Optics
Light intensity
Laws of radiation

The Wien's displacement law - spectral recording of the black body radiation

Description from SpectraLab (467 250)

For loading examples,
please use the SpectraLab help.

LD LD DIDACTIC

Investigation of Wien's displacement law

Experiment description

In an incandescent lamp, an electric conductor is heated by an electric current causing it to glow. The emitted spectrum is continuous and can be described with Planck's radiation formula. The radiation maximum of the radiation shifts with increasing temperature T according to Wien's displacement law

$$\lambda_{max} = 2.9 * 10^{-3} \, m*K \, / \, T$$

toward smaller wavelengths; at the same time the maximum value of the radiation increases. At the temperatures attained by normal incandescent lamps, about 2300 to 2900 K, the radiation maximum lies in the infrared spectral range. Halogen lamps reach a somewhat higher operating temperature of about 3000 K.

This experiment will record the spectra of a halogen lamp at different power levels. The specification for colour temperature at 12 V nominal voltage allows the wavelength dependency of spectrometer sensitivity to be determined and thus permits a corrected display for the course of spectra intensity. Subsequently voltage will be applied to a halogen lamp then reduced in steps. The lamp's colour temperature at each voltage step will be determined by adapting a suitable fit function.

Required equipment

1	Compact spectrometer, physics	467 251
1	Fibre holder	460 251
1	Halogen lamp, e.g.	459 032
1	Power supply, e.g.	521 485
1	Cable pair, 50 cm, black	501 451
1	Optical bench, S1 profile, 1 m	460 310
1	Clamp rider with fixing column	460 313
1	Clamp rider with clamp	460 311
1	PC with Windows 2000/XP/Vista/7/8	

Experiment setup (see picture)

Set up the experiment as shown in the picture.

Performing the experiment

- Activate ☐ to begin a new measurement.
- Select the **Intensity I1** display.
- Start the measurement with ▶.
- Switch on the halogen lamp, set voltage to 12 V.

LD DIDACTIC

- Adapt the integration time, either directly or with ⊖ or ⊕, such that maximum intensity lies between 75 % and 100 %. Adjust the fibre optic waveguide if necessary. Do not move the lamp or fibre optic waveguide afterwards.
- Switch off the light again to record the background spectrum.
- Open the **Offset I0** display.
- The displayed spectrum will be removed from subsequent measurements as the background spectrum.
- In ✳ Settings → Additional Settings select the **Relative Intensity** display and enter the colour temperature 3000 K.
- Change to the (now available) **Spectrometer sensitivity I2** display.
- Switch on the halogen lamp again, keep the voltage at 12 V.
- The displayed spectrum serves as a reference for relative I3 intensity spectra.
- Change to the **Relative Intensity I3** display.
- Save the spectrum with 🔴.
- Reduce the voltage on the halogen lamp in steps and save a spectrum of each step with 🔴.

Evaluation

In the **Intensity I1** display the halogen lamp exhibits a continuous spectrum with a maximum at about 620 nm. Thus the position of the maximum does not correspond to the position for T = 3000 K according to Wien's displacement law: λ_{max} = 967 nm. This deviation is caused by spectrometer sensitivity (grey curve), which is not constant for all wavelengths.

If one determines spectrometer sensitivity on the basis of filament temperature then the measured spectra can be corrected by this factor. Measured spectrometer sensitivity can be seen in the **Spectrometer sensitivity** display. It has its maximum at 520 nm and drops off substantially toward the range limits.

In the corrected display, **Relative Intensity I3**, the incandescent lamp's spectrum shows the expected distribution. Intensity increases for increasing wavelength, the maximum lies at about 970 nm. The halogen lamp therefore radiates primarily in the infrared range.

A comparison of spectra at the various levels of voltage reveals that for decreasing voltage, thus decreasing temperature, the intensity of the spectra diminish. Furthermore, the maximum of spectral distribution shifts out of the measured range. By using Diagram → Fit Function → Free Fit it is possible to fit a Planckian radiation curve to the spectra. Radiation laws for presentation against wavelength (formula with x^5) and against energy (formula with x^3) are provided in the formula's selection box f(x,A,B,C,D). The fit will produce values for maximum amplitude (parameter A, initial value 100) and colour temperature in K (parameter B, initial value 3000). According to Wien's displacement law, λ_{max} = 2.9 * 10^{-3} m*K / T, the wavelength can also be calculated with the maximum amplitude. The example measurement produces the following results:

E / V	A / %	B / K	λ_{max} / nm
12	99.3	2994	970
10	64.9	2750	1055
8	42.8	2528	1147
6	20.7	2121	1367

Notes

If spectra are displayed as a function of energy rather than of wavelength, the formula with x^3 must be selected as the fit function. Attention! Fits are only valid for the given selected display (wavelength or energy). If the display is subsequently changed, the appropriate fit function must again be fit.

Typical incandescent lamp temperatures by specified nominal power:

40 W incandescent lamp: 2200 K
60 W incandescent lamp: 2680 K
100 W incandescent lamp: 2800 K
200 W incandescent lamp: 3000 K
halogen lamp: 3000 K

In the **Relative Intensity** display, only those ranges are evaluated whose measurement curve intensity for spectrometer sensitivity amounts to at least 2 %.

The Σ control can be used to reduce noise by averaging multiple individual spectra (also Offset and Reference). Alternatively, Smoothing to 1 nm resolution can be set in the settings options.