



POLITECNICO
MILANO 1863

CAMERA INCEPTION

THE PROBLEM

If you project in real time what a camera is recording and use that camera to film this projection, you will see a pattern of recursively nested images (the so-called Droste effect). Due to the finite speed of light and processing time of the camera, each image will be slightly shifted in time. Determine under what conditions can the effect be used to measure the speed of light.



OUTLINE

-Our approach to the problem

-The setup

-Experimental results

-Improve the experiment

-Conclusions

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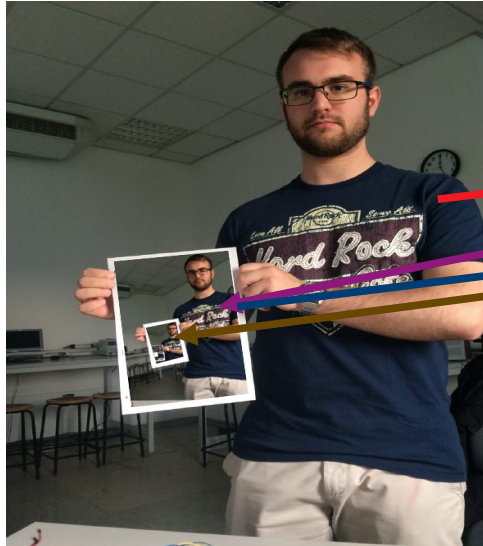
IMPRACTICALITY

A “normal” screen and with a “normal” camera we would have a frequency of 60fps.

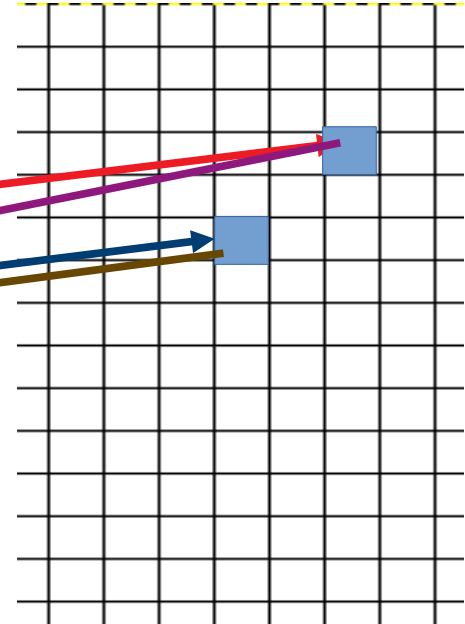
Therefore the delay due to the electronics is at least 0.017s.
In this time the light travels 5000km.

Therefore we would need at least this distance between the screen and camera for a reliable measurement and an impractically large screen and camera.

OUR APPROACH



Screen



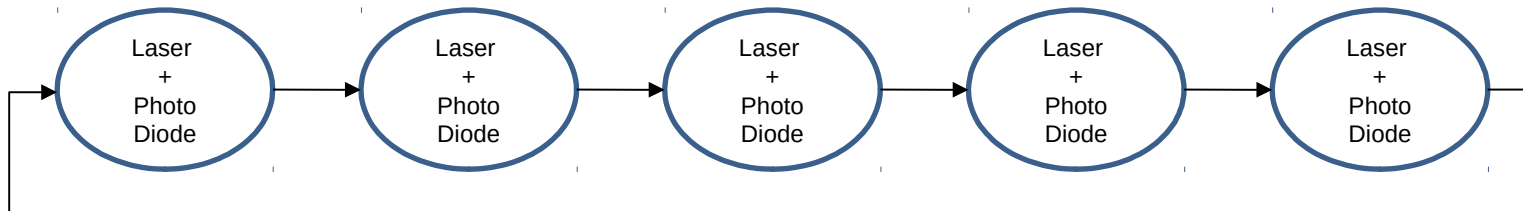
Camera

We can model it as a series of
LASER → PHOTO DIODE → LASER → PHOTO DIODE → LASER...
Laser and photo diodes are order of magnitudes faster than screens and
cameras.

OUR APPROACH

We notice that it is not an infinite repetition of the image due to the discretization of the screen with finite number of the pixels.

In order to have a changing signal, when the light reaches the last photo diode, we will turn off the first laser.



We will measure the frequency of this signal and we will vary the distance between the two elements.

THEORY

The frequency will be given by the delay due to the speed of the electronics and the delay due to the distance of the photo diode and laser.

$$f = \frac{1}{T_{electronics} + T_{light}}$$

where $T_{light} = cL$

where L is the distance between the laser and photodiode

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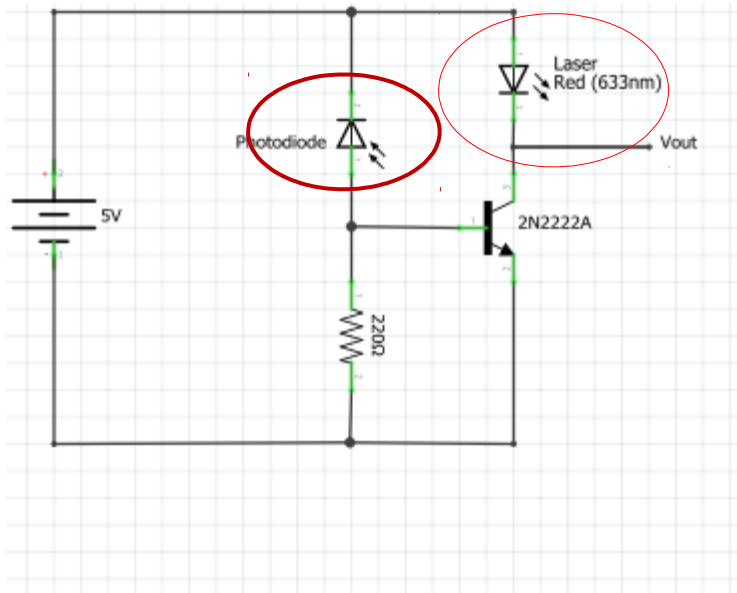
- The setup**

- Experimental results

- Improve the experiment

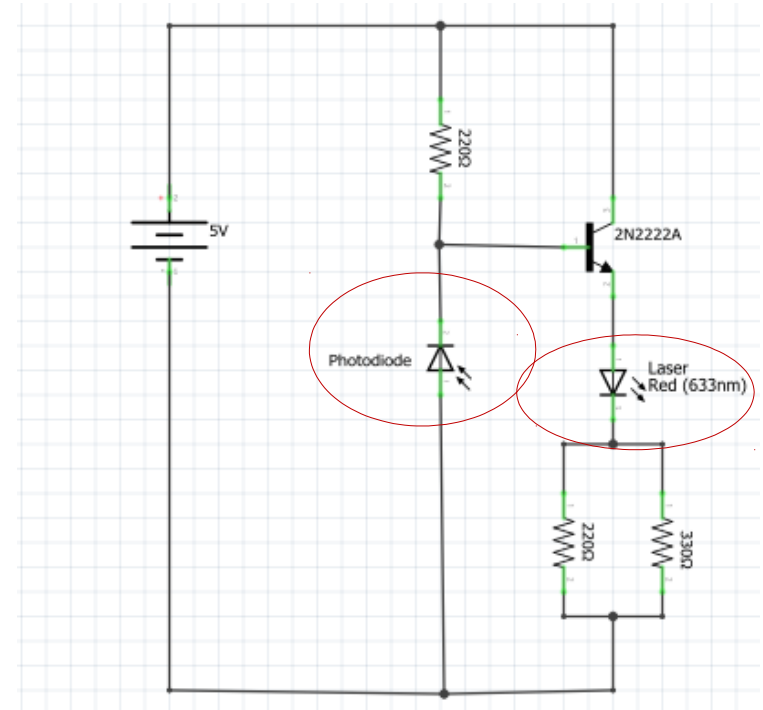
- Conclusions

THE CIRCUIT



ON-ON
CIRCUIT

LIGHT ON THE PHOTO DIODE	STATE OF THE LASER
ON	ON
OFF	OFF



ON-OFF
CIRCUIT

LIGHT ON THE PHOTO DIODE	STATE OF THE LASER
ON	OFF
OFF	ON

THE SETUP

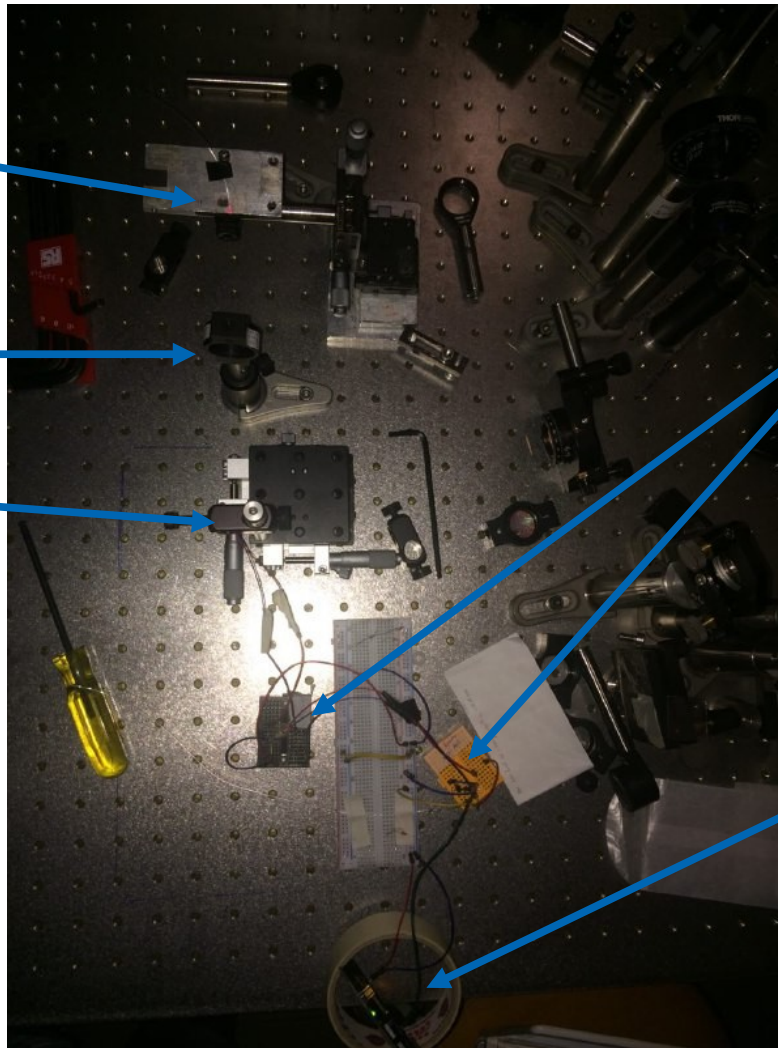
Optical fiber

Lens

Laser

Circuits

Arduino
UNO



OUTLINE

- Our approach to the problem

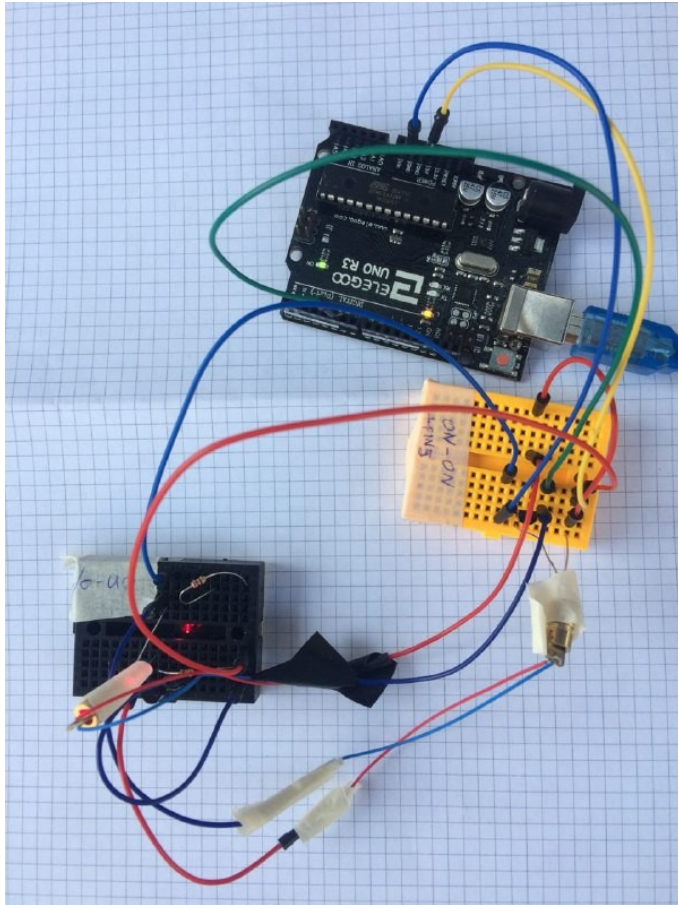
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RESULTS



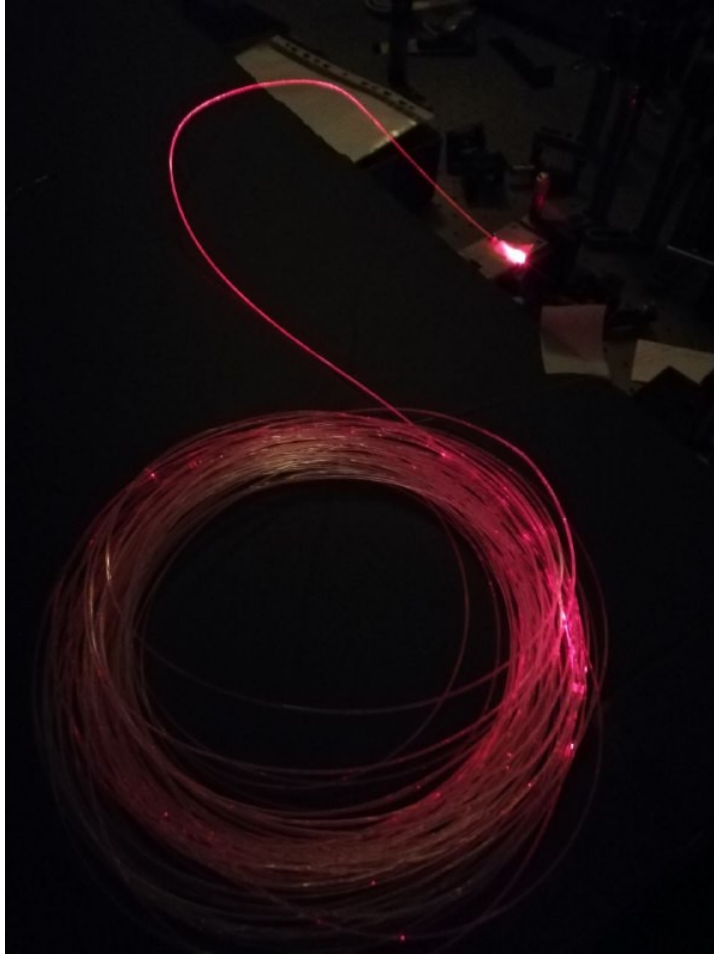
We then measured the frequency due to the electronics by putting the lasers on top of the photo diodes.

We found a frequency of 107 ± 1 kHz and therefore $T_{el} = 9.3 \pm 0.1$ μ s.

Looking at the datasheets of the components we used, we can say that our measurement is correct.

In 100ns the light travels 30m this will be the minimum distance to measure the speed of light.

THE SCATTERING



Firstly we tried to use a 26m fiber cable.

The fiber optics has a large number of scattering center.

After a short distance the intensity is not enough to activate the photo diode. So we were unable to make any measurement.

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HOW TO IMPROVE THE MEASUREMENT

- Using a better optical fiber in order to have a higher intensity of the beam over larger distances
- Amplify the signal before measuring it if we wanted to have clearer 0s and 1s
- Use an oscilloscope to directly measure the period ignoring the amplitude of the signal
- improve the circuit(use higher reverse bias on the photodiode, MOSFET)

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RECAP

- We have explained our approach to the problem
- We explained how we wanted to measure the speed of light with this method
- We then presented the circuit we made
- We showed that our setup works. But it was not possible to perform the measurement.
- We explained the main problems of the experiment and various ways to improve it

CONCLUSIONS

The problem asked to “determine under what conditions can the effect be used to measure the speed of light”.

Requirements:

- have a short delay of the electronic
- have a T_{light} big enough compared to the error of the measure
- having a consistent signal

THE SAMPLING

To sample our data we used an Arduino UNO board.

To read on the order of the 100s of kHz we needed to use a digital read function.

Therefore every value over 3 V is to be considered a 1 and less than 1V a 0.

Our output not always was high or low enough for Arduino to make a switch.

RESULTS

We measure the frequency without an optical fiber cable and found it to be equal to 107100 ± 300 Hz so the time of the electronics is around 10 μ s.

We then went into the Politecnico lab to couple the laser to the optical fiber.

There due to problems with the fiber optic cable we have not been able to estimate a reliable frequency.

Moreover the circuit was positively influenced by the sunlight, a condition that in the laboratory could not be reproduced