Spray jet control in transmitted light with sensors from Sensor Instruments

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The following document describes briefly the measurement principle, and, in the second section, the methods that can be used for inline control of spray jets in transmitted light. The final section deals with spray jet control in explosive areas.

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When designing spray systems, it is important to ensure that the sensor technology is matched to the size of the spray cone and the spray volume of the application in question. Furthermore, the geometry of the spray cone and the spray quantity depend on the medium used (primer, adhesive, solvent, water, alcohol, paint, etc.) as well as on the spray nozzle opening, the overpressure and the spray quantity dosage. Particularly when using tough, adhesive media (glue) as a spraying agent, it can happen that part of the spray nozzle opening sticks, which leads to a change in both the spray quantity and the spray geometry. As a result, the spray jet can be changed in terms of direction as well as opening angle.

When designing a spray jet control system, it is important to address some key questions:

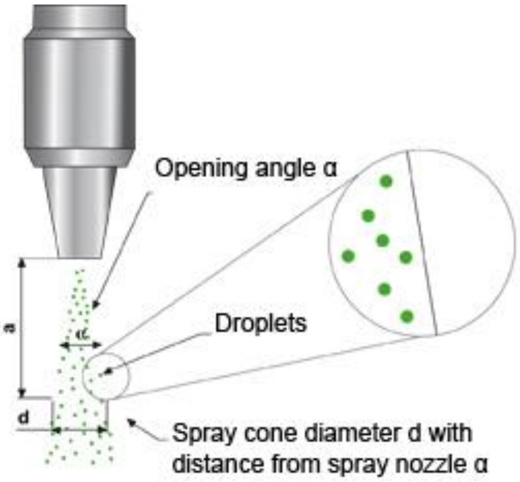
1. Is the qualitative evaluation of the spraying process (yes/no or spraying process is ok/not ok) sufficient, or is a more detailed analysis (jet geometry, spray quantity) also required?
2. Which medium (primer, adhesive, solvent, water, alcohol, paint, etc.) is sprayed and how is the medium optimally scanned (interaction with optical scanning: droplet size and distribution)?
3. Which influencing variables determine/disturb the quality of the spray jet in the process? What are the general conditions for optical scanning of the spray process?

The aim of inline spray jet control is automated quality control of the spray process during the production process.

Measuring principles

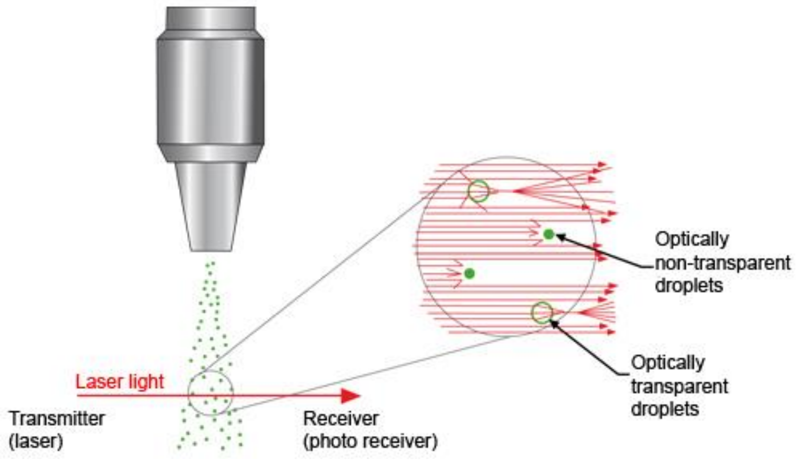
What characteristics define a spray jet?

A spray jet is usually a "loose structure" of small droplets (the droplet size is of the order of a few micrometers to a few hundred micrometers - it depends primarily on the spray medium used), which are created as a result of the atomization of the spray liquid at the spray nozzle outlet or as a result of the turbulence at the nozzle. These droplets leave the spray nozzle opening at a certain speed and are then decelerated as a result of air friction.

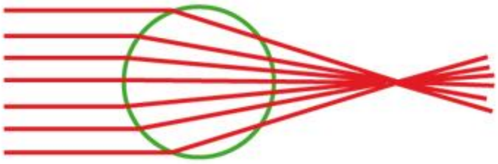


The spray jet is determined by the opening angle of the spray cone and the spray quantity (droplets/time unit or spray flow rate).

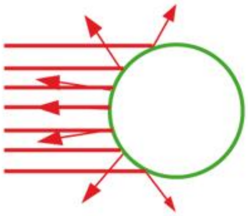
How is the spray jet characterized?



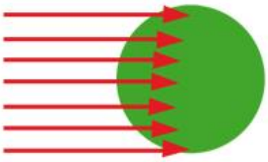
In order to characterize the quantity sprayed, we use the optical interaction of the particles sprayed with a light beam, e.g. laser, that at least partially penetrates the spray cone. On its way through the spray cone, the light beam is deflected by the individual droplets: the deflection is caused by reflection at the droplet surface or by focusing of the laser radiation, since the droplets, if they are optically transparent, work like micro lenses. However, some of the light is also absorbed by the droplets. In total, therefore, less light arrives on the opposite side of the spray beam.



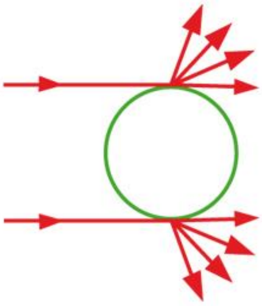
1. Focusing of the laser beam



2. Reflection of the laser beam



3. Absorption of the laser beam

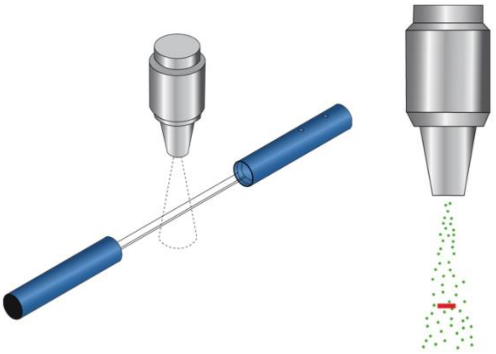


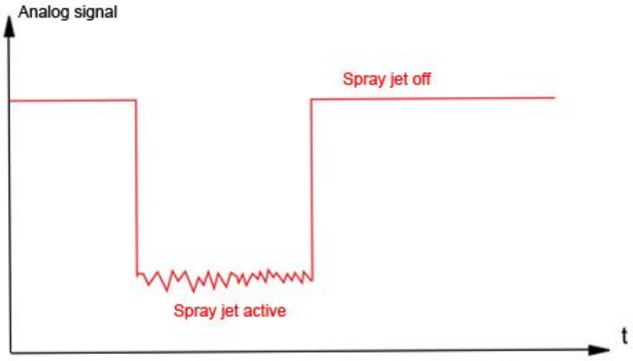
4. Deflection of the laser beam at the droplet

Methods of spray jet control in transmitted light:

1. The one-beam transmitted light method ➔ D-LAS2, SPECTRO-1-CONLAS & A-LAS sensors

This method uses, a laser beam, preferably with a slotted aperture, which is aimed centrally through the spray jet.



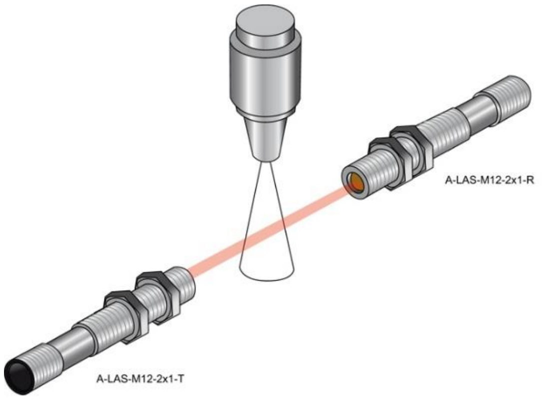


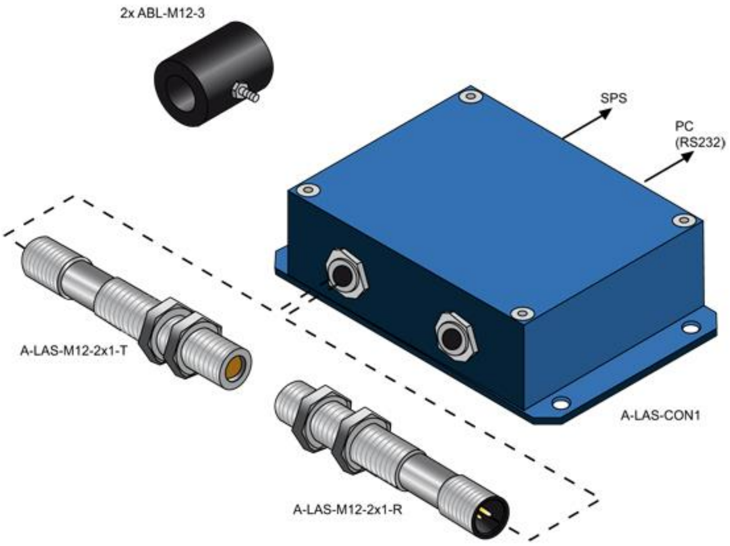
The signal decrease in comparison to the absence of the spray jet serves as a measure for the spray quantity. This method is mainly used when only a statement about the spray quantity is to be made or about whether a spray jet is present or not!

Example: Single-beam through-beam systems with controller: ➔ Sensor series: A-LAS series

Sensor type: A-LAS-M12-2x1-T (transmitter) + A-LAS-M12-2x1-R (receiver) + A-LAS-CON1 (controller)
With the help of the controller incl. the A-LAS-CON1-Scope software the system can be calibrated before the actual spraying process.

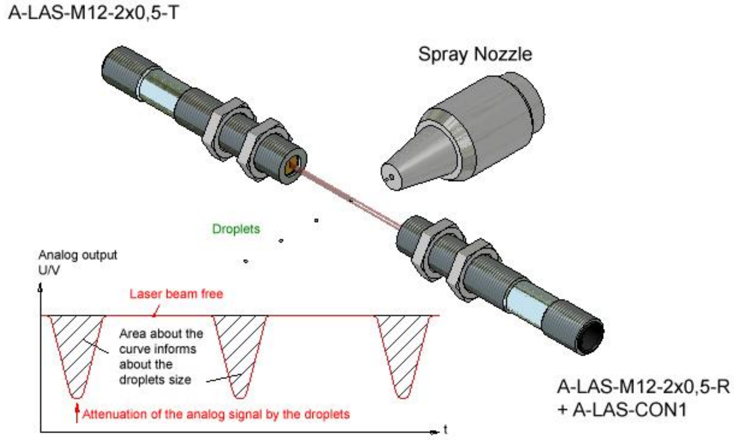
This makes it possible to even detect smallest spray quantities, because possible dirt accumulation can be compensated by way of calibration (to 100%), and the detection threshold can thus be close to the 100% value (e.g. 99.7%). The controller unit provides both an analog signal and a digital signal output that inform whether the value fell below the detection threshold.

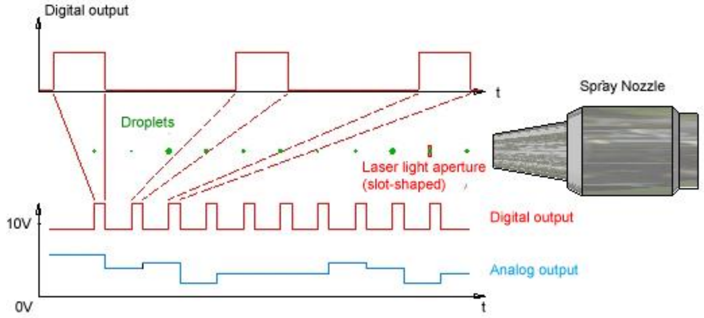




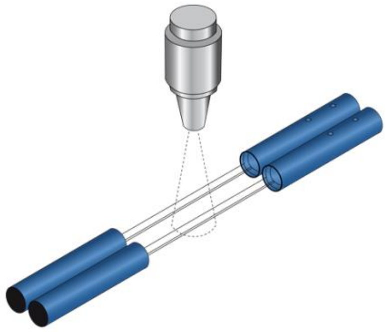
If the sensor is fast enough you could detect short interruptions caused by air bubbles. Within micro dosage control, where you need to characterize single drops, you could even analyze the size of drops.

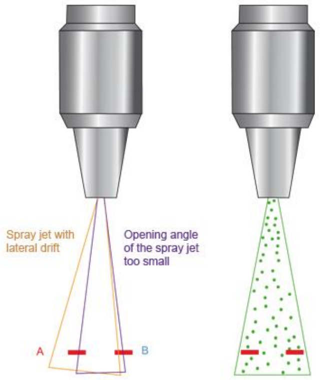
The ideal solution for micro dosage control is a sensor of the A-LAS series with an aperture that is matched to the droplet size, in combination with the A-LAS-CON1 control unit, because this sensor system features a high scan and switching frequency. At the analog output the droplet size is buffered until the next droplet arrives.

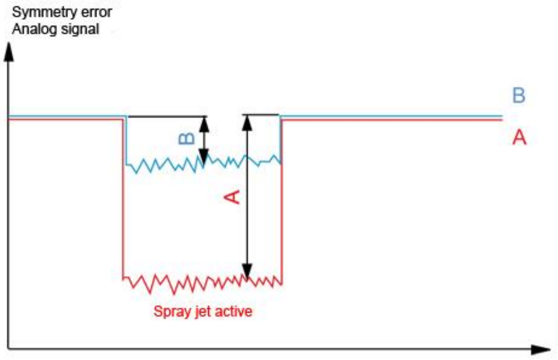




2. The two-beam transmitted light method ➔ A-LAS-CON1 sensors or SI-JET sensors







The beam symmetry is evaluated as follows, or spray quantities are calculated as follows:

$$\mathrm{NORM} = \frac{A}{A+B} * 4096 = \mathrm{SYMMETRY} \qquad \mathrm{INT} = \frac{A+B}{2} * 4096 = \mathrm{SPRAY\ QUANTITY}$$

In addition to spray quantity control, this method is also suitable for symmetry control to a certain extent. Lateral drifting of the spray cone can already be detected here. The two-beam system is mainly used when the symmetry of the spray cone needs to be checked in a simple but cost-effective way.

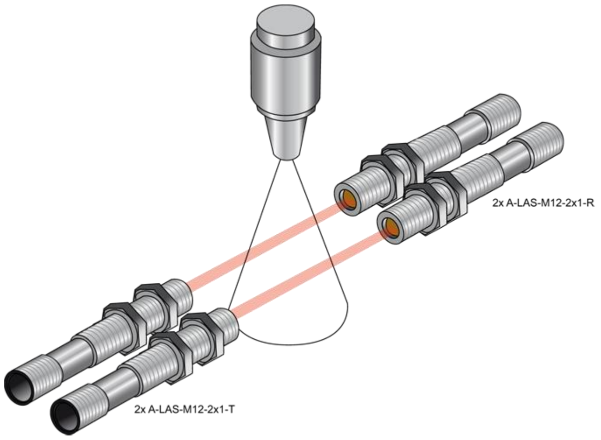
Example: Two-beam through-beam systems: ➔ *Sensor series: A-LAS series*

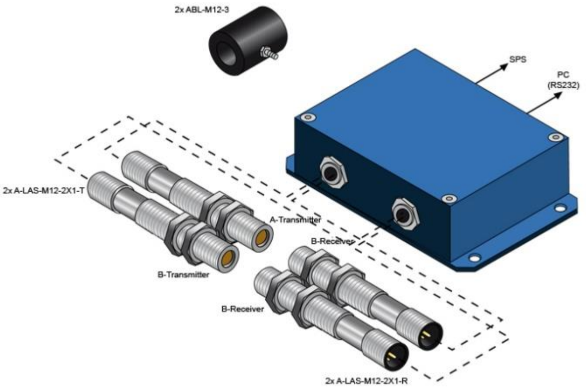
Sensor type: A-LAS-M12-2x1-T (transmitter 2x) + A-LAS-M12-2x1-R (receiver 2x) + A-LAS-CON1 (controller)

The two A-LAS laser sensors are controlled and evaluated by the A-LAS-CON1 control unit. Calibration is performed between the actual spraying processed, triggered by an external digital signal (e.g. from the PLC) that informs the controller when calibration can be performed. The two laser sensors can be used to carry out a simple symmetry check. The spray quantity also can be monitored. Blast-air top parts ABL-M12-3 are used to prevent dirt accumulation on the optics covers of the laser sensors.

3 digital output signals are available: SYMMETRY OK / NOK. - SIGNAL A OK / NOK. - SIGNAL B OK / NOK.

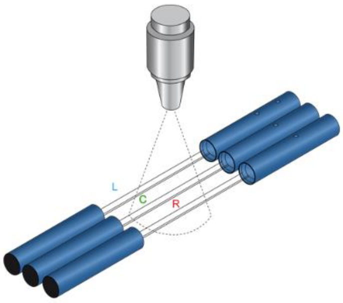
The system checks whether SIGNAL A, SIGNAL B, and SYMMETRY lie in the specified tolerance range.

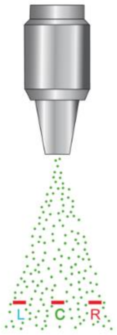


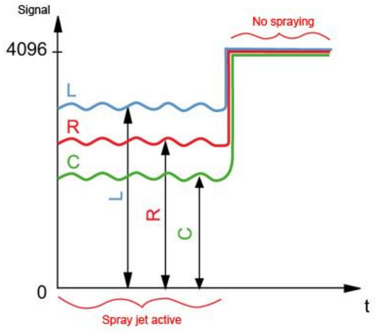


3. Three-beam transmitted light method ➔ SI-JET sensors and SI-JET-CONLAS3

With this method, even small symmetry or quantity deviations can be detected.







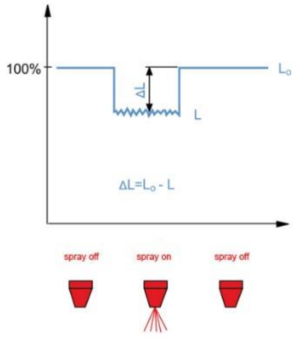
Two evaluation modes are available for selection: ABSOLUTE and RELATIVE. In both modes, the spray density (DENSITY) and the ratio of the two edge beams (SYM1) and finally the ratio of the center beam to the two edge beams (SYM2) are evaluated.

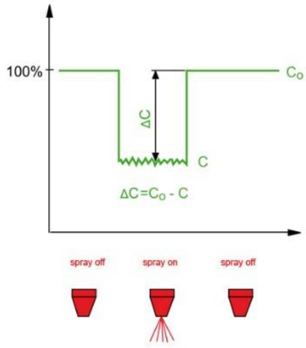
In ABSOLUTE mode, the values L, C, R are used directly in the following equations:

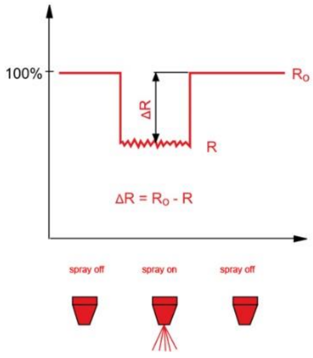
$$\text{DENSITY}=\frac{(L+C+R)}{3} \qquad \text{SYM1}=\frac{L}{L+R}*1000 \qquad \text{SYM2}=\frac{C}{C+\frac{L+R}{2}}*1000$$

L, C, and R are raw values of the 3 channels with a value between 0 and 4096 (12 bit).

In the RELATIVE mode, the ratio of the respective raw values L, C, R is formed during the spraying process with the raw data L_0, C_0, R_0 - which are present when spraying is not taking place. The raw data L_0, C_0 and R_0 thus form the 100% value in each case!







For the spray quantity applies in this case: and for the both symmetries:

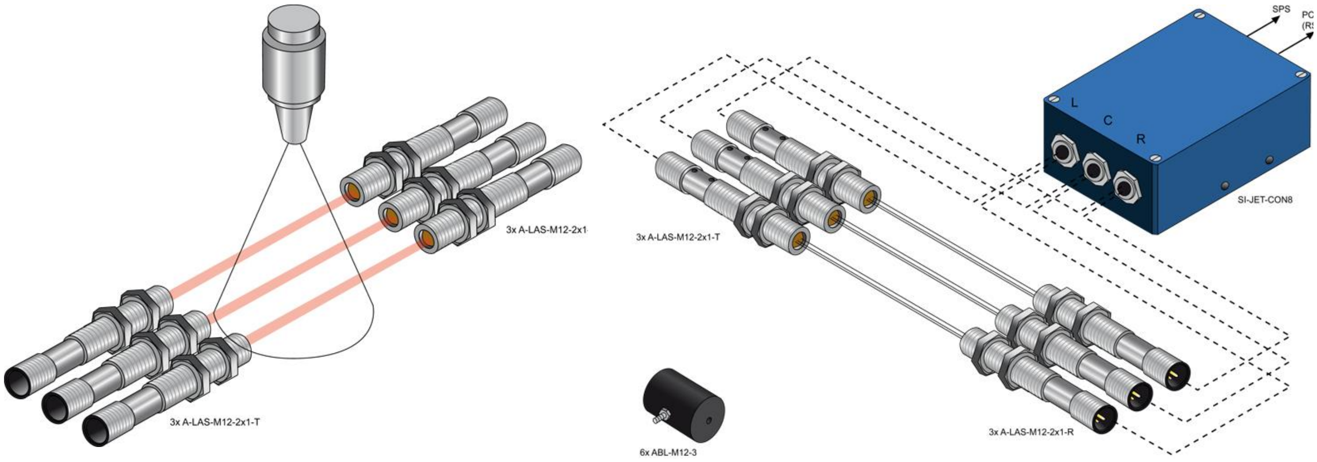
$$\text{DENSITY}=\Delta C$$

$$\text{SYM1}=\frac{\Delta L}{\Delta L+\Delta R}*1000 \qquad \text{SYM2}=\frac{\Delta C}{\Delta C+\frac{\Delta L+\Delta R}{2}}*1000$$

Example: Three-beam through-beam system – split version: ➔ *Sensor series: SI-JET series*

Sensor type: A-LAS-M12-2x1-T (transmitter 3x) + A-LAS-M12-2x1-R (receiver 3x) + SI-JET3-CON8 (controller)

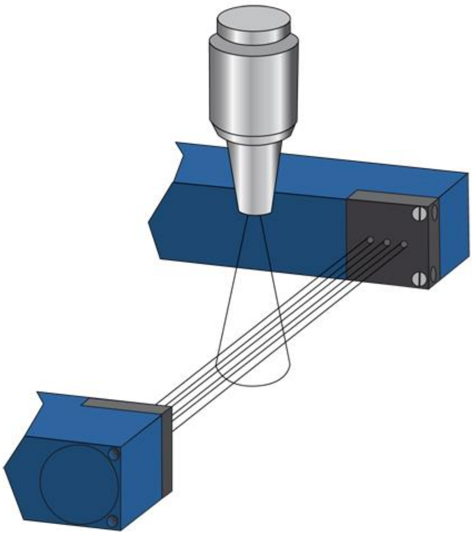
The three sensor frontends are evaluated by the SI-JET3-CON8 control unit. The SI-JET2-Scope V3.0 software is used for evaluation purposes. Both the spray quantity (DENSITY) and the symmetry (SYM1, SYM2) can be evaluated. In RELATIVE evaluation mode dirt accumulation is compensated by way of automatic calibration. Up to 31 different spray jet tolerances can be specified, and the 5 digital outputs can thus be used to inform about a drift of the spray jet at an early time.

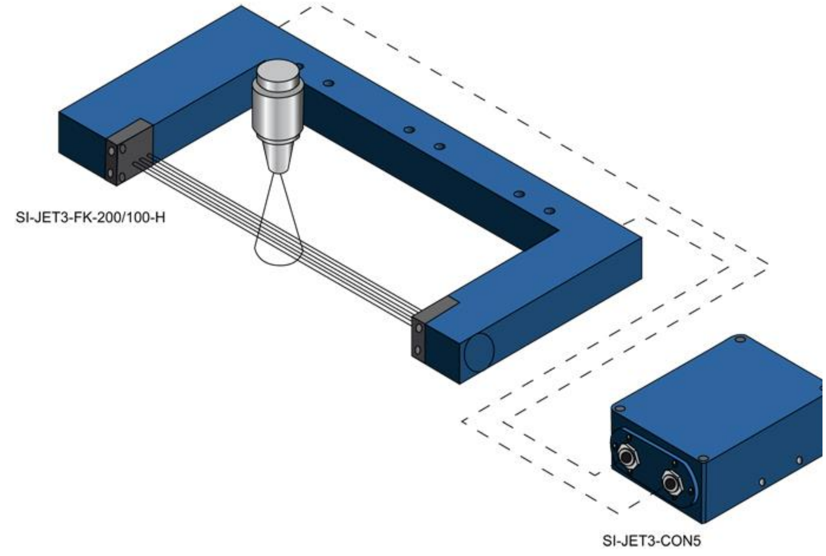


Example: Three-beam through-beam system – fork version: ➔ *Sensor series: SI-JET series*

Sensor type: SI-JET3-FK-200/100-H (frontend) + SI-JET3-CON5 (controller)

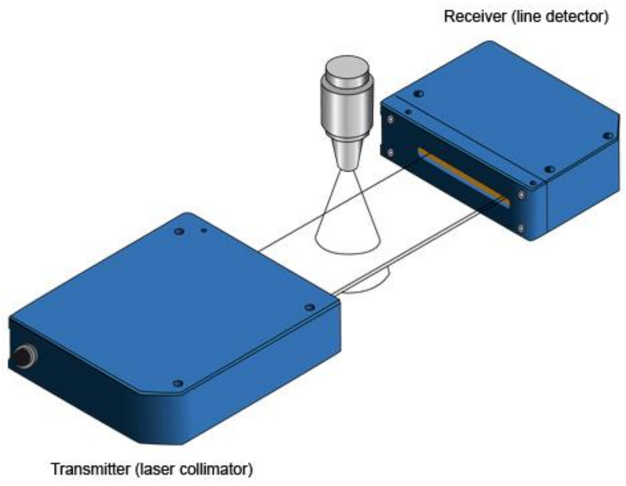
The fork features three light beams, each with a diameter of 3 mm and a centre-to-centre distance of 5 mm. The SI-JET2-Scope V3.0 software is used for the evaluation of the spray quantity (DENSITY) and of the symmetry (SYM1, SYM2). In RELATIVE evaluation mode, which can be used if a spray jet interval lies in the range of one minute, calibration is performed between the spray intervals and thus compensates possible dirt accumulation. The ABSOLUTE mode is used when there is a continuous spray jet. 5 digital outputs in up to 31 stages provide information about the respective tolerance levels. This also provides an easy way of realizing a trend display (e.g. through a PLC).

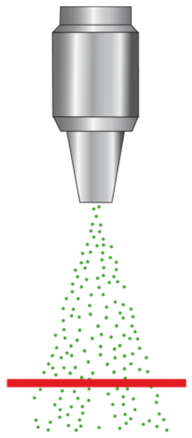



SI-JET3-FK-200/100-H
SI-JET3-CON5

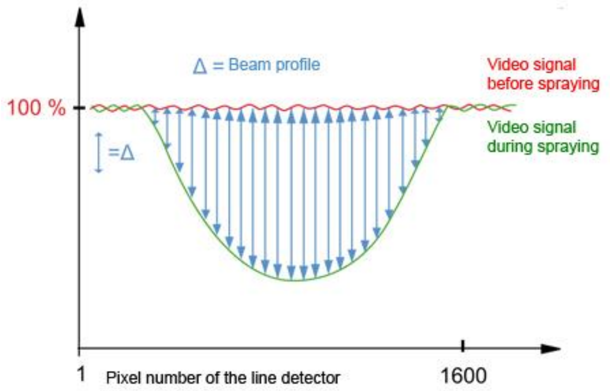
4. The light band method ➔ *L-LAS-TB-xx-AL-SC* sensors & L-LAS Spray Control Scope

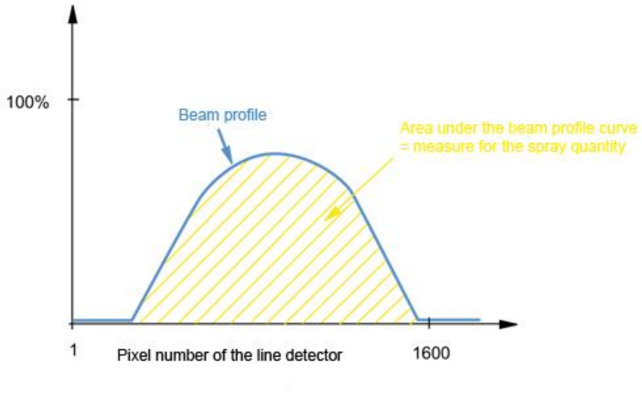
Here, a continuous band of light is directed onto the spray jet. The light band is usually wider than the spray cone diameter so that the spray jet is completely detected. On the opposite side of the spray jet is a CCD line receiver, which provides high resolution along the line. This enables the beam profile to be evaluated without gaps. To determine the beam profile, the percentage difference between the two video signals (line signals) recorded before the spraying process and during the spraying process is compared.





The beam profile (attenuation profile) provides information about the local distribution of the spray medium in the spray jet.





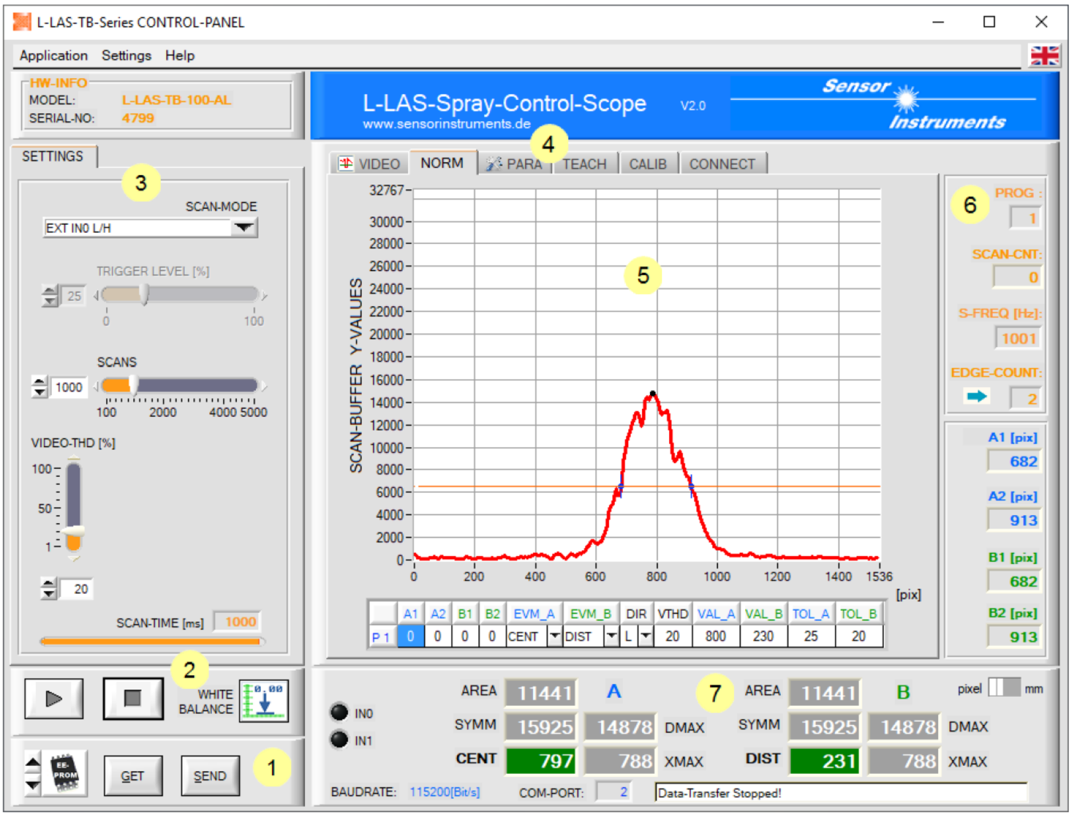
Beam profile based upon attenuation by the spray jet

Inverted beam profile as depicted in L-LAS-Spray Control

By recording many consecutive scans, a statistical distribution of the spray droplets can be calculated spatially resolved over the CCD line. The method is suitable for detailed analysis and QA control of spray nozzles.

The light band method analysis provides detailed data on the beam profile. It is suitable for robot based spray processes, in which the robot could periodically position the nozzle in a so called docking position to make a spray test for 1 – 2 seconds for analysis.

The following figure describes the most important functional and control elements of the PC operating software L-LAS-Spray-Control-Scope v2.0:



MODEL: L-LAS-TB-100-AL
SERIAL-NO: 4799

SCAN-MODE: EXT IN0 L/H
TRIGGER LEVEL [%]: 25
SCANS: 1000
VIDEO-THD [%]: 20
SCAN-TIME [ms]: 1000

PROG: 1
SCAN-CNT: 0
S-FREQ [Hz]: 1001
EDGE-COUNT: 2
A1 [pix]: 682
A2 [pix]: 913
B1 [pix]: 682
B2 [pix]: 913

	A1	A2	B1	B2	EVM_A	EVM_B	DIR	VTHD	VAL_A	VAL_B	TOL_A	TOL_B
P 1	0	0	0	0	CENT	DIST	L	20	800	230	25	20

	A				B		
AREA	11441			AREA	11441		
SYMM	15925	14878	DMAX	SYMM	15925	14878	DMAX
CENT	797	788	XMAX	DIST	231	788	XMAX

BAUDRATE: 115200[Bit/s]
COM-PORT: 2
Data-Transfer Stopped!

The *L-LAS-Spray-Control-Scope* user interface provides a great variety of functions:

- Visualization of measurement data in numeric and graphic output fields.
- Setting of the light source.
- Setting of the polarity of the digital switching outputs OUT0, OUT1, OUT2
- Selection of a suitable evaluation mode.
- Saving of parameters to the RAM, EEPROM memory of the control unit, or to a configuration file on the hard disk of the PC.

1 Function fields for sending / reading the setting parameters (parameter transfer).

2 START / STOP function fields for the RS232 data exchange with the sensor.

3 Presetting of current parameters at the sensor (trigger mode, evaluation threshold...).

4 Tab row to switch between different tab graphic windows.

5 Graphic output (display of the measured value over time, with teach value and tolerance band).

6 Numeric display elements (measuring frequency, number of edges, program number, ...).

7 Measured value display in [mm] or [pixel].

The evaluation of the spay jet is accomplished in the L-LAS-sensor, which could compare the spray jet parameters with target values. If all parameters are o.k, a digital output is set. Alternatively, the result including the beam profile could be read out by a PLC via RS-232 protocol.

Example: L-LAS-TB-xx-T/R-AL-SC series - Standard Laser-Line-Sensors for Spray Jet Control:

Line sensors are applied where precise measurement is required or where the dimensions of an object have to be determined with high accuracy.

An L-LAS-TB-xx-AL-SC sensor system comprises a transmitter (L-LAS-TB-xx-T-AL-SC) and a receiver including a control unit (L-LAS-TB-xx-R-AL-SC). Transmitter and receiver optics are normally protected with air blast devices.

Our spray control sensors of the L-LAS-series are shipped with a standard software package. The L-LAS-Spray Control-Scope v2.x software provides a spray jet profile that can be saved in the PC memory as a file with consecutive number, and can thus be used for studying the spray profile.

The following sensor types are presently available:

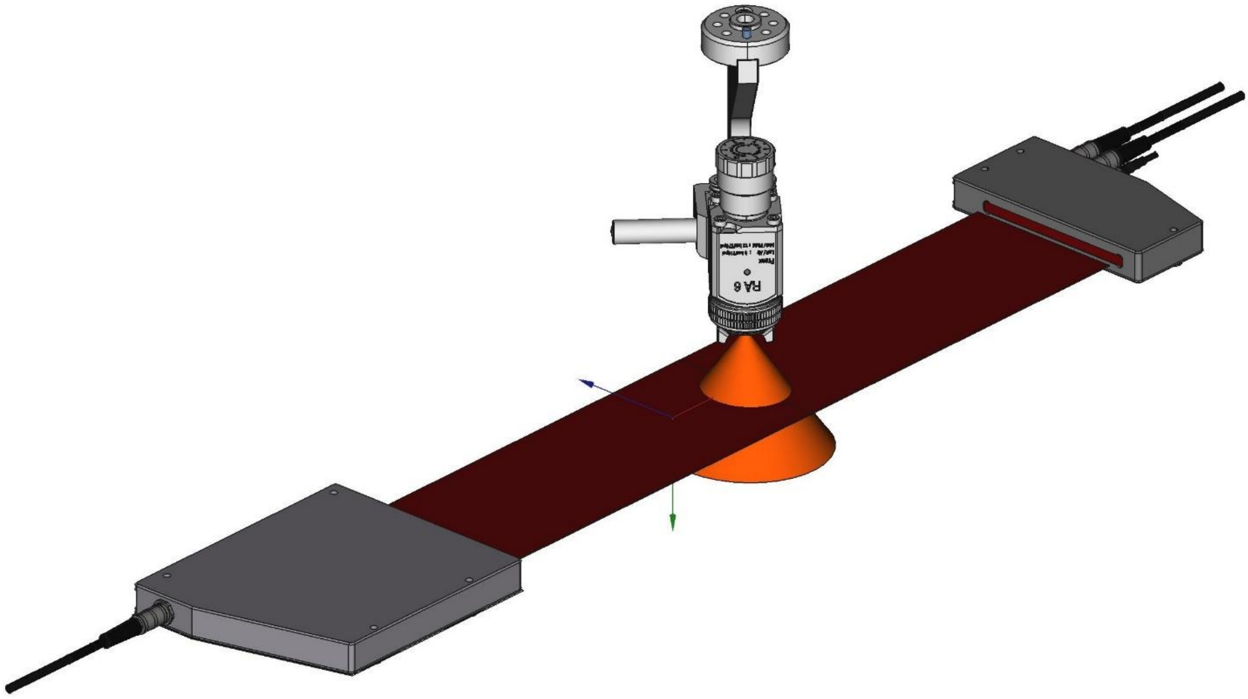
(a) L-LAS-TB-28-T/R-AL-SC provides with a 28 mm wide laser light curtain with a very high resolution. The line detector has approx. 2000 pixels.

(b) L-LAS-TB-50-T/R-AL-SC operates with a 48 mm wide laser light curtain. The line detector has approx. 770 pixels.

(c) L-LAS-TB-75-T/R-AL-SC with a laser light curtain of 73 mm width and a line detector with approx. 1200 pixels.

(d) L-LAS-TB-100-T/R-AL-SC with a laser light curtain of 98 mm width and a line detector with approx. 1600 pixels.

Depending on the requirements of the application other measurement ranges could be adopted (see L-LAS-TB-AL series).



L-LAS-TB-100-T/R-AL-SC – sensor system for spray jet analysis with 98mm light band

Applying spray jet control in explosive environments - ATEX

Depending on the sprayed media it might be necessary to adapt the spray jet control system to match explosion proof requirements.

The potential ex-zone hazard of an optical sensor systems arises from electrical components in the sensors electronics, as well as the irradiated light energy into the ex-zone. Depending on the ex-zone classification you could try to house the complete sensors and use windows in the ex-zone, or you could position the electronics outside the ex-zone and use optical fibers with lenses in the dangerous zone.

With optical fibers spray jet control is possible in explosive zone 0 of the ATEX guideline. The electronic and opto-electronic components of the spray jet control system are located outside the ex-zone Ex.

While the optical fiber help to position the sensor's electronics outside the Ex-zone, you have to ensure that the optical energy which is used for monitoring the spray jet stay well below the limits of IEC EN60079-28.

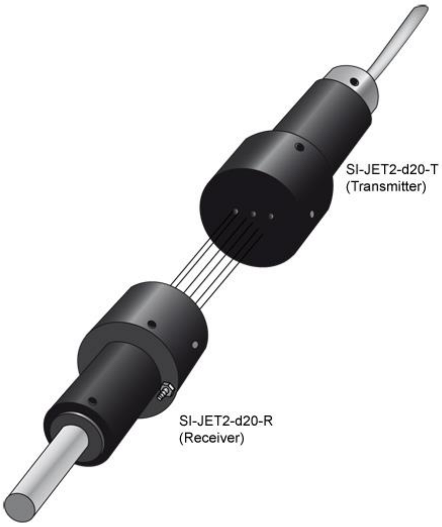
As a consequence, Sensor Instruments has put a focus on to design its spray control sensors in a way that the emitted optical radiation stays below the limit of 5mW/mm^2!

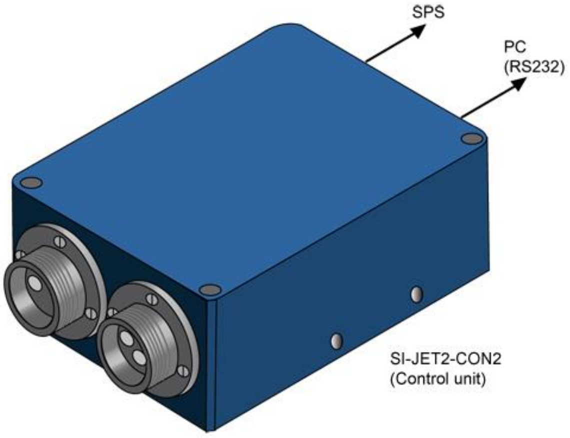
By utilizing optical fiber, one-beam, two-beam and three beam systems can be realized matching the requirements of the spray jet application.

The next pages provide a few examples of optical fiber systems with different measurement geometries.

Example for one beam sensor: SI-JET2-d20-T (transmitter) + SI-JET2-d20-R (receiver) + SI-JET2-CON2.

Red light is supplied to the special frontend by way of an optical fibre, and an aperture that is integrated in the blast-air top part generates 3 beams each with a diameter of 3 mm and a centre-to-centre distance of 5 mm. Evaluation is performed with the SI-JET2-Scope V3.0 software. The SI-JET2-CON2 control unit features 5 digital outputs that also can be used to realise a trend display (e.g. through a PLC).





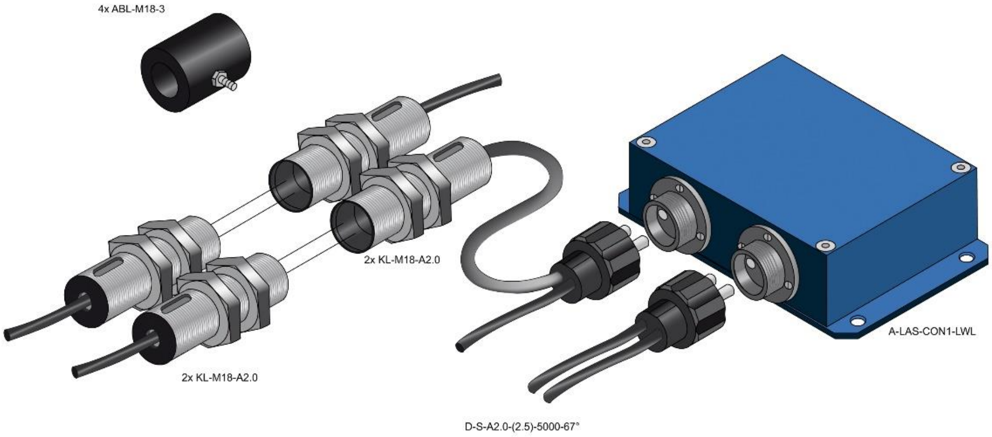
Example for two-beam through-beam system for use in ex-zone: ➔ Sensor series: A-LAS series

Optical fiber D-S-A2.0-(2.5)-500-67° + attachment optics KL-M18-A2.0 (2x) + control unit A-LAS-CON1-FIO.

A-LAS-CON1-FIO performs control and evaluation operations in the same way as A-LAS-CON1.

Since in this case the electronic and opto-electronic components are integrated in the control unit and not in the sensor frontends, this type is suitable for operating in Ex areas.

Blast-air top parts of type ABL-M18-3 are used to protect the optics units.

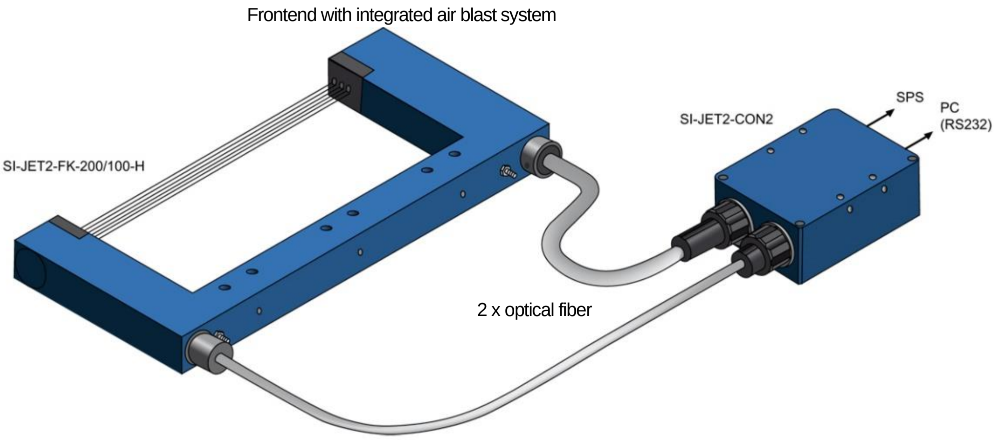


Example for a three beam sensor: KL-M18-A2.0 (frontend) + R3-M-A2.0-(2.5)-500-67°-3x (optical fiber) + SI-JET2-CON3 (control unit)

With this sensor type the three red light beams can be individually adjusted to the respective spray jet. The SI-JET2-Scope V3.0 software is used for evaluation. This type offers decisive advantages especially for spray jets that have a large opening angle.

Example for three beam sensor integrated in a fork: SI-JET2-FK-200/100-H (frontend) + SI-JET2-CON2 (control unit)

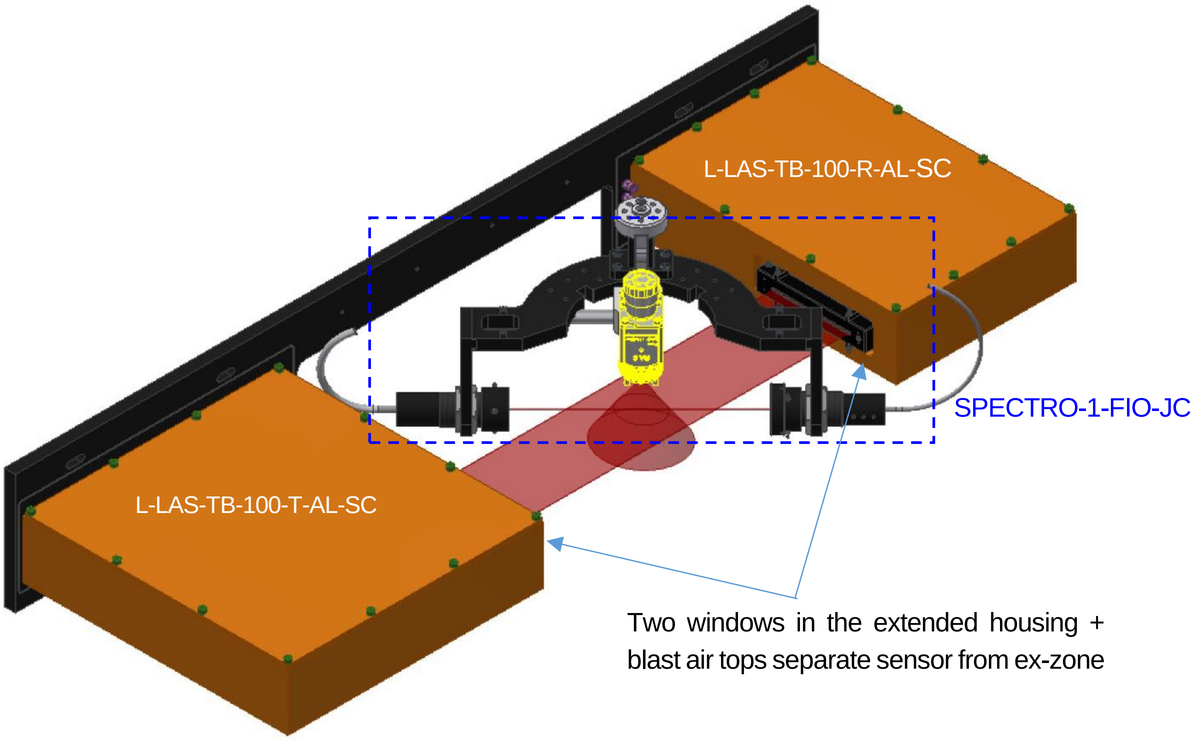
In this version the 3 beams also are arranged (centrally) at 5 mm with respect to each other, the red light beam has a diameter of 3 mm. With the help of the SI-JET-CON2 control unit a trend display of the spray jet parameters can be realized, e.g. in combination with a PLC.



Example for combined system: SPECTRO-1-FIO (attached to nozzle) and L-LAS-TB-100-T/R-AL-SC (docking station):

It is quite a challenge to integrate laser line systems (L-LAS) into an ex-zone, because you cannot use optical fiber. However, based on the application we also support our customers with designs that support an ex-zone operation.

Front view - docking station inside a cube (ex-zone):

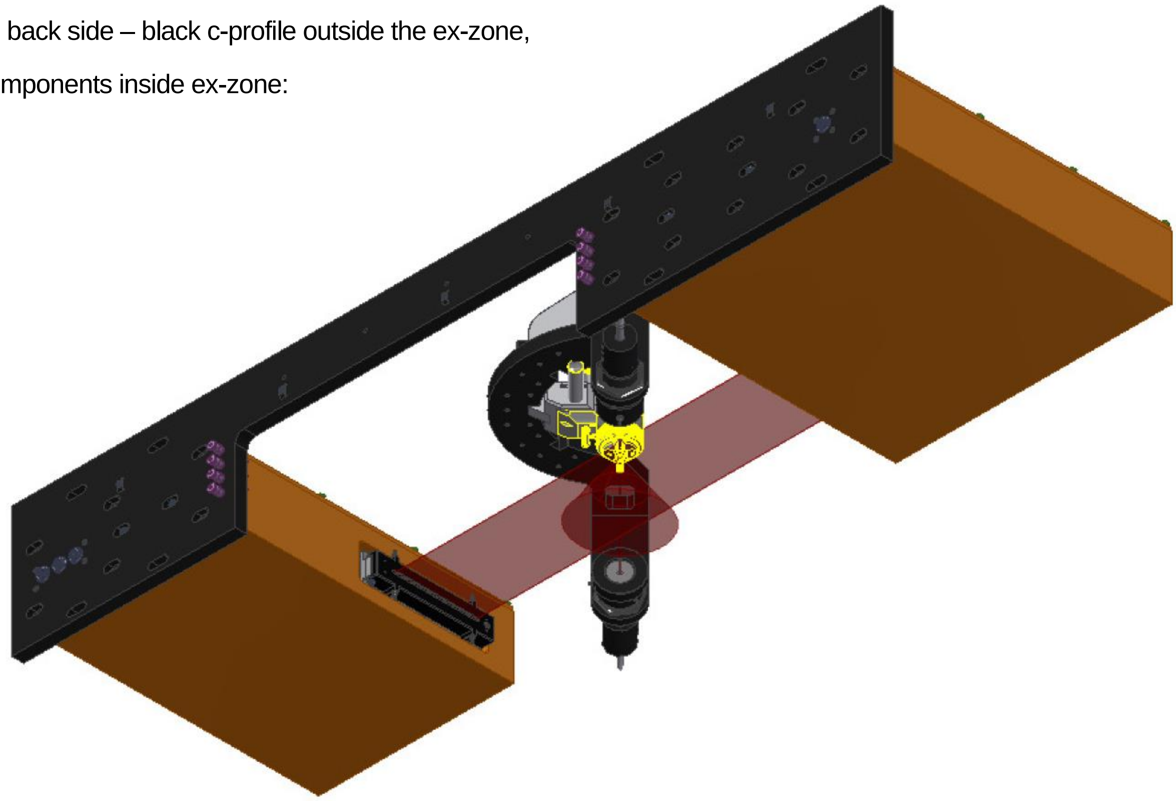


Two windows in the extended housing + blast air tops separate sensor from ex-zone

The combined system comprises a single beam system with optical fiber (**SPECTRO-1-FIO-JC**), for continuous control during the spray process, + **b. L-LAS-TB-100-T/R-AL-SC** in special housing. The laser through beam is crossing the ex-zone through two windows with air blast units, which separate the sensor's electronics from the ex-zone.

View from back side – black c-profile outside the ex-zone,

orange components inside ex-zone:



Since the sensor electronics are located outside the hazardous area, only the optical energy radiated into the flammable atmosphere for measurement is relevant for the hazard assessment (EN IEC 60079-28). The operation of the SI sensor technology is possible without any problems, since the irradiated light power (ignition energy) is significantly below the limit value of 5mW/mm^2.

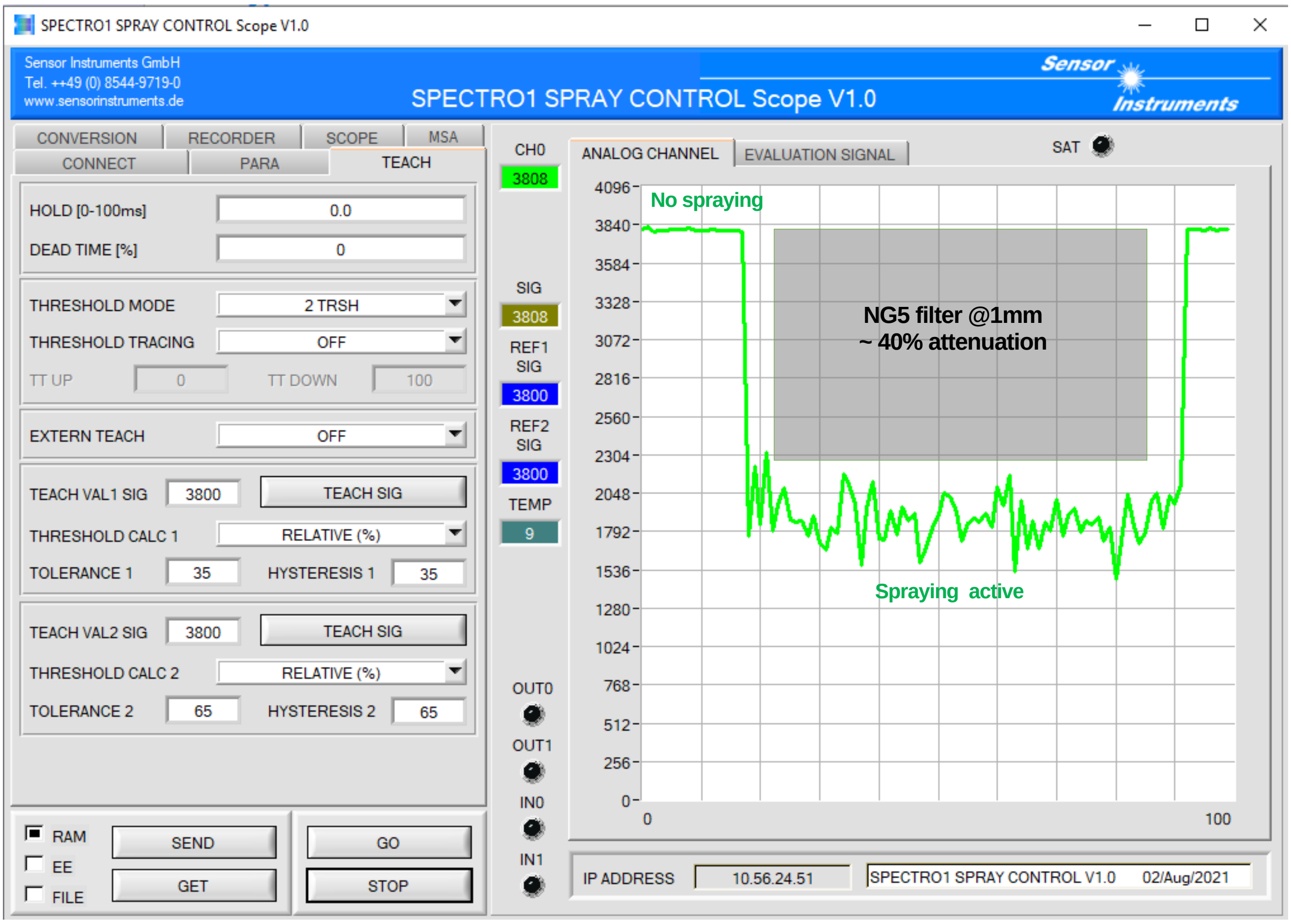
MSA-Concept for SI-Spray Jet Control Systems ("Measurement Sensor Analysis")

In spray jet control applications where the spray quantity is measured or correlated with the sensor signal, a test function is required to ensure the basic integrity of the optical sensor. Although this analysis, the measurement sensor analysis, is also abbreviated as MSA in our software, it should not be confused with the measurement system analysis. - Measurement system analysis (MSA), also known as measurement equipment capability analysis, is a statistical procedure used in quality assurance to evaluate the accuracy and reliability of measurement equipment and measurement systems. - The MSA function in the SI spray jet sensor only provides test functions to ensure the basic integrity of the sensor system.

SI spray control sensors essentially evaluate the signal attenuation caused by the spray droplets in the transmitted light. Since the occurrence of spray droplets in a spray jet is rather statistical, the use of defined optical attenuation filters is an elegant solution to generate a constant and reproducible attenuation to verify the sensor conditions.

Examples of the use of optical attenuation filters for basic "MSA" testing are described below.

1. Single channel and multichannel systems (INLINE systems)


SPECTRO1 SPRAY CONTROL Scope V1.0

Sensor Instruments GmbH
Tel. ++49 (0) 8544-9719-0
www.sensorinstruments.de

SPECTRO1 SPRAY CONTROL Scope V1.0

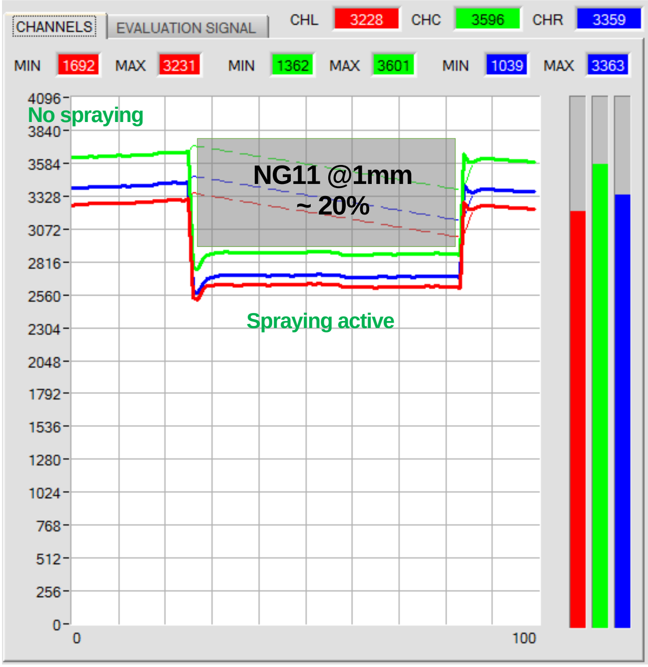
HOLD [0-100ms]: 0.0
DEAD TIME [%]: 0
THRESHOLD MODE: 2 TRSH
THRESHOLD TRACING: OFF
TT UP: 0
TT DOWN: 100
EXTERN TEACH: OFF
TEACH VAL1 SIG: 3800
THRESHOLD CALC 1: RELATIVE (%)
TOLERANCE 1: 35
HYSTERESIS 1: 35
TEACH VAL2 SIG: 3800
THRESHOLD CALC 2: RELATIVE (%)
TOLERANCE 2: 65
HYSTERESIS 2: 65

CH0: 3808
SIG: 3808
REF1 SIG: 3800
REF2 SIG: 3800
TEMP: 9

IP ADDRESS: 10.56.24.51
SPECTRO1 SPRAY CONTROL V1.0 02/Aug/2021

Signal curve SPECTRO-1-CONLAS + A-LAS-N-M18-7x3-2m-C @35mm distance (with NG5):

For 2-channel and 3-channel systems the same concept is possible The neutral glass (NG) filter provides a defined attenuation that produces a constant attenuation signal at a given power value and gain.



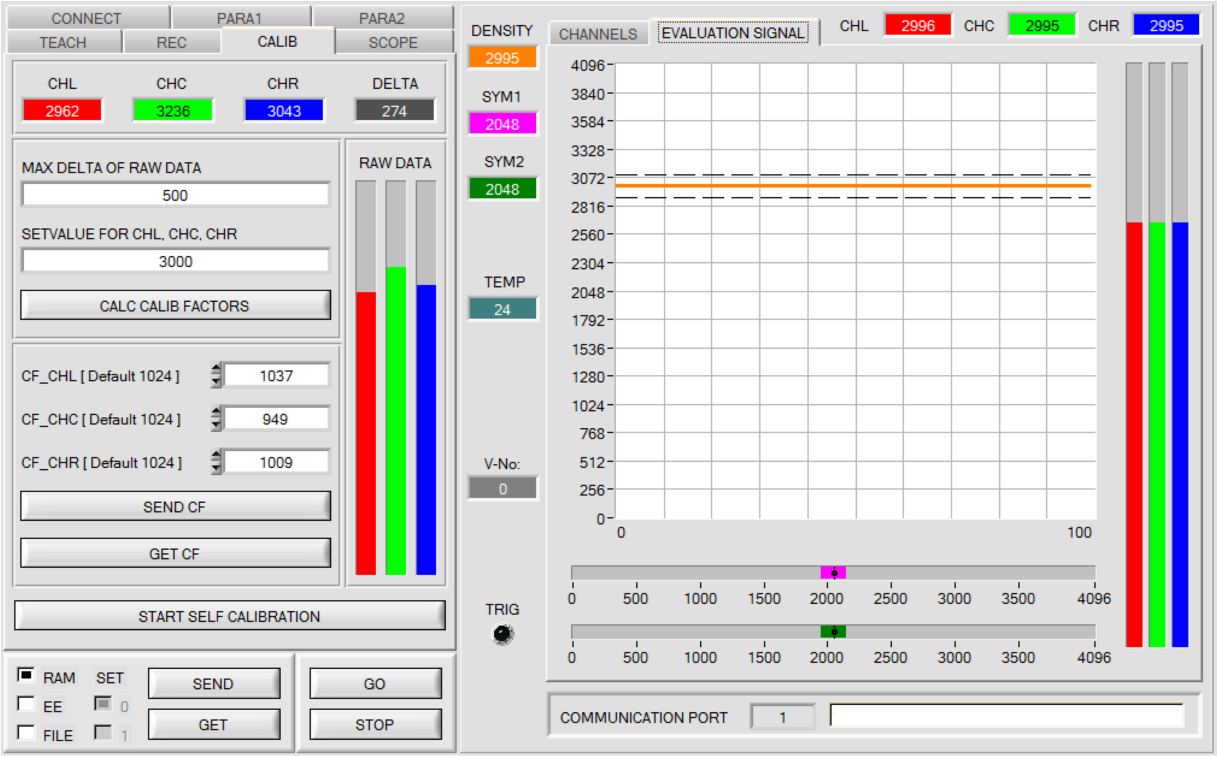
Behavior of a three-channel spray jet sensor with SI-JET-Scope v4.x:

- The signal attenuation in the spraying process is approx. 24%
- With the aid of an NG filter, a defined attenuation can be introduced into the measuring field of the sensor in this range.
- The power value of the sensor is adjusted in such a way that the mean value of the 3 channels in the free state (without filter) reaches a certain level.
- Then a channel adjustment (see below) is performed to calibrate the density and symmetry values of the sensor.
- When inserting the NG filter into the measuring field, DENSITY and SYM1 or SYM2 must provide defined values.

Signal curve SI-JET-system (with NG11)

In the case of multi-channel systems, a second step is also required, which adjusts the two/three channels to the same level with a free sensor:

With the sensors of the SI-JET series, a channel alignment can be performed. The alignment is performed in transmitted light mode, when there is no object between the transmitter and receiver.



CHL 2962 CHC 3236 CHR 3043 DELTA 274

MAX DELTA OF RAW DATA: 500

SETVALUE FOR CHL, CHC, CHR: 3000

CF_CHL [Default 1024]: 1037

CF_CHC [Default 1024]: 949

CF_CHR [Default 1024]: 1009

☒ RAM ☐ EE ☐ FILE SET ☐ 0 ☐ 1

DENSITY 2995

SYM1 2048

SYM2 2048

TEMP 24

V-No: 0

CHL 2996 CHC 2995 CHR 2995

COMMUNICATION PORT 1

Calculation example for determining the calibration factors:

As you can see from the example, a POWER value has been set where the three bars of the **RAW DATA** raw signals are in the dynamic range. Each of the three bars is at about 3000 digits. Now set a target value of 3000 (see **SETVALUE FOR CHL, CHC, CHR**) for the three bars. After the calibration has been started by pressing **CALC CALIB FACTORS**, the software automatically calculates the calibration factors for the channels **CHL, CHC** and **CHR**. The calibration factors are normalized as an integer to the value 1024

CF_CHL = (SETVALUE / RAW DATA CHL) * 1024 = (3000 / 2962) * 1024 = 1037
CF_CHC = (SETVALUE / RAW DATA CHC) * 1024 = (3000 / 3236) * 1024 = 949
CF_CHR = (SETVALUE / RAW DATA CHR) * 1024 = (3000 / 3043) * 1024 = 1009

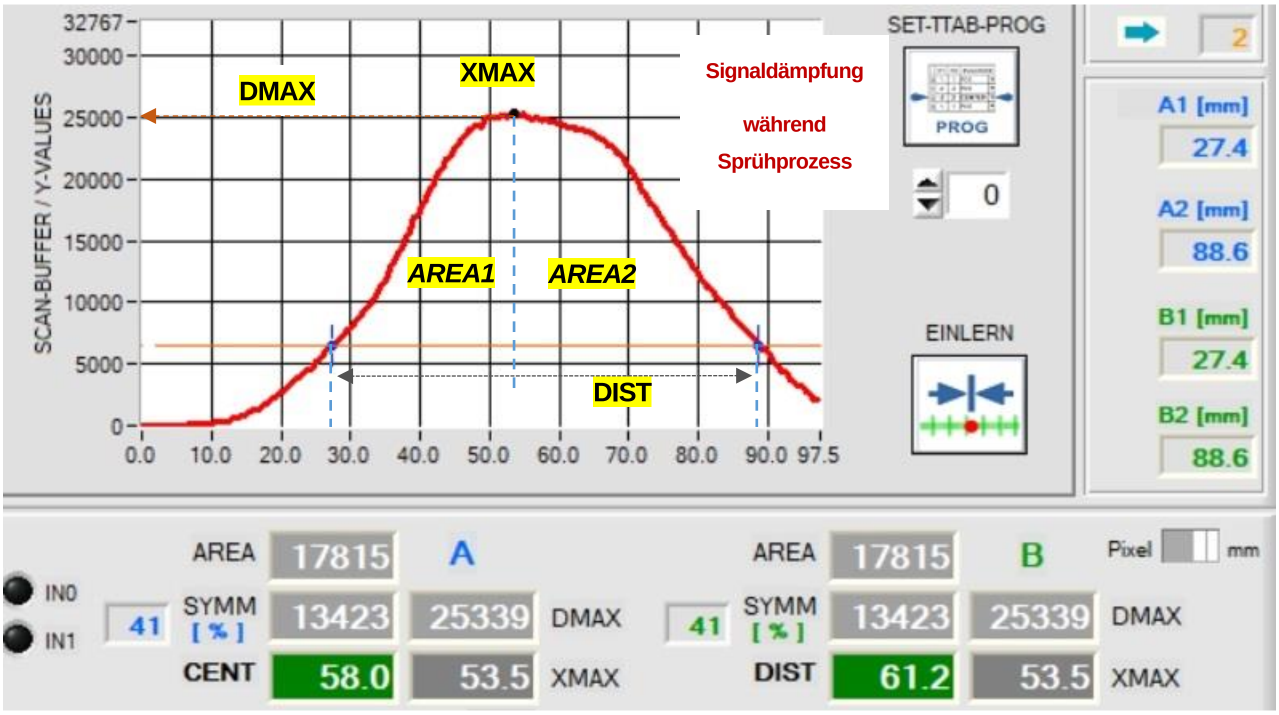
After the calibration factors have been calculated by the software on the user interface, they are automatically stored in the non-volatile memory EEPROM of the sensor. The calibration is now finished and you can continue working in the main panel.

If the sensor detects a raw signal, it applies the calibration factor stored in the **EEPROM** to this raw signal. This means that only the calibrated data for the channels **CHL**, **CHC** and **CHR** are displayed in the main panel. The evaluation on the part of the microcontroller is also carried out exclusively with the calibrated data.

Note: **DYN1:** A state is learned at position 0 in the **TEACH TABLE** in dynamic power mode, then static evaluation is performed. The **POWER MODE** is automatically set to **STATIC**. After setting **IN0** to high, the transmit power is adjusted so that the sensor is in the dynamic range, which is set with **DYN WIN LO** and **DYN WIN HI**. Subsequently, the currently present state is learned to position 0 in the **TEACH TABLE**.
The sensor continues to operate statically with the **POWER** value found. The learned vector is only stored in the RAM and not in the **EEPROM** of the sensor.

2. Light band systems - L-LAS-TB-xx-T/R-AL-SC (Periodic test systems)

Example of the signal trace recorded over one second with an L-LAS-TB-100-T/R-AL-SC @35mm distance:



2

0

A1 [mm] 27.4
A2 [mm] 88.6
B1 [mm] 27.4
B2 [mm] 88.6

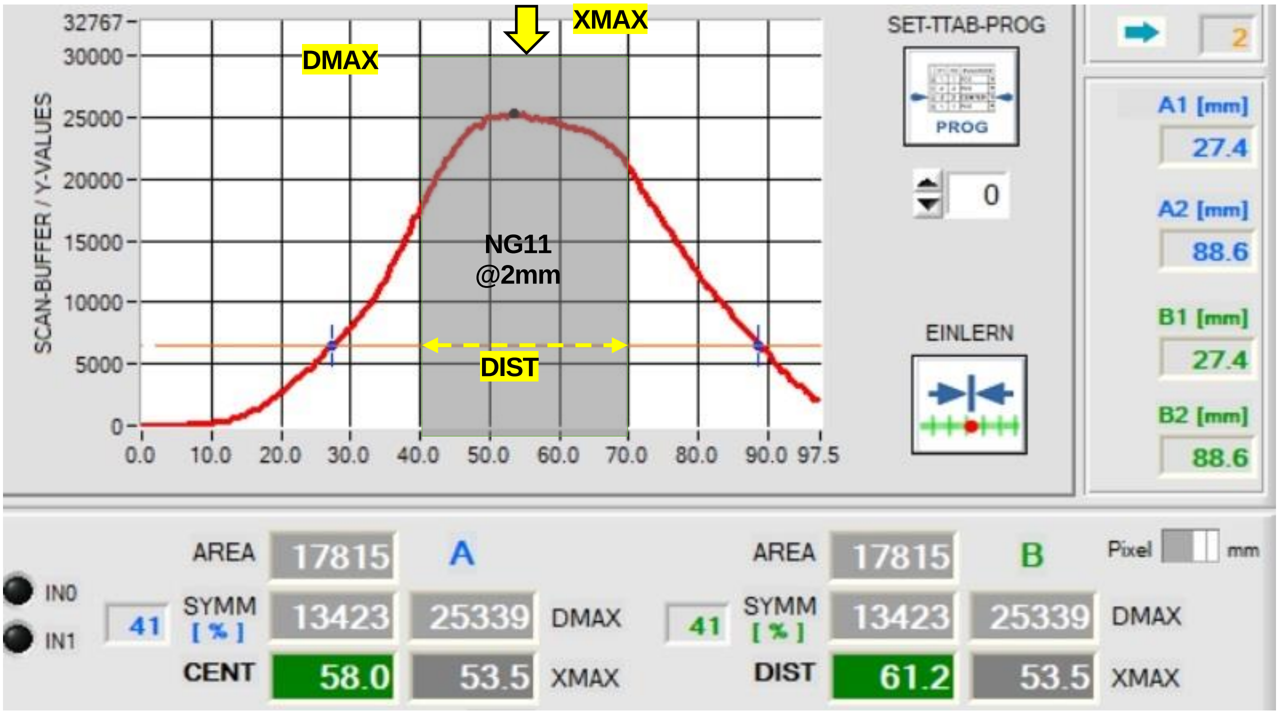
AREA 17815 A
41 SYMM [%] 13423 25339 DMAX
CENT 58.0 53.5 XMAX

AREA 17815 B
41 SYMM [%] 13423 25339 DMAX
DIST 61.2 53.5 XMAX

Signal curve L-LAS-TB-100-T/R-AL-SC for a spray jet, recording time approx. One second at scan rate = 1kHz

In laser line scan systems, the NG filters (neutral density glass filters) provide not only the attenuation property but also a defined signal curve via their geometry. This is represented as a rectangle in the video signal of the sensor.

By applying a video threshold, the dimension of the rectangle, as well as the measured values relevant for the system (DIST, DMAX, XMAX, AREA1 = AREA2) can be calculated and it can be checked whether the system behaves constantly.



2

0

A1 [mm] 27.4

A2 [mm] 88.6

B1 [mm] 27.4

B2 [mm] 88.6

A
AREA 17815
41 SYMM [%] 13423 25339 DMAX
CENT 58.0 53.5 XMAX

B
AREA 17815
41 SYMM [%] 13423 25339 DMAX
DIST 61.2 53.5 XMAX

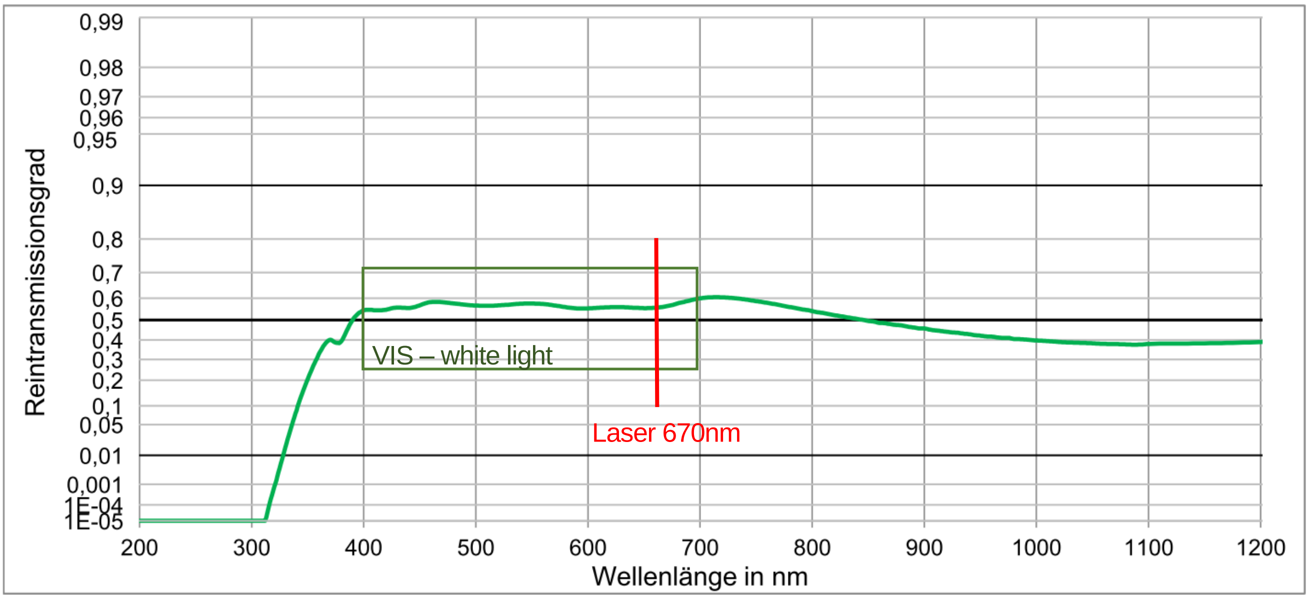
Signal curve L-LAS-TB-100-T/R-AL-SC – attenuation compared NG11 filter with 2mm thickness

The measurement principle of spray jet detection from Sensor Instruments is based on optical attenuation measurement in transmission.

Accordingly, the MSA concept for Sensor Instruments' spray jet sensors is based on MSA testing of the sensor technology by using a defined optical attenuation with neutral density glass filters to simulate the attenuation and thus control the integrity of the measurement system.

Appendix - Examples of neutral density glass filters:

NG5 - Attenuation in VIS approx. 40% at 1mm thickness



NG11 - Attenuation in VIS approx. 20% at 1mm thickness