**Unit: 6.1**

**Introduction to Spectroscopy**

**Dr. D. Chakravarty.**

**1.6. Representation of Spectrum – the width of Spectral Lines:**

**Representation of Spectrum**:-

A signal is a function of time which can be represented by a series of sinusoidal functions or sinusoidal components. Therefore, the plots of frequency versus amplitude and phase for the sinusoidal components which comprise the signal are called the Frequency Spectrum or Spectrum of the signal.

The frequency spectrum of an electrical signal is the distribution of the amplitudes and phases of each frequency component against frequency. A full-range device is any audio device capable of capturing, reproducing, or processing the full audio frequency spectrum of 20 Hz to 20 kHz.

The spectrum of a signal is the range of frequencies contained in the signal. The bandwidth is the difference between the lowest and highest frequency in the spectrum. It is therefore the width of the spectrum and is a measure of the information carrying capacity of the signal.

A spectrum is a condition that is not limited to a specific set of values but can vary, without steps, across a [continuum](https://en.wikipedia.org/wiki/Continuum_%28theory%29). The word was first used scientifically in [optics](https://en.wikipedia.org/wiki/Optics) to describe the [rainbow](https://en.wikipedia.org/wiki/Rainbow) of colours in [visible light](https://en.wikipedia.org/wiki/Visible_light) after passing through a [prism](https://en.wikipedia.org/wiki/Triangular_prism_%28optics%29) (**Figure: 01)**. As scientific understanding of light advanced, it came to apply to the entire [electromagnetic spectrum](https://en.wikipedia.org/wiki/Electromagnetic_spectrum).



**Figure: 01 Rainbow**

**Width of Spectral Lines:**

Width of Spectral lines in an optical spectra of atoms, molecules, and other quantum systems are characterized by a range of frequencies (v) or a range of wavelengths (λ = c/v), where c is the speed of light. Such a frequency or wavelength range is called the width of spectral lines (**Figure:** **02)**.



**Figure:** **02** **Width of Spectral Lines**

The line width of a laser, e.g. a single-frequency laser, is the width of its optical spectrum. More precisely, it is the width of the power spectral density of the emitted electric field in terms of frequency, wavenumber or wavelength.

Emission lines occur when the electrons of an excited atom, element or molecule move between energy levels, returning towards the ground state. For this reason, we are able to identify which element or molecule is causing the spectral lines. Assuming this is an absorption spectrum, if there is a thick dark line, it means that photons of a particular range of wavelength have been absorbed by the atom. A thick bright line means that photons of that range of wavelength have not been absorbed and allowed to pass through.

The line width is proportional to the square of the resonator bandwidth divided by the output power.

The line width is also called natural line width is generally very small and reduces the effective life time of a state, leading to broader lines.

Mercury is having the strongest line, at 546 nm, gives mercury a greenish color. When heated in a electric discharge tube, each element produces a unique pattern of spectral `lines'. As many as there are 10 transitions and hence 10 spectral lines possible.

From spectral lines astronomers can determine the element present, temperature and density of that element in the star. The spectral line also can tell us about any magnetic field of the star. The width of the line can tell us how fast the material is moving.

Based on the wavelengths of the spectral lines, Bohr was able to calculate the energies that the hydrogen electron would have in each of its allowed energy levels. He then mathematically showed which energy level transitions corresponded to the spectral lines in the atomic emission spectrum **Figure 03.**



**Figure 03. Electron transition of hydrogen atom**

**\*\*\*\*\*\*\*\*\***