
Atomic Spectroscopy

Absorption and
Emission Spectra

Lodovico Lappetito

Table of Contents

Atomic Spectra	3
Diffraction Grating Spectrometer.....	4
Spectral Lamps.....	5
Hydrogen	5
Carbon Dioxide	6
Nitrogen.....	6
Spectra of Commercial Lamps.....	7
CFL Lamp.....	7
Neon Lamp	8
Sodium Vapor Lamp	8
Xenon Lamp.....	8
Absorption / Emission Spectra	9

Atomic Spectra

The **emission spectrum** of a chemical element or a chemical compound is the set of frequencies of the electromagnetic radiation emitted by the electrons of its atoms when they perform a transition from one state to a higher energy towards a lower energy .

For each transition between states , the energy of the emitted photon is equal to the energy difference of the two states according to the equation :

$$E = h \cdot \nu$$

which correlates the energy of the transition with the frequency of the photon of light emitted (h is Planck's constant) . Since in each element or chemical compound there are many possible transitions, the set of photons of different frequencies emitted by the element or by the molecule is its the spectrum .

The emission spectrum of each element or molecule is unique, for this reason its analysis, known as spectroscopy, can be used to qualitatively and quantitatively analyze a substance.

The emission spectra are distinguished:

- Discrete lines spectra: it correspond to a succession of discrete wavelength
- Band spectra: the lines are close to each other around some wavelength forming separate bands
- Continuous spectra: continuous succession of wavelength

The discrete spectra and band spectra are emitted by gas and vapor at low pressure. The first are due to isolated atoms, the second to diatomic molecules. The spectra are characteristic of the elements that emit them.

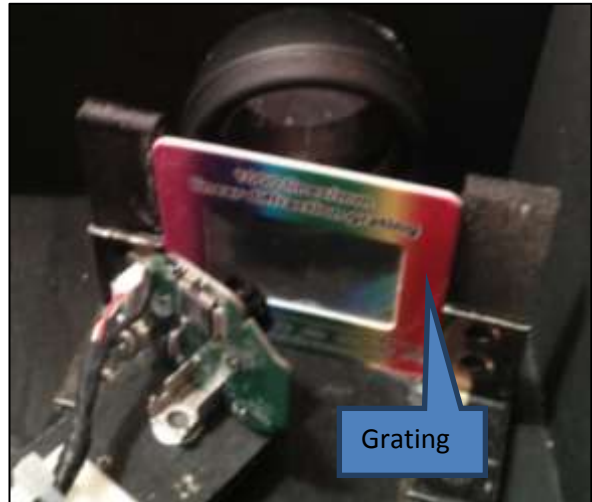
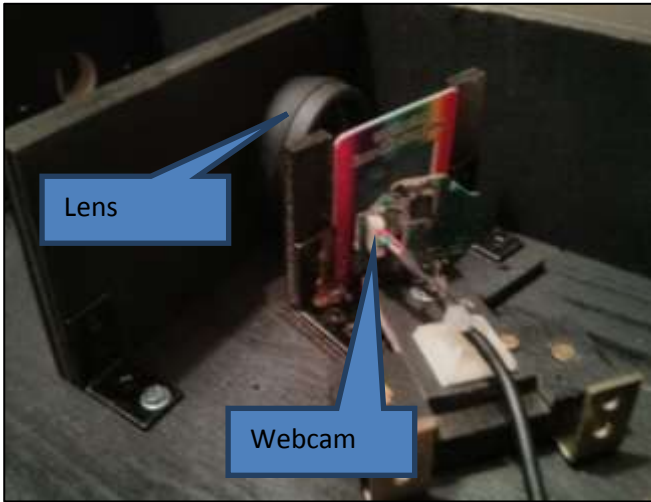
In the hydrogen atom, the quantum leaps of an electron between the orbitals are described by the equation Rydberg :

$$\frac{1}{\lambda} = \frac{m_e e^4}{8ch^3 \epsilon_0^2} \left(\frac{1}{n_i^2} - \frac{1}{n_f^2} \right)$$

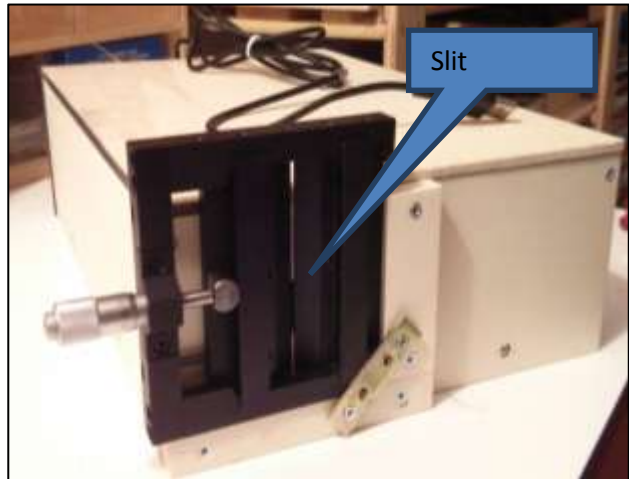
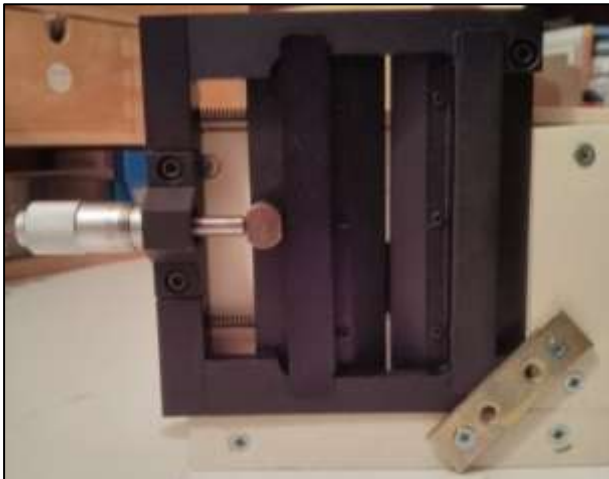
with **ni** > **nf** represent the initial and the final energy levels, **me** and **e** respectively the mass and the charge of the electron, **c** is the speed of light, **h** Planck's constant and **ε₀** the dielectric constant.

In the spectrum of hydrogen this equation realizes perfectly the presence of some series of lines, called Lyman, Balmer and Paschen. The Balmer series is the only which fall in the visible, and corresponds to the transition from the energy levels greater than level 2; the most important line of this series is called **H α** , its wavelength is approximately 6563Å, which corresponds to red light, and is given by the electron transition between levels 3 and 2.

Diffraction Grating Spectrometer

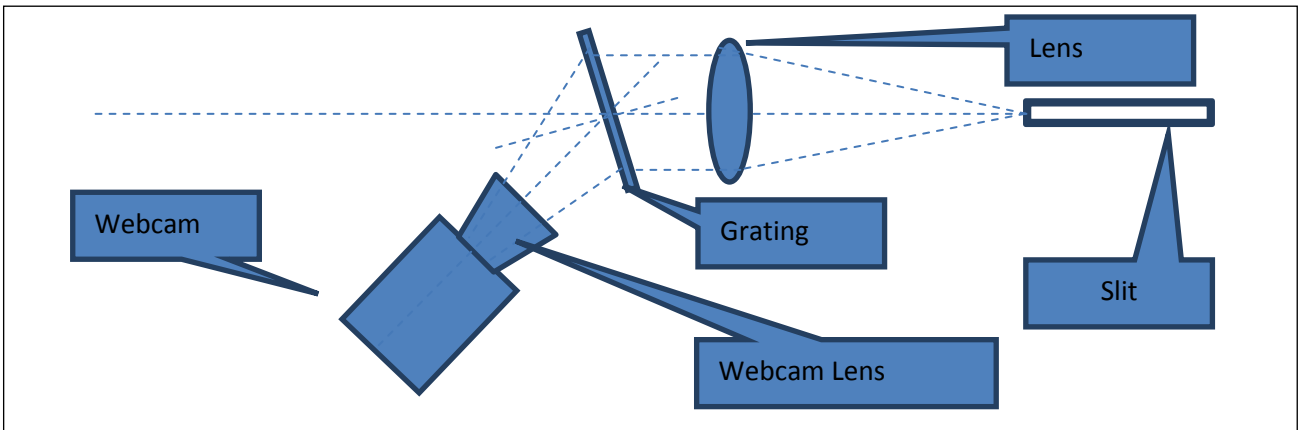


Inside view with collimating lens, grating and webcam

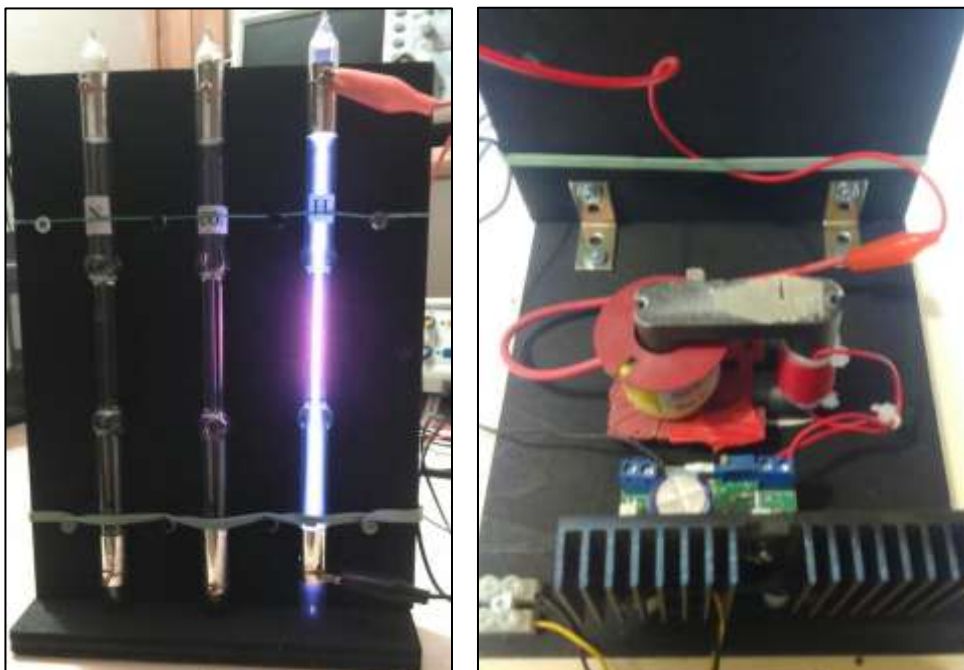


Detail of the micrometric slit and the spectrometer assembled

Spectrometer Design :

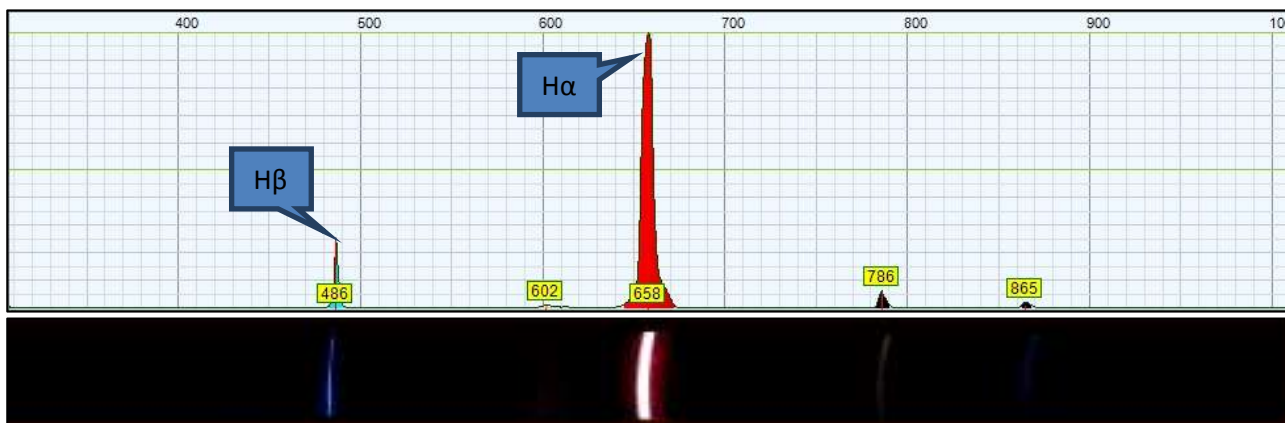


Spectral Lamps

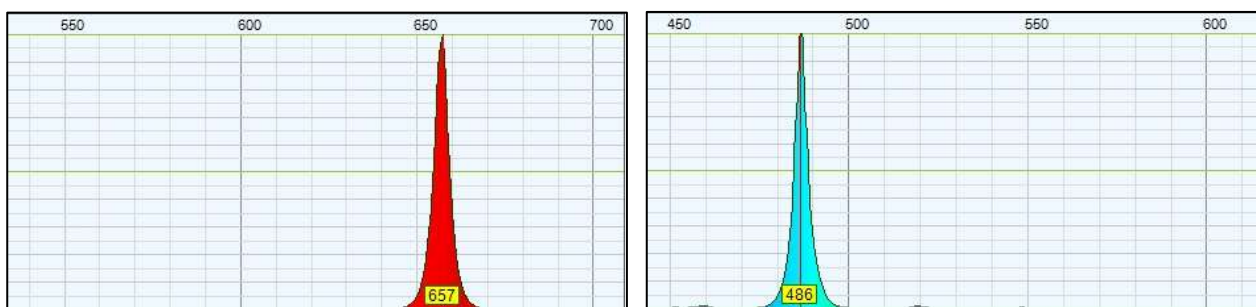


Spectral Tubes and HV Fly-Back Transformer

Hydrogen

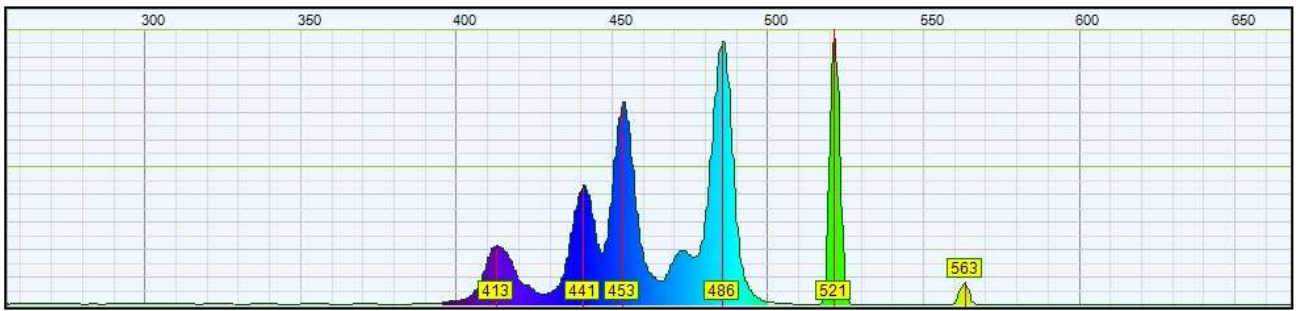


Low pressure hydrogen spectral lamp with high voltage high frequency power supply. The main hydrogen emission lines are evident.



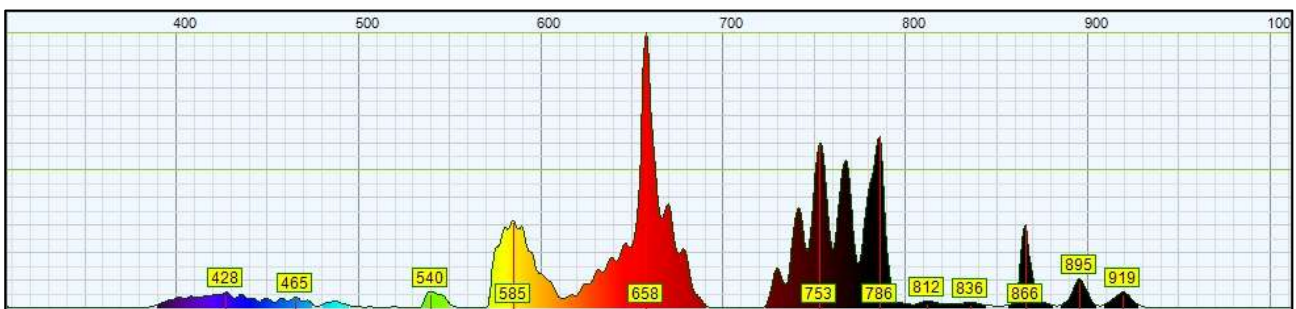
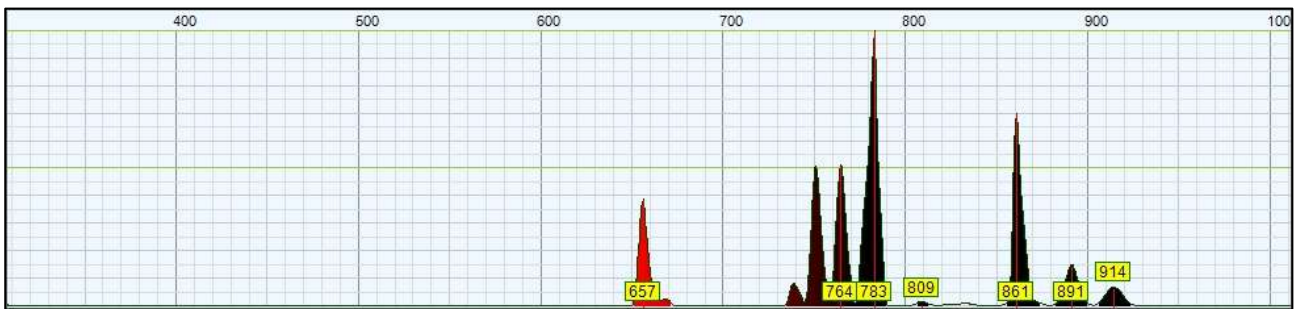
Detail of hydrogen H α line (656nm) and hydrogen H β line (486nm)

Carbon Dioxide



Low pressure carbon dioxide spectral lamp with high voltage high frequency power supply.
The main carbon dioxide emission bands are evident.

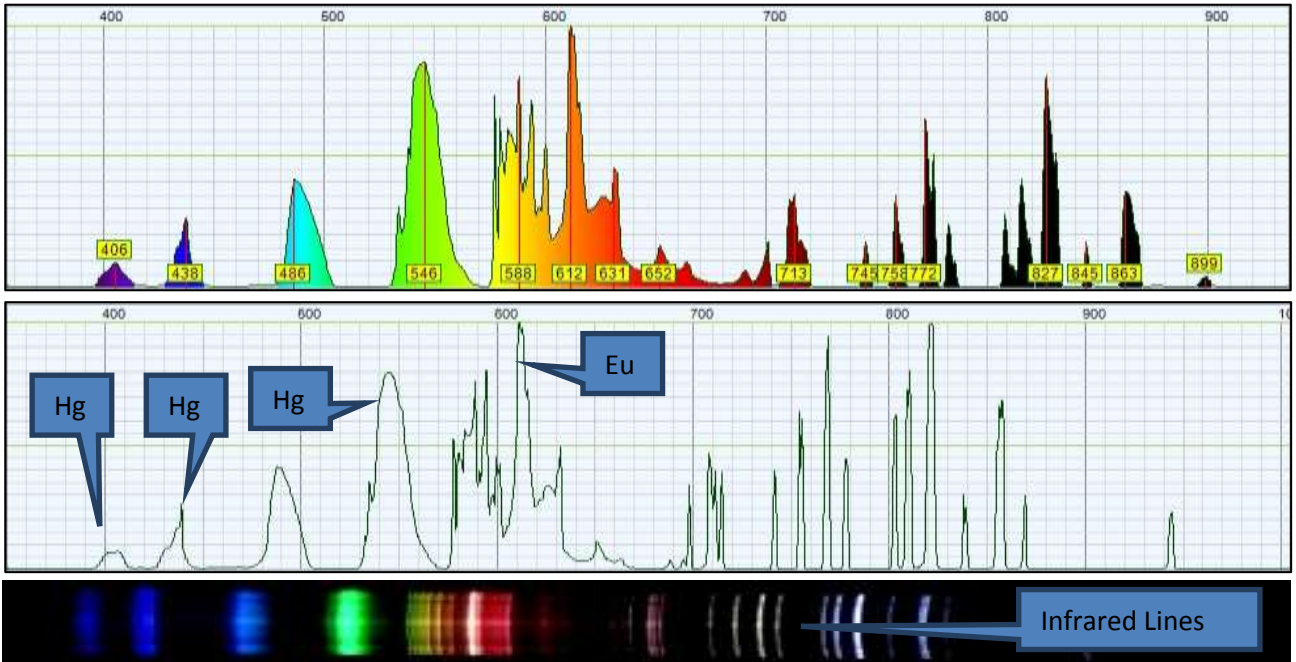
Nitrogen



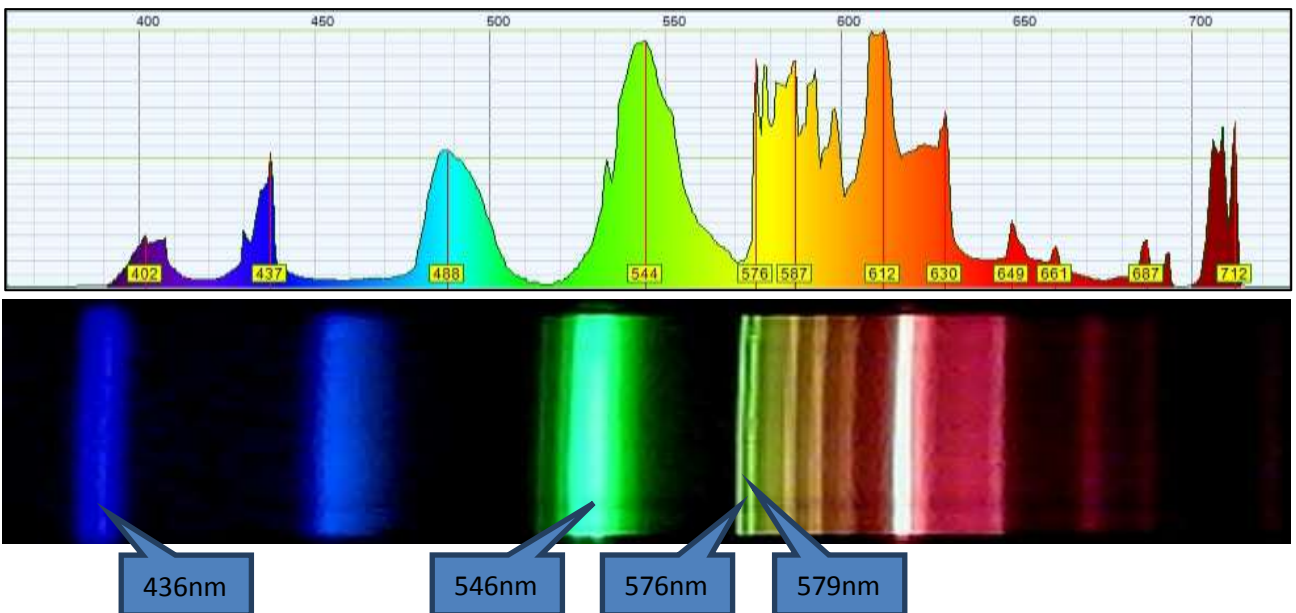
Low pressure nitrogen spectral lamp with high voltage high frequency power supply.
The main nitrogen emission lines are evident.
The second spectrum has been acquired with a broader slit in order to show more emission lines.

Spectra of Commercial Lamps

CFL Lamp

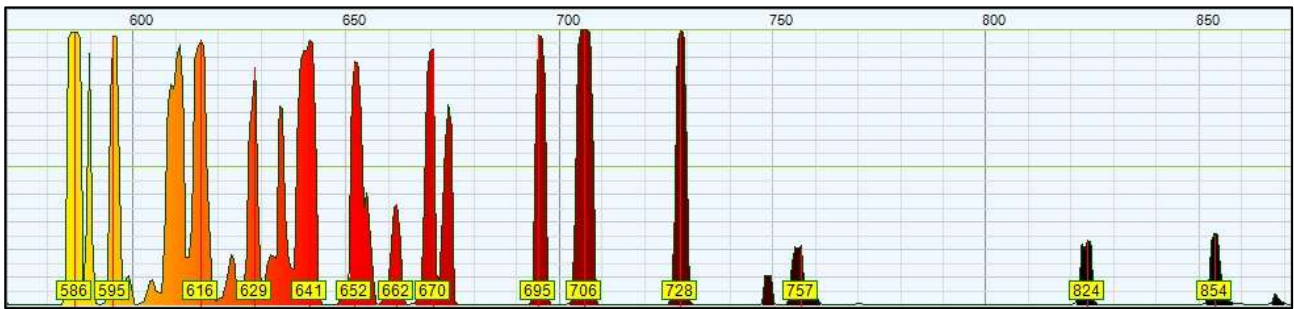


CFL lamp just lit – presence of lines broadened by phosphorus – infrared emission ($\lambda > 750\text{nm}$)



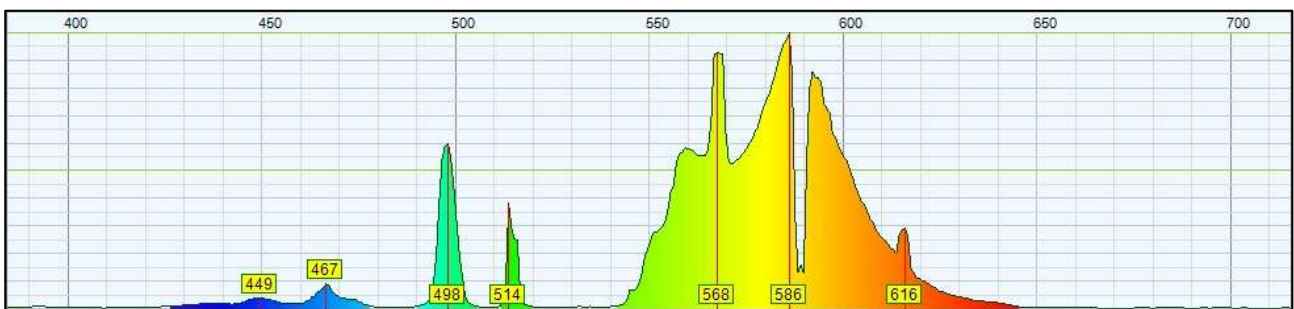
CFL lamp after warm-up (detail 400nm – 800nm) – no infrared emission

Neon Lamp



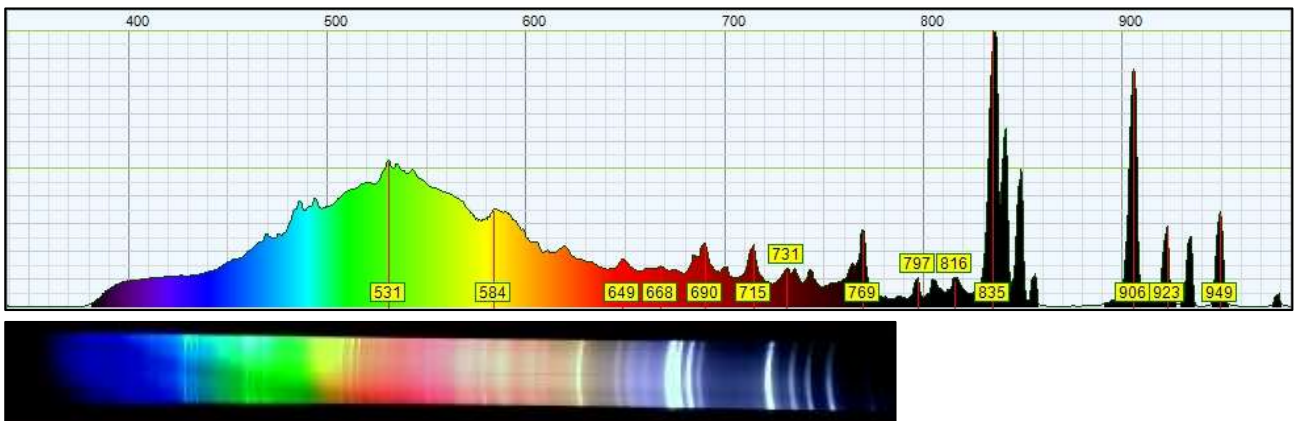
Low pressure neon lamp – discrete spectrum with many narrow lines

Sodium Vapor Lamp



Sodium-vapor lamp (street lamp) – evidence of the sodium doublet absorption line at a 589nm – further lines at 568nm, 616nm, 514nm, 498nm all corresponding to emission lines of the sodium spectrum

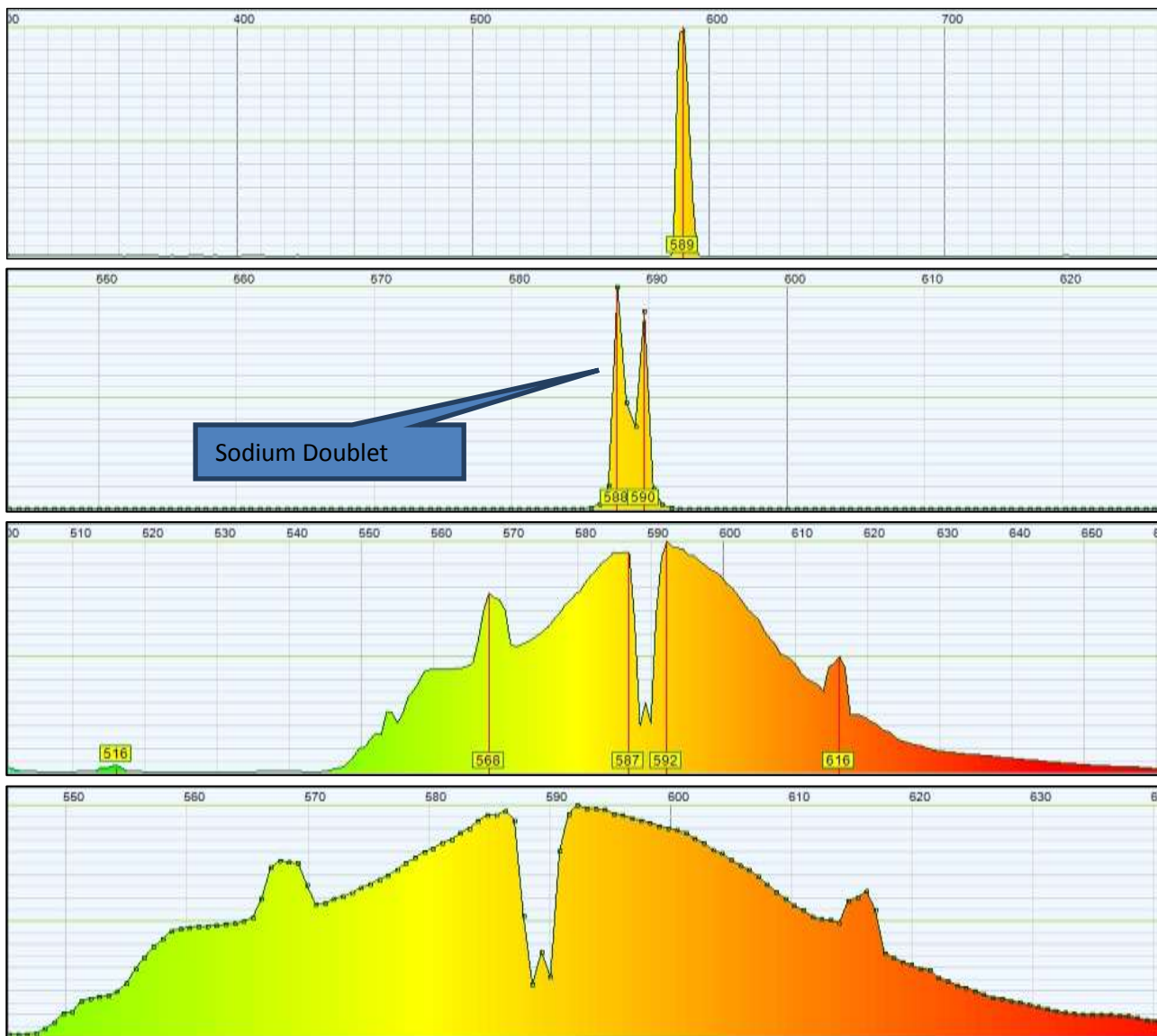
Xenon Lamp



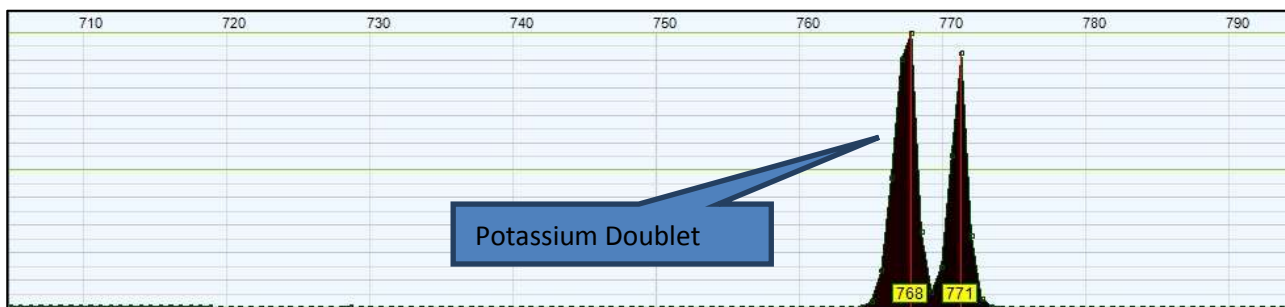
Xenon lamp

Due to the broad extension of the emission, from 350nm to 950nm, this lamp is used in absorption and fluorescence spectroscopy

Absorption / Emission Spectra



In the first spectrum of HV plasma with sodium chloride is evident the sodium line at 589nm. In the second spectrum the detail shows the sodium doublet at 589,0nm and 589,6nm. The third and fourth spectra show the detail of the absorption line in a sodium-vapor lamp



Spectrum of potassium chlorate match – evidence of potassium doublet at 770nm