A Double Beam Spectrometer

A QuickTime movie and a (soundless) GIF animation are both available that illustrate the workings of a double beam spectrophotometer.

Introduction

The following is a brief description of a double beam spectrophotometer. The purpose of this instrument is to determine the amount of light of a specific wavelength absorbed by an **analyte** in a sample. Although samples can be gases or liquids, an analyte dissolved in a solvent is discussed here. [In the infrared, solid pellets using an IR. transparent matrix (like a high purity salt such as Kr) can be used for solid analytes. Thin disks are made using a pellet press and the disk suspended in the sample cell through which the sample beam passes.]

The starting point in our movie is the **light source**. Depending on the wavelength of interest, this can be an electrically powered ultraviolet, visible, or infrared lamp. Not shown in the animations that accompany this page is the spectrophotometer's monochromator which selects the analytical wavelength from the source lamp's broad spectrum containing many wavelengths of light. The analytical wavelength is chosen based on the absorbance characteristics of the analyte. Monochromators are instruments whose sole purpose is to allow polychromatic (that is many wavelength containing) light into the **entrance slit** of the monochromator and only allow a single (or at least very few) wavelength (monochromatic light) out via the **exit slit**. This exiting, well-shaped, narrowly-defined beam now contains a small region of the electromagnetic spectrum. The spread, or band-pass, of the wavelengths depends on the slit settings of the monochromators (usually adjustable) and the quality of the light dispersing element in the monochromator (usually a **grating** in most modern monochromators).

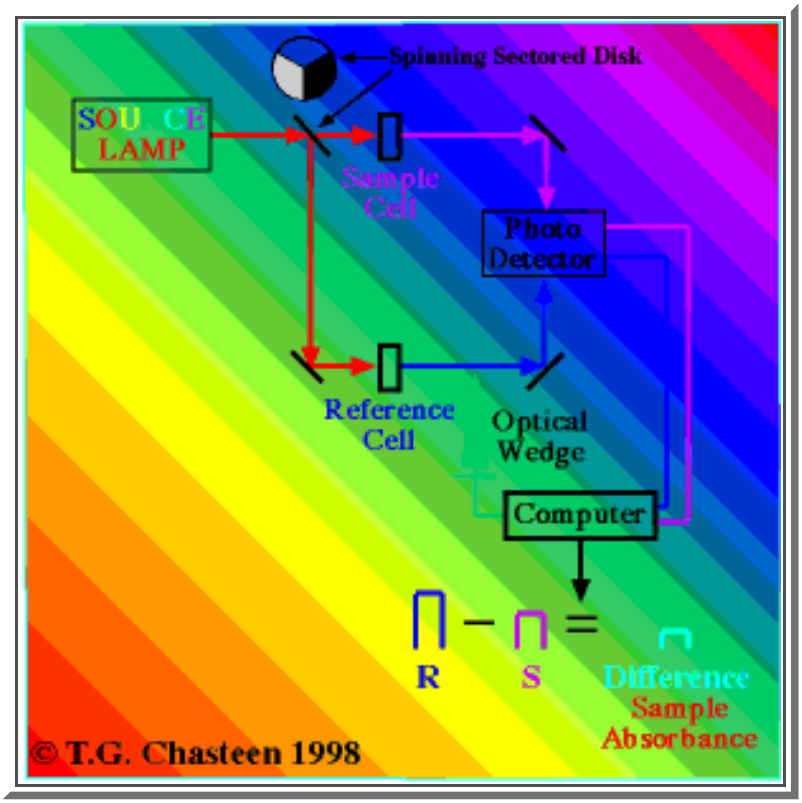
In the instrumental design shown schematically in the animation and below here the source lamp's beam is alternately diverted at right angles by a rotating disk with three distinct panels. One sector allows the beam to past straight through the disk, another has a mirror surface, and a third is black. When the beam passes though the disk it shines directly into the **sample cell**. If the sample is a liquid then this cell contains a cuvette and is made of a transparent material, such as quartz, that does not absorb light in the spectral region of interest. The analyte is dissolved in a solvent held in the cuvette. When the source light is reflected at 90 degrees by the

rotating disk instead of striking the sample cuvette it passes through a cuvette in the **reference cell** which contains ONLY solvent.

During the third sequence, when the black sector blocks the source beam, NO light passes through the disk. And as can be seen below, therefore no light arrives at the phototranducer. This part of the cycle is used for the computer to digitize and measure the **dark current**--the amount of light produced by the phototransducer circuit when no light impinges on the phototransducer. The dark current can be subtracted from the overall light measurements made by the system.

After travelling through either the sample cell or reference cell the light that was not absorbed--by far, most of the beam-- is directed onto the phototransducer or light detector. This component converts the arrival of photons into an electrical signal. By the way, the light path through the spectrophotometer need not be in a straight line since the light beam can be redirected using mirrors as can be seen here. Sometimes, lenses are also used to collect and collimate the light.

A Figure from the QuickTime and GIF animation illustrating a Double Beam Spectrometer



The alternating light signals, from either the reference beam or sample beam generate alternating electrical phototransducer signals. A computer, sampling those

signals, can now determine the analyte absorption in two ways. Some instruments merely subtract the sample beam signal's digitized light intensity from that of the reference beam. The difference is a measure of the amount of light absorbed by the analyte.

Since phototransducers-based system are relatively poor at measuring the absolute difference in two different light intensitiesóespecially if that difference is large, light absorbances determined in this manner can contain unacceptable amounts of error. Phototransducer are, however, good at generating signals from light intensities that are close together in intensity; therefore, an alternate means of determining the analyte absorption is used by some instruments:

Some spectrophotometer design uses the digitized reference-minus-sample signal difference to activate a servor motor connected to the computer and a device called an **optical wedge**. The servor motor slides the optical wedge into the brighter reference beam's path somewhere after the reference cell but before the phototransducer. Remember that since the reference cell does not have any light absorbing analyte, the light exiting the reference cell will always be brighter than that from the sample cell even if the solvent itself absorbs some at the analyte wavelength since both cuvettes contain solvent. The optical wedge is made of a material that absorbs light so that the more the wedge intersects the reference beam the more of that beam will be absorbed by the wedge and the less will be the difference between the sample and reference signals. The wedge is automatically fed into the reference beam until the reference and sample beam signals are of exactly identical intensity as measured by the phototransducer (remember the system is good at this). When the signals are equal the amount of wedge needed to produce this 0 signal difference is a measure of the analyte absorption. Since the computer controls the wedge it converts wedge position to an absorbance reading of the analyte.

If Beer's Law holds then absorbance in the linear range will correlate well with concentration and a calibration plot can be constructed and used to determine the concentration of analyte in unknown samples.

Double Beam Spectrophotometer Movie

A QuickTime movie and a (soundless) GIF animation are both available that illustrate the workings of a double beam spectrophotometer. Here is the address: **http://www.shsu.edu/~chm_tgc/sounds/sound.html**

These notes were written by Dr. Thomas G. Chasteen at Sam Houston State University, Huntsville, Texas.