LEOI-96 Kirchhoff Bunsen Spectroscope

Instruction Manual

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COMPANY PROFILE

Lambda Scientific Systems, Inc. specializes in developing and marketing lab equipment and scientific instruments that are designed and manufactured specifically for experimental education in physics at colleges and universities. We are not an online store to just resell products of other brands with limited services or no services at all, but a corporation engaging in the design, R&D, sales, and most importantly, technical support of our own products bearing our unique brand - Lambda Scientific. So our customers are fully protected for the money that they have spent with us.

We supply high-quality, reliable, easy-to-use, and affordable lab equipment and scientific instruments to college educators and students for their teaching and learning of both fundamental and advanced physics principles through hands-on experiments and comprehensive instructional materials. Our products cover an extensive range of physics experimental kits and apparatus, spectroscopic equipment, as well as laboratory light sources. Subjects include mechanics, heat & thermodynamics, electromagnetism, optics, and advanced physics. All products except turn-key laboratory light sources come with detailed instructional manuals.

Lambda Scientific Systems, Inc. was founded by Ph.D. physicists with extensive experience in academic and industrial fields, who are committed to providing high-quality/cost-effective products and in-depth technical support to the higher education community, both domestic and abroad. Since its foundation in 2010, Lambda Scientific Systems, Inc. has evolved rapidly to become a major supplier offering a full range of physics teaching apparatus in the US and around the world with products sold all over the globe.

Introduction

This basic spectrometer is an experimental instrument, consisting of collimator, telescope, dispersion prism, wavelength calibrated scale, and stand. It provides a high quality optical system and an easy-to- read scale, allowing to measure discrete atomic spectral lines. It can be used to illustrate the construction of a spectroscope, observe and measure the wavelengths of emission and absorption spectral lines. Especially, combined with our Hydrogen-Deuterium lamp (LLE-8), the wavelengths of Balmer series of Hydrogen atoms can be measured and then the Rydberg and Planck's constants can be determined.

Apparatus Structure

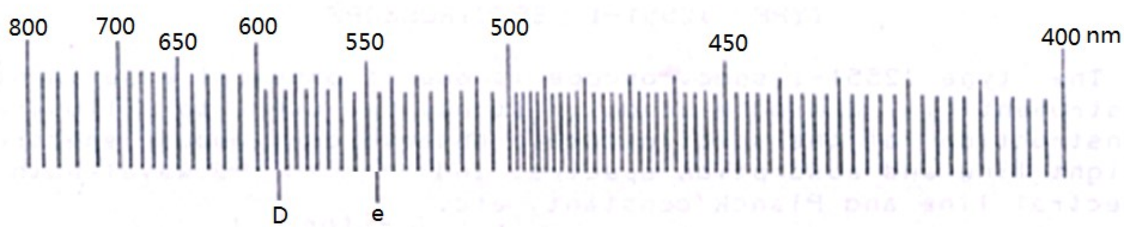
Configuration of Kirchhoff Bunsen spectroscope

1. Prism chamber, 2. Wavelength graduation tube, 3. Wavelength scale adjust screw, 4. Collimator tube, 5. Narrow slit, 6. Plane mirror, 7. Right angle prism, 8. Slit width adjust screw, 9. Post, 10. Base, 11. Supporting stage, 12. Hand wheel, 13. Telescope support plate, 14. Eyepiece, 15. Telescope tube

This apparatus mainly consists of a collimator, a telescope, a wavelength graduation tube, a dispersion prism, and other adjust and support parts, as shown in above photo.

The collimator consists of an objective lens and an adjustable narrow slit. A small right angle prism and a rotary plane mirror are mounted in front of the slit, which divide the entrance slit into upper and lower halves, so the collimator can collect the light of two different sources for their spectra comparison.

The wavelength graduation tube is composed of an objective lens and a wavelength scale ruler. The wavelength scale ruler is calibrated and the D-line 589.3 nm and e-line 546.1 nm are marked at the corresponding locations, as shown in the figure below. The wavelength scale ruler is projected to the eyepiece through the surface reflection of the dispersion prism, so the ruler image and the spectrum pattern of the light source are overlapped in the eyepiece and the wavelengths of spectral lines can be read out. In the front end of the tube, there are two adjust screws on both sides for the adjustment of the ruler position, which are used to calibrate the reading value of scale ruler by using a standard spectral calibration source.



Wavelength scale ruler

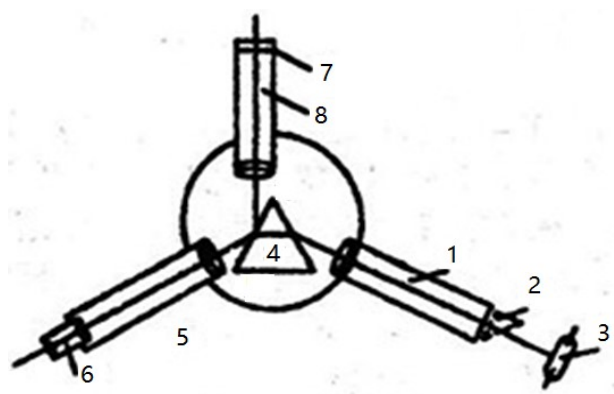
The telescope is equipped with achromatic objective and two exchangeable eyepieces, one with high power and the other low power. The dispersion prism is mounted in the center of the supporting stage. The telescope can rotate on an alidade, keeping the directional axis in the center of the apparatus.

Specifications

Wavelength range	400 ~ 800 nm
Collimator focal length	Objective: 150 mm
Telescope focal length	Objective: 150 mm
	Eyepiece: 25 mm (low power); 12.5 mm (high power)
Wavelength calibration tube	Objective focal length 100 mm

Minimum graduation of wavelength scale	400 - 500 nm: 2 nm	
	500 - 600 nm: 5 nm	
	600 - 700 nm: 10 nm	
	700 - 800 nm: 20 nm	
Prism	Angle 60°	
	Side length: > 32 mm	
Resolving power	Mercury doublet 577 nm and 579 nm using low-power eyepiece	
	Sodium doublet 589 nm and 589.6 nm using high-power eyepiece	
Dispersion power	At focal plane of the telescope, the distance between spectral lines 656.3 nm and 434 nm of hydrogen atom is > 9 mm. Average line dispersion power is 24.7 nm/mm	

Working Principle



Schematic of optical path

1. Collimator, 2. Right angle prism, 3. Light source, 4. Dispersion prism,
5. Telescope, 6. Eyepiece, 7. Wavelength scale ruler, 8. Wavelength scale tube

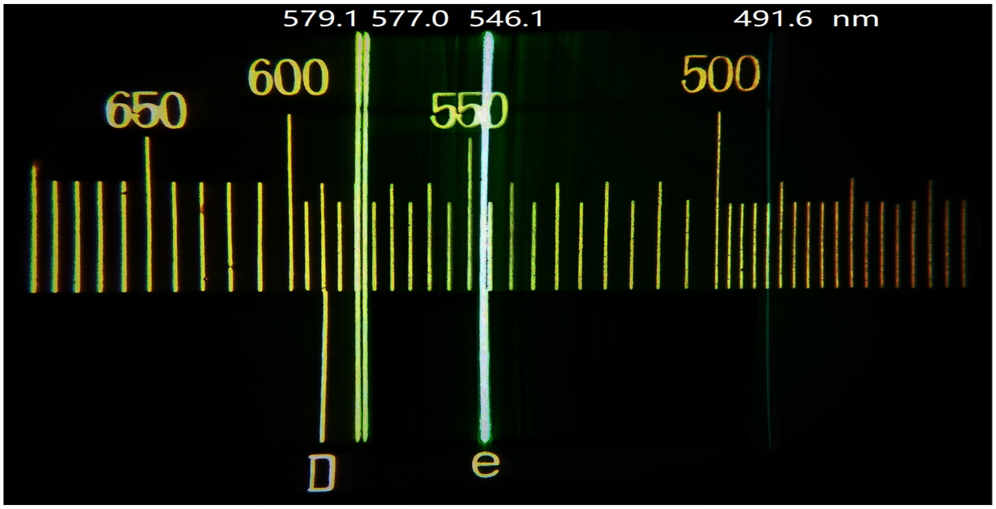
The schematic of optical path is shown in above figure. The beam of the light source is collimated by the collimator and incidents onto the dispersion prism. After being refracted by the prism, the beam enters the telescope and is focused onto its focal plane, where an image of the entrance slit of the collimator is created. Through the eyepiece, the image can be observed. If the light source is monochromatic, only one slit image can be observed. If the light source is composed of multiple wavelengths, due to the dispersion effect of the prism, beams of different wavelengths will have different deviation angles to enter the telescope. Therefore, multiple slit images of different wavelengths (colors) can be observed in the eyepiece. The pattern arrangement of these slit images is called as the optical spectrum of the light source.

In order to determine the wavelength of a specific spectral line, a wavelength scale ruler is equipped in the apparatus. The ruler illuminated by an external source is projected onto the focal plane of the telescope through lens imaging of the wavelength scale tube and the reflection of the back surface of the dispersion prism. The image of wavelength scale ruler is overlapped with the spectrum of the tested light source. After adjusting and fixing the relative positions of the collimator, dispersion prism and wavelength scale ruler, and using a wavelength known light source (such as sodium or mercury lamp) to calibrate the position of the scale ruler, spectral wavelengths of the tested light source can be directly read out from the eyepiece.

Experiment examples

1. Observe the spectrum of a low pressure mercury lamp

Place a low pressure mercury lamp in front of the entrance slit of the collimator. Adjust the eyepiece and the width of the slit proper to achieve clear spectral lines in the eyepiece. A photo taken from the eyepiece is shown below. It is one segment of the mercury spectrum.



2. Measure wavelengths of hydrogen spectral lines and determine Rydberg constant

Spectrum of Hydrogen atoms is the simplest and the most typical atomic spectrum. Using electricity to excite rarefied Hydrogen gas (pressure around 10^2 Pa) in a Hydrogen discharge tube, line style spectrum of Hydrogen atom can be achieved. Switzerland physicist Balmer presented an empirical formula for Hydrogen emission spectrum in the visible region based on experimental results:

$$\lambda_H = \lambda_0 \frac{n^2}{n^2 - 4}, \tag{1}$$

where λ_H is the wavelength of Hydrogen atomic spectral line in vacuum; λ_0=364.57 nm, is an empirical constant; n is an integer 3, 4, 5, ….. .

If representing in wave number, the above formula becomes:

$$\nu_H = \frac{1}{\lambda_H} = R_H \left(\frac{1}{2^2} - \frac{1}{n^2}\right), \tag{2}$$

where R_H is called the Rydberg constant of Hydrogen atoms.

According to Bohr's theory, the calculation result of Rydberg constant for Hydrogen and Hydrogen-like atoms is:

$$R_Z = \frac{2\pi^2 m e^4 z^2}{(4\pi\varepsilon_0)^2 c h^3 (1 + m/M)} \quad , \tag{3}$$

where M is the mass of the atomic nuclei, m is the electron mass, e is the electron charge, c is the speed of light, h is the Planck constant, ε_0 is the dielectric constant in vacuum, z is the atomic number.

When M→∞, i.e. equivalent to a static atomic nuclei, the universal Rydberg constant is:

$$R_\infty = \frac{2\pi^2 m e^4 z^2}{(4\pi\varepsilon_0)^2 c h^3} \tag{4}$$

Therefore,

$$R_\infty = R_H (1 + m/M) \tag{5}$$

For Hydrogen atoms,

$$R_H = \frac{R_\infty}{(1 + m / M_H)} \tag{6}$$

where M_H is the mass of Hydrogen nuclei.

In the experiment, a hydrogen lamp (e.g. LLE-8 from Lambda Scientific Systems, Inc) is used to illuminate the entrance slit of the collimator. Four spectral lines can be observed from the eyepiece, they are respectively H_α, H_β, H_γ and H_δ of Balmer series lines.

From above discussions, it can be seen, through experimental measurement of wavelengths of Hydrogen spectral lines of the Balmer series, using formulae (2) and (6), the Rydberg constant of Hydrogen atoms can be obtained (the recognized value of Rydberg constant is 1.0974×10^7 m^{-1}). Furthermore, using formula (4), the Planck's constant can be derived (the recognized value is 6.626×10^{-34} joule second).

An example of experiment results

Spectral lines	H_δ	H_γ	H_β	H_α
n	6	5	4	3
Measured wavelength (nm)	412	435	488	657
Calculated Rydberg constant (10^7 m^{-1})	1.09	1.09	1.09	1.10
Planck's constant ($\times 10^{-34}$ J.S)	6.65	6.63	6.65	6.63