DLF
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Experiment 24

Recording linear emission spectra using a grating spectrometer

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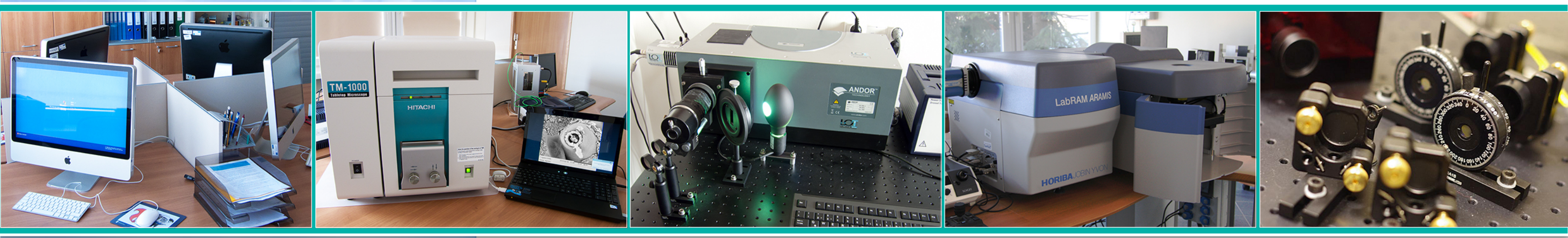


I. Background theory.

1. Characteristics of the apparatus: prismatic, grating, interferometers.
2. Operating principles of the spectroscopic apparatus:
   a) difference between a spectrograph and a monochromator;
   b) optical spectrograph;
   c) dispersive element: grating, prism;
   d) characteristics of spectroscopic instruments: spectral range, resolving power, linear dispersion, luminosity, magnification;
   e) spectral line width of the apparatus.
3. CCD camera:
   a) CCD camera construction;
   b) operating principles.
4. Spectral sensitivity characteristics of radiation detectors.
5. Spectral lines:
   a) shape and width of spectral lines;
   b) qualitative and quantitative analysis of a spectrum.
6. Resolution criteria of spectral lines.
7. Photometric quantities.

II. Experimental tasks.

1. Refer to the setup shown in *Picture 1* .

Picture 1. View of apparatus for recording linear emission spectra: 1 – CCD camera; 2 – slits; 3 – spectrometer; 4 – mercury lamp power supply; 5 – computer; 6 – mercury lamp; 7 – mirrors.

2. Turn on the power to each individual component.

> **ATTENTION!**
> 1. **Before turning on the power, set both slits 2 in *Picture 1* to minimum width!!!**
> 2. **The number of counts should not exceed $6 \cdot 10^5$**

Perform the following steps:

- turn on the power strip for the CCD camera and spectrometer, ensuring that the switch on the camera power supply housing is set to position II;
- turn on the computer (the switch is on the front cover);
- turn on the spectrometer (the switch is on the right-hand side);
- turn on the mercury lamp(the switch is on the back of the power supply); The mercury lamp should be turned on for at least a half hour before starting measurements.

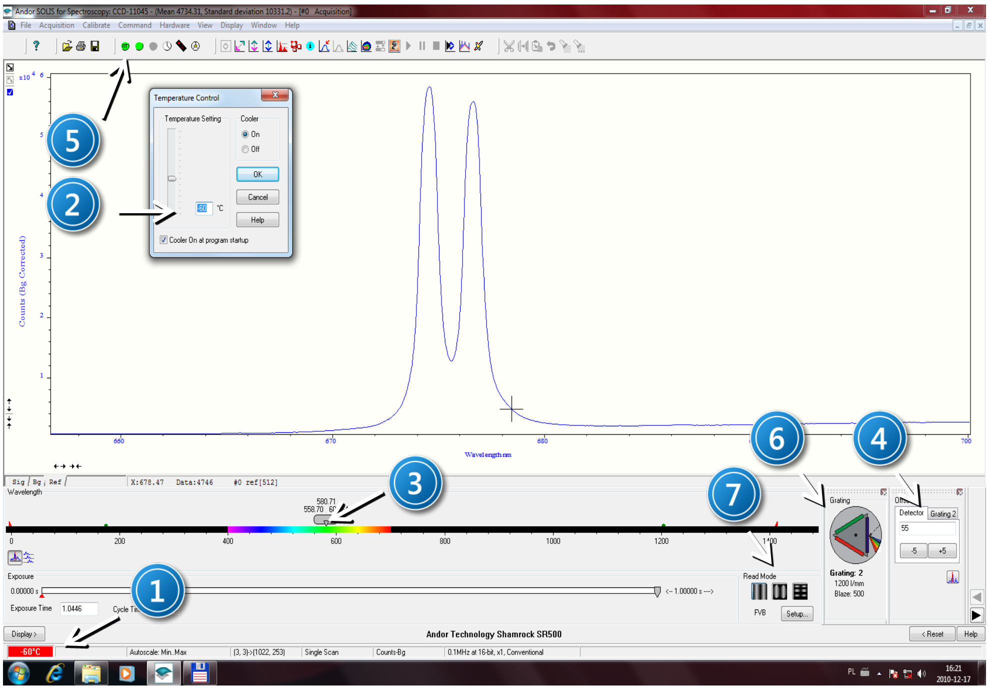
3. Start the program "*Andor Solis for Spectroscopy"* by clicking the desktop icon 1, *Picture 2.*

Picture 2. View of the screen after turning on the computer: 1 – "Andor Solis for Spectroscopy" program icon.

4. Before starting measurements, verify that the temperature of the CCD camera shown on indicator 1 in *Picture 3* is set to –60 ^{o}C.

5. Set the camera to FVB mode through its menu: *Acquisition, Setup Acquisition, Setup CCD, Readout Mode* 16,25 µs and scanning speed *Readout Pixel Shift* set to 100 kHz AT 16 bit.
6. Based on II.5., calculate the CCD camera's effective working time.
7. Record the spectrum of the lamp as a function of exposure time using the instructions in steps II.8. – II.13.
8. Specify the method of data collection using the menu: *Acquisition, Setup Data Type* or pressing Ctrl+D. When recording the spectra, set the camera to correct for the background signal → Counts (Background corrected).
9. For the shortest exposure time, set the minimal width of the slits *2, Picture 1* , such that the number of counts does not exceed 100.
10. Use the diffraction grating rotor *6, Picture 3* to choose a single grating, and then use slider *3, Picture 3* to set the spectral range.

    For the mercury lamp, choose a grating with 1200 lines/mm and a spectral range centred at 580 nm.



Picture 3. View of the CCD camera and spectrometer control software: 1 – CCD camera temperature indicator (red – camera has not yet attained desired temperature, blue – camera has reached the desired temperature); 2 – CCD camera temperature control dialogue found in Hardware in the main menu; 3 – slider showing selected spectral range, 4 – Detector and Grating tab for entering a relative offset between the detector and diffraction grating; 5 - toolbar; 6 – diffraction grating selection; 7 – CCD camera mode selection and results display.

11. Cover the spectrometer entrance slit and record a background signal by pressing Ctrl+B or through the menu: *Acquisition*, *Take Background*.

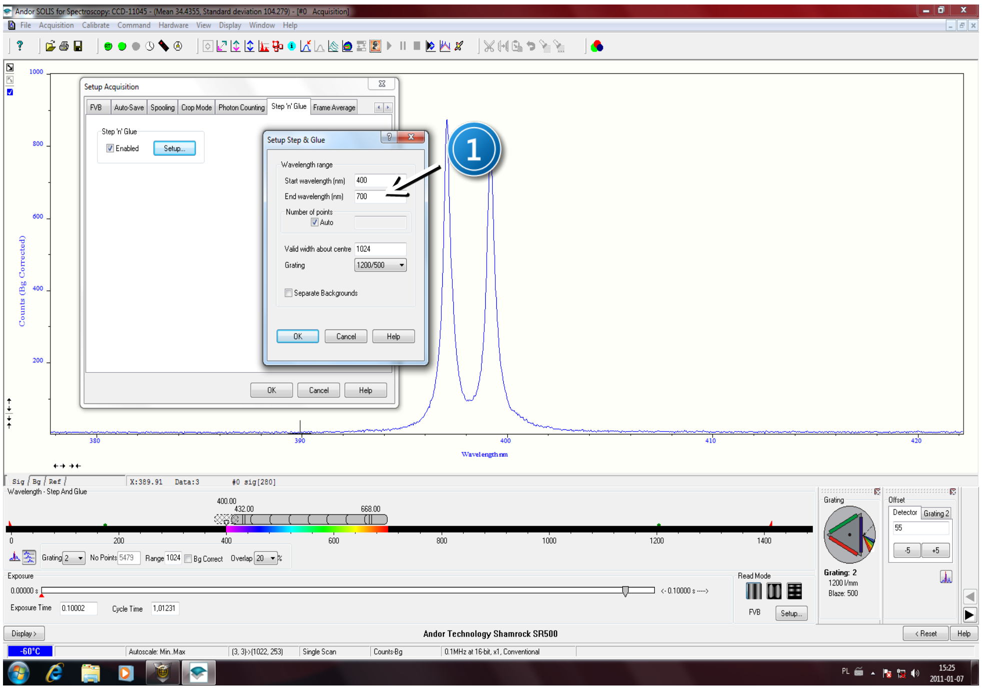
12. Record and save the spectrum for 11 different exposure times: 10 µs, 50 µs, 100 µs, 500 µs, 1 ms, 5 ms, 10 ms, 50 ms, 1 ms, 500 ms, 1 s.

    All recorded spectra must be taken with the same spectral range. Create a plot of intensity as a function of exposure time.
13. In order to work further with the recorded spectra, save them in ASCII format using the menu: *File, Export as ASCII*, *Signal* or *Background, Reference, Lamp Calibration*.

> **Hint**
> Remember that the background signal will increase with increased exposure time and gap width. Each time you change these two parameters, you must take a new measurement of the background signal.

14. Estimate the effective working time of the CCD camera and compared with the value calculated.
15. Record the spectrum of mercury lamp as a function of the width of the spectrometer's input slit ranging from 0,05 do 1,5 mm following steps II.16. – II. 18.
16. Set the camera's exposure time to more or less the effective time.
17. Set both slits to minimum *2* in *Picture 1* and use slider *3, Picture 3* to specify the spectral range.
18. Record and save 12 spectra as a function of slit width ranging from 0,05 to 1,5 mm.
19. Compile your measurements into a graph of the type: $I = I_0 \cdot r + B$, where I_0 - initial intensity, r – slit width, B – constant associated with the background signal.
20. Check the Rayleigh resolution criterion for the two emission lines by following steps II.21. – II.25.
21. Set the camera's exposure time to more or less the effective time.
22. Using the diffraction grating selection icon *6, Picture 3,* select a grating with 1200 lines/mm.
23. Use slider *3, Picture 3* to set the spectral range centred on 580 nm.
24. Set the both slit widths *2* in *Picture 1* to minimum.
25. Record and save 12 spectra as a function of slit width ranging from 0,05 to 1,5 mm.
26. Adjust the Lorentz curve for your recorded spectra.
27. Determine the Rayleigh criterion for the two selected spectral lines.
28. Record the emission spectra for two diffraction gratings: 100 lines/mm and 1200 lines/mm using the option to scale the spectra by following steps II.29. – II.34.
29. Using the diffraction grating selection icon *6, Picture 3,* select the grating with 100 lines/mm.
30. Set the same range for both grids e.g.: ranging from 400 to 700 nm.
31. Record and save the spectrum for the grating with 100 lines/mm.
32. Using the diffraction grating selection icon 6, *Picture 3*, select the grating with 1200 lines/mm.
33. Stitch the two spectra together using the menu: Acquisition, Setup Acquisition, Step 'n' Glue 1, *Picture 4.*

    Select the range and degree of overlap of the spectra.



Picture 4. CCD camera and spectrometer software menu showing spectrum stitching: 1 – wavelength range selection.

34. Record and save the spectrum for the grating with 1200 lines/mm.
35. Compare the measurements for the two diffraction gratings in steps II.31. and II.34.

III. Apparatus.

1. Andor Shamrock spectrometer, model SR-500i.
2. Andor CCD camera, model iDus 401.
3. Mercury lamp.
4. Mercury lamp power supply.
5. Adjustable slit.
6. Mirrors.
7. Computer.

IV. Literature.

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