



Exercise 8: Analysis of scattering and absorbing matter in water with hyperspectral transmissometry

Introduction

Since the availability of compact polychromators equipped with a diode array instead of a single photodetector, the transmission of light in water can be measured with high spectral resolution. When compared with instruments for single wavelength operation, the advantage of multispectral transmissometry lies in the information content of the entire attenuation spectrum (Kirk 183, Mobley 1994), from which substance-specific features can be extracted:

- phytoplankton and its pigment *chl a* which scatter and absorb light
- suspended matter, i.e. mineral particles which predominantly scatter light,
- dissolved organic macromolecules from biodegradation of plants, which absorb light at ultraviolet and blue wavelengths, denoted as gelbstoff.

In this exercise, a hyperspectral transmissometer is used to investigate the attenuation characteristics of these substances in water samples. From the measured transmission spectra, substance specific contributions are derived with an inversion algorithm.

Methods

The *in situ* polychromatic transmissometer (Barth et al. 1997) measures the intensity loss of a near-parallel light beam from a flashlamp along a light path r in water, yielding data on the total attenuation coefficient c in Lambert's law $dl/l = -cr$, in integral form: $I(r) = I(o) \exp(-cr)$ with the Intensity $I(o)$ at $r=0$. The path length in water can be changed by use of a motor-driven retroreflector. This allows

- to adapt the pathlength to water with a broad range of absorbing and scattering matter concentrations
- to correct the recorded spectra for the emission spectrum of the flashlamp and the spectral sensitivity of the polychromators; this is done by an additional measurement at another pathlength, e.g. $r=0$.

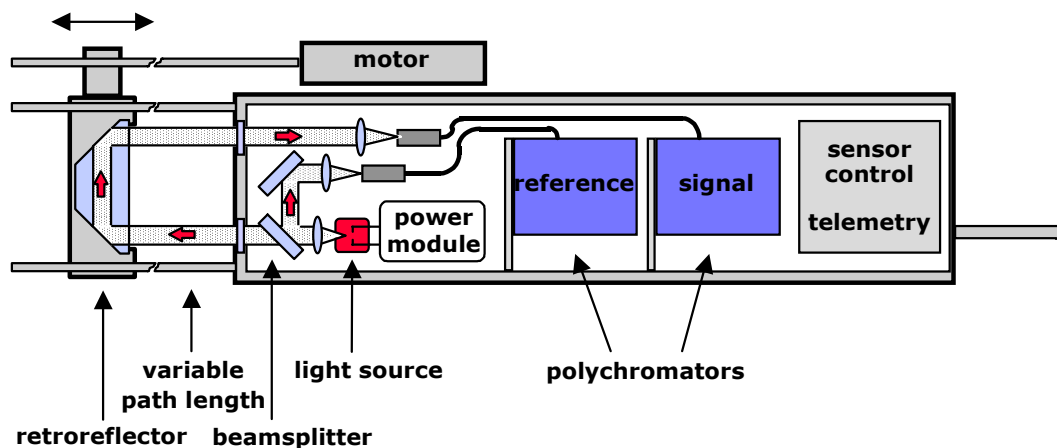


Fig. 1: Schematics of the hyperspectral transmissometer

The attenuation coefficient c is a composite of several terms, which describe absorption and scattering by molecules and particles:

$$c(\lambda) = c_w(\lambda) + c_{pp}(\lambda) + c_{tp}(\lambda) + a_d(\lambda)$$

where the indices w , pp , tp , and d refer to contributions from water, phytoplankton, transparent (mineral) particles, and gelbstoff (Fig. 2).

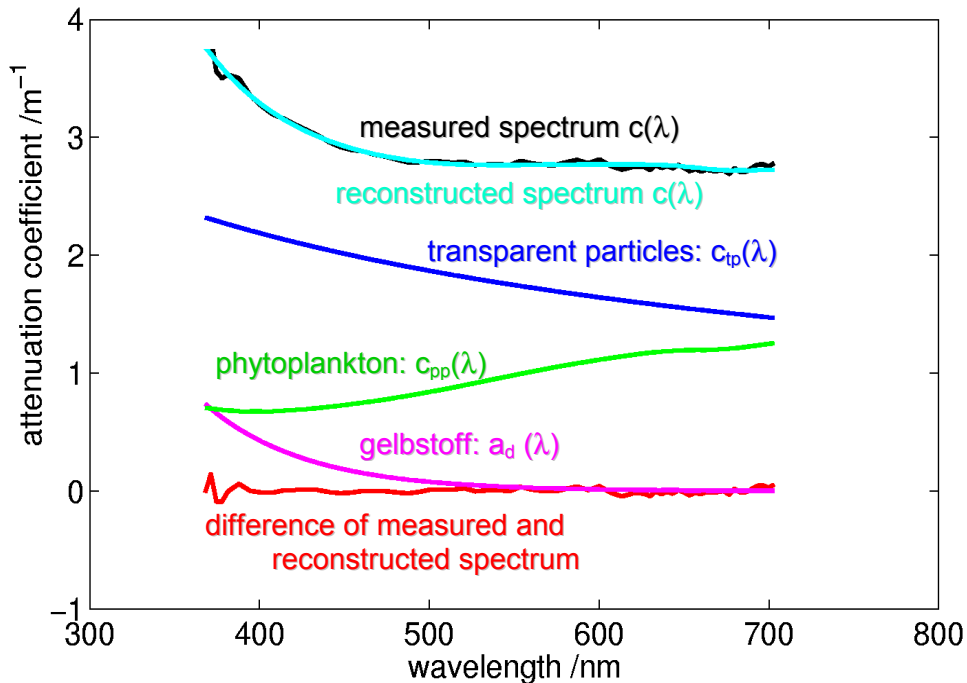
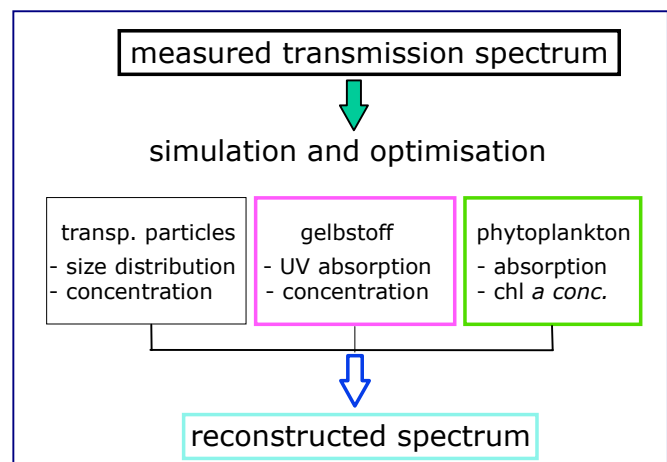


Fig. 2: Spectrum of the attenuation coefficient c , measured *in situ* in the Seine estuary, France, 8 May, 1998, and its substance-specific contributions. The spectral attenuation coefficient of pure water has been subtracted prior to the inversion (Barth et al., 2001)

The inversion of the measured spectra and identification of its substance-specific contributions (Fig. 2) is done with the Levenberg-Marquard least square algorithm in MATLAB[®]. For this, the optical properties of phytoplankton, transparent particles and gelbstoff are assumed to be as follows:

- scattering and absorption of phytoplankton is calculated according to Mie theory, i.e. assuming spherical particles having a single size, and with *chl a* homogeneously distributed in the particle. Particle size and *chl a* content are variables with values that are optimised by the algorithm.
- transparent particles are spherical and non-absorbing, with a hyperbolic (Junge-type) size distribution. Particle number and steepness of the size distribution are estimated by the algorithm.
- gelbstoff absorption coefficients are exponentially decreasing versus wavelength.



Experiments

1. The first step of a transmission measurement is the spectral calibration of the instrument. The transmissometer is submerged into pure water, the retro-reflector is set to its zero position ($r=0$), and a calibration is done. T
2. The retro-reflector is set to the maximum position, and the pure water transmission is registered.
3. Transmission spectra of water samples with different loads of phytoplankton, suspended transparent particles and gelbstoff are taken. For this, a suitable position of the retro-reflector is chosen to ensure signal intensities of approx. $\frac{1}{2}$ of the value found at the $r=0$ position. The transmission spectra are observed, and their shape is discussed.
4. The spectra are analysed with the data evaluation algorithm using MATLAB[®] software to retrieve the specific contributions and identify the corresponding substances in the water samples.
5. All spectra are compared and the observed differences are discussed.

Further reading

Barth, H., Grisard, K., Holtsch, K., Reuter, R. and Stute, U. 1997. A polychromatic transmissometer for in situ measurements of suspended particles and gelbstoff in water. Applied Optics, 36:7919-7928.

Barth H., R. Reuter & M. Schröder 2001: Measurement and Simulation of substance specific contributions of phytoplankton, gelbstoff, and mineral particles to the underwater light field in coastal waters. In: Lidar Remote Sensing of Land and Sea, R. Reuter (editor), EARSeL eProceedings 1, 165-174, 2001

see also: http://las.physik.uni-oldenburg.de/projekte/earsel/4th_workshop.html#proceedings
section Bio-Optics

Kirk, J.T.O. 1983. Light and Photosynthesis in Aquatic Ecosystems. (Cambridge University Press)

Mobley, C.D. 1994. Light and Water. (Academic Press)

Contact

Dr Frank Terjung & Dr Rainer Reuter
Carl von Ossietzky University of Oldenburg
Institute of Physics
D-26111 Oldenburg
frank.terjung@uni-oldenburg.de

Karin Munderloh
TriOS Optical Sensors
Werftweg 15
D-26135 Oldenburg
munderloh@trios.de