Shedding light on color

Sensing what customers want

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In theory, the measurement of color is a question of shining a light with a known spectrum onto the paper and observing the spectrum of the reflected light. In a real production environment, however, the sensor is working under hostile conditions with ambient dirt and moisture and temperature variations, not to mention shocks and vibrations. The measurement apparatus must withstand these as well as possible while still delivering the most accurate results.

The complexity of perceiving color is reflected in the sensor that must measure it. A schematic of the ABB color sensor principles is shown in 1 and 2. The source of optical radiation is a Xenon lamp 2b. Approximately 5.6 Joules of energy are released via a 400 microsecond discharge. This produces a luminous flux equivalent to a 14 kW watt lamp radiating at a color temperature between 6500 and 7000 °K. The illuminator provides a short, high intensity pulse of mostly visible and ultraviolet radiation. This is collected in integrating cavities 2c. The exit aperture of the lower cavity is focused onto the sheet by the toroidal mirror 2e, providing a homogenous 12 mm diameter spot of illumination on the process (paper) 2i.

The accuracy and precision of these measurements rival modern laboratory instruments, but operate continuously and in very harsh environments.

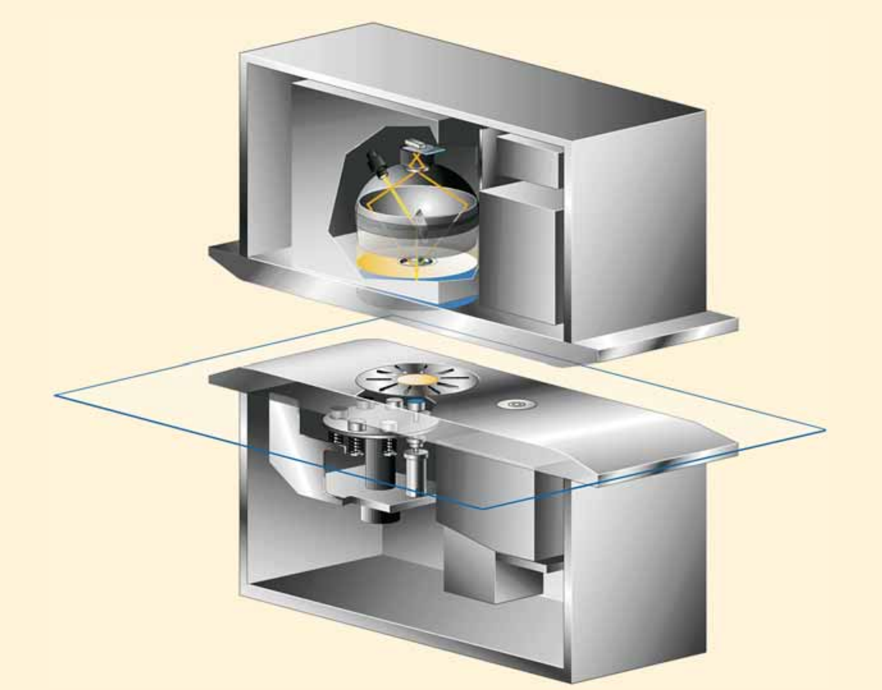
Radiation reflects from the process in all directions – the perpendicular part of this is detected. The detection optics consist of an angular mirror 2f, a collimating lens and a fiber-optic pick-up. The collected energy is delivered to an imaging spectrometer 2l.

The optical system incorporates a holographic diffraction grating 2n that spatially disperses detected radiation according to wavelength (from 340 nm to 780 nm) spreading it on a 256 element linear photodiode array 2o.

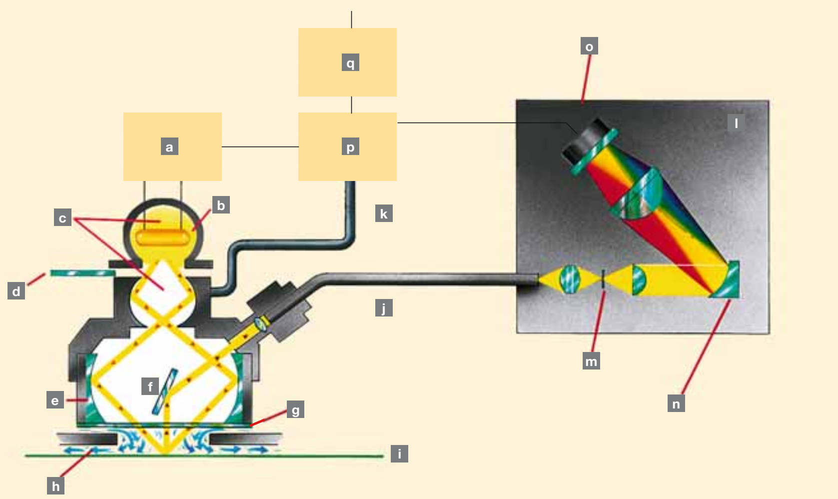
The reference radiation from the lamp is measured in two separate measurements with the help of two filtered detectors: One measures the lamp intensity in the red portion of the spectrum, the other in the blue. These signals normalize the detected signals for source intensity shift and color temperature shift from one flash to the next. This instrument is called an "abridged" dual beam spectrometer.

The voltages captured in the photodiode array 2o are serially shifted to an analog to digital converter where they are stored as an array of 256 digitized values. These are wavelength-corrected by evaluation of Xenon emission lines, whose center-wave-

1 A peek inside a color sensor



2 Principle of ABB's on-line color measurement

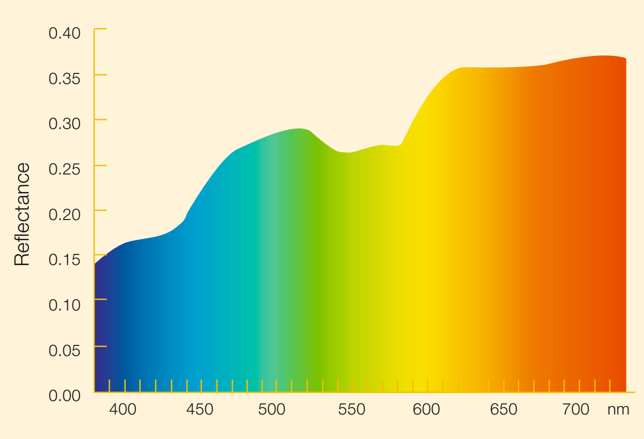


Sensing and controlling

lengths are known. In this way, the values are corrected for the intensity and color temperature of the illuminator and normalized on the basis of previous measurements of a reflectance standard. The processed array accurately represents the reflectance spectrum of the process.

Colorimetrics are computed on the basis of the measured spectrum. These are based on psychophysical measurements of the way a human brain interprets colors. A representation of the reflectance spectrum of the color of human complexion is shown in 3. This spectrum is very different from what the human brain interprets! (see also the factboxes on color perception on page 41 and the Land Effect on page 43).

3 Spectrum of the color of human complexion



The backing tile

The color sensor module is positioned on the top or bottom of the sheet (or both) and a so-called backing-tile module is positioned on the opposite side of the sheet 4. This backing tile module maintains the sheet in the focal plane of the color module mechanically. The module also permits one of its tiles to be positioned behind the sheet during measurement, or in the focal plane when the instrument is off sheet for automatic calibration.

During the on-line measurement, a black tile and then a white tile are used as backing. Using the two resulting spectra, a third spectrum is computed for the sheet as if this were infinitely thick (a stack of sheets). This is necessary because the customer‘s QC laboratory characterizes their product by measuring a stack of sheets. This is usually the way that the end user "sees" the product.

The other tiles in the carousel are used to normalize the spectrometer for influences of dust on the sensor window (black hole), reflectance calibration (standardize tile), variation in the exact focal plane position (auto-focus tile) and reading a ceramic tile of known color (blue tile).

By algebraic manipulation of measured reflectance spectra, many different colorimetrics of the sheet can be derived. Some of these are shown in the Factbox .

In this manner, the ABB online color sensor derives colorimetrics of the process based on measurement of high-resolution reflectance spectra. The accuracy and precision of these measurements rival modern laboratory instruments, but operate continuously and in very harsh environments.

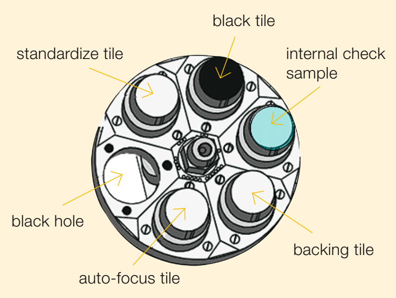
The instruments have been adapted to changing requirements: Deep shade measurement once represented 80 percent of ABB's color sensor business – today white shades make up this percentage. New customer standards have necessitated handling of compensation for fluorescent whitening agent.

But measurement, sophisticated as it may be, is only one part of the story. The use these measurements are put to is an equally important part of the paper machine's control story. This is explored in more detail in the next article.

Factbox Some of the colorimetrics that are computed

- CIELAB L*, a*, b* or L* u*, v*
- Hunter L, a, b
- DWL, Excitation purity and Y
- Tristimulus, X Y Z
- CIE Whiteness
- UV excluded brightness, TAPPI or ISO
- UV included brightness, TAPPI or ISO
- UV brightness (emission due to fluorescent whitening agents)
- Metameric mismatch with the target
- Color difference in dE*, CMC, FMC and others
- Opacity, TAPPI or PRINTERS

4 Backing tile module, carousel and tiles



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