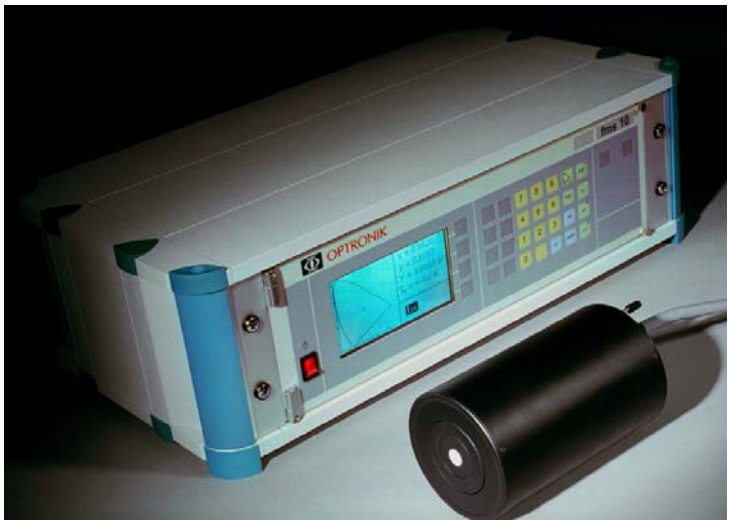
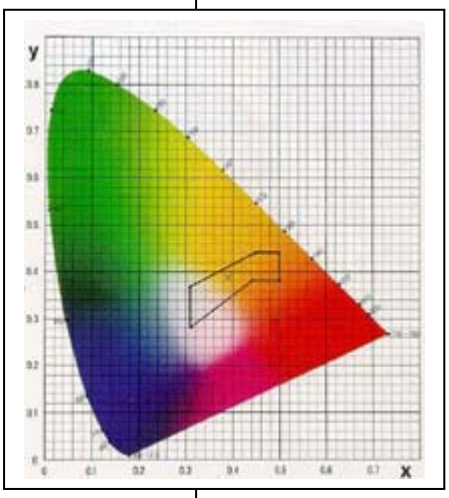
OPTRONIK



Technical Manual FMS10
Tristimulus Colourimeter



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1 INTRODUCTION

Be it for research, development, or quality and production control, colourimeters are essential for classifying and analyzing colours in the most varied of fields, in addition to their indispensable contribution to standards of acceptance in the colour industry.

The so called colour difference instruments detect relative differences in colour between a sample and a standard where absolute colourimetric values are not essential.

To determine the absolute results of e.g. tristimulus values (chromaticity coordinates x, y, etc.), colourimeters are necessary. The demands on these instruments exceed those placed also on colour difference instruments, for instance high reproducibility and long term stability. An added significant criterion of merit is the spectral analysis.

Colourimeters as well as colour difference instruments can be designed according to two different measuring principles, the spectral or the integral principle.

Spectrometers are instruments which measure a sample spectrally, namely wavelength by wavelength. The values obtained spectrally are then used to calculate the desired colourimetric value. All OPTRONIK colourimeters for measuring object colours (COLOURFLASH, MULTIFLASH, TELEFLASH) are such spectrophotometers.

2 INTEGRAL MEASUREMENT DEVICES

These are instruments which operate along the lines of the tristimulus colourimetric process (in accordance with German Industrial Standard (DIN) 5033). The functional principle of these devices is that of using optically filtered photoelectronic receivers to find the standard colour matching functions $x(\lambda)$, $y(\lambda)$, and $z(\lambda)$.

This process determines the tristimulus values X, Y, and Z directly, without additional calculation.

Tristimulus colourimeters are particularly suited for measuring light sources and primary light sources of the most varied types (lamps, luminaires, monitors). Simple operability, freedom from maintenance, and high measuring sensitivity make precisely those colourimeters which function according to the tristimulus process ideal for measurements of this type.

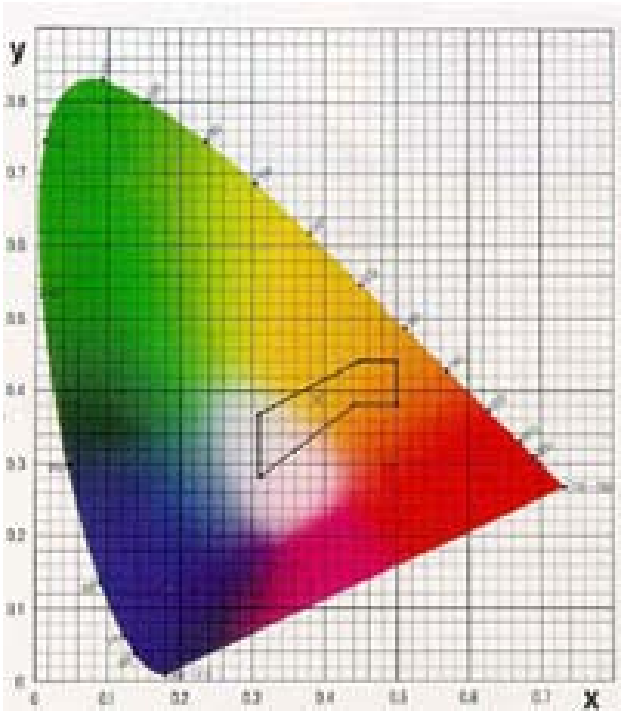
Active for almost 40 years in the field of colour and light measurement, Optronik Berlin GmbH Optronik Berlin has developed the FMS 10, a product which sets standards in every aspect of measurement accuracy, operational reliability, user-friendliness, and price/performance relation. The latest developments in photoreceptor technology were used in its design. The most modern electronic components were used in its construction.

High quality components coupled with conscientious assembly guarantee first rate long term constancy and outstanding sensitivity. This combination of factors places the FMS 10 well beyond its competitors at the head of the international market.

The FMS 10 colourimeter consists of a colour measurement head and a display unit, which were calibrated together in order to ensure that their joint operation produces correct test results. The silicon photocells in the measuring head and the filter sets are thermostabilized; temperature influence between ca. 0 °C and +35 °C can be excluded. The adjustment standard for the y_channel is the brightness sensitivity of the human eye $V(\lambda)$. This enables illuminance measurements to be performed for vertical light incidence. The y-channel is calibrated in lx.

Fig.: Luminous Colour

Value	Symbol	Unit
Colour temperature	T_{cp}	[K]
Colour rendering index, Colour rendering group	R_a	[1]
Trichromatic values	X, Y, Z	[1]



3 DELIVERY PACKAGE

The standard delivery package for the FMS 10 colourimeter is composed of the following items:

- Control and display unit in a 19" housing, 3 height modules, closed, usable as table device or integrated in measuring tower
- Colour measurement head (thermostabilized), 60 mm diameter light entry area
- Manual
- 3 m connecting cable
- Power cord

4 MEASUREMENT PRINCIPLE

The colour measurement head contains the silicon photocells in four independently constructed and filtered measurement channels. The division of the x-channel over two photocells for x1 and x2 guarantees higher spectral accuracy than for the conventional use of only one cell.
These photocells are operated in a short circuit with feedback precision operation amplifiers. This assures strict proportionality between the illuminance on the receiver area and the photocurrents created by the photo cells. Four operation amplifiers convert the photocurrents into the corresponding voltages. Each of the four amplifier channels has its own auto-ranging with 6 measurement ranges. Independent range control ensures that each amplifier is optimally driven. Manual ranging is therefore not necessary. The voltages from the amplifiers are converted into digital signals by a fast-operating analog/digital converter. The digital information is further processed by a microprocessor and displayed.

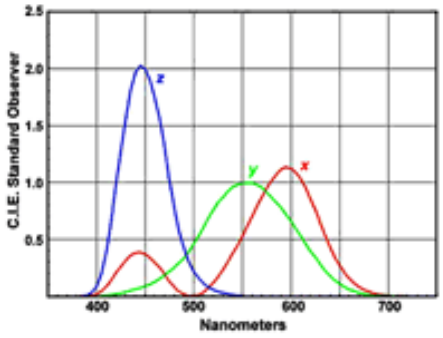
4.1 COLOUR MEASUREMENT HEAD DESIGN

The colour measurement head consists of selected silicon photocells which are adjusted very accurately to the standard colour matching functions x1(λ), x2(λ), y(λ), and z(λ) for the 2° field of view. The photocells are located on a heat isolated carrier, thermo-stabilized with the cells to 35 °C. The heating procedure takes a few minutes after the device has been switched on; a "Thermo o.k." LED display lights up on the control unit when the final temperature has been reached.

The light entry area consists of fibre bundle of a diameter of 14 mm. This plate should be illuminated as uniformly as possible during measurements. If it is necessary to reduce the size of the light entry surface, this is done by means of a centred stopping down process. The colourimetric accuracy is not significantly affected, but the calibration of the y-channel in lx can no longer be assured.

4.2 SPECTRAL MATCHING

Full filtering with coloured glass filters allows the relative spectral sensitivity of the selected silicon photocells to be very closely adjusted to the standard colour matching functions x(λ), y(λ), and z(λ) for the 2° field of view. This can only be achieved as a result of careful individual spectral matching.
The thermostatic stabilization ensures that the very accurate spectral matching is not affected by ambient temperatures between 0 and 35C. An individual measurement record is supplied with each device.



Tristimulus functions

4.3 ABSOLUTE SENSITIVITY

The absolute sensitivity of the colour measurement head is an essential criterion of merit, particularly for measurements at low illuminances. Due to the use of very sensitive silicon photocells with high internal resistance, the absolute sensitivity s of the colour measurement head for illumination with standard illuminant A of the light receptor area is a few nA/lx for each of the tristimulus values.

This ensures that the colour measurement head together with the display unit can perform exact colour measurements on the light receptor area for illuminances starting at 1 lx (standard illuminant A). Thermostabilization of the colour measurement head ensures that the absolute sensitivity remains constant at ambient temperatures between 0 and 35 °C.

4.4 MEASUREMENT and EVALUATION UNIT

The measurement and evaluation unit consists of a 19" housing, which can be used either as table housing or a slide in module. This unit contains the analog-digital converter with corresponding amplification, a control unit with microprocessor, and the power supply for the device.

On the front panel of the measurement and evaluation unit are located:

- Mains switch
- Graphic LC display for measurement output and operational status.
- Keyboard for operating the device

On the back plate of the measurement and evaluation unit are:

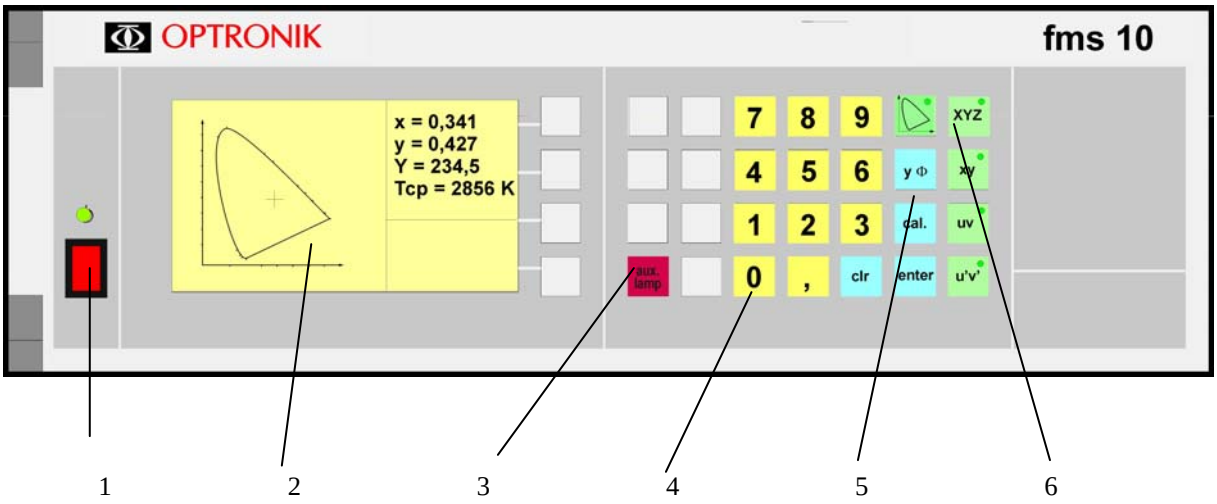
- Mains input socket with fuse and voltage selector
- Socket for the connecting cable to the colour measurement head

Before starting up, connect the colour measurement head to the control unit with the cable supplied for this purpose; use the screws to protect the connection. Connect the mains cable to a standard mains socket for 220-230V/50Hz.

The device is switched on with the mains switch on the front panel. The microprocessor first performs a short self test and then starts the measurement. For precise measurement results, one should wait until the "Thermo o.k." LED display lights up to signal that the division of the measurement head's thermostats is completed.

4.5 DISPLAY and CONTROL UNIT

The following picture shows the front view of the colour measurement system ***FMS 10***



1 Main power switch
2 Graphic Display
3 Switch for auxiliary lamp (in conjunction with sphere photometer)
4 Figure keyboard
5 Special Function keys
6 Keys for the representation in different systems of co-ordinates

Optionally the FMS 10 is equipped with a function key serving to switch on an auxiliary lamp when measuring in conjunction with sphere photometer (see also point 5).

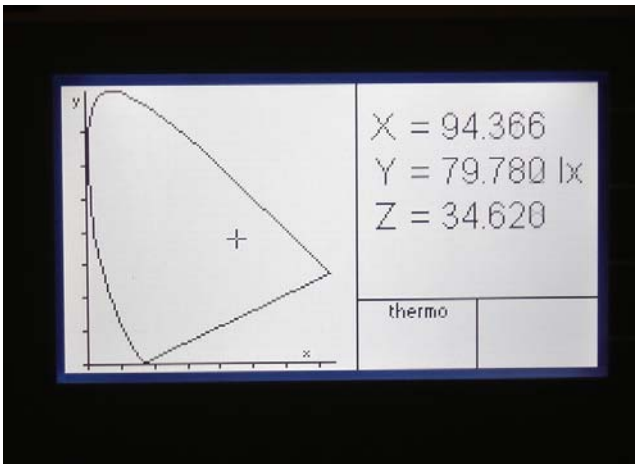
4.6 KEY FUNCTIONS

The FMS 10 is able to display test results in different colour coordinate systems. The output system desired can be selected at the keyboard at any time.
A control lamp (integrated in the key) lights to confirm that the key has been pressed. The display shows the values in the same order as the labelling for the keys.
Thermostatic stabilisation of the photometer head is indicated in the lower section of the graphic display. It is a small thermometer with an **OK** added.

KEY **DISPLAY**

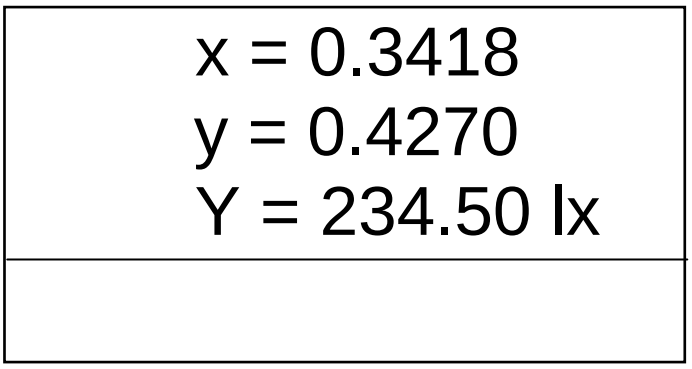
Standard CIE-LAB tristimulus values X Y Z

XYZ



Standard CIE-LAB chromaticity coordinates x y Y

xy



Standard CIE-UCS chromaticity coordinates u v Y in colour space 1960

uv

u = 0.3357
v = 0.4538
Y = 234.57 lx

Standard CIE-UCS chromaticity coordinates u' v' Y in colour space 1976

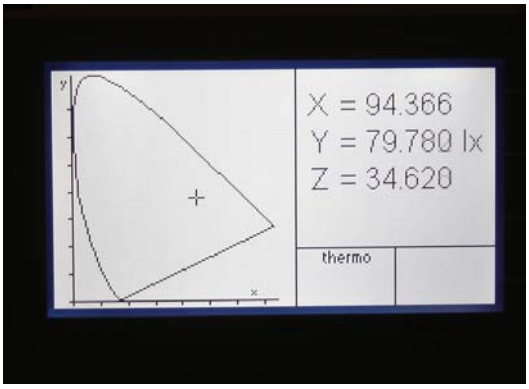
u'v'

u' = 0.2967
v' = 0.3679
Y = 234.57 lx

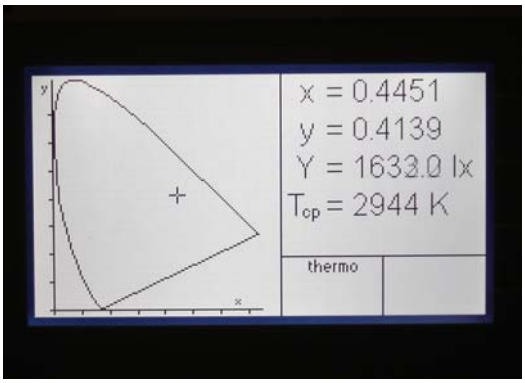
Colour temperature T_{cp}

Having pressed the key

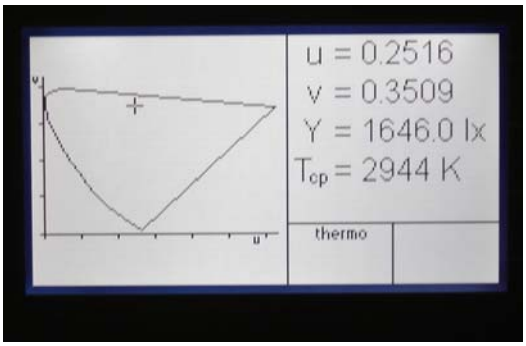
the values currently measured are shown in a system of colour co-ordinates in form of a diagram. There is also indicated the colour temperature T_{cp} referring to the actual values for xy, uv und u'v'.



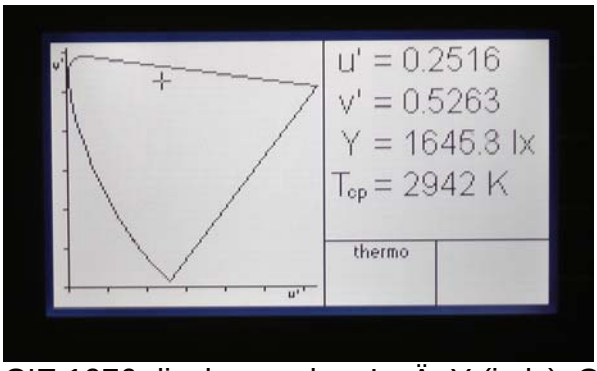
CIE 1931 display mode, X, Y, Z



CIE 1931 display mode, x, y, Y (in lx), Correlated Colour Temperature



CIE 1960 display mode, u, v, Y (in lx), Correlated Colour Temperature



CIE 1976 display mode, u', vÄ, Y (in lx), Correlated Colour Temperature

Option: Instead of **Y in lux,** luminous flux Φ can be indicated here
(in lm – meas. Units)

By pressing:

Y/Φ

the FMS10 can switch over from illuminance in lux to luminous flux in lumens

If the FMS 10 is connected to a computer via the RS232 interface, all functions can be executed by software, any other manual use of the keyboard is not necessary then.

FMS10 in Goniometer control rack

5 MEASURING WITH ULBRICHT SPHERE (Optional)

The colourimeter FMS 10 can be used for measuring of the luminous flux Φ of lamps.

Therefore the included colour measuring head will be put into the corresponding flange of the sphere and fixed. As soon as the sample shows stable photometric characteristics after an adequate burn-in time, the luminous flux can be determined due to the FMS 10. This will be made by pressing the T_{cp} Φ - key.

The measured colour temperature T_{cp} as well as the measured luminous flux ø will be indicated on the display of the FMS 10.

Luminous flux Φ

$T_{cp}\Phi$	2856 K 338.50 lm
	(T_{cp}) (Φ)

Due to the optional function "luminous flux measuring" it is possible to find a factor for the measured value as well as to calibrate the FMS 10 to this new value with help of a calibration lamp with well-known luminous flux.

Therefore the cal-key will be pressed, than the new luminous flux will be entered via the numeric key pad. It will be shown on the display. You have always to make sure to respect that the burn-in time for the samples is always long enough.

6 TECHNICAL DATA of the FMS 10

6.1 TECHNICAL DATA of the FMS 10 - In accordance with german industrial standard (DIN 5032 part 8)

Instrument name:	OPTRONIK tristimulus colourimeter FMS 10
Areas of application:	laboratory and precision measurements on primary light sources, determining tristimulus values X,Y,Z and chromaticity coordinates in various colour coordinate systems measurement of colour temperature and luminous flux (in combination with Ulbricht sphere; option)
Display range:	measurement range (for Y-channel) smallest display value: 0.0001 lx greatest display value: 600,000 lx no. of measurement ranges: 6 measurement ranges in decades, all over load protected
Colour measurement head:	4 highly stable, spectrally adjusted silicon photocells 4 preamplifiers with 6 measurement ranges each separate autoranging thermostabilization light sensitive area: 14 mm ∅ individual measurement report
Display unit:	AD conversion rate ca. > 100 measurements/sec automatic mean value calculation automatic range switching time: 0.5 sec Graphic LC display range switching: automatic digital data output: V.24 (RS 232) electrical operating mode: mains operation

Typical error limits:
(see measurement record)

x(λ) adjustment f_1x < 3.0%
y(λ) adjustment f_1y < 1.5%
z(λ) adjustment f_1z < 3.0%
UV sensitivity u < 0.1%
IR sensitivity r < 0.1%
linearity error f_3 < 0.1%
display unit error f_4 < 0.15%
temperature coefficient α_0 < 0.01%
fatigue f_5 < 0.1%
modulated light f_7 < 0.1%
adjustment error f_{11} < 0.1% (Y-channel)
total error f_{to} < 3.0% (Y-channel)
low frequency f_l < 25 Hz
high frequency f_h > 100 Hz

Resolution of colour coordinates: **0.0000**

Calibration:

for standard illuminant A, calibration temp. 25 °C
uncertainty of calibration standard ± 0.6% (PTB certified Federal Physical Technical Bureau)
time interval before new calibration < 2 years
standard calibration of Y-channel in lx

Power supply:

rated voltage: 230 V ±10%
power requirement: < 50 VA
rated frequency: 50 Hz
operating temperature: 10 to 50 °C
storage temperature: 0 to +75 °C

Dimensions:

Device without carrying handle 450x325x135 mm
colour measurement head 98 mm ∅, height 165 mm
connecting cable 3 m (longer if desired)

Weight:

device ca. 8 kg
colour measurement head ca. 0.9 kg

Technical specifications may be subject to change.
Errors reserved.

6.2 Description of serial interface

The serial interface of the measuring system meets the RS-232-standard. It is realised as 3-wire-interface (RxD, TxD, Ground). A Hardware-Handshake is not planned at the moment. If the Host-Computer should need active levels at the Hardware-Handshake-wires, you should connect the pins 4 with 5 and 6 with 8 with 20 in the connecting cable.
The connection is made via a 25-pole Sub-D-plug. The pin occupancy is as follows:

Signal	Pin-No.	Direction
TxD	2	SNT → Host
RxD	3	Host → SNT
Ground	7	to chassis

The transmission parameters are adjusted and fixed as follows. You cannot change them at the moment:

Baud rate	9600
Parity	none
Data bits	8
Stop bits	1

The communication is realised via a simple ASCII- report. The description of the order code you can find in chapter 1.2.

6.3 Set of Commands

The FMS 10 replies to every valid order which can be executed correctly by the SNT 10 with <ACK> (ASCII 6 dec.). In case of some special orders afterwards there is sent additionally an answering string which is finished with <CR> (ASCII 13 dec.).
Syntactically false and not able to be executed orders are countered with <NAK> (ASCII 21 dec.).
Each order which is sent to the measuring system must be ended with a <CR>. In order to ensure compatibility with all terminals to the greatest possible extend, Linefeeds (<LF>, ASCII 10 dec.) are in principle ignored.
The parameters of an order (as far as in existence) must be separated from each other and from the order word with a Blank (ASCII 32 dec.).
In order to avoid order overlapping and buffer overflows, a new order is only allowed to be sent, when the system has received the complete reply answering the previous order.

The FMS 10 accepts following orders:

ST Status interrogation
The system answers:

<ACK>ST X.XXXXE+XX
Y.YYYYE+YY
Z.ZZZZE+ZZ x.xxxx
y.yyyy TTTT I.IIIIE+II<CR>.

In that respect the meaning is:

X.XXXXE+XX		standard colour value X, scientific formate
Y.YYYYE+YY		standard colour value Y = illuminance/Lux , scientific formate
Z.ZZZZE+ZZ		standard colour value Z, scientific formate
x.xxxx		standard chromaticity co-ordinate x
y.yyyy		standard chromaticity co-ordinate y
TTTT		colour temperature / Kelvin
I.IIIIE+II		luminous flux Lumen, scientific formate

Example:
<ACK>ST 4.2206E+02 4.5546E+02 4.5188E+02 0.3174 0.3427 6188 1.0388E+02

SV Scanning software-versions.
The system feeds out the version-strings of the connected sub-systems and it's own version - string.
The output looks like:

<ACK>Steuerprogramm FMS10<CR>
Dreibereichs-Farbmeßgerät<CR>
Version E 2.0 25.Jul.06<CR>
(c)1993-2007 M.Senft<CR>

7 CUSTOMER SERVICE

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