Absorption Spectroscopy

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Within this laboratory course, laser absorption spectroscopy [1] of iodine is realized with a simple setup (see fig. 1). A pulsed laser is frequency-doubled (via “second harmonic generation”, SHG) and transmitted through an iodine cell. A commercial grating spectrometer records the transmitted spectra. This is a very short summary that is supposed to support you in your independent preparation for this advanced laboratory course.

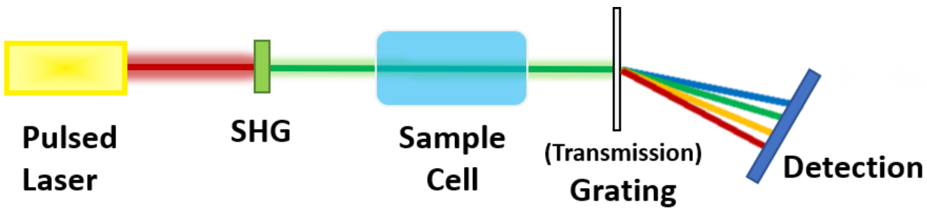

Fig 1: Simplified setup of iodine absorption spectroscopy. A pulsed near-infrared laser is frequency-doubled via second harmonic generation (SHG) and transmitted through the iodine gas cell. The transmission spectra are recorded with a commercial grating spectrometer.

Main tasks:

1 Iodine spectra are recorded

a) at different temperatures and
b) with two different interaction lengths (one pass and three passes through the gas cell).

2 The iodine absorption spectra are calculated from the measured transmission spectra and compared with literature [2]. The discussion should include uncertainty statements and a strategy for improving the measurements.

Keywords for preparation:

Dielectric mirrors
Temperature broadening
Nonlinear crystals
Principle of a laser
Optical density
absorption
coherence
Grating spectrometer
time-bandwidth-limit
Pulsed laser
Natural linewidth of absorption resonances
(second) harmonic generation
Beer-Lambert-Law
(central) wavelength

For further reading: mode locking, dispersion, autocorrelation, laser frequency combs

Detailed task list:

1. Characterize the laser source by measuring its average power with a power meter (Thorlabs, [3a]), and its output spectrum with the grating spectrometer (APE, [3b]). Specify its central wavelength and the full width half maximum (FWHM) of the laser output.
2. Setup the second harmonic generation (SHG) stage consisting of a focusing lens, a nonlinear crystal, and a recollimation lens. Optimize for green power and characterize the conversion efficiency.
3. Record the SHG spectrum (green) with the APE spectrometer.
4. Place the iodine cell between SHG stage and spectrometer. Record the transmitted spectrum at three different temperatures (T = 20 °C – 60 °C).
5. What is the length of the cell? At a sample cell temperature of ~ 60 °C, try to triple the interaction path length through the cell with the help of two mirrors. Record the spectra again. Compare with the single pass measurement.
6. Data analysis:
   6.1 Plot the fundamental laser spectrum and determine the central wavelength and the FWHM.
   6.2 Plot the visible (SHG spectrum and give the central wavelength and the FWHM.
   6.3 Calculate the "absorbance" or the optical density OD with the formula

$$OD = -log_{10}\frac{I_t}{I_0} \tag{1}$$

   for the different temperature and interaction path cases. I_0 is the measured laser intensity without iodine and I_t is the intensity transmitted through the gas sample. Determine the concentration in the cell based on your values for the absorbance.

   6.4 Include into your discussion a comparison to the literature curves, i.e. visualize your absorbance spectrum together with one literature curve [5], and a strategy for improving the experiment.

The lab protocol should be structured along the guidelines of the NAWI Graz Laboratory Courses [4].

Protocol deadline: two weeks after the lab course

Literature:

[1] Wolfgang Demtröder, Laser Spectroscopy, Volume 1, Springer
- Chapters: 2 Absorption and Emission of Light (esp. 2.6 & 2.7)
  3 Widths and Profiles of Spectral Lines
  4.1 Spectrographs
  5.1 Fundamentals of Lasers
  6.3 Second Harmonic Generation

[2] A. Saiz-Lopez et al., Absolute absorption cross-section and photolysis rate of I_2, Atmos. Chem. Phys. Discuss., 4, 2379–2403 (2004)

[3] Manuals (Thorlabs powermeter, APE wavescan spectrometer,)

[4] Protokoll-Richtlinien, NAWI Graz, Chapter 3 in „Einführung in die physikalischen Mess-methoden", 2022

[5] https://uv-vis-spectral-atlas-mainz.org/uvvis/cross_sections/Halogens+mixed%20halogens/I2_Saiz-Lopez(2004)_295K_182-750nm.txt

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