Optics
Dispersion and chromatics
Absorption spectra

Absorption spectra of PMMA optical waveguide - Recording and evaluating with a spectrophotometer

Description from SpectraLab (467 250)

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SpectraLab (2013-09-18)

Absorption spectrum of an optical waveguide

Experiment description

Depending on type, the inside of an optical waveguide (optical fibre) consists of quartz glass or transparent plastic. The plastic materials (e.g. PMMA, polymethyl methacrylate) are particularly prone to wavelength-dependent absorptions. Due to the length of a fibre optic waveguide, even small absorption cross-sections play a role and result in clearly visible bands of higher absorption in the spectrum as well as optical windows in which the fibre passes light with low losses.

Required equipment

1	Compact spectrometer, physics	467 251
1	Fibre holder	460 251
1	Lamp socket, E 27	451 17
1	Incandescent lamp, E 27, 60 W	505 301
2	Saddle base	300 11
1	Optical fibres, set of 2	579 44
1	PC with Windows 2000/XP/Vista/7/8	

Experiment setup (see picture)

Put the incandescent lamp into the lamp socket. Set up the spectrometer's optical fibre in the fibre holder at a distance of about 1 m from the incandescent lamp. Lay the optic waveguide at the ready.

Performing the experiment

- Activate 🗋 to begin a new measurement.
- Select the **Intensity I1** display.
- Start the measurement with ▶.
- Switch on the incandescent lamp.
- Align the fibre optic waveguide to maximise intensity. Adapt the integration time, either directly or with ⊖ or ⊕, such that maximum intensity lies between 75 % and 100 %. Do not change the integration time again after this.
- 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.
- Change to the **Reference I2** display.
- Switch on the incandescent lamp again.
- The displayed spectrum serves as a reference spectrum for the following measurement.
- Change to the **Transmission T** display. A continuous line at 100 % results.

- Remove the spectrometer's fibre optic waveguide from the lamp then hold a piece of the fibre optic waveguide (PMMA) directly in front of the spectrometer's waveguide and the other end in the direction of the lamp. If necessary, change the distance to match the aperture angles of the fibres.
- Stop the measurement with ⏸, which may require a third hand.
- For the **Transmission T** display, the relationship of the spectrum with fibre optic waveguide (PMMA) + fibre optic waveguide (quartz), one after the other, will be calculated and displayed as a reference curve for the spectrometer's fibre optic waveguide alone.
- Extinction (optical density) will be calculated and presented in the **Extinction E** display.
- The 🔴 control can be used to save the transmission spectrum for all displays simultaneously.

Evaluation

When the plastic fibre optic waveguide (PMMA) is in place, transmission T is generally attenuated due to coupling losses but there are also special absorption bands at which transmission breaks down and losses in the fibre are severely increased.

In view of these absorption bands, one can now make a selection of lasers and light emitting diodes which will radiate through such a fibre optic waveguide with a minimum of losses. These ranges without specific absorption are also called optic windows. The red LED for 660 nm or infrared LED for 950 nm find preferred usage in practical applications.

As an advanced experiment, one can cut off a length of about 10 cm fibre optic waveguide for investigation as described above. In the ranges of higher absorption this will reveal further details about absorption at 870 and 900 nm because this short piece of fibre does not completely absorb these ranges.

For historic reasons, an energy scale in cm^{-1} is often used in molecular physics. The x-axis units of measure can be switched to Wavenumber (1/cm) via Settings → Additional Settings.

The C-H bonds in the material are primarily responsible for absorption. The resonant oscillation of hydrogen in C-H bonds lies far into the infrared range (about 3,3 µm or 3000 cm^{-1} in methane) but higher order overtones can also be generated which lie in the visible and near-infrared ranges. Since this bond represents an anharmonic oscillator, overtones are not quite exactly a multiple of the base frequency but rather somewhat less energetic because the bond is weaker in the middle.

The highest energy visible absorption at 625 nm (16 000 cm^{-1}) is the 6th overtone of the C-H bond, the others lie at: 735 nm (13 700 cm^{-1}) for the 5th overtone and 890 nm (11 200 cm^{-1}) for the 4th overtone.

Other absorption bands originate from overtones of the O-H bond of diffused water.

Notes

Depending on the type of fibre optic waveguide, absorption spectra can be slightly different.

A different procedure is necessary to perform a precise measurement of fibre optic waveguide losses without coupling losses: the PMMA fibre optic waveguide is fitted with appropriate F-SMA adapters and screw-fastened to the fibre holder and the spectrometer. A reference spectrum is recorded with a short piece of fibre (10 cm) and compared to a long piece of fibre such that loss differences are only a function of the difference in length.

Use Settings → Additional Settings to select the **Transmission/Loss** display. This will present the fibre's losses in dB, the unit of measure used in practical applications.

In the **Transmission, Extinction** and **Loss** displays, only those ranges are evaluated whose intensities in the reference curve amount 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.