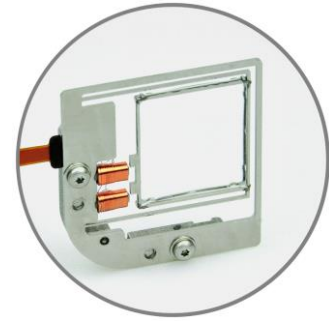


## Reluctance force-based LSR-4C for cinema projectors



A promising way to reduce speckle noise from a laser-based system is by dynamically diffusing the laser beam. Optotune's LSR-4C speckle reducer has an aperture of 18.5x18.5 mm and is especially suitable for laser-based cinema projectors where high laser powers and large beam diameters are used. The diffusor is mounted in a metallic frame. As part of a larger metallic structure the frame is set into motion by the reluctance force, generated by the oscillating magnetic field of a driving coil. If required, the LSR-4C can combine two oscillating diffusors rotated by 90°, realizing optimized despeckling in both directions. The compact driving electronics, assembled on a flexible plastic substrate, stabilizes the resonance frequency in closed-loop mode and includes an error signal.

### Mechanical specifications

Clear aperture	18.5 x 18.5	mm
External dimensions (WxHxD)	~40 x 40 x 6	mm
Weight LSR	11	g
Weight diffusor	0.29	g
Minimal weight for anchor mass	>300	g
Shock test	500	g

### Electrical specifications

Power supply (micro-USB or solder pads) <sup>1</sup>	3.4 - 5	VDC
Power consumption (with std. electronics)	50	mW

### Optical specifications

Diffusion angle (FWHM)	8.5° (up to 20° on request)	
Transmission wavelength	440 – 660 (coated), fused silica (uncoated)	nm
Transmission	> 98 (coated), > 94 (uncoated)	%
Material	Fused silica	
Coating	High power, double sided	
Damage threshold	> 600	W/cm <sup>2</sup>
Oscillation frequency	120 +/- 10	Hz
Scratch/dig <sup>2</sup>	60/40	
Oscillation amplitude (peak to peak) minimal / typical / max.	0.6 / 0.8 / 2.0	mm

### Thermal specifications

Storage temperature range	[-40,+85]	°C
Start-up temperature range	[-30,+85]	°C
Operating temperature range at fixed start-up temperature Ts <sup>3</sup>	[Ts-5,Ts+55]	°C

### Standard products

LSR-4C-L-18x18-9-T2-VIS	VIS coated
LSR-4C-L-18x18-9-T2-NC	uncoated

<sup>1</sup> 100-230 VAC to 5 VDC micro-USB power supply available

<sup>2</sup> Over full clear aperture of diffusor

<sup>3</sup> Outside this temperature range speckle reduction can decrease

## Speckle reduction

Figure 1 (a-c) shows the effect of speckle reduction of the LSR-4C on a laser beam. For all three situations, the intensity distribution and a horizontal line cut is shown. In a), the bare laser beam with a wavelength of 532 nm is shown. The speckle contrast  $S$  is 0.27. In b) the LSR is placed in the beam path but turned off. The divergence of the beam is increased due to the additional diffusion angle of the 8.5° standard diffusor. The speckle contrast remains almost constant at 0.26. Only when the LSR is turned on, the speckle contrast is significantly reduced by a factor  $> 4$  to 0.06, as one can see in c).

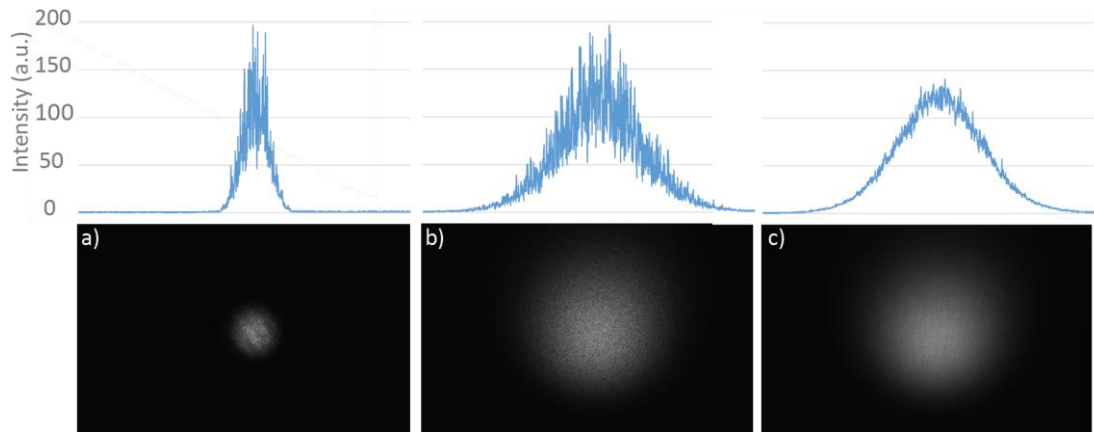


Figure 1: a) shows the intensity distribution of the bare laser beam with a wavelength of 532nm. The speckle contrast  $C$  is 0.27. In b) the LSR is placed in the beam path but turned off and the speckle contrast is 0.26. In c) the LSR is oscillating, reducing the speckle contrast to 0.06.

It is important to note that the effect of speckle reduction, quantified by the speckle contrast  $S$ , relates to several parameters and is system dependent. The quantity  $S$  is defined as the standard deviation from the mean intensity distribution hence a smaller value means less speckle. More information can be found in the general application note about speckle reduction. Optotune's test setup to measure the speckle reduction is presented in Figure 2.

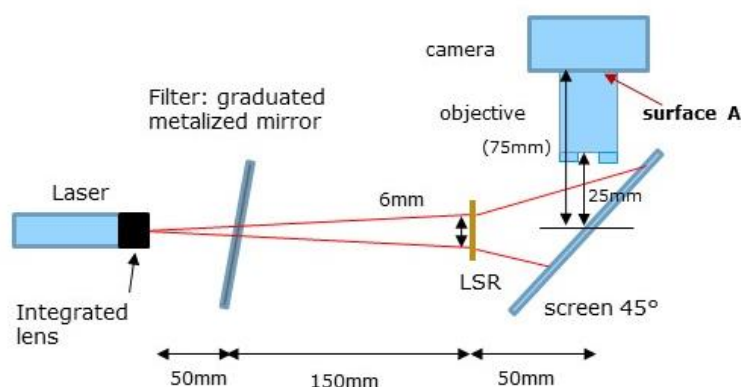


Figure 2: Outline of the speckle reduction test setup. The screen at 45° consists of a white, diffusive surface. The camera takes images of the intensity distribution present on the screen.

Optimal speckle reduction is guaranteed only within a certain temperature range. When the LSR is turned on, the resonance frequency and hence the oscillation amplitude is maintained within  $[T_s - 5^\circ\text{C}, T_s + 55^\circ\text{C}]$  where  $T_s$  is the start-up temperature. When the LSR is operated outside this temperature range, the performance might drop. Graphically, this is illustrated in Figure 3. The temperature at the point where the LSR is turned on is the

start-up temperature  $T_s$  with a maximal range of  $[-30^\circ\text{C}, +85^\circ\text{C}]$ . In the example,  $T_s = 25^\circ\text{C}$ . As a result, the allowed operating temperature range goes from  $25 - 5 = 20^\circ\text{C}$  up to  $25 + 55 = 80^\circ\text{C}$  as shown in Figure 3.

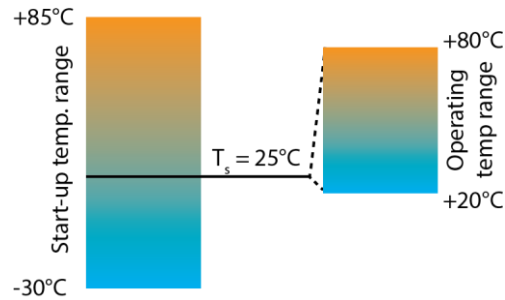


Figure 3: Graphical illustration of the final operating temperature range based on a start-up temperature of  $25^\circ\text{C}$ .

### Transmission

Figure 4 shows the transmission spectrum of the LSR-4C with the coated standard diffuser. The transmission stays above 98 % over the specified range of wavelengths from 440 to 660 nm.

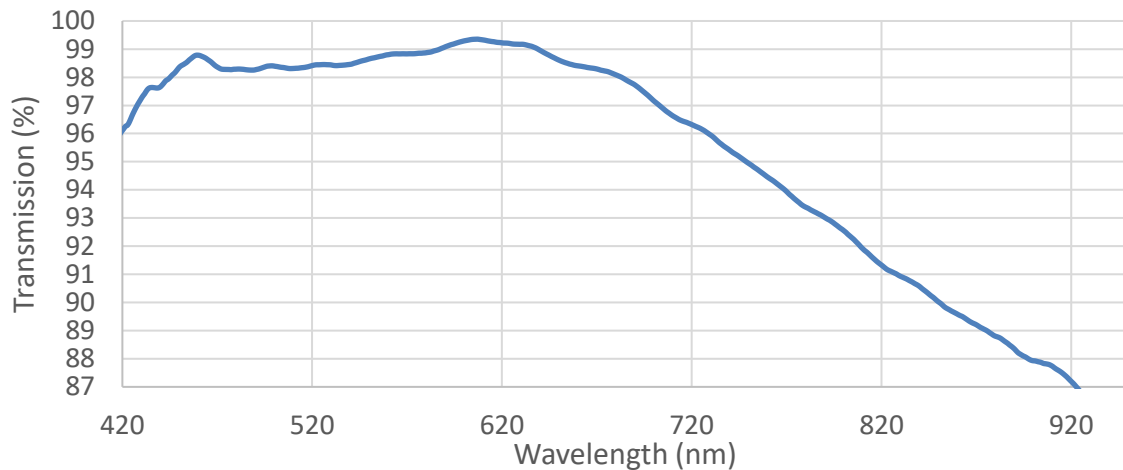


Figure 4: Transmission spectrum of the LSR-4C with the coated standard diffuser.

Figure 5 shows the transmission spectrum of the LSR-4C with the uncoated standard diffuser.

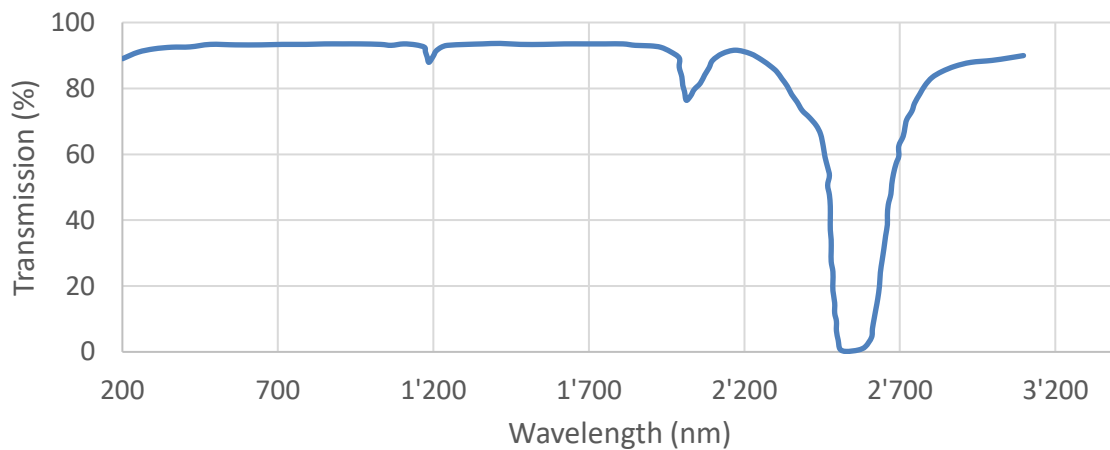


Figure 5: Transmission spectrum of the LSR-4C with the uncoated standard diffuser.

## Mechanical drawing

The outer dimensions of the LSR-4C are very compact. The steel frame is 37.9 x 35.2 mm and the whole device has a thickness of less than 6 mm. Figure 6 shows the mechanical drawing of the LSR-4C, together with the flex electronics which is attached to the LSR.

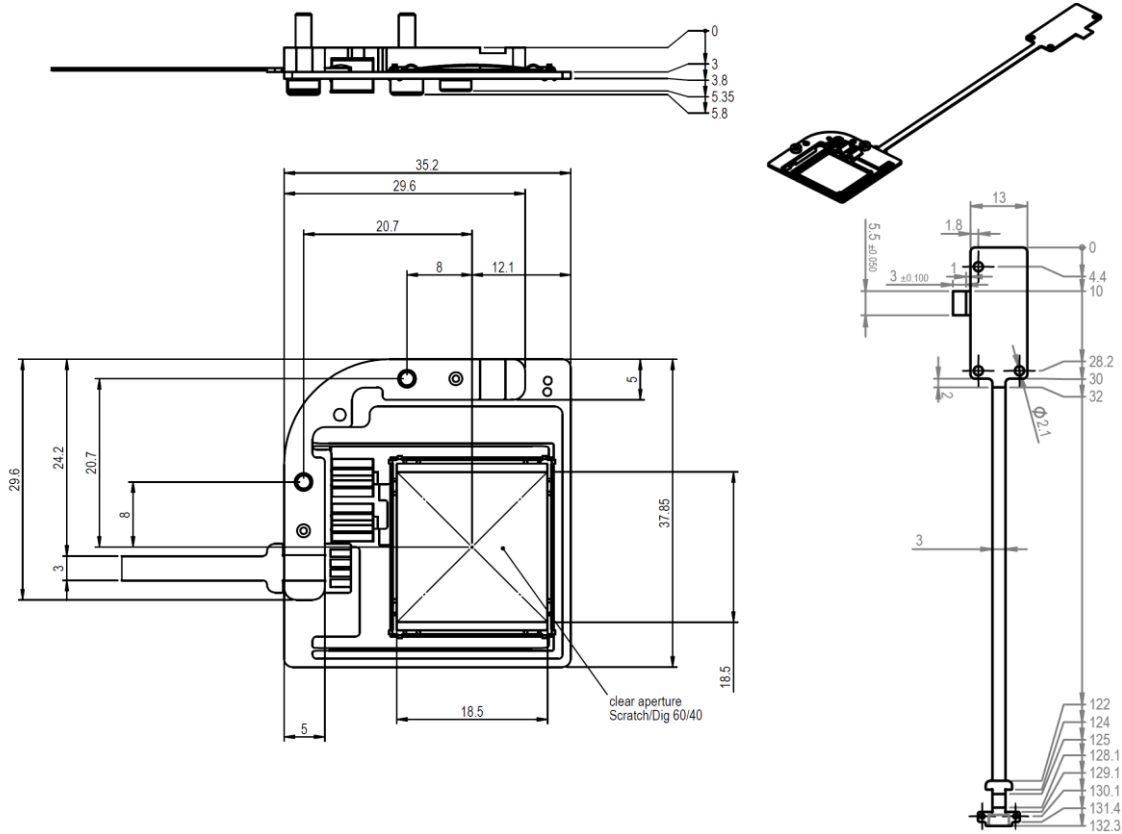


Figure 6: Mechanical drawing of the LSR-4C (left) and the outer dimensions of the flex electronics (right). The units are in mm.

## Electrical schematic

The connection to the LSR-4C is straight forward. A micro USB is available to provide 5V supply voltage. Instead of using the USB connector, the LSR-OEM can be directly driven by a voltage source using the GND and V<sub>cc</sub> (3.4V to 5V) soldering pad (see Figure 7).

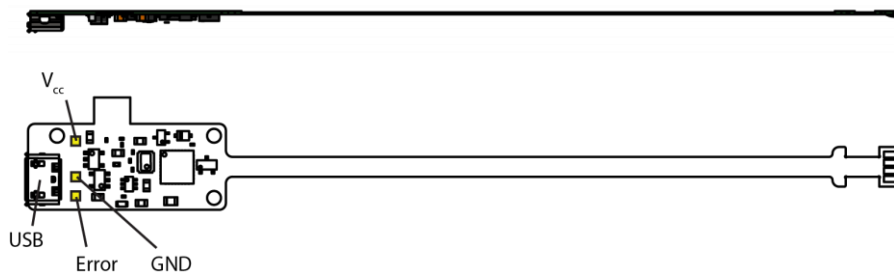


Figure 7: Pinout of the flex electronic. Power can be supplied via the micro USB connector or the soldering pads.

For visual indication, there is an LED on the flex electronics that lights up when the LSR is working stable and is turned off otherwise. The same signal is given to the Error pin. If the LSR is not working stable (oscillation amplitude is not within a certain range) the error signal switch to “high”.

For stable working the signal is “low”. The error signal is realized as an open collector.

### Mechanical mounting

In order to guarantee highest performance and maximum oscillation amplitude it is recommended to mount the LSR onto a rigid mechanical holder. For that purpose, two mounting holes for M2 screws are available.

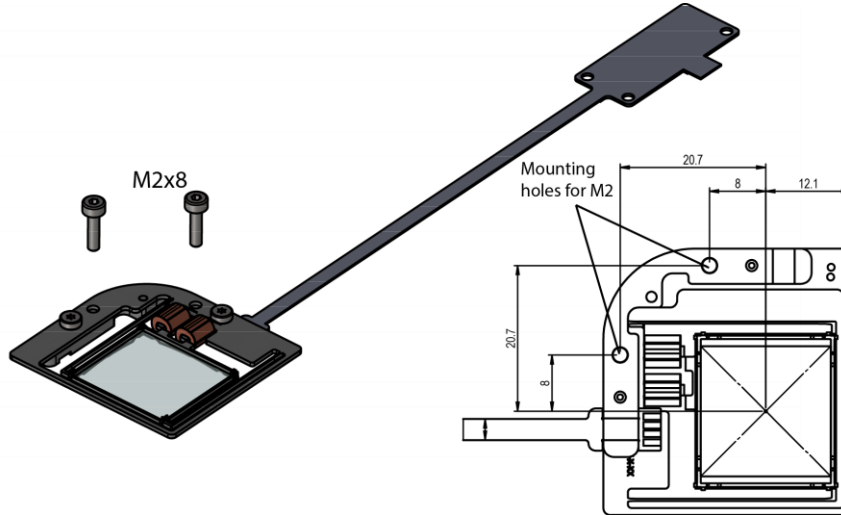


Figure 8: The mounting of the LSR frame is possible with two M2 screws.

Additionally, Optotune offers a mechanical holder (bracket) made of brass that allows for mounting the LSR into an existing setup. By that, rigid mechanical integration is guaranteed. It further allows for mounting two crossed LSR-4C (rotated by 90°) in order to have even higher speckle reduction if required. The holder is not part of the LSR-4C standard package and has to be ordered separately. Please contact [sales@optotune.com](mailto:sales@optotune.com) for further questions.

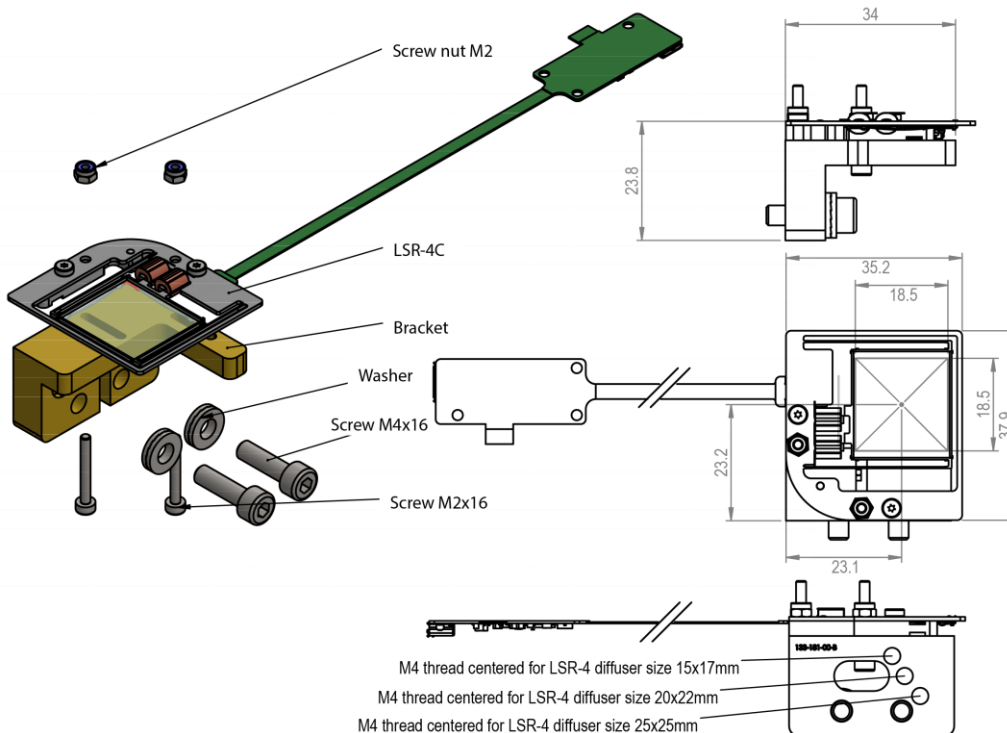


Figure 9: Mechanical layout of the bracket. The LSR-4C is mounted onto the bracket which can then be mounted into an existing setup. The weight of the bracket is 43 g.

## Reliability tests

Several reliability tests have been performed and passed. Further lifetime tests are ongoing. The following tests are passed.

### High temperature (non-operating):

- Test temperature:  $85^{\circ}\text{C} \pm 2^{\circ}\text{C}$
- Test duration: 16 hours
- Relative humidity 5%
- Pass criteria: LSR shows full function after the test. Oscillation amplitude change of all LSRs  $<11\%$

### Low temperature (non-operating):

- Test temperature:  $-40^{\circ}\text{C} \pm 3^{\circ}\text{C}$
- Test duration: 16 hours
- Relative humidity 50%
- Pass criteria: LSR shows full function after the test. Oscillation amplitude change of all LSRs  $<11\%$

### Condition of use – Low and high temperature\* (operating):

- Low temperature:  $-30^{\circ}\text{C}$
- High temperature:  $+85^{\circ}\text{C}$
- Test duration: 30 min for each low and high temperature
- Recovery time: No recovery time
- Pass criteria: LSR shows full function during the test

\*LSR is restarted at the set temperature

### Shock Test:

- G-value: 500g 1mS Duration
- Number of drops: 5 pulses in each of the orientations X1 X2, Y1 Y2, Z1 Z2. 30 pulses in all. Test equipment: Suitable Shock Tower or equivalent
- Reference: JESD22 B104-A/B

### Damp heat cycling (operating):

- Low temperature:  $+25^{\circ}\text{C}$ , high temperature:  $+55^{\circ}\text{C}$
- Test humidity: 92-95% relative humidity
- Test duration: 2 hours dwell
- Temperature change rate: Less than  $1^{\circ}\text{C}$  per minute
- Number of cycles: 5 cycles
- Recovery time: No recovery time
- References: IEC 60068-2-30 Db amended
- Pass criteria: LSR shows full function during the test

### Operating lifetime test (ongoing):

- Test temperature:  $25^{\circ}\text{C} \pm 5^{\circ}\text{C}$
- 40'000 hours accomplished
- Driving frequency:  $\sim 120$  Hz

Table 1: Environmental and lifetime tests performed with the LSR-4C.

## Custom products

Optotune offers customized versions of the LSR. For stronger speckle reduction a custom version with two diffusers is available. The diffusers are 90° rotated with respect to each other and can be mounted on the holder presented in this datasheet.

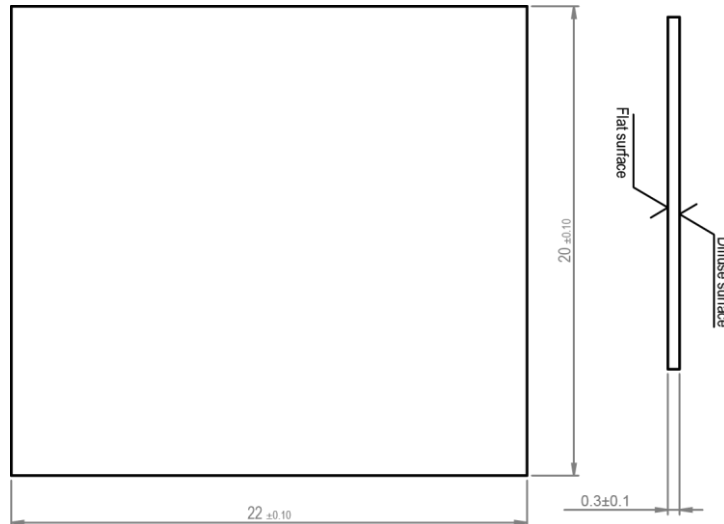
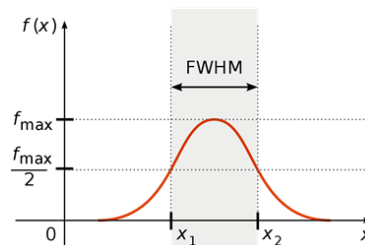


Figure 10: Outer dimensions of the diffuser that can be integrated into the LSR-4C frame as a custom product.

Diffusers with different diffusion angle can be used and special coatings are available on request. However, the diffuser needs to have the mass within -6 to +16% to the standard diffuser.

The diffuser angle is defined as full width half maximum (FWHM).



The required outer dimensions and tolerances are shown in Figure 10. For further information, please contact [sales@optotune.com](mailto:sales@optotune.com).

## Safety and compliance

The product fulfills the RoHS and REACH compliance standards. The product is delivered without housing. The customer is solely responsible to comply with all relevant safety regulations for integration and operation.

For more information on optical, mechanical and electrical parameters, please contact [sales@optotune.com](mailto:sales@optotune.com).