{2\pi}{T} = \frac{2\pi}{3.17\text{s}} = 1.982\ \text{s}^{-1} \tag{4}$$

2. The maximum deflection from the resting point is 0.162 m. The maximum speed of the load is calculated as shown below.

$$v = r \cdot w = 0.162m \cdot 1.98s^{-1} = 0.321m/s \tag{5}$$

3. The translational kinetic energy of the load:

$$E = \frac{mv^2}{2} = \frac{0.098 \text{ kg} \left(0.321 \text{ m/s}\right)^2}{2} = 5.052 \cdot 10^{-3} \text{ J} \tag{6}$$

4. The deflection angle of the suspension line:

$$\gamma = \arcsin\left(\frac{r}{L}\right) = \arcsin\left(\frac{0.162 \text{ m}}{2.24 \text{ m}}\right) = 0.0724 \tag{7}$$

5. The height to which the load was lifted is calculated as the following:

$$h = L\left(1 - \cos\gamma\right) = 2.24 \text{ m} \cdot \left(1 - \cos 0.0724\right) = 5.868 \cdot 10^{-3} \text{ m} \tag{8}$$

6. The work done while lifting the load (gain in potential energy):

$$A = mgh = 0.098 \text{ kg} \cdot 9.8 \text{ m/s}^2 \cdot 5.868 \cdot 10^{-3} \text{ m} = 5.636 \cdot 10^{-3} \text{ J} \tag{9}$$

7. The linear momentum gained by the load amounts to:

$$p = mv = 0.098 \text{ kg} \cdot 0.321 \text{ m/s} = 3.146 \cdot 10^{-3} \text{ kg-m/s} \tag{10}$$

8. As it can be seen from the graph on Fig. 4, the maximum acceleration of the load most likely occurred during the first second of movement. However, it is not possible to determine its value because pendular oscillations of the laser pointer prevent measuring deflection and angular velocity of the load at this time. That is why the acceleration is calculated for the second speed-up interval, from 10th to 12th second since the beginning of movement.

$$v_{10} = r_{10}w_{10} = 0.025 \text{ m} \cdot \frac{2\pi}{4.1 \text{ s}} = 0.0383 \text{ m/s} \tag{11}$$

$$v_{12} = r_{12}w_{12} = 0.057 \text{ m} \cdot \frac{2\pi}{4.54 \text{ s}} = 0.0789 \text{ m/s} \tag{12}$$

Therefore the average acceleration will be the following:

$$a = \frac{v_{12} - v_{10}}{\Delta t} = \frac{0.0383 \text{ m/s} - 0.0789 \text{ m/s}}{2\text{s}} = 0.0203 \text{ m/s}^2 \tag{13}$$

9. The average accelerating force acting on the load during this time interval is the following:

$$F = ma = 0.098 \text{ kg} \cdot 0.0203 \text{ m/s}^2 = 1.988 \cdot 10^{-3} \text{ N} \tag{14}$$

7. Conclusion

In the principle experiment the load began to move without explicit application of any external force and without expulsion of reaction mass. Furthermore, the movement of the load did not exhibit pendular oscillations. That is to say the conducted experiment demonstrated that the gyroscope exhibits its own intrinsic thrust. It is suggested to name this thrust gyroscopic and the uncovered phenomenon is to be called the *Laithwaite effect.*

The suspended load (gyroscope, washer and laser pointer) was moving along the spiral-like trajectory. The center of the spiral is at the resting point, i.e. the point at which the laser pointer aims when the load is at rest. The spiral is curved in the direction of the precession rotation. During the first 30 seconds after releasing the load the spiral radius (deflection) demonstrated wavelike increase. After 30 seconds the spiral radius showed wavelike decrease related to the slow-down of the gyroscope spinning.

On the basis of the alternative experiment it is determined that the gyroscopic thrust happens only in the conditions of precession.

The dependencies on time for the following parameters were determined as a result of the principle experiment:

- deflection of the load from the resting point
- angle of orbiting around the resting point relatively to the chosen polar axis
- angle of spin axis orientation relatively to the same polar axis
- rate of deflection change
- angle between the spin axis and the normal line to the trajectory
- period of orbiting around the resting point
- precession period

The author has calculated the maximum translational kinetic energy of the load, work done on its lifting as well as its maximum linear momentum. The acceleration and the accelerating force were calculated for a segment of the trajectory.

In the context of energy transformation it is possible to say that the rotational kinetic energy of the gyroscope rotor was transformed into translational kinetic energy of the load (46%) and into the work done for lifting the load, i.e. into potential energy gain (54%). In contrast to pendular oscillations where kinetic energy transforms into potential energy and vice versa, the conducted experiment reveals the increase in both kinetic and potential energy.

Considering changes in momentum, it is possible to say that total linear momentum of the load is equal to zero at initial moment of time. (It is known that the total momentum of material points of spinning rotor equals to zero and other parts of the load such as gyroscope frame, washer and laser pointer were at rest at this moment.) At the moment of maximum deflection, the linear momentum of the load was equal to 0.003146 kg- m/s.

The wave-like change of deflection is especially interesting. At first thought it may seem that the gyroscopic thrust is not stable. However, thorough analysis of data shows that this is not the case. The dependencies in the graph of Fig. 8 show that the rate of change of the deflection radius correlates with the angle between the spin axis and the normal line to the trajectory. Positive value of the angle corresponds to deflection increase, i.e. to acceleration of the load. Negative value of the angle corresponds to deflection decrease, i.e. to slowdown of the load. This observation suggests that **acceleration and slowdown of the load are caused by the change in the direction of gyroscopic thrust**. The scalar value of the thrust gradually decreases with the decrease of angular speed of gyroscope rotor.

The direction of the vector of gyroscopic thrust changes periodically. The graph in Fig. 9 shows that such phenomenon is due to periodical change of the difference between the angular speed of precession and the angular speed of the load orbiting around resting point. In fact, the material system of the load exhibits periodic self-regulated process with a negative feedback loop and a time lag element which minimizes the difference in these two angular speeds. The phases of this process are shown in Fig. 11.

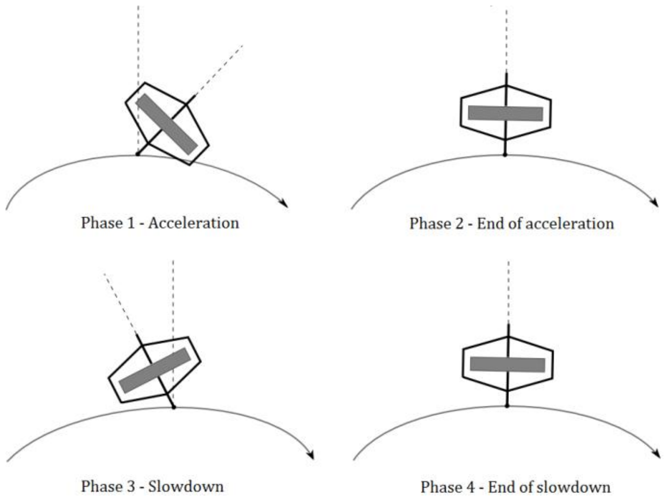

Fig. 11. Phases of gyroscope orientation relative to trajectory

As far as the gyroscope is suspended on the line, its precession is free and the angular speed of the precession is not aligned with the angular speed of the load orbiting. During the acceleration of the load (*Phase 1*) the spin axis is oriented towards the load motion. The load gets accelerated and its angular speed increases. As a result, the spin axis begins to lag. Gradually the trust vector turns into direction opposite to motion transitioning the process into *Phase 2* and then into *Phase 3* which results in the load slowdown. The angular speed of orbiting becomes low and the load is now lagging. As a result, the thrust vector turns towards the direction of motion and transitions the process into *Phase 4* and then into *Phase 1*.

It is worth to mention that during the first 30 seconds of the motion when the energy of rotor spinning was relatively high, the absolute value of the angle between the spin axis and the normal line to trajectory in average were higher for *Phase 1* then for *Phase 3*. This resulted in general acceleration of the load. The graph in Fig. 9 clearly supports this conclusion.

The existence of gyroscopic thrust can be proven just by the gain in linear momentum of the load. However the analysis of the load deflection as a periodic process conducted by author is yet another strong argument supporting the phenomenon of gyroscopic thrust.

Additionally, this analysis suggests that the vector of thrust is aligned with spin axis as it is shown in Fig. 12.

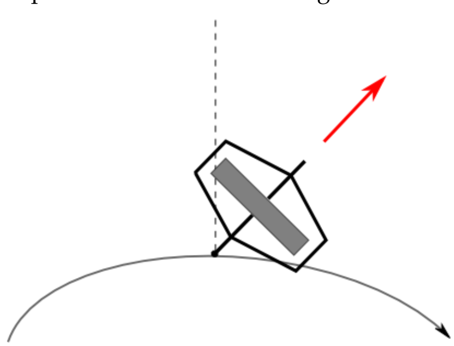

Fig. 12. Suggested direction of the gyroscopic thrust vector

On the basis of the law of conservation of linear momentum, the author suggests the following conclusions:

- The material system of the load is not closed.
- *The force of gyroscopic thrust is external* to the material system of the load.
- This *external force is induced by the material system* of the load.

Although these conclusions may seem too ambitious, there are physical effects exhibiting similar phenomenon: Brown effect and Searl effect. The experiments that demonstrate these effects in a very clear way were set up by Valery Delamure [2][3].

Lately the term “reactionless thrust” is widely used in popular-science publications. Such a term appears to be incorrect because it violates cause-effect relations as well as the law of conservation of momentum. In cases of Laithwaite, Brown or Searl effects there is no “reactionless thrust”, however there is an external force applied to and induced by a material system.

In order to explain the nature of the Laithwaite effect, the author suggests a hypothesis based on the aether theory. Within this theory, aether appears as hyperelastic liquid with certain pressure [4]. In case of Laithwaite effect, some low pressure area is formed in front of the rotor of a precessing gyroscope. The gyroscope gets pushed into this area by high pressure acting on the gyroscope from other sides. In other words it is suggested that the force of the gyroscopic thrust has buoyant nature.

It is worth to note that the experiments conducted by the author are relatively simple and inexpensive. They can be easily set up at a school laboratory or at home.

The fragment of video footage is available on YouTube [5].

Acknowledgements

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