**MEASURING WITH A LASER BEAM**

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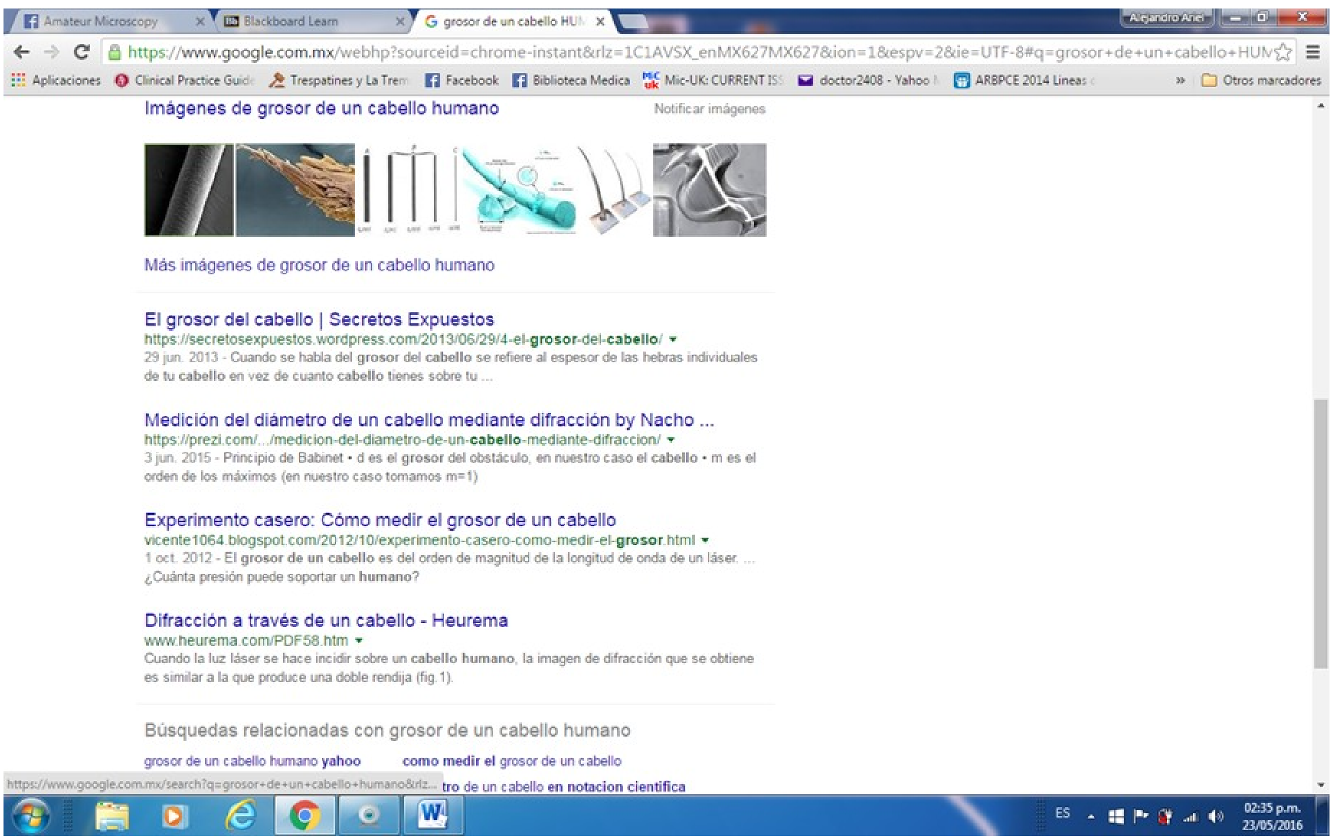
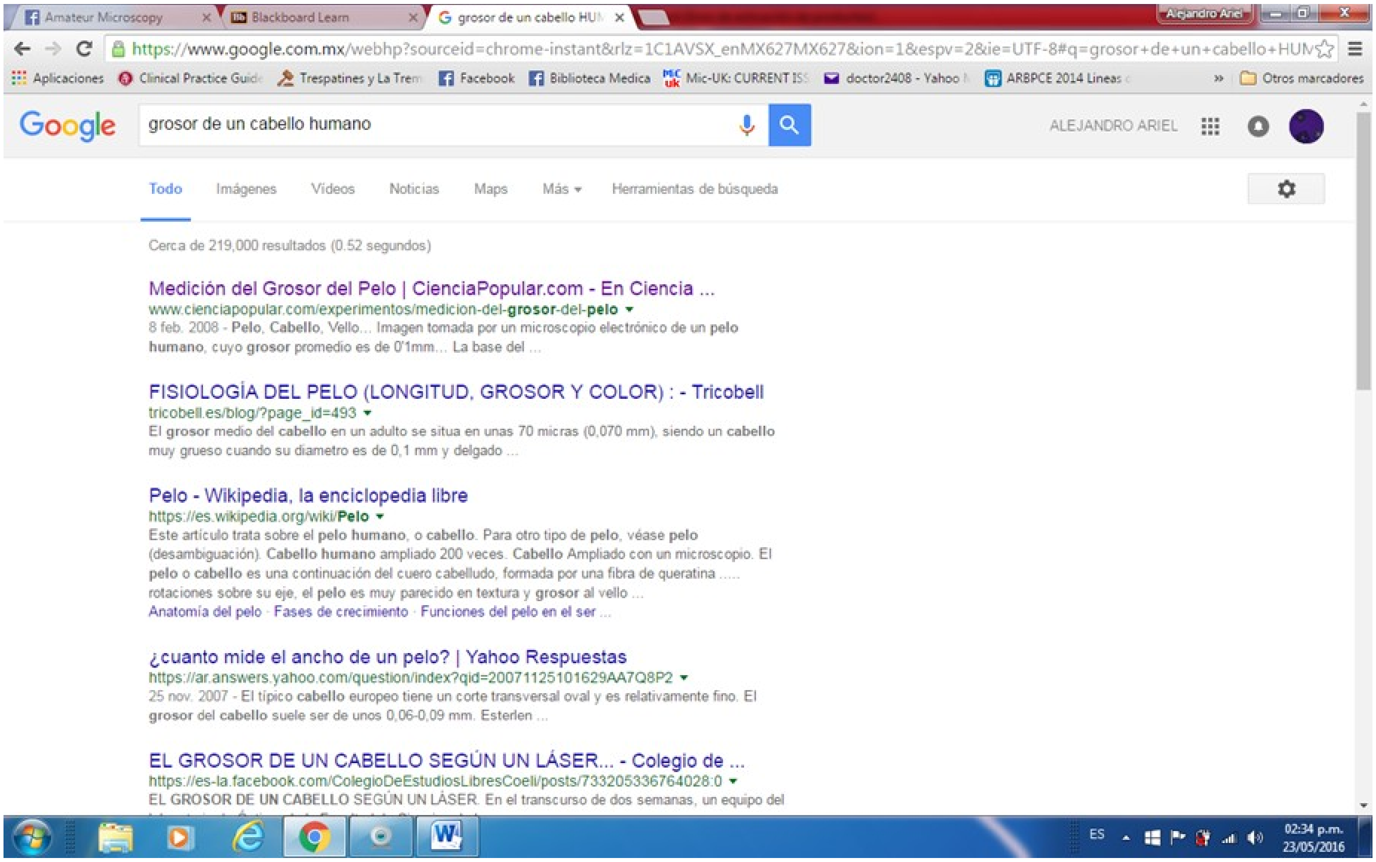
**INTRODUCTION:**

In my article about [Measurements of the micro world part 1. Calibrating the camera], I used a micrometer slide that came with the installation software of my camera. After that I thought of presenting a second part to this article on the possibility of calibrating the camera without the help of a micrometer slide. This would be intended for those people that have a microscope camera but for one reason or another lack a micrometer slide. I did in fact succeed in calibrating my camera with the help of a conventional rule but just for the 4x and 10x objectives. The 40x and 100x were more difficult because of the thickness of the rule, nevertheless I did want to calibrate them.

So I was looking around for different subjectsb of a very small known size that can be used to calibrate the camera without the need of a micrometer. Finally, I thought of a hair and I said to myself "if I look for the average size of a hair I would be able to study under the 40x, 100x lenses and would be able to calibrate too."

But I found something much, much better. I entered into Google in Spanish the phrase "GROSOR DE UN CABELLO HUMANO" that means "the width of a human hair" and I was taken to many marvelous articles that explain how to measure with a good degree of accuracy any hair, using the laser beam of a conventional laser pointer. This opens up a world of possibilities because I could now have the object that I needed to calibrate my camera without the help of a micrometer and that I could measure by myself accurately.






This way I learnt how to measure with a laser pointer and here is the explanation of the procedure.

*Note: The article about calibrating without the need of a micrometer is still in process, I have postponed it because I would like to show first how to measure with a laser pointer.*

**DEVELOPMENT:**

To answer the question, how can we use a laser pointer as an instrument for measuring? The answer is very simple, the monochromatic light of a laser beam when it passes through a pair of holes (since light behaves as a wave) becomes diffracted - this is called double slit diffraction, and it can be seen at a distant point from where it is produced as showing an interference pattern light waves. The bright spots are presented to each other at the same distance and are separated by dark spaces where the interference of the light becomes negative.

This beautiful and outstanding pattern is call Fraunhofer diffraction in honor of Joseph von Fraunhofer, although he was not exactly who developed the theory of this pattern, his equation is still used to explain the phenomenon.

Another concept to consider within this phenomena is what is called the Babinet principle: this establishes that when a very thin opaque object is set in front of a monochromatic beam such as the one from the laser pointer, it is going to produce a pattern similar to that for the double slit mentioned above. The same will happen with a very thin slit. This phenomenon will allow us to obtain the size in terms of width of the object in front of the beam.

The equations to obtain a value are the following:

$$d = \frac{2*m*\lambda*D}{L} \quad \text{or} \quad d = \frac{m*\lambda*D}{L(1/2)}$$

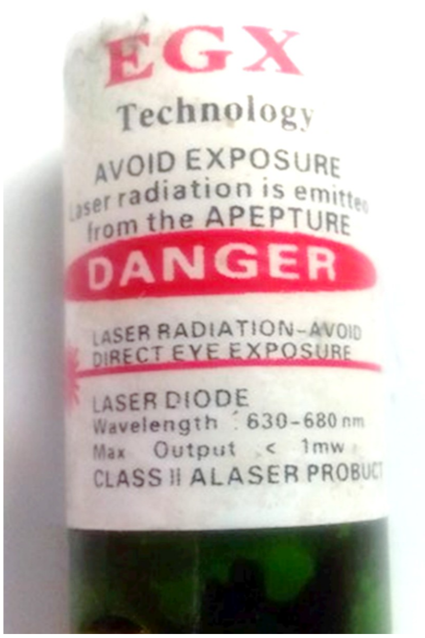
- ✓ d is the width of the object in front of the beam
- ✓ m is the number of maximums one at each side of the center, see below
- ✓ $\lambda$ is the wave length of the laser beam, it is said that for a green laser beam it is 532nm and for a red one it is 650nm
- ✓ D is the distance from the object to the screen where it is projected
- ✓ L is the distance between the maximums either side of the center, see below.

Today we are going to consider the pattern produced by a very thin opaque object for example a hair, a thin wire, a hair of a pet fur, etc.

**THE MATERIALS NEEDED:**

- ❖ A tape measure
- ❖ A clear screen can be a wall, a cardboard, etc.
- ❖ A laser pointer, any color
- ❖ A table and/or a holder to place the laser pointer
- ❖ Something to keep the laser pointer on could be some tape
- ❖ Obviously thin objects

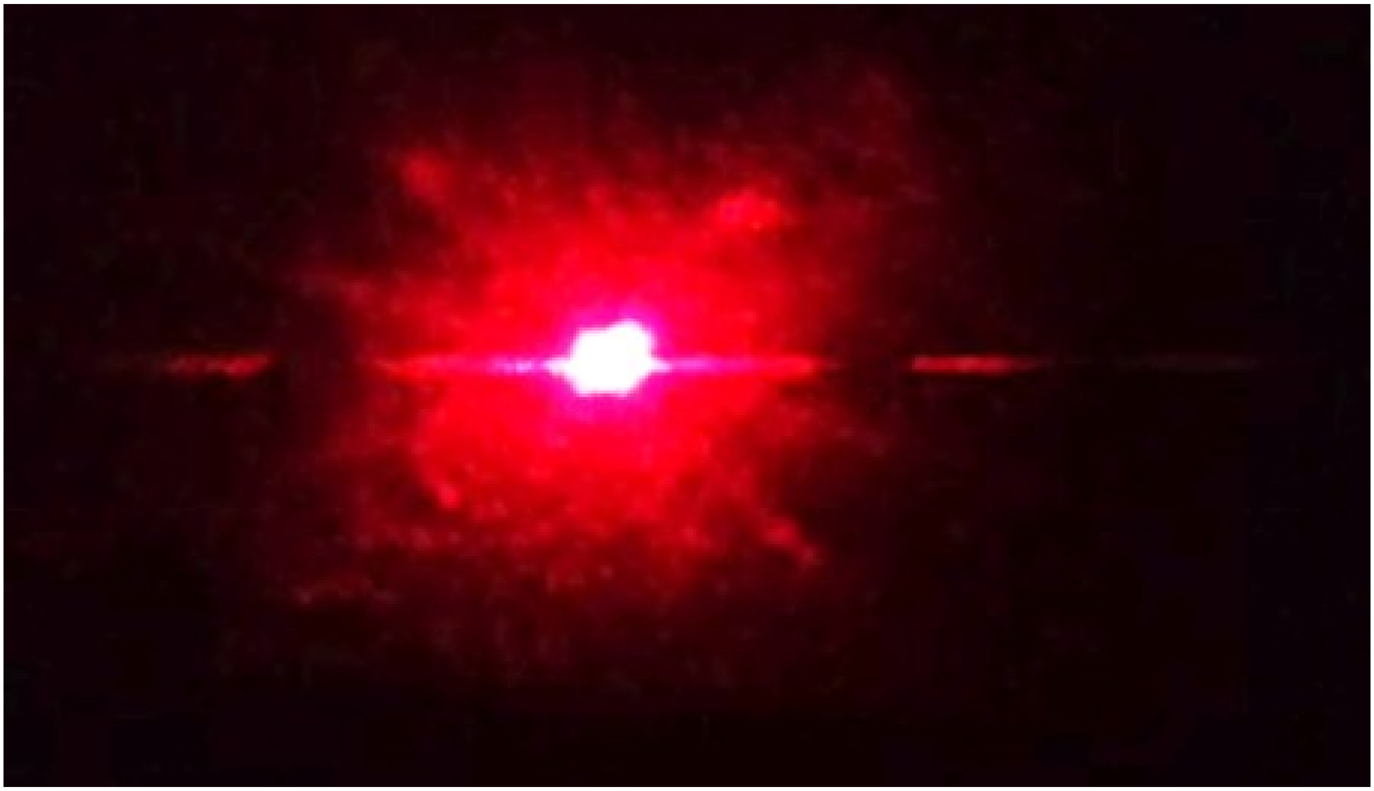
Note: regularly the wavelength of the laser beam is given by the manufacturer .



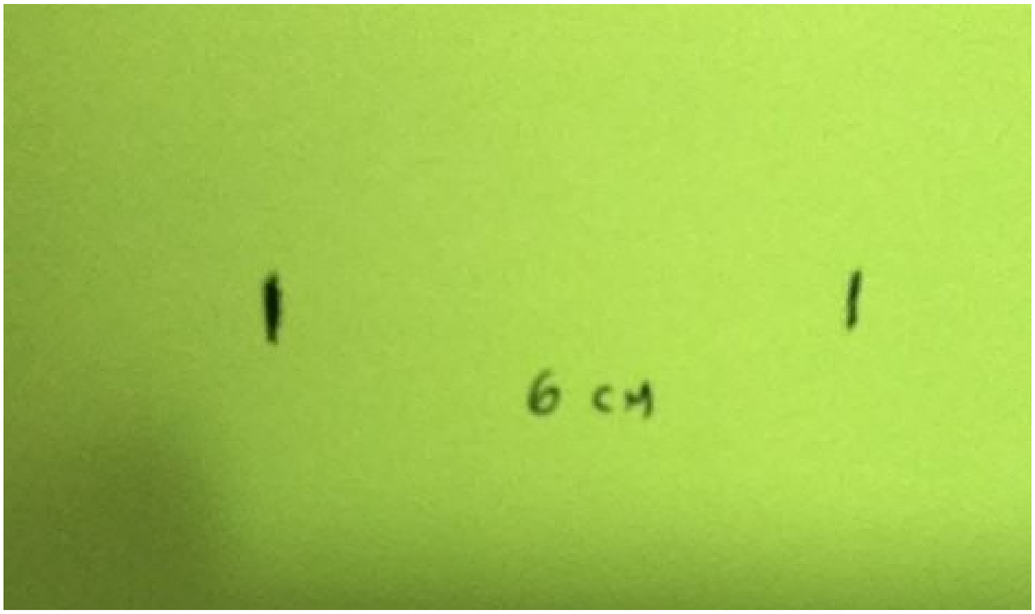

In my case since a wide range is given for the wavelength of the laser beam, I am going to take for granted the common data as an average of 650nm for the moment. But at the end of this paper I am going to demonstrate how to calculate more accurately the wavelength of my laser pointer and how an accurate value of the wavelength can give a better result.

**RESULTS:**

This is part of the pattern produced by a piece of hair when placed in front of the laser beam at 2 meters from the screen which in this case is a green piece of cardboard.



With the help of a pen I marked the distance between the two maximums at each side of the central line and the result is as follows.




When we applied the formula mentioned above:

$$d = \frac{m \cdot \lambda \cdot D}{L(1/2)}$$

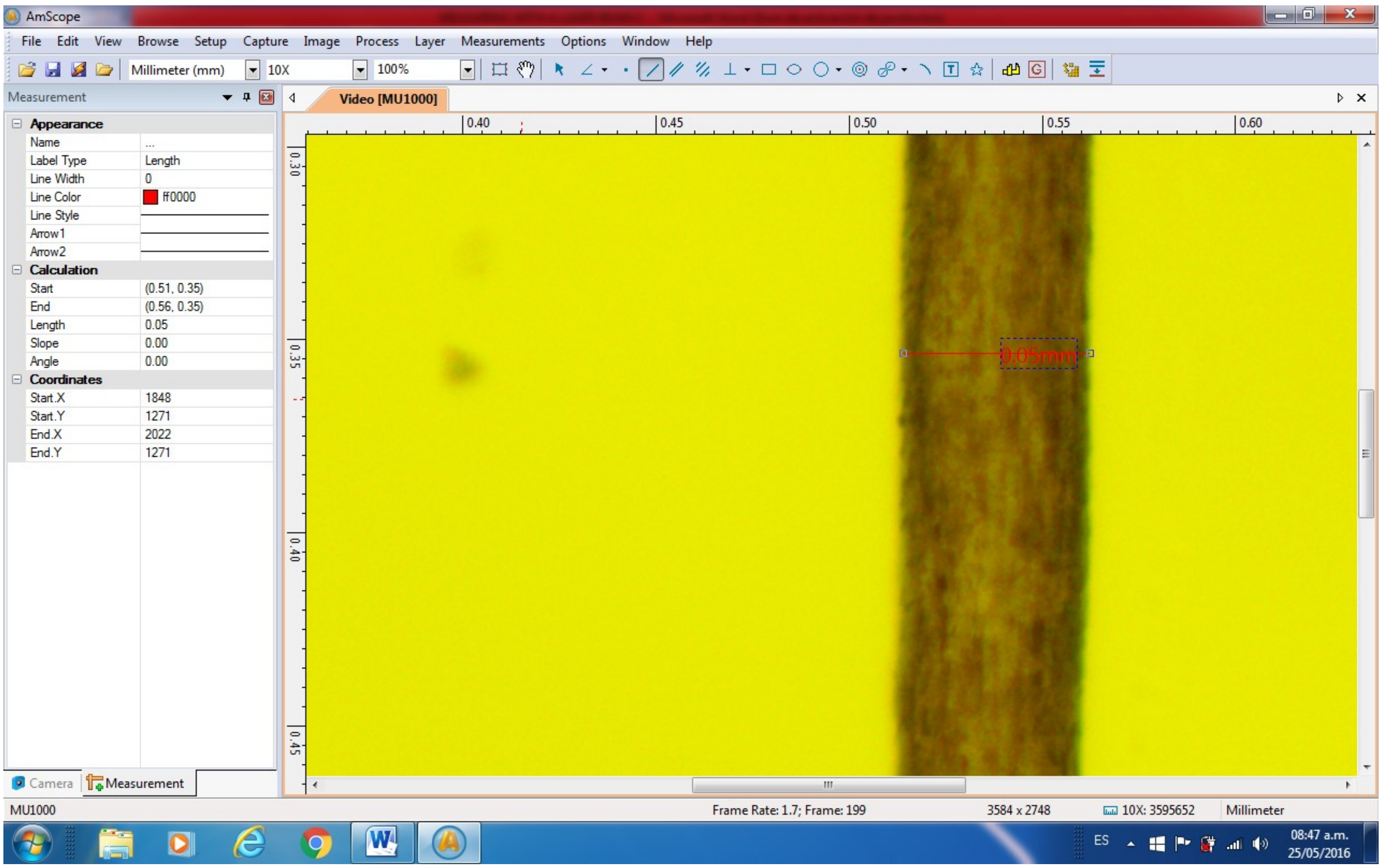
First of all it is necessary convert every value into meters for an easy management of the calculation

so, we obtain:

$$d = \frac{1*0.000000650m*2m}{0.06m/2} = \frac{0.0000013m}{0.03m} = 0.00004333333m \text{ or } 0.0000433m \text{ or } 43.3 \text{ micrometers}$$

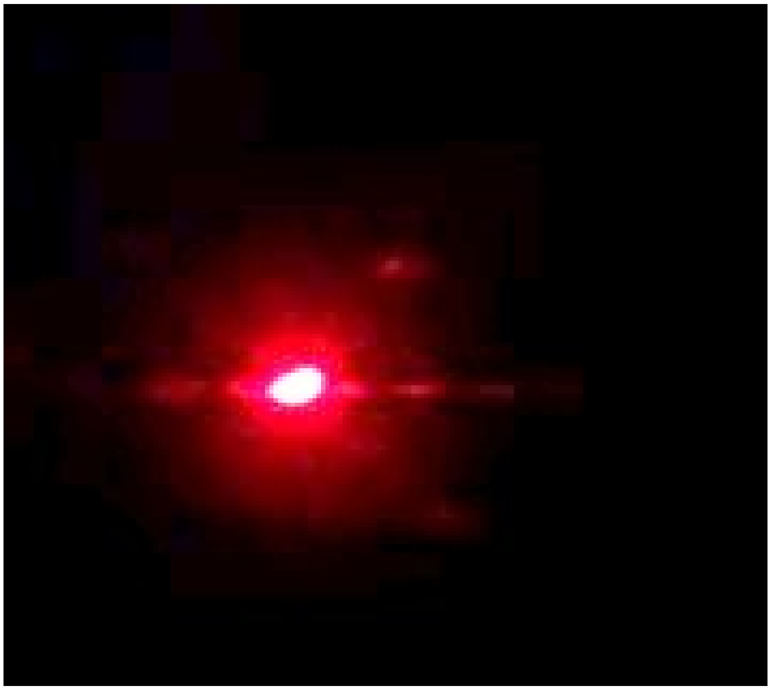
Or **0.0433 mm, this is the width of the hair employed.**

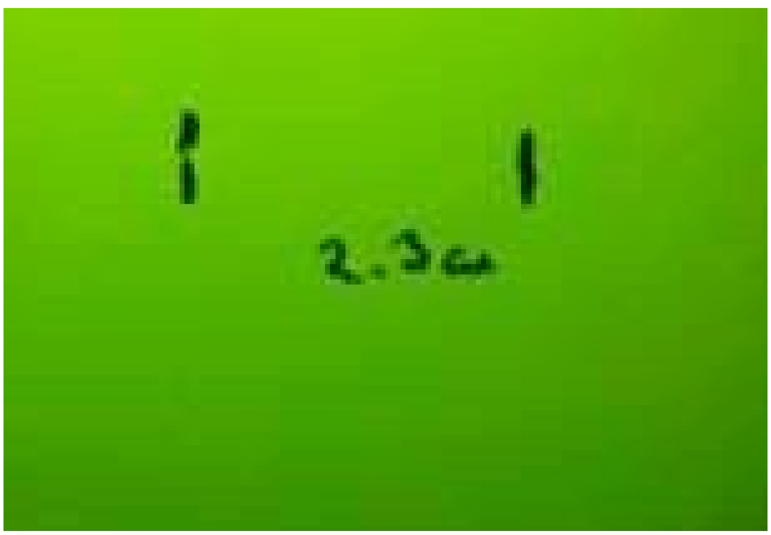
The purpose of this is to get an accurate measure to be used without the need of a micrometer. To demonstrate the usefulness of this method I am going to place the same hair under the microscope and measure it with my already calibrated camera to show the accuracy of the method. Here is the result.




As you can see it varies but is about 7 hundredths of a millimeter.

Let’s try the next sample – a wire strand.

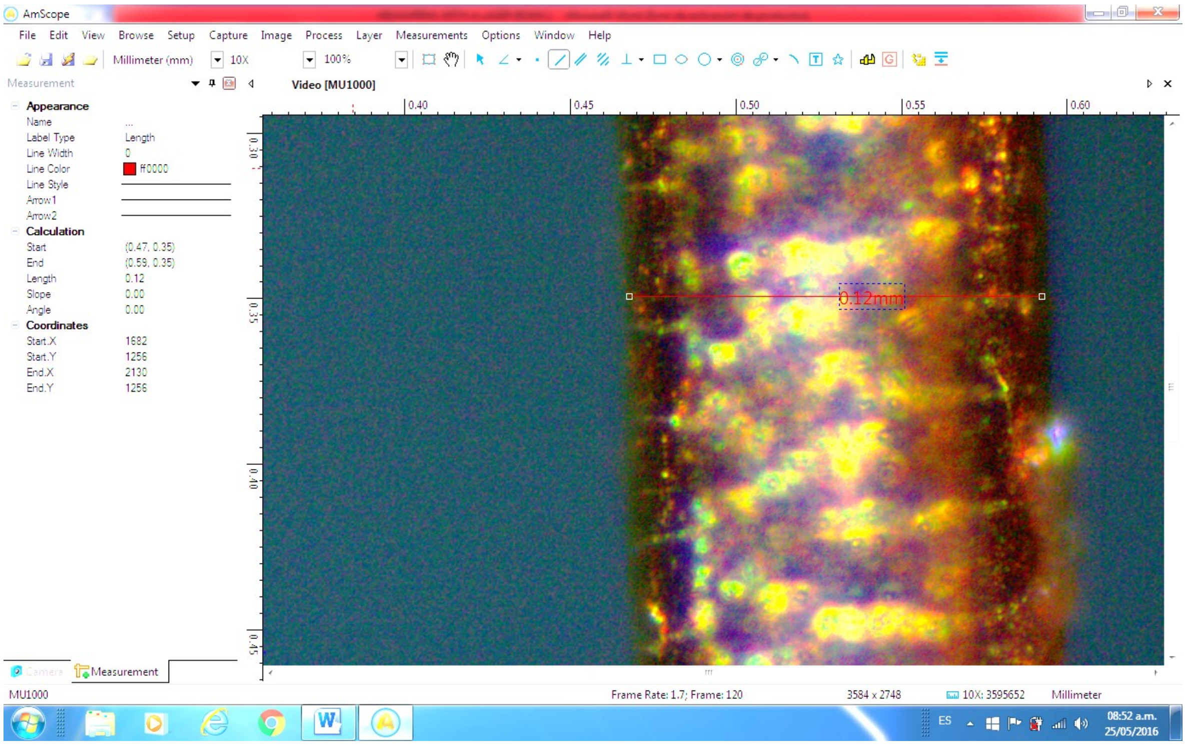





$$d = \frac{1 * 0.000000650\text{m} * 2\text{m}}{0.023\text{m} / 2} = \frac{0.0000013\text{m}}{0.0115\text{m}} = 0.00011304347 = 0.1130 \text{ mm} = 113 \text{ micrometers}$$

This is the width of the **wire strand employed.**

Here is the same wire strand with the microscope camera:




Also measured with the digital caliper.

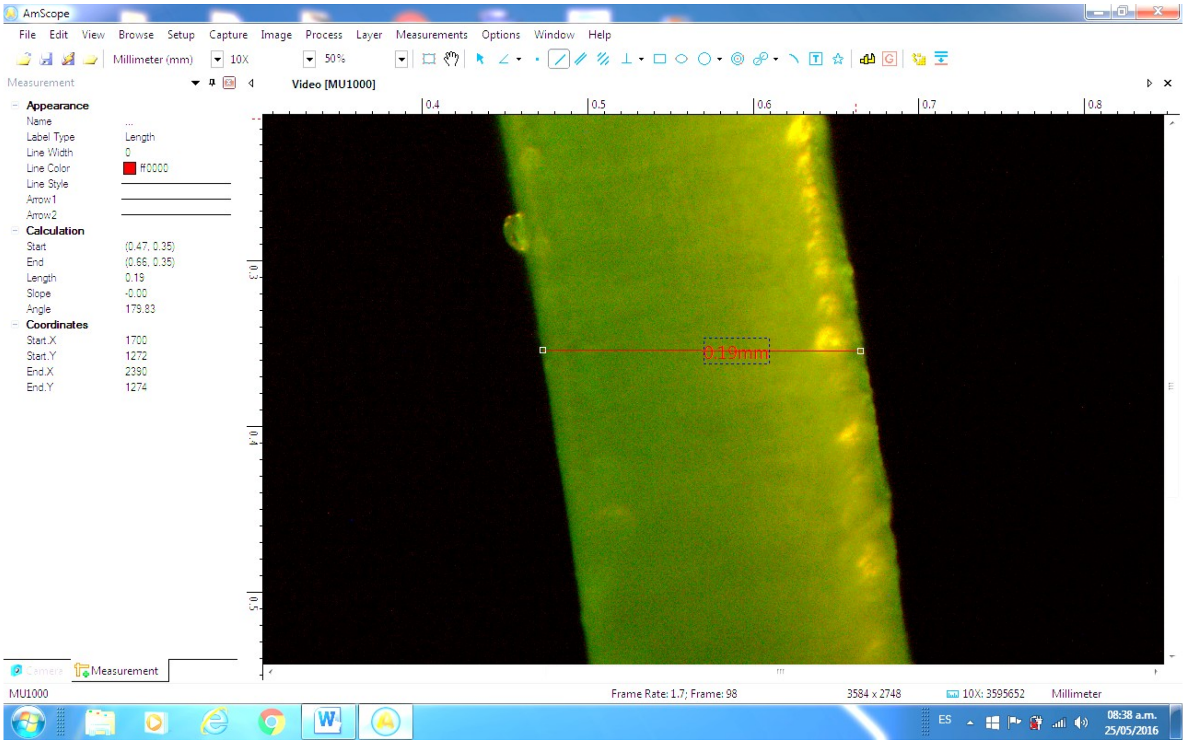

Finally the last sample, a toothbrush bristle, but now with a variation of the distance to the wall to see that no matter the distance the method is accurate:

***It is 1.8 cm, but it is a little blurred.***

$$d= \frac{1*0.000000650m*2.36m}{0.018 /2} = \frac{0.000001534m}{0 .009m} = 0.00017044444 = 0.17mm = 170 \text{ micrometers}$$

This is the width of the **toothbrush bristle employed**.

Now the bristle with the microscope camera.




Also measured with the digital caliper.


**Note:**

Since I have never liked to take anything for granted, I am going to calculate the wavelength so that it may be closer to the real value. I count now with a pair of known values the wire and the bristle. So let's calculate the wavelength using both of them.

So the formula above uses the wire width measured with the caliper:

$$d = \frac{m*\lambda*D}{L(1/2)} \quad = \quad \lambda = \frac{L/2*d}{m*D} \quad = \quad \frac{0.023m/2*0.00012m}{1*2m} \quad = \; 0.0115m*0.00012m \; = 0.00000069 = 690nm$$

And with the bristle measured with the caliper:

$= \frac{0.018/2*.00018m}{1*2.36m} = \frac{0.009m*.00018m}{2.36m} = 0.00000068644 = 686.44nm$ very close to the last value of 690nm

Finally when we correct the values for the samples to the wavelength found (690nm) the values are closer to the value given by the caliper and/ or the microscope camera.

**Hair: 0.000046m or 0.046 mm or 46 micrometers**

**Wire: 0 .00012m or 0.12 mm or 120 micrometers**

**Bristle: 0.0001809 or 0.1809 or 180.9 micrometers**

**CONCLUSION:**

As it can be seen, it is very simple to obtain the width of a thin object with a laser pointer. This is the kind of experiment that nobody should miss because this could be a very good reference to measure the microscopic world.

**REFERENCES:**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