Planck Constant

Measurement of the Planck Constant with LED and Optical Spectrometer

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Planck Constant

The Planck constant (denoted **h**, also called Planck's constant) is a physical constant that is the **quantum of action**, central in quantum mechanics. This constant determines that the fundamental physical quantities does not vary in a continuous way, but are quantized, that is they can only take on multiple values of this constant .

Planck's constant has the dimensions of **energy x time** and in the atomic units system it is the measurement unit of **angular momentum**. It allows quantization of quantities such as energy, momentum and angular momentum, and its discovery has been instrumental to the emergence and subsequent development of quantum mechanics.
It is also one of the fundamental constants that define the fine structure constant or Sommerfeld constant.
It is named after Max Planck, who introduced in 1900 in the studies on the black body radiation spectrum.

Planck's constant is related to the quantization of the dynamic quantities that characterize the state of matter at the microscopic level, ie the particles that make up matter and light : electrons, protons, neutrons and photons.
For example , the energy **E** carried by an electromagnetic wave with constant frequency **ν** can only have these values :

$$E = nh\nu \quad n = 0, 1, 2, 3, ...$$

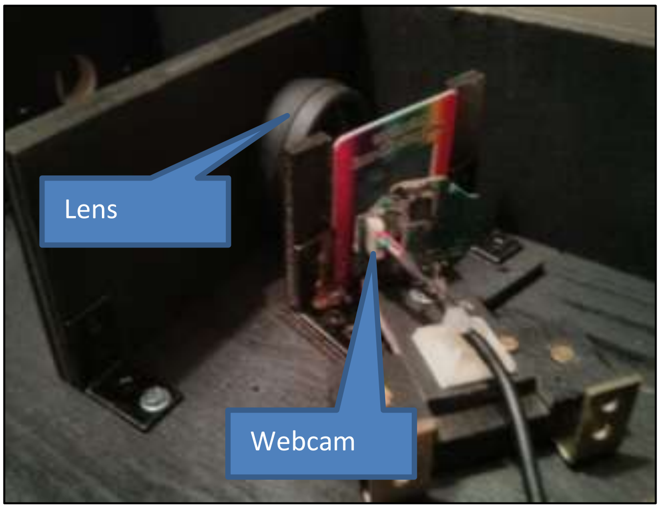
Measurement of the Planck Constant

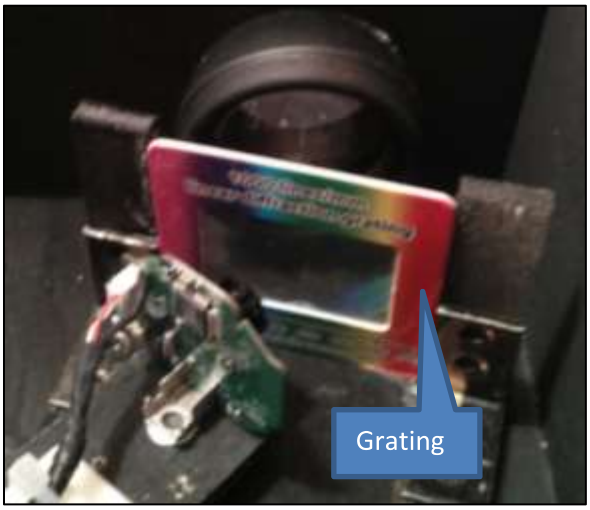
The proposed measurement method utilizes the light emission from the semiconductor devices known as LED.
The idea of the experiment with LED is the following : a direct current flows through the junction (electrons from the doped zone N to zone doped P and holes in the opposite direction) : the electrons recombining with the holes in the vicinity of the junction produce photons of energy $h \times f$ close to the energy gap value (gap between the valence band and conduction band) of the junction material. The energy of the emitted photons is provided by the work done by the electric field applied at the junction (V_{LED} x e, where V_{LED} is the voltage applied to the LED) thus the following linear relation should be valid :

$$\boldsymbol{E = V_{LED} \times e = hf}$$

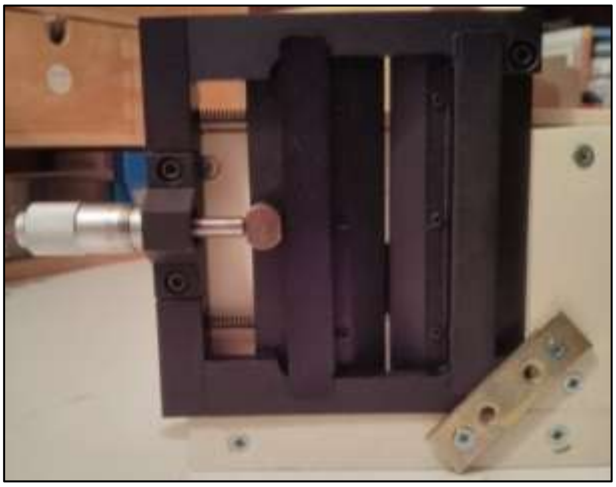
The materials most used for electroluminescent diodes are Gallium Arsenide (GaAs) for the infrared band and Gallium Arsenide-Phosphide (GaAs1-x Px), where x is the percentage of Phosphorous, for the visible band. When x increases the energy gap of the material goes from 1.43 eV for x=0 to 2.26 eV for x=1; the peak wavelength, linked to the energy gap by the relation l(mm) = hc/Eg = 1.24/Eg(eV), therefore goes from about 850nm to about 550nm. In order to obtain blue emission SiC or the alloy In0.06 Ga0.94 N are used and the red LED will get very bright with Al0.4 Ga0.6 As doped with Zn on substrate of GaAs.

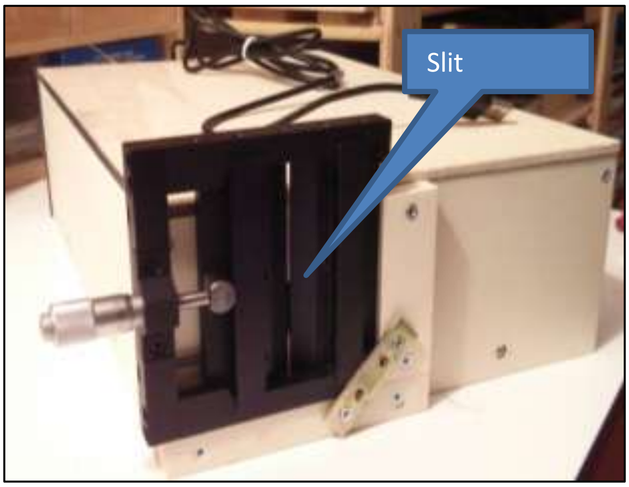
Diffraction Grating Spectrometer





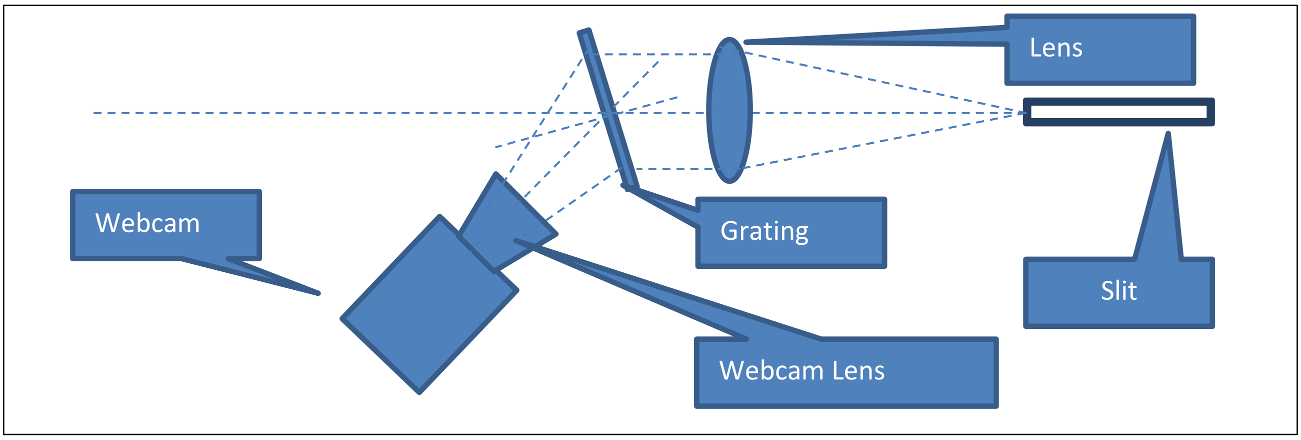
Inside view with collimating lens, grating and webcam



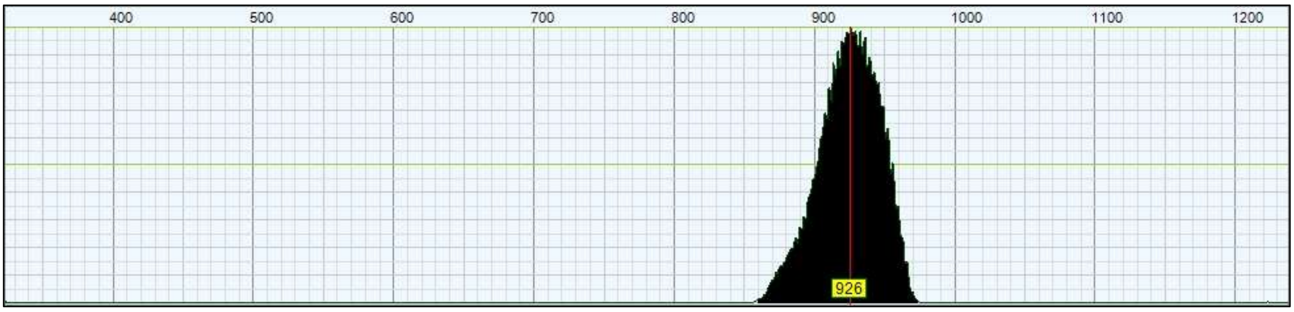


Detail of the micrometric slit and the spectrometer assembled

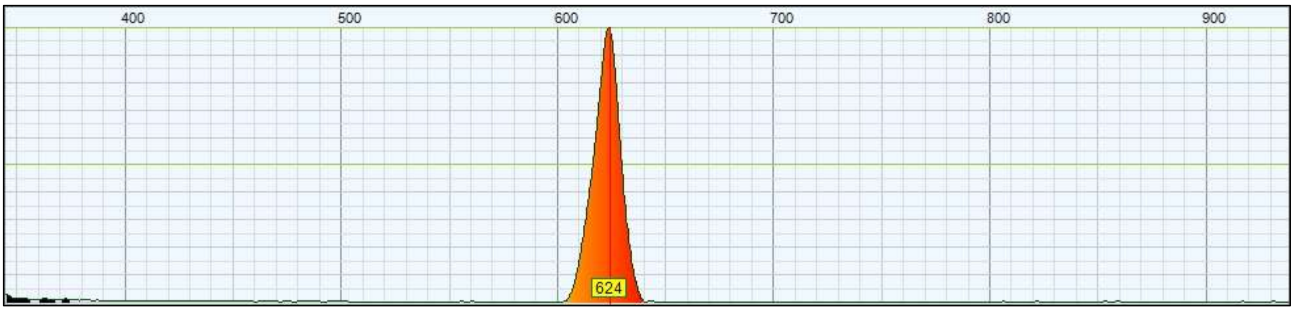
Spectrometer Design :



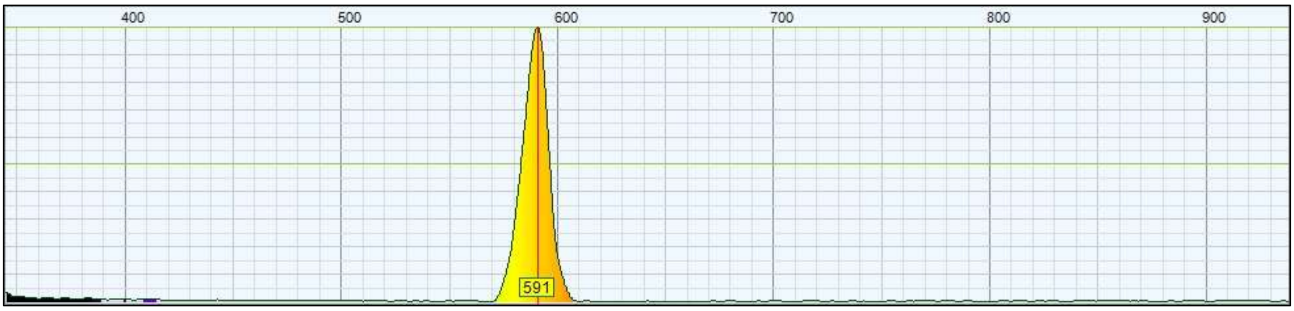
Spectra of LED



Infrared LED – 930nm



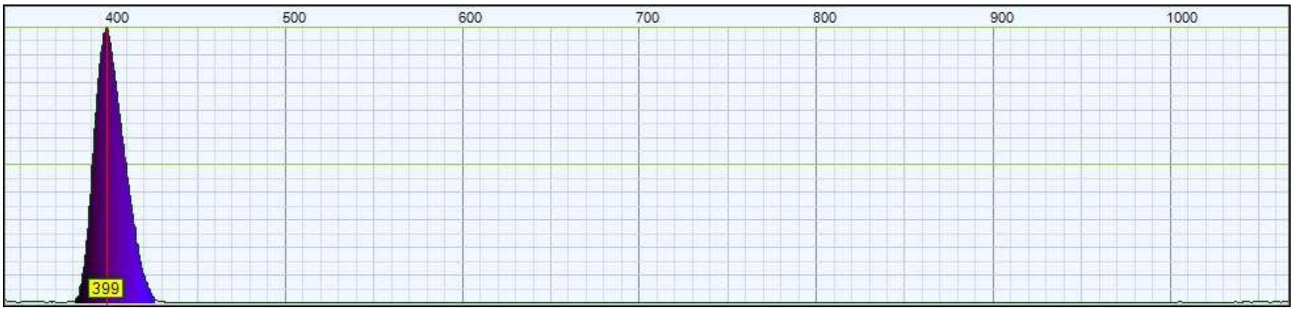
Red LED – 624nm



Yellow LED – 590nm

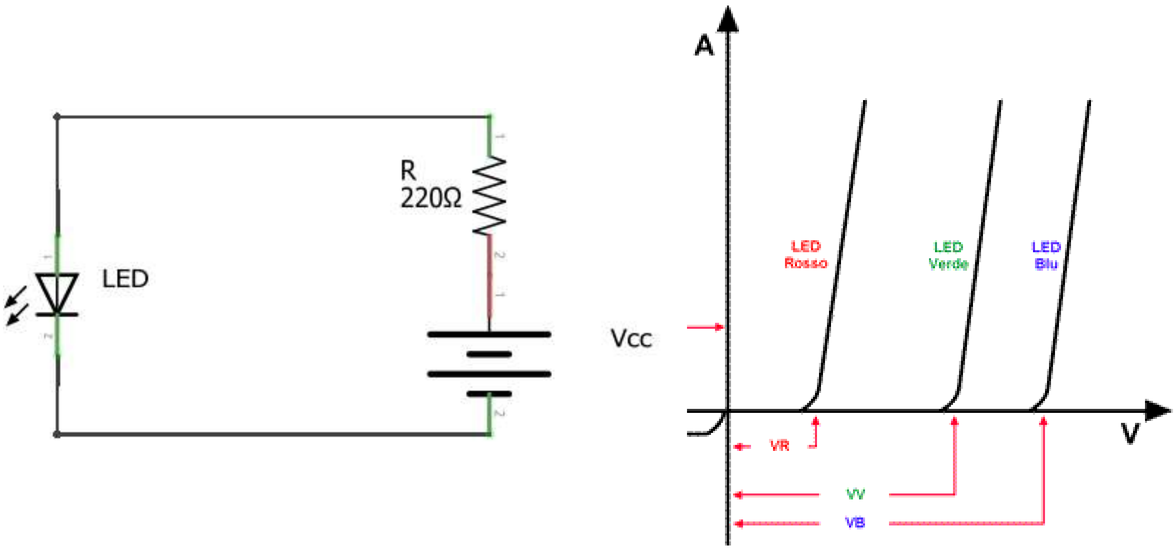
Green LED – 530nm

Blu LED – 470nm



UV LED – 400nm

Circuit for measuring the LED activation voltage

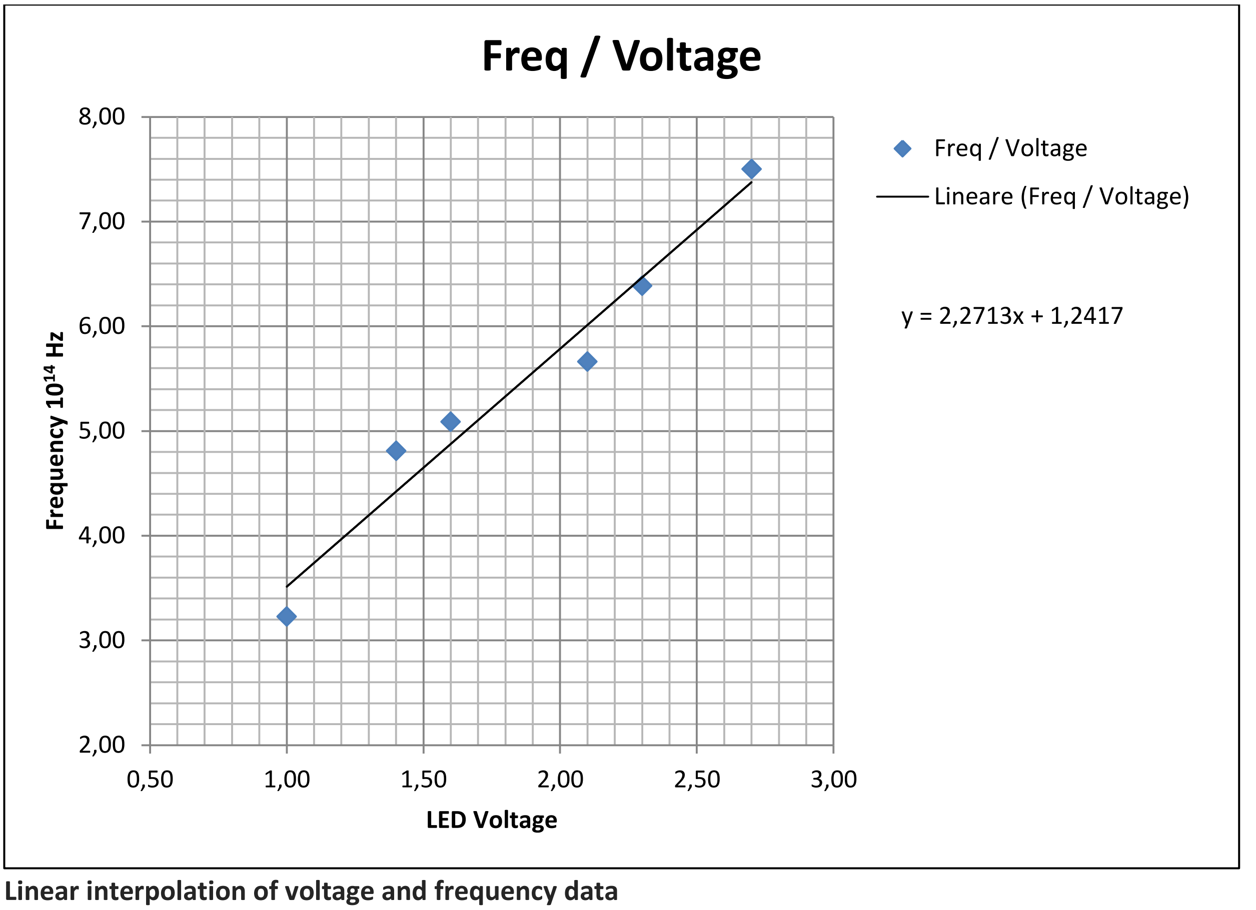


The activation voltage of the LED is determined by measuring the voltage that occurs across the diode LED when the LED starts to emit light. In order to accurately determine this voltage value the test was done in a darkened room.

As an alternative for the determination of the activation voltage may be measured I / V characteristic of the LED so as to accurately determine the voltage value corresponding to the "knee" of the curve.

Measurement Data

LED	Wavelength (nm)	Frequency 10^{14} Hz	Activation Voltage (V)
Infrared	930	3.22581	1.0
Red	624	4.80769	1.4
Yellow	590	5.08475	1.6
Green	530	5.66038	2.1
Blue	470	6.38298	2.3
UV	400	7.50000	2.7



Linear interpolation of voltage and frequency data

Planck Constant Calculation

The energy of the photons emitted by the LED can be calculated with the following equation, where V_{LED} is the voltage at which the LED begins to light and f is the frequency of the emitted photon :

$$E = V_{LED} \times e = hf$$

$$h = \frac{V_{LED}}{f} \times e$$

Where V_{LED} / f is the inverse of the slope of the line obtained in the graph. Substituting the values we get:

$$h = \frac{1}{2.2713 \times 10^{14}} \times 1,602 \times 10^{-19} = 7.05 \times 10^{-34}$$

While the correct value is :

$$h = 6.626 \times 10^{-34}$$