

# REFLECTIONS



Magazine of photometry and colorimetry

**Technique special**

Reflections Nr. 10

**Nanomania**

Reflections Nr. 9

**The spectrum of  
illumination technology**



MINOLTA

# Nanomania

**The quality of some of the components is difficult to quantify and cannot be adequately described in a brochure.**

**The first spectral sensor chip built into the portable CM-2000 series was developed by Minolta in the late 80s. It had a 10-nm pitch interval and an array with 31 diodes. Two bands of interference filters covered the spectrum from 400 to 700 nm.**

When it comes to measuring body colour, spectrophotometers have ousted three-filter meters into a niche position. This is because of their higher absolute accuracy in the face of increasing requirements on colour quality and above all due to their much lower prices. But these meters are also becoming ever more compact as well as more powerful and convenient to use thanks to developments in microelectronics. Whoever needs a colour meter today is faced with a wide choice of models and suppliers – and that can be a real headache.

What criteria should the decision be based on? The most obvious would seem to be price and features: the number of displayed colour spaces, the size and ease of handling of the equipment, the accessories... But accuracy is even more important – and this is where the confusion already begins.

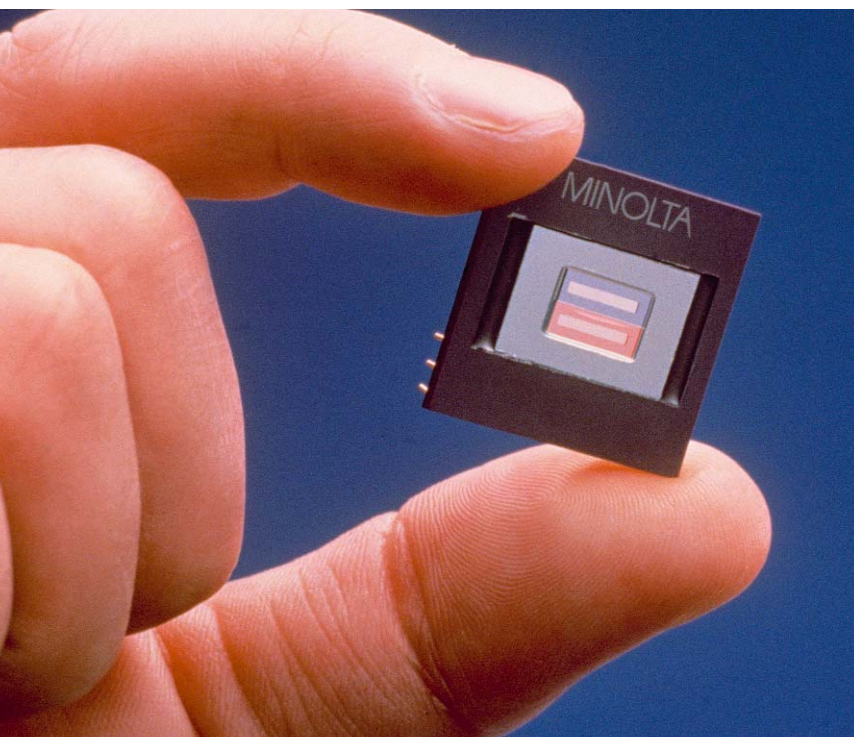
## **More important than resolution...**

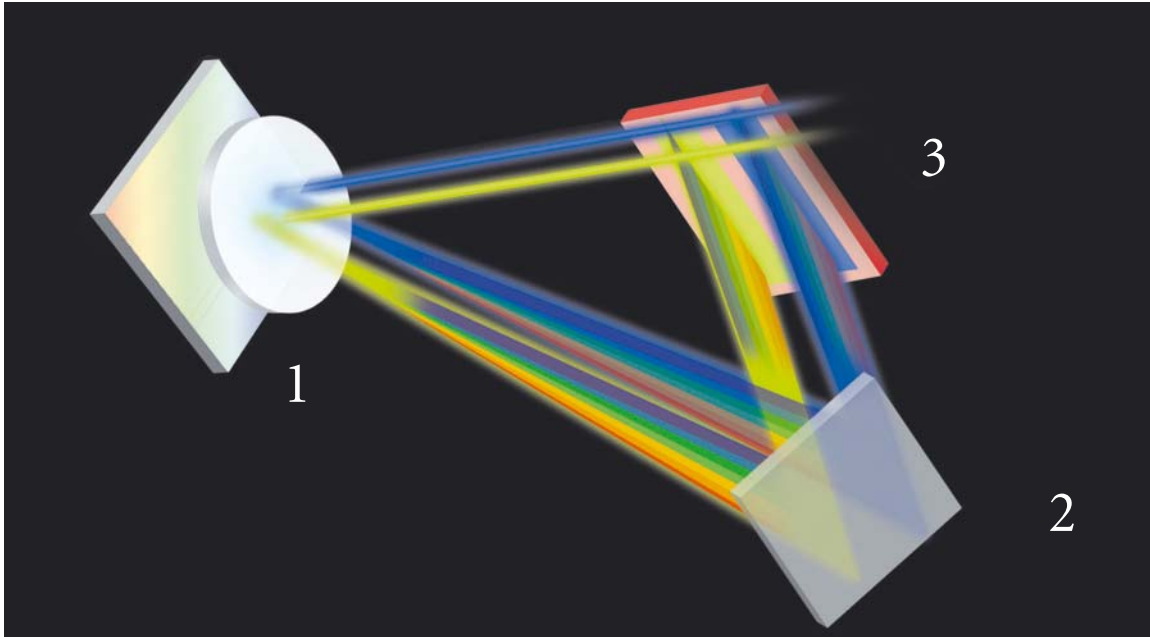
A spectrophotometer measures the spectrum of a colour, or rather the spectral reflection of the specimen to be measured in the visible light range. So the accuracy depends on the spectral sensor. But this is only half the story. The illumination, the geometry (e. g. symmetry and opening ratio of the Ulbricht sphere) and the optics have a considerable effect, especially on the absolute accuracy and on agreement between different meters. However, the quality of these factors is difficult to quantify and cannot be easily described in a brochure.

In contrast, the sensor performance can be easily expressed in figures. The spectral resolution in particular is often highlighted as the essential quality feature. But this is quite wrong: with otherwise identical meters and sensors a better resolution will certainly also yield more accurate results. But no manufacturer offers the same meter with different sensors. So the comparison must always be made between the meters as a whole.

## **...is the accuracy of measurement**

The spectral reflection of the specimen is defined as the percentage of the reflected radiation at various wavelengths. The accuracy with which this spectral curve is determined reflects the accuracy of the colour measurement. Each point on the curve has two coordinates: its wavelength in nm and its degree of reflection in percent (fig. 1). It is important for both these coordinates to be measured with precision and above all with repeatable accu-





Latest models such as the CM-3600d and CM-2600d series offer a newly developed monolithic grating system. In a very compact body, the grating (1), a light separating device (2) and a dual silicon diode array (3), one each for the sample- and the reference light, provide 10 nm pitch resolution at a full wavelength range from 360 to 740 nm.

acy. The spectral resolution (the number of points at which the measurement is made) is less important than the accuracy with which these points are determined. What is the point of a high resolution if the wavelengths shift from one measurement to another or the degree of reflection fluctuates in the tenths of a percent range?

Only if these parameters are determined with high accuracy does the resolution also become important. But the required resolution also depends on the steepness of the curve. A value of 10 nm is completely sufficient for measurements of body-colour reflection, and even 20 nm are enough as a rule. In contrast, higher resolutions are required for transmission measurements (e. g. filter glass) and for chemical analyses or photometry. Minolta has developed a colorimeter for these applications: with a resolution of 0.9 nm (the CS-1000), it can also measure the discontinuous spectra of fluorescent lamps. However, spectra of this kind do not occur in body-colour measurements.

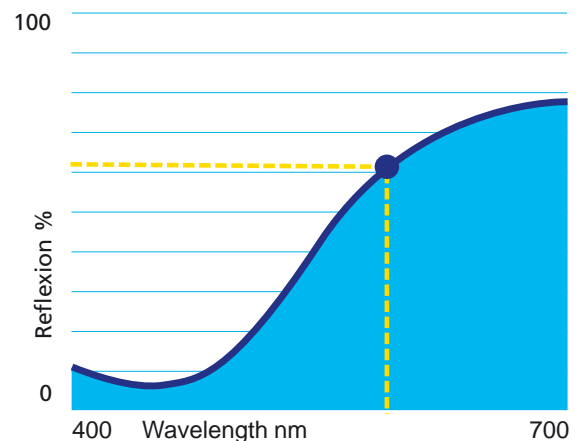
**A value of 10 nm is completely sufficient for measurements of body-colour reflection, and normally even 20 nm are enough.**

### Is the half-intensity bandwidth of the monochromator correct?

The monochromator resolves the light reflected by the specimen into its spectral components and the sensor then converts it into electrical signals. So the monochromator is responsible for the spectral resolution, while the sensor determines the accuracy of the signal measurement, i. e. the degree of reflection. The number of sensors behind the monochromator determines the spectral resolution as specified in the brochure. But does the monochromator actually reach this resolution? This can be determined by the half-intensity width which specifies the degree of “smudge” with which a wavelength is resolved by the monochromator. It should be of the same order of magnitude as the sensor resolution. A resolution of 3 nm is of little use if the pre-connected monochromator can only manage 10 nm. This would be rather like designing a standard car engine with the power of a Formula-1 engine.

In practice, however, these rather academic differences hardly play any part at all. The accuracy of

measurement depends rather on the colour and surface fluctuations of the specimen or of application problems at small or highly curved surfaces than on the resolution. That’s why the quality cannot be expressed in mere figures. The true quality of a spectrometer is only brought to light by a practical test with real specimens.

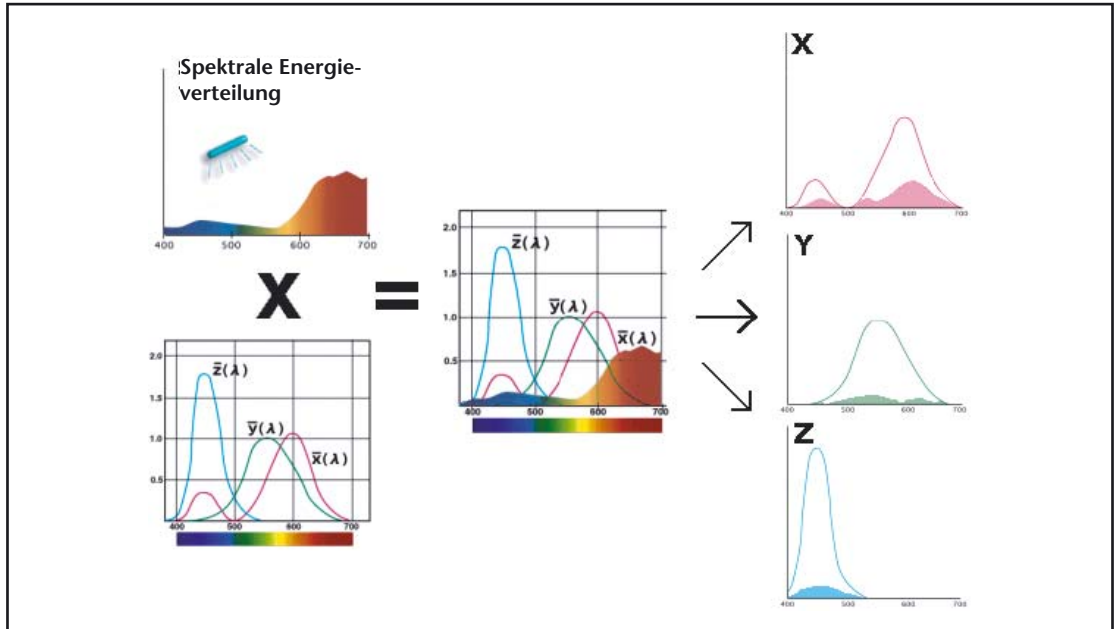


**Only the accuracy of both coordinate points, the reflection (R%) and the wavelength (nm) over the whole spectral range make up the quality level of repeatability of a spectrophotometer.**

Three-sector colorimeters and spectroradiometers

## The spectrum of illumination

The principle of colour perception: the integration of the spectral energy distribution of the light source (top left) over the standard colour-mixture curves (bottom left) leads to the standard valences X, Y and Z (right), the basis of every colour space.



High cost-effectiveness thanks to lower power consumption, long service life, minimal heat generation, better matching to daylight – at first sight, fluorescent tubes appear to have nothing but advantages. However, discharge lamps reveal their shortcomings when it comes to measuring the colour of their light: instruments which give perfect readings for classical halogen searchlights suddenly begin to display incorrect values. The reason: incandescent lamps belong to the class of continuous radiation sources, whereas luminescent tubes (and other discharge lamps) are discontinuous.

Luminescent tubes show clear peaks in the visible part of the spectrum. These are known as spectral lines, so that the term «line spectrum» is also used. Although usually superposed by a continuous spectrum, the characteristic lines are still present.

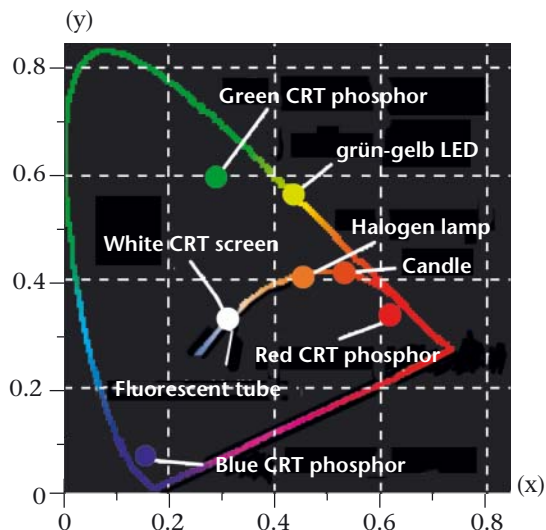
### Line spectrum or colour temperature

In thermal radiators such as candles, incandescent bulbs or halogen lamps, the light is produced exclusively by the heating of the incandes-

cent filament. This generates a continuous flat spectral-energy distribution. As the name implies, the light colour can be expressed in these cases as a temperature in degrees Kelvin. The colour temperature  $T$  is then referred to the temperature of a (standardised) black body which would produce the same light colour. Thus standard light of type D65 has a colour temperature of 6500 K, which corresponds to average daylight and is perceived by the eye as white light. If all the colour locations of the black body are plotted in the chromaticity diagram, the Planckian locus is obtained, going from red via yellow and white to blue. All thermal radiators lie on or close to this curve.

The specification of a colour temperature is meaningful only if the light source lies on or very near to the Planckian locus. It loses its meaning as it becomes further removed from it or as the colour of the light source must be characterised with increasing precision. It is fundamentally pointless to try and characterise a green LED with a colour temperature. However, a colour temperature which lies closest to the colour location is often specified for mixed light. The same applies to the light from many discharge lamps, which represents a mixture of the individual spectral lines and the superposed continuous spectrum. Colour temperatures are particularly inadequate for characterising

Standard chromaticity diagram for a normal observer with the Planckian locus and the colour locations of several light sources.



# technology

deviations towards green or purple. In these cases, the  $x$  or  $y$  values of the colour location as well as the brightness  $Y$  ( $L_v$ ) of the light source must be specified. Advanced meters such as the Chroma meters  $xy-1$ ,  $CL-100$  or  $CS-100$  from Minolta measure all three characteristic values for a light source in order to determine the colour location.

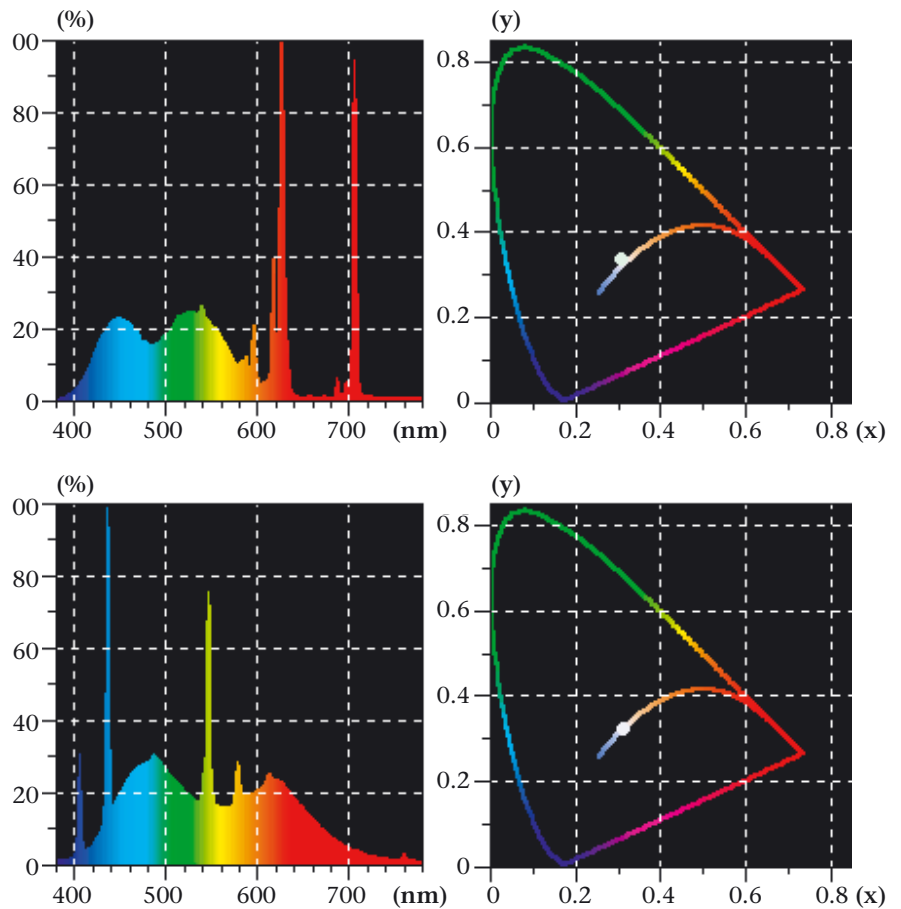
## Three-filter instruments or spectroradiometers?

Instruments designed for measuring the colour light make use of three filters whose spectral sensitivity is matched to the standard colour-mixture curves. These comprise high-quality photodiodes with series-connected filters. The terms «three-filter» or «three-range» meters are therefore also used. The incident light is converted by the photodiodes into signals which directly yield the standard colour values  $X$ ,  $Y$  and  $Z$ . However, matching to the standard CIE colour-mixture curves can be achieved only with finite accuracy. Deviations occur in the defined curves and in the sensitivity curves in the measuring instrument. These differences can be neglected as long as the light to be measured exhibits a continuous energy output over the entire spectrum (thermal radiator). However, the error may be significant if steep edges occur in the spectrum or in individual lines (fluorescent tubes). Three-filter instruments are not usually suited to measure discharge lamps, light sources with spectral lines or with narrow spectral energy distributions (LEDs).

In addition to the simple and low-cost spectroradiometers in three-filter technology, other models are also available which measure the spectral energy distribution of the light source as a physical parameter. Thus the  $CS-1000$  from Minolta measures the light with a pitch of  $0.9$  nm and also records very fine spectral lines. The colour values are determined by calculating the spectral curve with the standard CIE colour-mixture curves.

## Calibration of three-filter instruments on discharge lamps

Non-thermal radiators can be measured with precision only by means of the spectral procedure; they are standard equipment in the optical laboratories of the lamp manufacturers.



However, spectroradiometers have disadvantages for the TV and video industry, as they are still significantly larger, heavier and more expensive than three-filter meters.

The Chroma meters  $xy-1$ ,  $CL-100$  and  $CS-100$  are calibrated at the works to the Minolta standard with respect to standard illuminant A, thus ensuring their celebrated high measurement accuracy for incandescent lamps, halogen searchlights and sunlight. The  $CL-100$  and  $CS-100$  models can also be calibrated to the user's own standard (fluorescent tubes, HMI radiators, etc.). Conversion between the user's and the Minolta standard (standard illuminant A) is possible at any time by switching over the calibration setting. For the user calibration, the lamp's colour coordinates  $Y_{xy}$  must be known. As a rule, the manufacturers of such lamps supply data sheets specifying these values. For the calibration, the colour values of the selected light source are entered into the Chroma meter. The accuracy is usually also sufficient if the calibration cannot be performed under laboratory conditions.

*Approximately 6500 Kelvin in both cases and yet completely different: a white monitor and a Biolux daylight fluorescent tube from Osram. The spectral curves are shown on the left, the position of the colour location in the standard chromaticity diagram on the right.*