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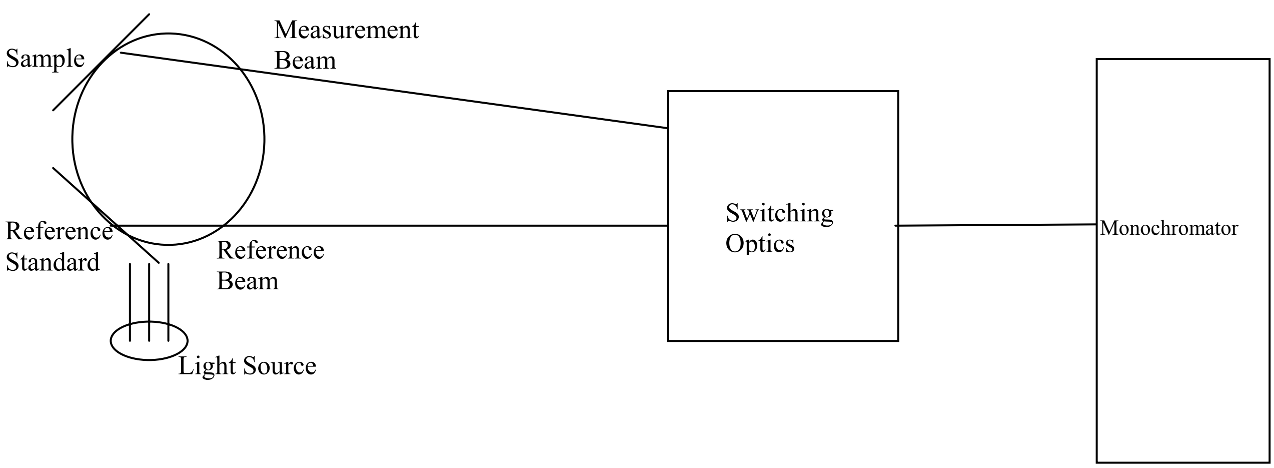
Double vs. Single Beam Spectrophotometers

Spectrophotometers are instruments which measure the wavelength distribution of light. They may be used to characterize the color of objects. When used in this manner, they give the percent reflectance or transmittance of the object relative to some reference. For most spectrophotometers used for color measurement this reference is a Perfect Reflecting Diffuser to which the white standardization tile may be traced. The output is a spectral curve which is like a fingerprint of the color of the object. From these spectral curves tristimulus values and then other color metric values may be calculated. These spectral curves may also be used in computer color matching. Spectrophotometers come in many sizes, shapes, geometries, and configurations. Here we will discuss double and single beam configurations.

In a double beam configuration, the beam from the light source is split in two. One beam illuminates the reference standard and the other illuminates the sample. The beams may be recombined before they reach a single monochromator. In some cases two monochromators may be used. The splitting of the beam is normally accomplished in one of two manners: statically, with a partially-transmitting mirror or similar device, or by attenuating the beams using moving optical and mechanical devices. Double beam instruments became quite popular in the early days of spectrophotometry due to the instability of light sources, detectors, and the associated electronics. The figure below illustrates the general configuration of a double beam spectrophotometer.



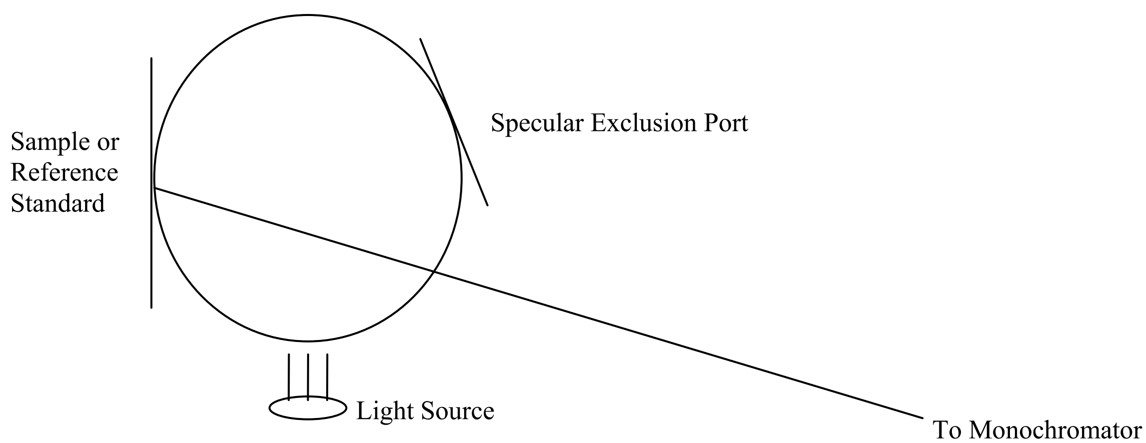
In the double beam configuration, fluctuations in the light source, detector, or electronics, and changes in the sphere are removed from the measurement each time a measurement is taken.

There are some disadvantages to double beam instruments. Recombining of the beam prior to reaching the monochrometer must be done very carefully in order for the beams to spatially become one again. The light paths must be optically equal and have similarly efficient optical components. Mirrors, if used, need to be coated at the same time and therefore must be replaced in pairs. Also, build up of film or dust over time may affect the beams. These requirements may make dual beam instruments complicated, difficult to align, and expensive to service. In more recent years, advances in technology have allowed double beam instruments to be manufactured which do not have as many moving parts and are not as expensive to service. In the case of xenon flash instruments, a dual beam configuration is necessary due to the variability from flash to flash. In some cases fiber optic technology provides the means for the reference measurement. A listing of double beam instruments may be found in Table 1.

Table 1: Double Beam Instruments (Current and Historic)

HunterLab UltraScan XE	Macbeth 3000
BYK/Gardner Color Sphere	Macbeth 7000
ACS/Datacolor CS-5	**HunterLab MiniScan Tristimulus, Basic, Spectral, Textile, and MiniScan XE**
ACS/Datacolor CS-3	Diano Corporation MatchScan
ACS Datacolor SpectraFlash	IBM 7842 Color Analyzer II System
Optronik ColorFlash	CarlZeiss DMC26
Colorgen CS-1100	CarlZeiss RFC16
Nippon Denshoku SQ-300H	

In a single beam configuration, there is a single beam from the light source. The reference standard is measured to standardize the instrument, then removed. A neutral gray standard is also measured during the standardization process and a mathematical correction is made based on the reflectance of the gray standard to compensate for the changes in the sphere wall. For a single beam configuration to perform well, the light source, detector, and electronics must be reasonably stable over time. Recent advances in electronics and the stability of the tungsten halogen lamp have made reliable single beam instruments possible. The figure below illustrates the general configuration of a single beam spectrophotometer.



In the true single beam configuration, corrections for changes in the sphere or light source are made based on the data obtained during the measurement of the neutral gray standard tile during standardization. Having a relatively stable light source and standardizing the instrument frequently (every four to eight hours) ensures that these corrections will be valid for the length of the calibration. The advantages to a single beam configuration are that there are often fewer moving parts. This makes the instrument simpler and less likely to have parts wear out or get out of alignment. A listing of single beam instruments may be found in Table 2.

Table 2: Single Beam Instruments (Current and Historic)
HunterLab ColorQuest Sphere
HunterLab ColorQuest II

The distinctions between double and single beam instruments are not as clear as they used to be. Color measurement instruments are designed for maximum long-term stability, which may be achieved in more than one manner. Some instruments fall into a category which could be called either single beam or double beam depending on who is doing the categorizing. In such instruments, there is a mechanism for monitoring the stability of the lamp. These instruments are listed in **Table 3**.

Table 3: Lamp Monitoring Instruments
HunterLab UltraScan
HunterLab LabScan (0/45)
ACS Spectro-Sensor

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