Press Release Sensor Instruments

October 2021

Spray jet control in transmitted light

21.10.2021. Sensor Instruments GmbH:

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)?

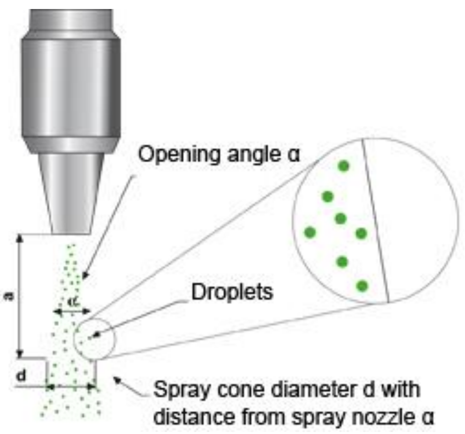
3. Which influencing variables determine/disturb the quality of the spray jet in the process? What are the general conditions for optical scanning of the spray process?

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

Measuring principles

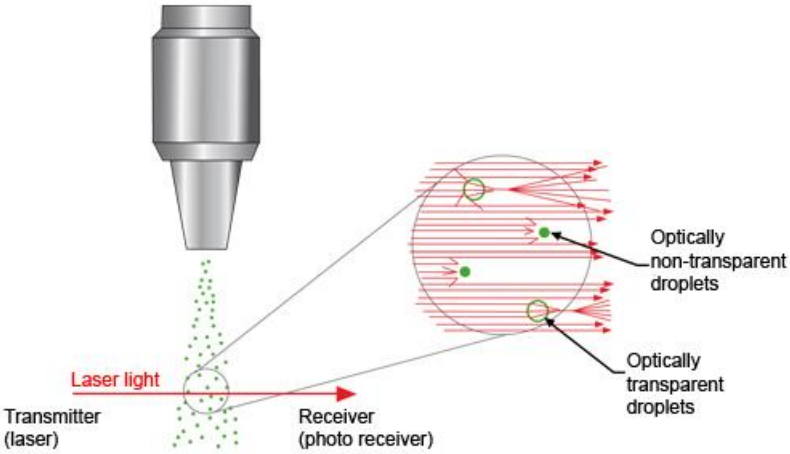
What characteristics define a spray jet?

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.



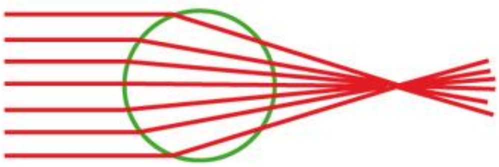
The spray jet is determined by the opening angle of the spray cone and the spray quantity (droplets/time unit or spray flow rate).

How is the spray jet characterized?

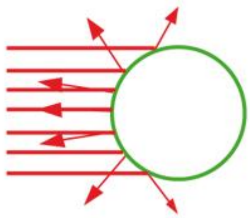


In order to be able to make a statement about the spray quantity, a light beam, e.g. with a laser transmitted light barrier, is placed through the spray cone. After exiting, the intensity of the light beam is measured at the receiver. On its way through the spray cone, part of the laser beam is deflected by the individual droplets of the spray and does not reach the receiver.

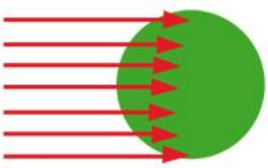
The deflection is caused by the reflection at the droplet surface or by focusing the laser radiation, because the droplets, if they are optically transparent, work like microlenses. However, some of the light is also absorbed by the droplets or does not reach the receiver due to diffraction at the interface.



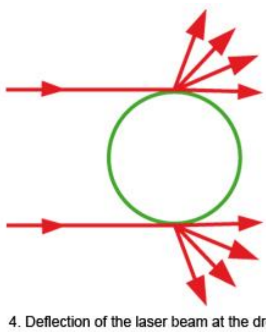
1. Focusing of the laser beam



2. Reflection of the laser beam



3. Absorption of the laser beam

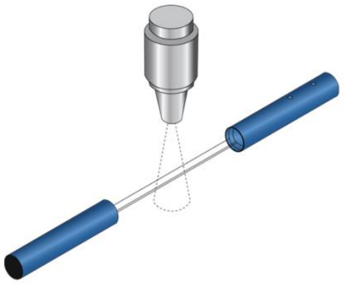


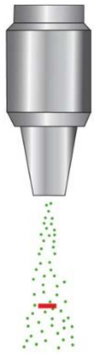
4. Deflection of the laser beam at the droplet

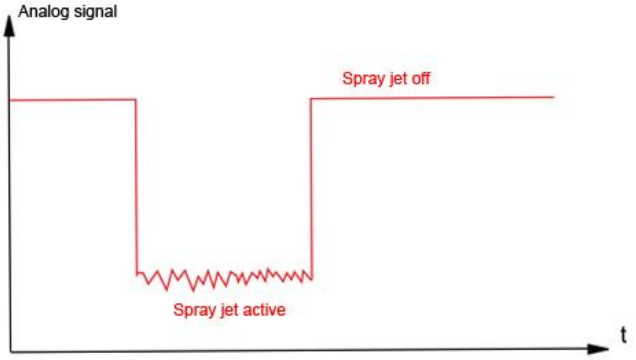
Methods of spray jet control in transmitted light:

1. The single-beam transmitted light method
➔ D-LAS2, SPECTRO-1-CONLAS or 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!

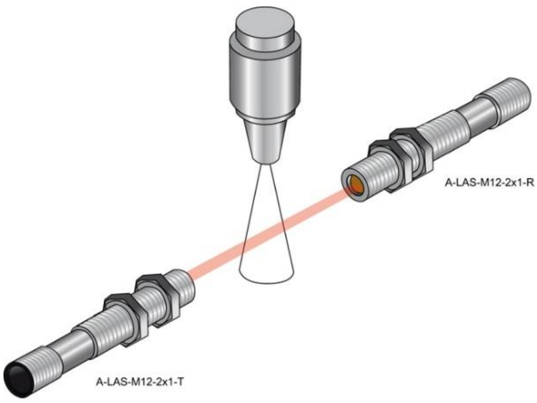
The mode of operation of an A-LAS-CON1 system for spray jet control and micro-dosage control are explained in more detail in two training videos. By clicking on the respective link, you will be redirected to the corresponding video on our YouTube channel.

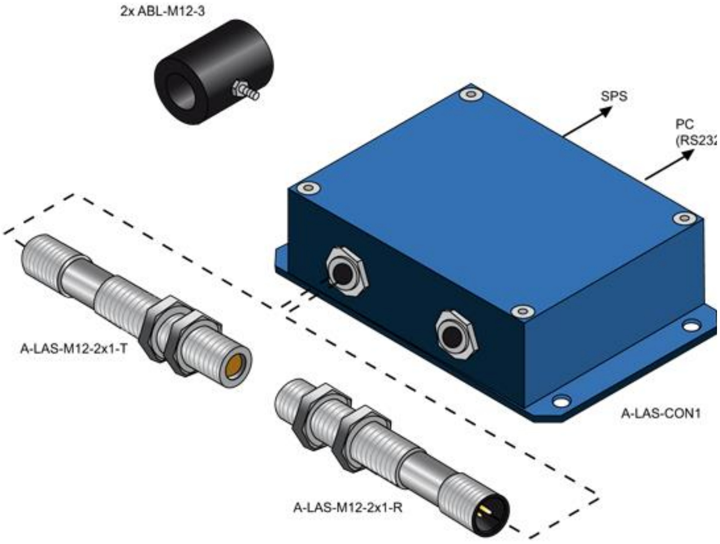
Example: Single-beam through-beam systems with controller: Sensor series: A-LAS series

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.

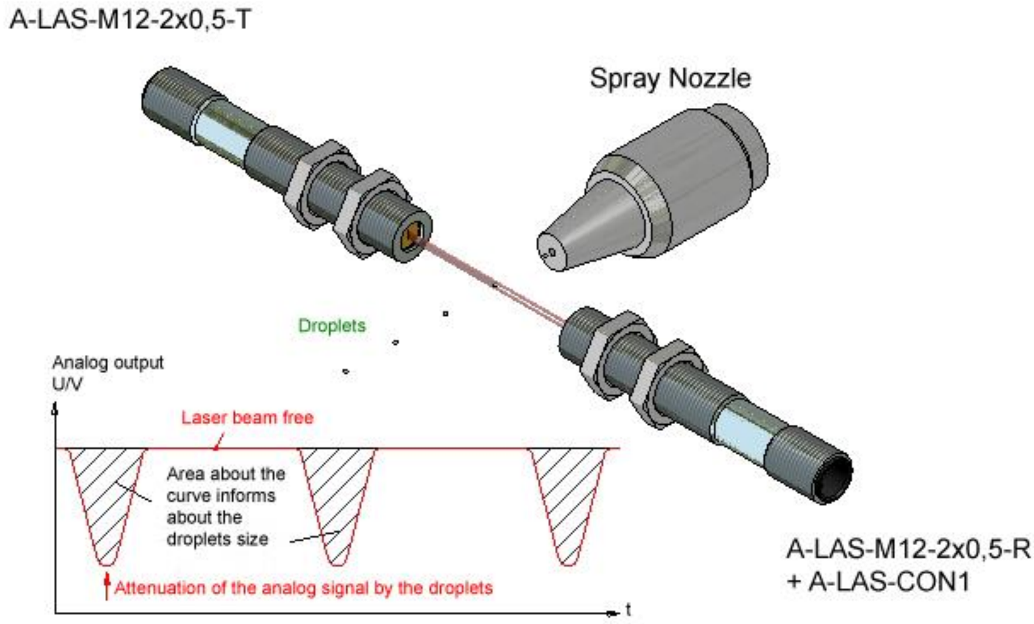
This makes it possible to even detect smallest spray quantities, because possible dirt accumulation can be compensated by way of calibration (to 100%), and the detection threshold can thus be close to the 100% value (e.g. 99.7%). The controller unit provides both an analog signal and a digital signal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

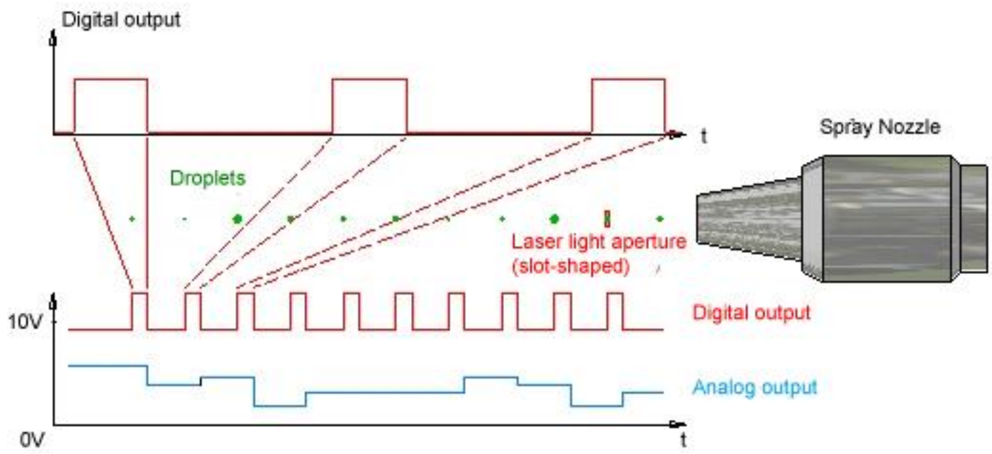




If the sensor is fast enough you could detect short interruptions caused by air bubbles. Within micro dosage control, where you need to characterize single drops, you could even analyze the size of drops.

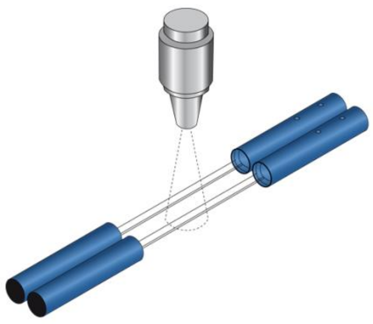
The ideal solution for micro dosage control is a sensor of the A-LAS series with an aperture that is matched to the droplet size, in combination with the A-LAS-CON1 control unit, because this sensor system features a high scan and switching frequency. At the analog output the droplet size is buffered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

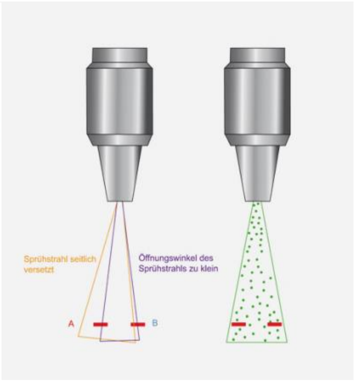


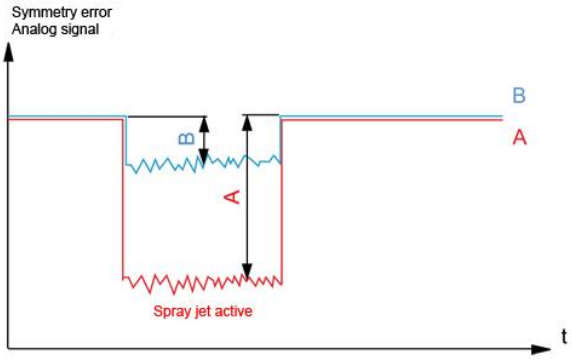


2. The two-beam transmitted light method

➔ A-LAS-CON1 sensors or SI-JET sensors







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

$$NORM = \frac{A}{A+B} * 4096 = SYMMETRIE \qquad INT = \frac{A+B}{2} * 4096 = SPRÜHMENGE$$

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.

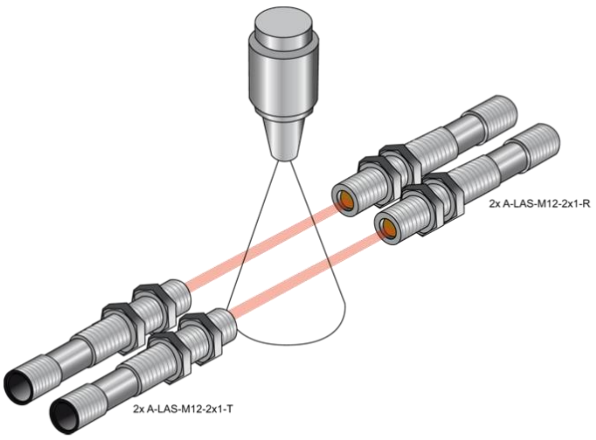
Example: Two-beam through-beam systems: Sensor series: A-LAS series

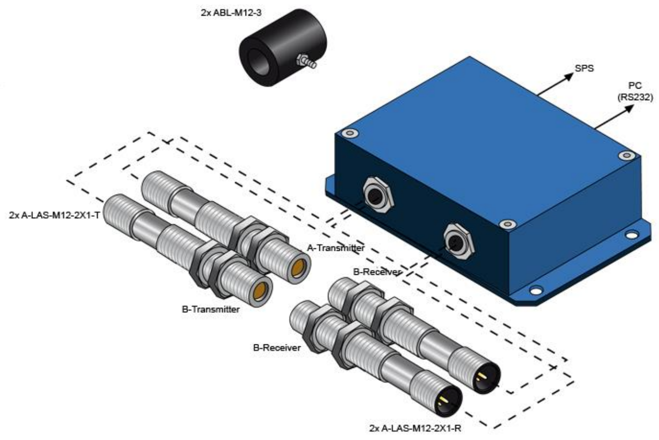
Sensor type: A-LAS-M12-2x1-T (transmitter 2x) + A-LAS-M12-2x1-R (receiver 2x) + A-LAS-CON1 (controller)

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.

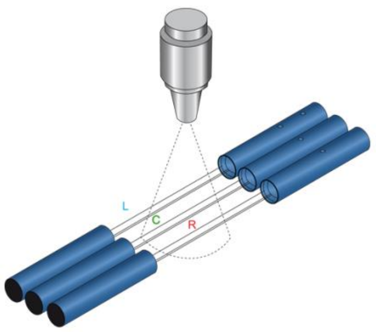


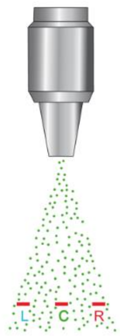


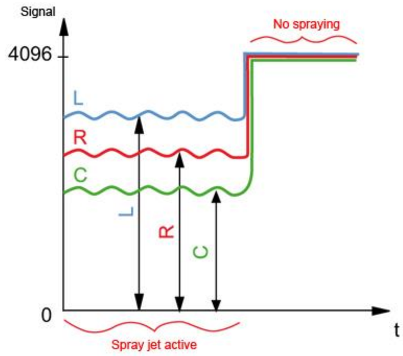
3. Three-beam transmitted light method

➔ ***SI-JET sensors, or the new laser system SI-JET-CONLAS3***

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







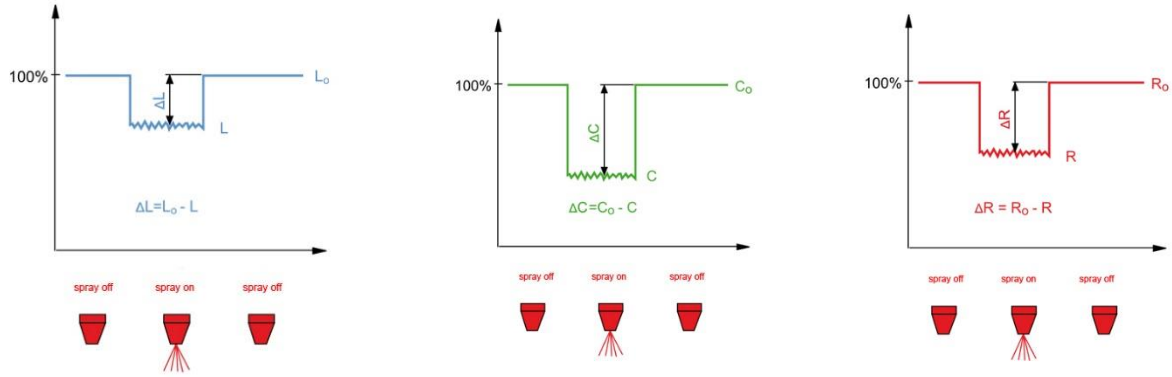
Two evaluation modes are available for selection: ABSOLUTE and RELATIVE. In both modes, the spray density (DENSITY) and the ratio of the two edge beams (SYM1) and finally the ratio of the center beam to the two edge beams (SYM2) are evaluated.

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

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

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 L0, C0, R0 - which are present when spraying is not taking place. The raw data L0, C0 and R0 thus form the 100% value in each case!



For the spray quantity applies in this case:

$$DENSITY = \Delta C$$

And for both symmetries:

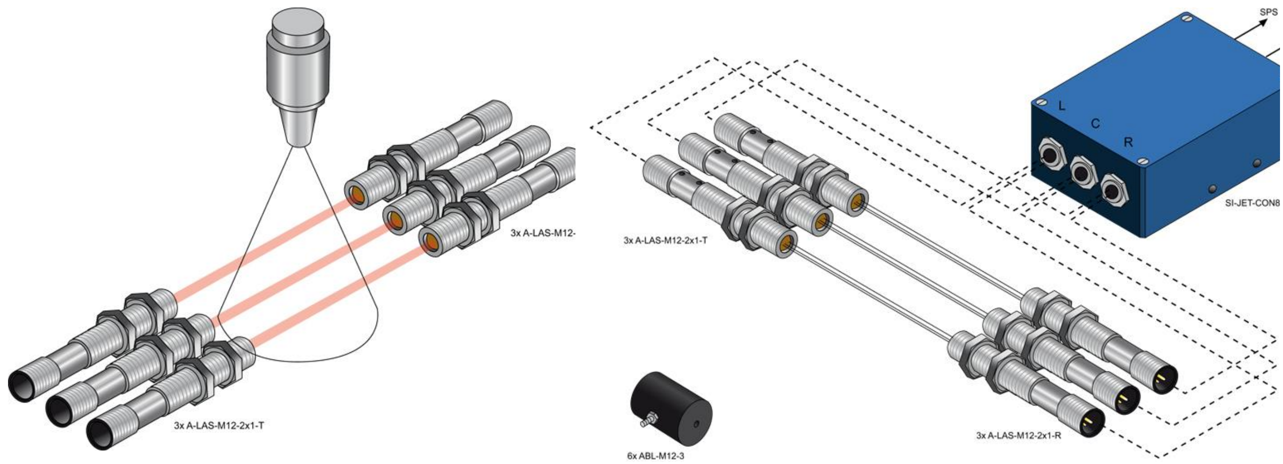
$$SYM1 = \frac{\Delta L}{\Delta L + \Delta R} * 1000$$

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

<u>Example: Three-beam through-beam system – split version: Sensor series: SI-JET series</u>

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

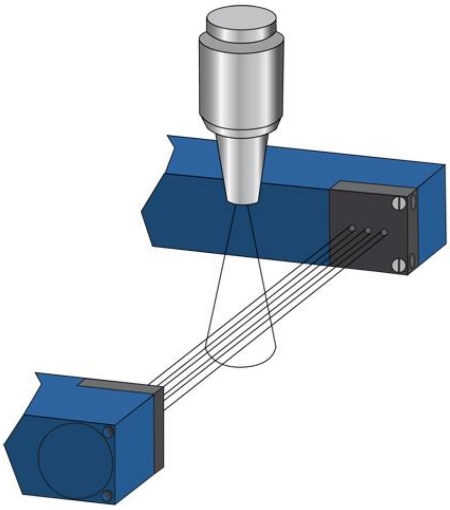
The three sensor frontends are evaluated by the SI-JET3-CON8 control unit. The SI-JET2-Scope V3.0 software is used for evaluation purposes. Both the spray quantity (DENSITY) and the symmetry (SYM1, SYM2) can be evaluated. In RELATIVE evaluation mode dirt accumulation is compensated by way of automatic 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.

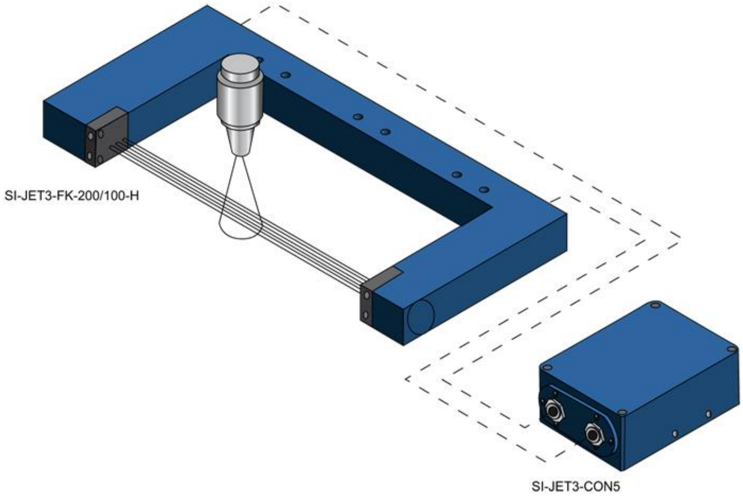


Example: Three-beam through-beam system – fork version: Sensor series: SI-JET series

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

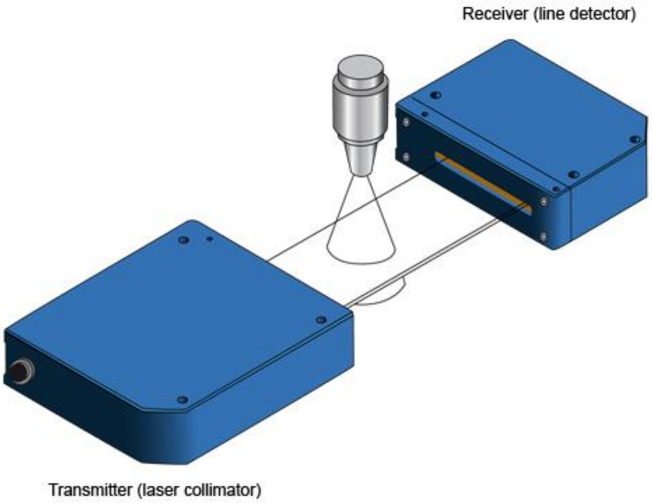
The fork features three light beams, each with a diameter of 3 mm and a centre-to-centre distance of 5 mm. The SI-JET2-Scope V3.0 software is used for the evaluation of the spray quantity (DENSITY) and of the symmetry (SYM1, SYM2). In RELATIVE evaluation mode, which can be used if a spray jet interval 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).

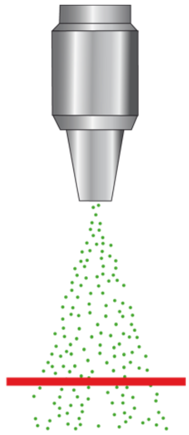




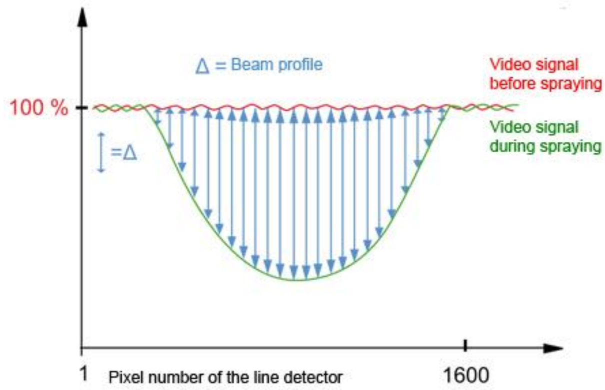
4. The light band method
➔ L-LAS-TB-xx-AL-SC sensors with L-LAS Spray Control Scope software

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.

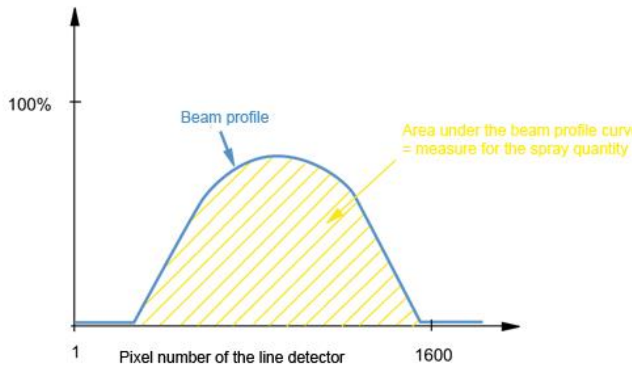




The beam profile (attenuation profile) provides information about the local distribution of the spray medium in the spray jet.



Beam profile based upon attenuation by the spray jet

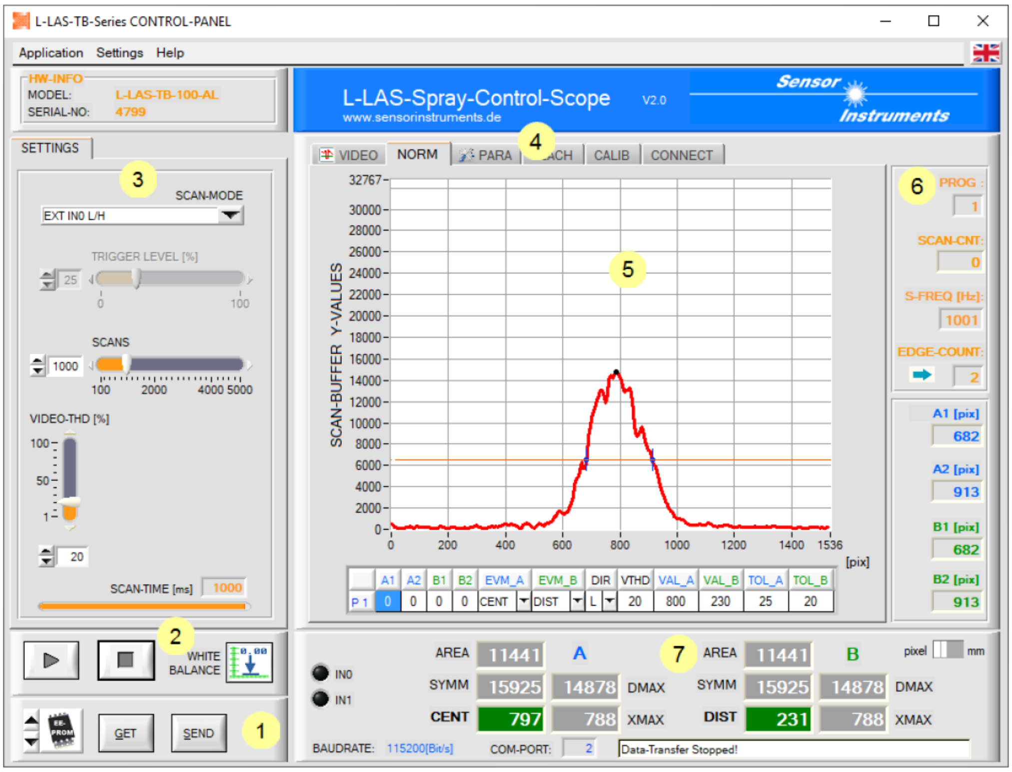


Inverted beam profile as depicted in L-LAS-Spray Control

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:



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

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:

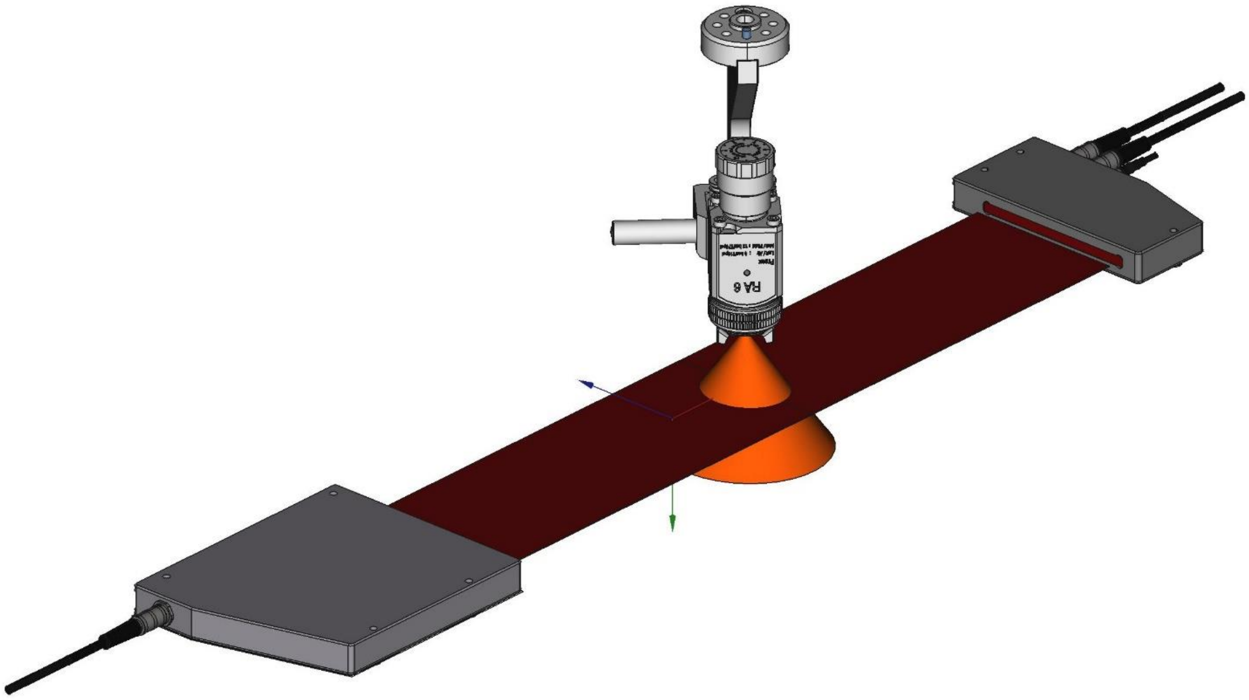
(a) L-LAS-TB-28-T/R-AL-SC provides with a 28 mm wide laser light curtain with a very high resolution, the line detector has approx. 2000 pixels

(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-SC series).



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

5. *Applying spray jet control in explosive areas*
➔ SI-JET sensor systems with fiber optics

To ensure that spray jet control can also be carried out in an environment where a hazardous explosive atmosphere as a mixture of air and flammable gases, vapours or mists prevails over longer periods of time, light guides are used.

In this way, work can also be carried out in the potentially explosive zone Ø of the ATEX operating directive. The electronic and optoelectronic components of the spray jet control system are located outside zone Ø. Only the optical and optomechanical components are located outside zone Ø. Only the optical and opto-mechanical components (opto-mechanical front end) are located in the hazardous area. The connection between the front end and the evaluation unit is established via fibre optic cables.

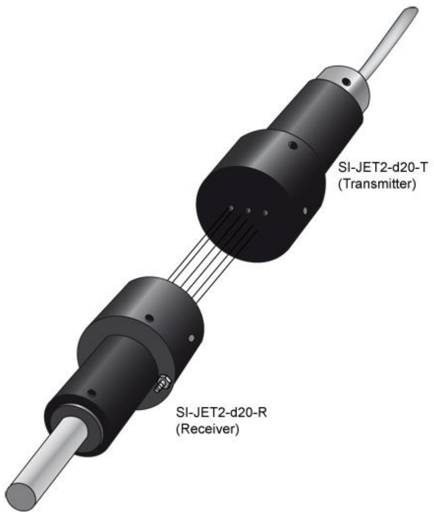
It is important to ensure that the optical power density does not exceed a certain limit. With SI products, however, the optical power density is far below the permissible limits.!

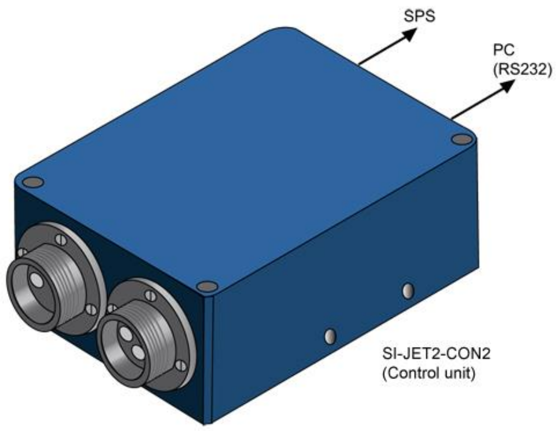
More information on our website: ➔ WHAT IS …? ➔ Spray jet control

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

Example for single-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).



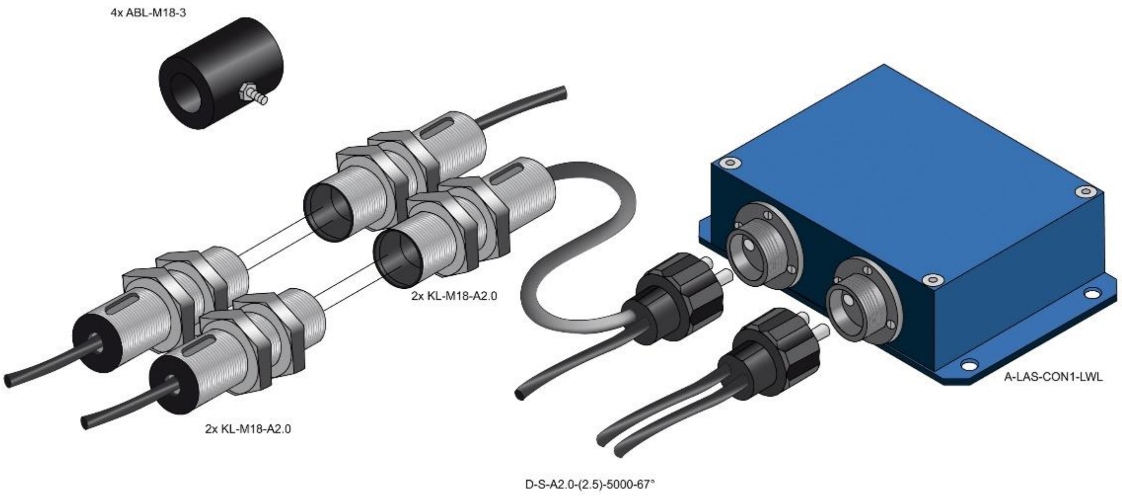


Example for two-beam through-beam system for use in Ex zone: Sensor series: A-LAS series

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.

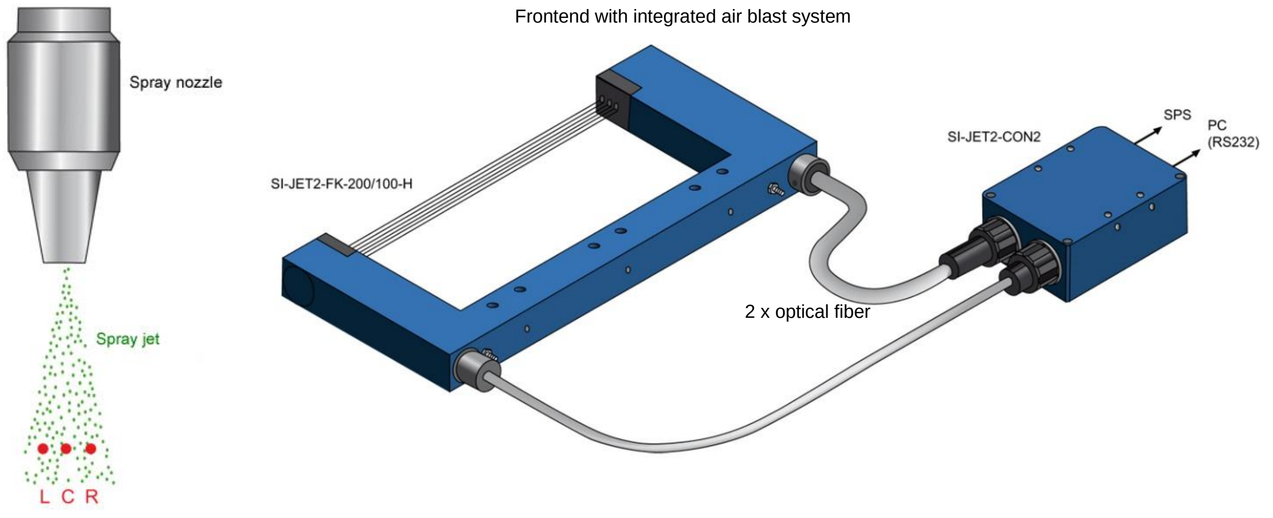


Example for a three-beam sensor: KL-M18-A2.0 (frontend) + R3-M-A2.0-(2.5)-500-67°-3x (optical fiber) + SI-JET2-CON3 (control unit)

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

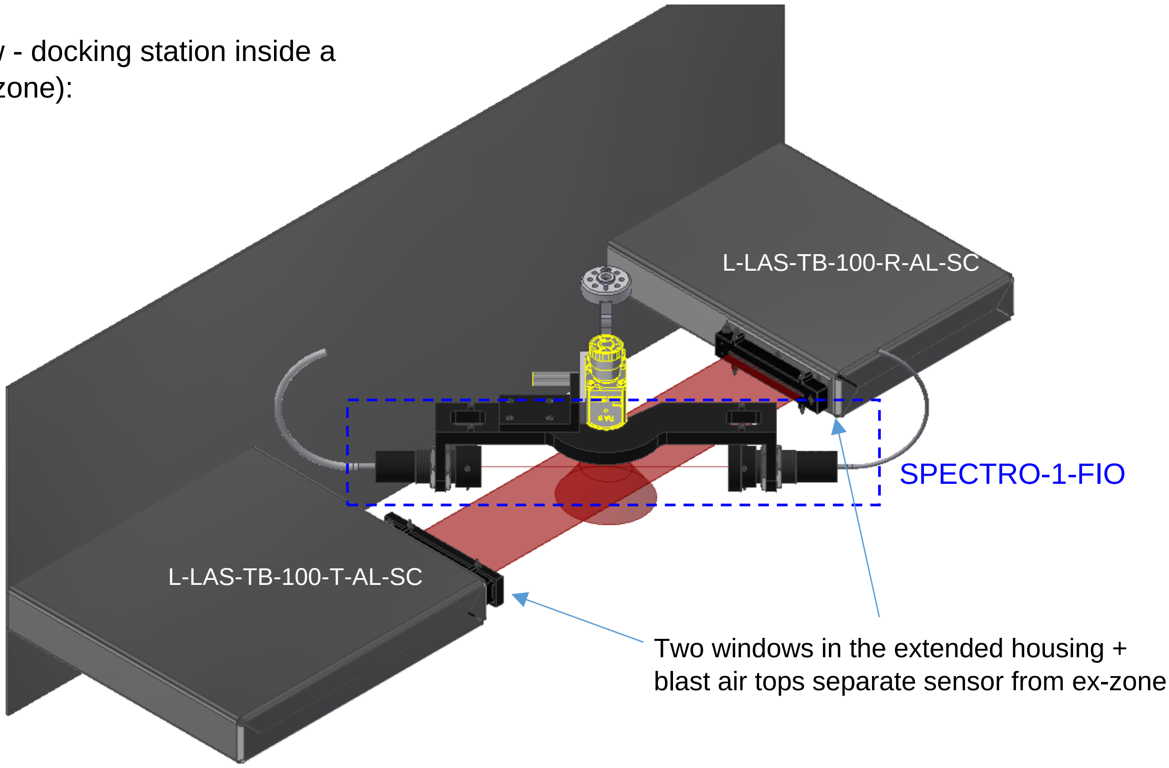
In this version the 3 beams also are arranged (centrally) at 5 mm with respect to each other, the red light beam has a diameter of 3 mm. With the help of the SI-JET-CON2 control unit a trend display of the spray jet parameters can be realized, e.g. in combination with a PLC.



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

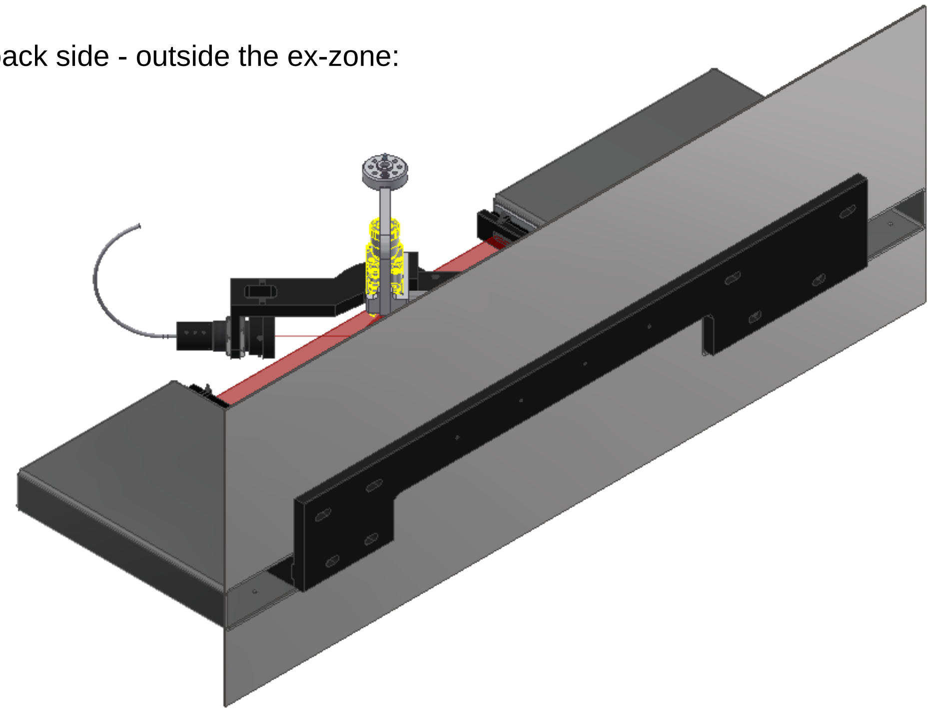
It is quite a challenge to integrate laser line systems (L-LAS) into an ex-zone, because you cannot use optical fiber. However, based on the application we also support our customers with designs that support an ex-zone operation.

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



The combined system comprises a single beam system with optical fiber (SPECTRO-1-FIO), 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 - outside the 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.

Contact:

Sensor Instruments
Entwicklungs- und Vertriebs GmbH
Schlinding 11
D-94169 Thurmansbang
Telephone +49 8544 9719-0
Fax +49 8544 9719-13
info@sensorinstruments.de