Test Report issued under the responsibility of:

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SWEDEN

TEST REPORT
IEC 60825-1
Safety of laser products -
Part 1: Equipment classification and requirements

Report Number. .....:	105105-146043-1
Date of issue .....:	20 August 2021
Total number of pages.....:	20
Name of Testing Laboratory preparing the Report.....:	RISE Research Institutes of Sweden AB
Applicant's name.....:	ArtEffect SAS
Address .....:	104 avenue de la Résistance 93100 Montreuil FRANCE
Test specification:	
Standard.....:	IEC 60825-1:2014 (Third Edition)
Test procedure .....:	CB Scheme
Non-standard test method .....:	N/A
Test Report Form No.....:	IEC60825_1E
Test Report Form(s) Originator ....:	ÖVE
Master TRF .....:	Dated 2014-07

If this Test Report Form is used by non-IECEE members, the IECEE/IEC logo and the reference to the CB Scheme procedure shall be removed.

This report is not valid as a CB Test Report unless signed by an approved CB Testing Laboratory and appended to a CB Test Certificate issued by an NCB in accordance with IECEE 02.

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The test results presented in this report relate only to the object tested.

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Test item description .....:	Laser scanner for entertainment IVL lighting
Trade Mark .....:	Minuit Une
Manufacturer.....:	ArtEffect SAS 104 avenue de la Résistance 93100 Montreuil FRANCE
Model/Type reference .....:	IVL™ Photon
Ratings .....:	Supply: 100 – 240 VAC, 50/60 Hz, 200 W

Responsible Testing Laboratory (as applicable), testing procedure and testing location(s):			
☒	**CB Testing Laboratory:**		
Testing location/ address .....:		**RISE Research Institutes of Sweden** Box 857 SE-501 15 Borås SWEDEN	
Tested by (name, function, signature) .....:		 Signed by: Mikael Lindgren Reason: I am the author of this document Date & Time: 2021-08-23 13:27:04 +02:00	
Approved by (name, function, signature)...:		 Signed by: Stefan Källberg Reason: I have reviewed this document Date & Time: 2021-08-23 17:39:44 +02:00	
☐	**Associated CB Testing Laboratory:**	N/A	
Testing location/ address .....:			
Tested by (name, function, signature) .....:			
Approved by (name, function, signature)...:			
☐	**Testing procedure: TMP/CTF Stage 1:**	N/A	
Testing location/ address .....:			
Tested by (name, function, signature) .....:			
Approved by (name, function, signature)...:			
☐	**Testing procedure: WMT/CTF Stage 2:**	N/A	
Testing location/ address .....:			
Tested by (name, function, signature) .....:			
Witnessed by (name, function, signature)..:			
Approved by (name, function, signature)...:			
☐	**Testing procedure:** **SMT/CTF Stage 3 or 4:**	N/A	
Testing location/ address .....:			
Tested by (name, function, signature) .....:			
Witnessed by (name, function, signature)..:			
Approved by (name, function, signature)...:			
Supervised by (name, function, signature) :			

List of Attachments (including a total number of pages in each attachment):

None

Summary of testing:

The device MinuitUne IVL™ Photon is classified as “Class 3R Laser Product”.

Tests performed (name of test and test clause):	**Testing location:**
Testing was performed according to IEC 60825-1:2014	See page 3

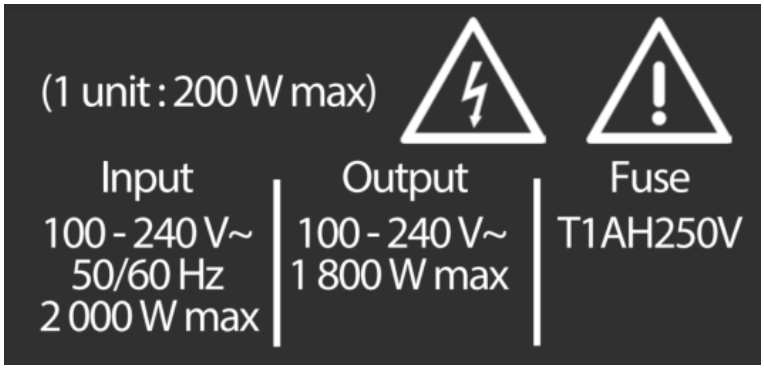
Summary of compliance with National Differences:

List of countries addressed

Not applicable

Copy of marking plate:

Marking on product



MinuitUne IVL™ Photon Marking plate

Print color: White

Background color: Black

Size: 115 × 28 mm

Test item particulars .....:	The test item was received in good working order. One unit was used during testing.
Classification of installation and use .....:	Laser class 3R during normal use.
Supply Connection.....:	Input: 100 – 240 V *ac*, 50/60 Hz Output: 100 – 240 V *ac*
Possible test case verdicts:	
- test case does not apply to the test object..... :	N/A
- clause contains no requirement ..... :	N/R
- test object does meet the requirement ..... :	P (Pass)
- test object does not meet the requirement..... :	F (Fail)
Testing:	
Date of receipt of test item ..... :	17 May 2021
Date (s) of performance of tests..... :	May 2021

General remarks:

The test results presented in this report relate only to the object tested.

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"(See Enclosure #)" refers to additional information appended to the report.

"(See appended table)" refers to a table appended to the report.

Throughout this report a ☒ comma / ☐ point is used as the decimal separator.

Manufacturer's Declaration per sub-clause 4.2.5 of IECEE 02:

The application for obtaining a CB Test Certificate includes more than one factory location and a declaration from the Manufacturer stating that the sample(s) submitted for evaluation is (are) representative of the products from each factory has been provided.....:	☐ **Yes** ☒ **Not applicable**

When differences exist; they shall be identified in the General product information section.

Name and address of factory (ies) .....:	SOREAM Centre d'activités Pasteur 150 bd Pasteur 13730 Saint-Victoret FRANCE

General product information:

The MinuitUne IVL™ Photon laser product is a laser scanner for entertainment purposes and the intended use is on stage for professional shows. The product emits scanning red, green, and blue beams which are overlaid to create any choice of colour. The scanned beams are reflected by DMX-controllable mirrors or a central diffuser.

IEC 60825-1			
Clause	Requirement + Test	Result - Remark	Verdict
4	**CLASSIFICATION PRINCIPLES**		
4.3	Classification rules		---
4.3 a	Radiation of a single wavelength		N/A
4.3 b	Radiation of multiple wavelengths		---
	1) Laser product emits at two or more wavelengths shown as additive in Table 1	The product emits three wavelengths shown as additive	P
	2) Laser product emits at two or more wavelengths not shown as additive in Table 1	The product does not emit wavelengths shown as non-additive	N/A
4.3 c	Radiation from extended sources (see 5.4.3)	The product's laser sources are treated as both point sources and extended sources; see section on measured laser radiation.	P
4.3 d	Non-uniform, non-circular or multiple apparent source	The product's laser sources are uniform, circular and single apparent source; see section on measured laser radiation.	N/A
4.3 e	Time bases		---
	1) 0,25 s		P
	2) 100 s		N/A
	3) 30000 s		N/A
4.3 f	Repetitively pulsed or modulated lasers		---
	1) Any single pulse	See section on measured laser radiation	P
	2) Average power for pulse trains	See section on measured laser radiation	P
	3) Pulse duration $t \leq T_i$ ..... : Number of pulses N and C_5 ..... :	See section on measured laser radiation	P
	3) Pulse duration $t > T_i$ ..... : Number of pulses N and C_5 ..... :	See section on measured laser radiation	P
4.4	Laser products designed to function as conventional lamps.		N/A
	α measured at 200 mm distance from closest point of human access (α > 5 mrad).		N/A
	Un-weighted radiance L measured at 200 mm distance (comparison with $L_T = 1\ MWm^{-2}sr^{-1}/\alpha$) under reasonably foreseeable single fault conditions.		N/A

IEC 60825-1			
Clause	Requirement + Test	Result - Remark	Verdict
	Evaluation of emission according to IEC 62471 series (optional): Standard applied (IEC 62471 series)…….. .... : Risk Group…….……..... : Labelling…….. : Classification of product based on accessible laser radiation (if no laser radiation accessible: Class 1).		N/A

IEC 60825-1			
Clause	Requirement + Test	Result - Remark	Verdict
5	**DETERMINATION OF THE ACCESSIBLE EMISSION LEVEL and PRODUCT CLASSIFICATION**		
5.1	Tests		---
	Compliance under reasonably foreseeable single fault conditions.	See section on single fault conditions	P
5.3	Determination of the class of the laser product ... : For Class 1C: vertical safety standard applied with requirements for Class 1C.	Class 3R Laser	---
5.4	Measurement geometry		---
5.4.1	General		---
5.4.2	Default (simplified) evaluation		---
	Conditions applied ..... :	3	N/R
	Aperture diameter ..... :	7,0 mm	N/R
	Reference point : ..... :	Scanning vertex	N/R
	Measurement distance ..... : (for each condition)	Condition 3 closest point of human access; 257 mm from scanning vertex t_p = 5 µs: 762 mm from scanning vertex C_6 = 1: 9330 mm from scanning vertex	N/R
5.4.3	Evaluation condition for extended sources		---
	Conditions applied ..... :	3	N/R
	Most restrictive position ..... : (distance from reference point)	See section on calculations for classification	N/R
	Angular subtense of the apparent source α and C_6: (for each condition)	See section on calculations for classification	N/R
5.4.3 a	Aperture diameters (for each condition). ..... :	7,0 mm	N/R
5.4.3 b	Angle of acceptance (for each condition)……..:	See section on calculations for classification	N/R

IEC 60825-1			
Clause	Requirement + Test	Result - Remark	Verdict
6	**ENGINEERING SPECIFICATIONS**		
6.2	Protective housing		---
6.2.1	General		---
	Protective housing prevents access to energy levels in excess of the AEL for Class 1.	The housing prevents access to radiation in excess of class 1, except for the performance of the function of the product.	P
	Protective housing prevents access to energy levels equivalent to Class 4 and withstands exposures under reasonably foreseeable single fault conditions.	The housing is judged to withstand exposures.	P
	Maintenance of Class 1, 1C, 1M, 2, 2M, or 3R (access to emissions of Class 3B or 4 is prevented).	No maintenance which permits access to radiation of class 3B or 4 is required.	P
	Maintenance of Class 3B product (access to emission of Class 4 is prevented).		N/A
6.2.2	Service	The product is not serviceable by the user.	N/A
6.2.3	Removable laser system (laser system complies with requirements of Clauses 6 and 7).	The product does not contain a removable laser.	N/A
6.3	Access panels and safety interlocks		---
6.3.1	Panel is intended to be removed during operation (or maintenance) and would give access to higher energy levels (see Table 13).	The product does not have a removable panel.	N/A
	Accessible emission (after removal of the panel) corresponds to product Class (designated by “X” in Table 13)		N/A
	Emission through the opening if interlocked panel of Class 1, 1C, 1M, 2, or 2M is removed (Emission < AEL of Class 1M or 2M).		N/A
	Emission through the opening if interlocked panel of Class 3R, 3B, or 4 is removed (Emission < AEL of Class 3R).		N/A
	Requirements regarding reasonably foreseeable single fault condition.		N/A
6.3.2	Override mechanism	The product does not have an override mechanism	N/A
	Behaviour of override in operation when the panel is replaced.		N/A
	Visible or audible warning for override mode.		N/A
6.4	Remote interlock connector	Not required for Class 3R	N/A
6.5	Manual reset	Not required for Class 3R	N/A

IEC 60825-1			
Clause	Requirement + Test	Result - Remark	Verdict
6.6	Key control	Not required for Class 3R	N/A
6.7	Laser radiation emission warning		---
6.7.1	Laser product is a 3R (λ<400 nm; λ>700 nm), 1C, 3B or 4 laser systems.		N/R
6.7.2	Audible or visible warning.	Not required for this product configuration	N/A
	Warning is failsafe or redundant.	Not required for this product configuration	N/A
	Viewing of the visible warning does not require exposure to emissions > AEL for Class 1M and 2M.	Not required for this product configuration	N/A
6.7.3	Operational control and laser aperture are provided with a warning device when they are separated more than 2 m from warning device.		N/A
6.7.4	Visible indication of output aperture if laser emission may be distributed through more than one output.	Not required for this product configuration	N/A
6.7.5	Switch for handheld Class 3R device must be depressed for emission (in lieu of emission indicator).	Not required for this product configuration	N/A
6.8	Beam stop or attenuator	Not required for Class 3R	N/A
6.9	Controls	The control is through remote computer (DMX)	P
6.10	Viewing optics	The product does not have a viewing optics	N/A
	a) Human access to laser radiation in excess of Class 1M prevented when the shutter is opened or attenuation varied.		N/A
	b) Opening of the shutter or variation of the attenuation prevented when exposure to laser radiation in excess of Class 1M is possible.		N/A
6.11	Scanning safeguard	The product has protection against scan failure by two independent means, see section on scanning safeguard.	P
6.12	Safeguard for Class 1C products	Not required for Class 3R	N/A
	a) Human access to laser radiation in excess of AEL for Class 1 measured under Condition 3 is prevented.		N/A
	b) Human access to laser radiation in excess of AEL for Class 3B measured through 3,5 mm aperture at 5 mm distance from applicator is prevented.		N/A
6.13	Walk-in access		---

IEC 60825-1			
Clause	Requirement + Test	Result - Remark	Verdict
	a) Means provided so that any person inside the housing can prevent activation of Class 3B or 4 laser hazards.	The product does not have walk-in access	N/A
	b) A warning device provides adequate warning of emission to any person within the housing.	The product does not have walk-in access	N/A
	c) Where “walk-in” access during operation is intended or reasonably foreseeable, emission of laser radiation that is equivalent to Class 3B or 4 while someone is present inside the enclosure of Class 1, Class 2 or Class 3R product is prevented by engineering means.	The product does not have walk-in access	N/A
6.14	Environmental conditions		---
	- climatic conditions	See section on climatic testing.	P
	- vibration and shock	Not tested	N/A
6.15	Protection against other hazards		---
6.15.1	Non-optical hazards (product safety standard)	Not tested	N/A
	- electrical hazards;	Not tested	N/A
	- excessive temperature;	Not tested	N/A
	- spread of fire from the equipment;	Not tested	N/A
	- sound and ultrasonics;	Not tested	N/A
	- harmful substances;	Not tested	N/A
	- explosion;	Not tested	N/A
6.15.2	Collateral radiation	No hazardous collateral radiation was detected	N/A
6.16	Power limiting circuit	The product uses a driver circuit limited to a maximum drive current and voltage, see section on single fault conditions	P

IEC 60825-1			
Clause	Requirement + Test	Result - Remark	Verdict
7	**LABELLING**		
7.1	General		---
	Labels durable, permanently affixed	The label is affixed to the product.	P
	Labels clearly visible	The label is affixed to the product.	P
	Reading of labels is possible without exposure to laser radiation in excess of AEL for Class 1.	The label can be read without exposure	P
	Colour combination	The label uses black text on yellow background 	P
	Labelling impractical due to the size or design of the product.		N/A
	Warning label – Hazard symbol (Figure 3)	The label uses a black figure on yellow background 	P
7.2 - 7.7	Text on explanatory label or pictogram (laser class, warning text)	LASER LIGHT AVOID DIRECT EYE EXPOSURE CLASS 3R LASER PRODUCT	P
7.8	Aperture label		P
7.9	Radiation output and standards information	Laser standard and radiation output stated on the label	P
	Max output of laser radiation ..... :	Radiation output stated on the label	---
	Pulse energy ..... :	17,4 µJ	---
	Pulse duration ..... :	14,8 µs	---
	Emitted wavelength(s) ..... :	λ_R = 638 nm λ_G = 520 nm λ_B = 450 nm	---
	Name and publication date of the standard..... :	EN IEC 60825-1:2014	---
7.10	Labels for access panels		---

IEC 60825-1			
Clause	Requirement + Test	Result - Remark	Verdict
7.10.1 a) – f)	Labels for panels - warning wording used ..... :		N/A
7.10.2	Labels for safety interlocked panels - Warning wording used ..... :		N/A
7.11	Warning for invisible laser radiation ..... :		N/A
7.12	Warning for visible laser radiation ..... :		N/A
7.13	Warning for potential hazard to the skin or anterior parts of the eye - warning wording used..... :		N/A

IEC 60825-1			
Clause	Requirement + Test	Result - Remark	Verdict
8	**OTHER INFORMATIONAL REQUIREMENTS**		
8.1	Information for the user		---
	a) adequate instructions for assembly, maintenance and safe use and description of the classification limitations, if appropriate.	MinuitUne IVL™ Photon User's Manual, Rev: V7	P
	b) additional warning for Class 1M and 2M		N/A
	c) laser beam parameters for radiation above the AEL of Class 1		---
	• Wavelength ..... :	User's Manual	P
	• Beam divergence ..... :	User's Manual	P
	• Pulse pattern ..... : (pulse duration, repetition rate, …)	User's Manual	P
	• Maximum power or energy output ..... :	User's Manual	P
	d) safety instruction for embedded laser products and other incorporated laser products.	Not accessible for the user	P
	e) MPE and NOHD for Class 3B and 4 laser products; For collimated beam Class 1M and 2M lasers the extended NOHD (ENOHD).	Not required for Class 3R	N/A
	f) information for the selection of eye protection.	User's Manual	P
	g) reproduction of all required labels and warnings.	User's Manual	P
	h) location of laser apertures	User's Manual	P
	i) list of controls, adjustments of procedures for operation and maintenance - and warning statement.	User's Manual	P
	j) information (compatibility requirements) about laser energy source if not incorporated.		N/A
	k) additional warning for Class 1, 1M, 2, 2M, and 3R regarding skin or corneal burns.	No risk of skin or corneal burns	N/A
	l) Information for Class 1C products (e.g. warning that repeated application may pose a risk).		N/A
8.2	Purchasing and service information	Not tested	---
	a) safety classification of each laser product stated in all descriptive material (e.g. brochures).		N/A

IEC 60825-1			
Clause	Requirement + Test	Result - Remark	Verdict
	b) adequate instructions for servicing available: • warnings and precautions regarding exposure of laser emission above Class 1 • maintenance schedule • list of controls and procedures that could increase accessible emissions • description of displaceable parts • protective procedures for service personnel • reproduction of labels and hazard warnings		N/A

IEC 60825-1			
Clause	Requirement + Test	Result - Remark	Verdict
9	**ADDITIONAL REQUIREMENTS FOR SPECIFIC LASER PRODUCTS**		
9.1	Applicable other parts of the standard series IEC 60825		---
	IEC 60825-2 (Safety of optical communication systems)		N/A
	IEC 60825-4 (Laser guards)		N/A
	IEC 60825-12 (Safety of free space optical communication systems used for transmission of information)		N/A
	EN IEC 62471 (Photobiological safety of lamps and lamp systems)		N/A
9.2	Medical laser products: Class 3B and Class 4 medical laser products comply with IEC 60601-2-22		N/A
9.3	Laser processing machines: Comply with IEC/ISO 11553 series.		N/A
9.4	Electric toys: Comply with IEC 62115		N/A
9.5	Consumer electronic products: Comply with IEC 60950 (IT-equipment) or IEC 60065 (AV equipment)		N/A

Measured accessible laser radiation and comparison with AEL:

The scanning laser radiation from the MinuitUne IVL™ Photon is emitted via folding mirrors into eight independent scanning lines.

The scanning frequency is fixed at 335 Hz. The scanning motion means the resulting pulse width decreases with distance to the product. The divergence also results in decreasing power through a 7-mm aperture as the distance increases.

The product, shown in Figure 1, contains three individual lasers emitting *cw* radiation, Red (R), Green (G), and Blue (B). The beams are collinear and additive in terms of laser safety, why measurements have been performed on White (W) radiation only – corresponding to maximum output of the three channels. The power from each laser can be individually controlled via the DMX interface. The beam is 14,0 mm in diameter at the scanning vertex and its divergence is 1,7 mrad. The distance from the surface to the scanning vertex is 257 mm (closest point of human access).

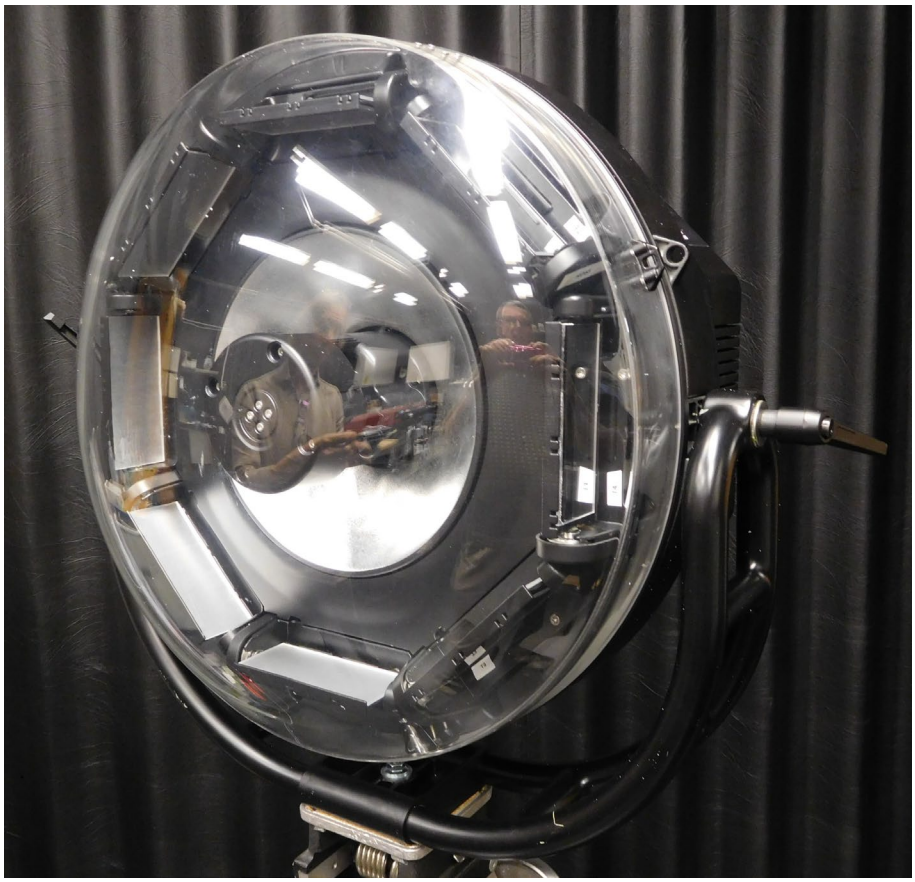

Figure 1. The laser beam is emitted from the central rotating element and directed through the clear enclosure lid.

The wavelengths of the radiation were measured to λ_R = 637 nm, λ_G = 520 nm, λ_B = 447 nm, see Figure 2.

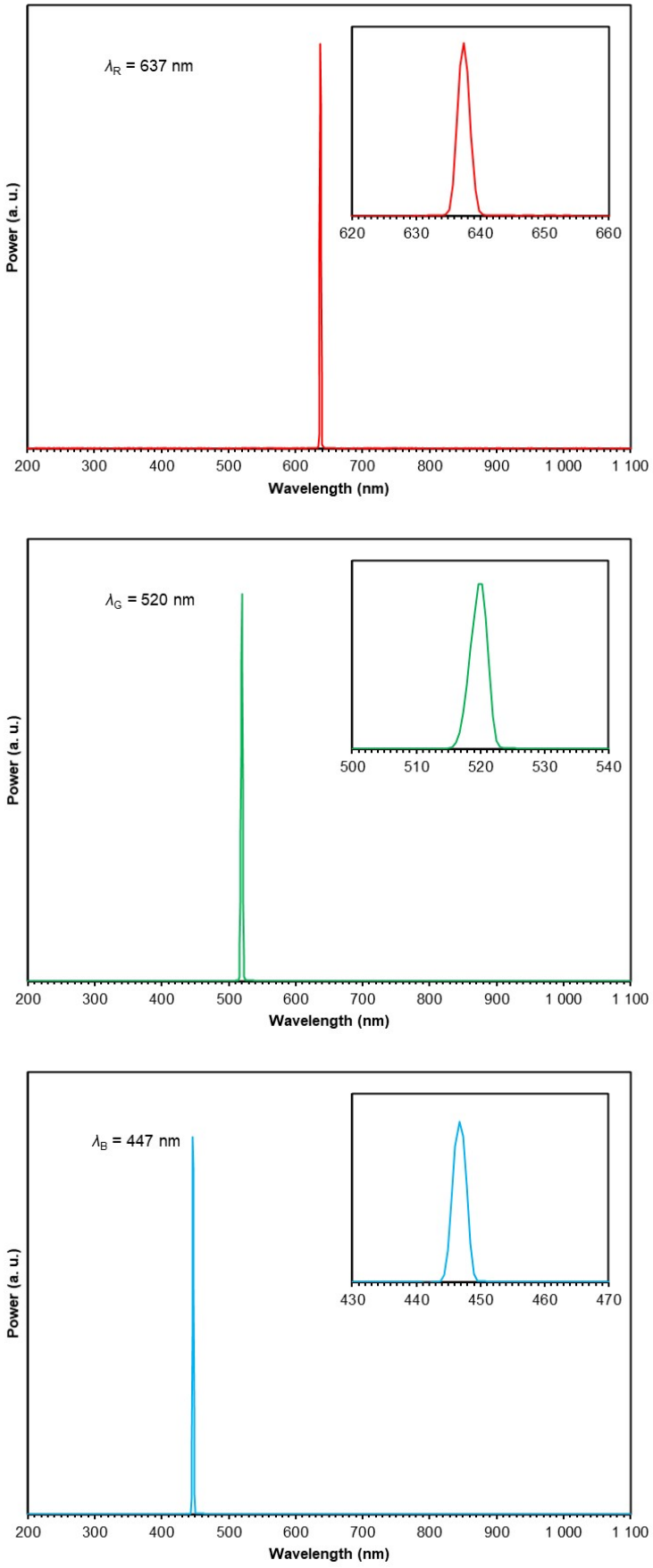

Figure 2. Spectral measurements.

The repetition period for the scanning is T_p = 2,98 ms (f_{rot} = 335 Hz), see Figure 3.

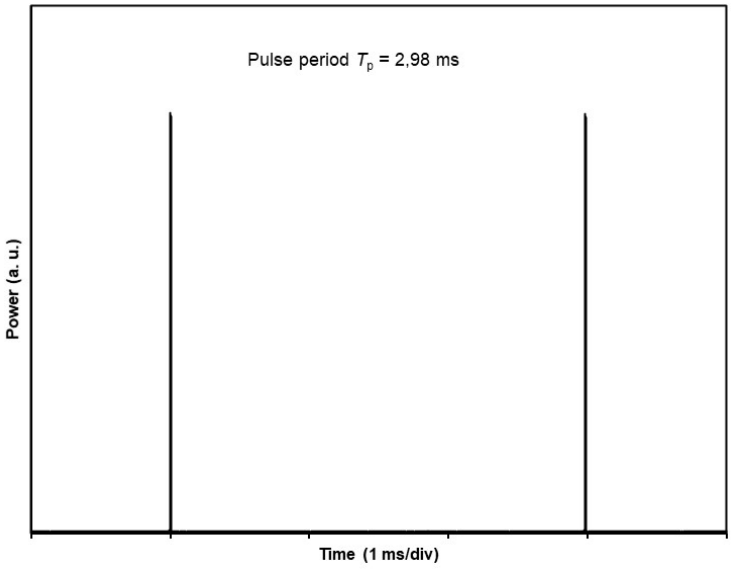

Figure 3. The pulse pattern of the laser radiation due to the scanning motion. The perceived pulse width depends on the distance from scanning vertex.

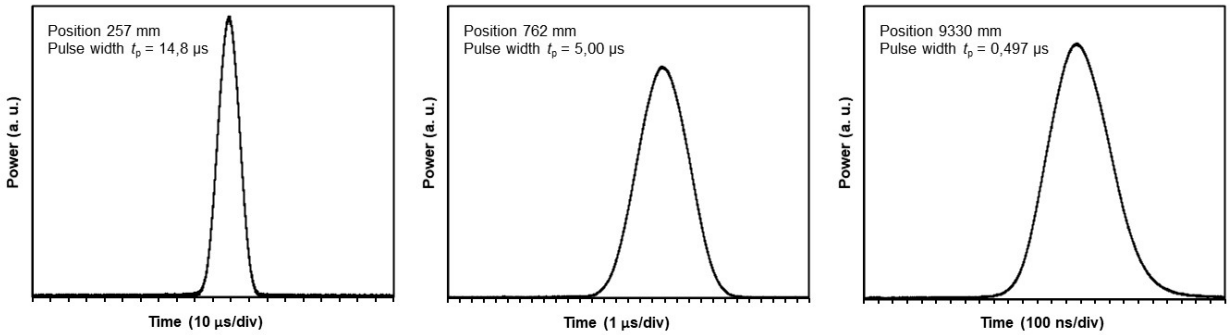

Figure 4. The measured pulse widths at different characteristic positions.

Test of environmental conditions:

Equipment temperature limits and resistance to heat. The following tests from EN 61010-1, section 10 and IEC 60825-1, section 6.14 have been assessed:

Extreme temperatures

The product was exposed to extreme temperatures in accordance with the Manufacturer's instructions.

Measurement condition	**Measurement result**		
Temperature	T = +5 °C	T = +22 °C	T = +35 °C
Output power	96 %	100 %	77 %

The power does not increase when the temperature changes, room temperature measurements have been used for classification.

Measurements for classification:

The measurement results are shown in Figure 4 and summarized in Table 1.

Table 1. Summary of measurement results.

MinuitUne IVL™ Photon				
Position (mm)	**Beam characteristics**	**t_p (µs)**	**Average power (µW)**	**Pulse energy (µJ)**
257	Diverging	14,8	5830	17,4
762	Diverging	5,00	1690	5,05
9330	Diverging	0,497	107	0,32
Beam profile				
Diameter (1/e)		14 mm		
Divergence		1,7 mrad		

For determining the AEL for Class 3R, the method described in IEC/TR 60825-13:2011 has been used. The disposition and terms of example A.2.1 have been followed. In addition, the method described in document *Comments on the application of ICNIRP laser exposure limits*, K. Schulmeister, D.H. Sliney, and B.E. Stuck, Fachverband für Strahlenschutz 50. FS-Jahrestagung NIR 2018, Dresden (2018) has been used to evaluate the angular subtense of the apparent source for scanned radiation.

Calculations for classification:

The three lasers all fall within the same wavelength range (400 – 700 nm) for classification, so the result for W can be used as the worst case. The AEL for class 3R using time base 0,25 s is calculated for four different cases.

1) The eye is focused on the scanning element and the *AEL* is calculated at the closest point of human access (286 mm). Radiation will form a spot on the retina.

   The beam diameter was measured to

$$d_{\mathrm{nscan}} = d_{\mathrm{scan}} = 14{,}0\ \mathrm{mm}$$

   The angular subtense of the apparent source is

$$\alpha = \frac{14{,}0}{257} = 54{,}5\ \mathrm{mrad}$$

   The maximum angular subtense is

$$\alpha_{\max} = 5\ \mathrm{mrad; for}\ t < 625\ \mu s$$

   The angle of acceptance *γ* shall be limited to $\alpha_{\max}$, which gives a correction factor κ for C_6 equal to

$$\kappa = \frac{\alpha^2}{{\alpha_{\max}}^2}$$

   The factor C_6 is

$$C_6 = \kappa \frac{\alpha_{\max}}{\alpha_{\min}} = \frac{\alpha^2}{\alpha_{\min} \cdot \alpha_{\max}} = \frac{54{,}5^2}{5 \cdot 1{,}5} = 396$$

For a single pulse:

$$AEL_{1nE} = 3{,}5 \cdot 10^{-3} \cdot (14{,}8 \cdot 10^{-6})^{0{,}75} \cdot 396 = 331\ \mu J$$

For a pulse train, average power over the emission duration (T = 0,25 s):

$$AEL_{2nT} = 5{,}0 \cdot 10^{-3} \cdot 396 = 1{,}98\ W$$

The pulse width was measured to t_p = 14,8 µs, >5 µs. The repetition rate was measured to 335 Hz. The breakpoint T_2 is

$$T_2 = 10 \cdot 10^{\frac{54{,}5 - 1{,}5}{98{,}5}} = 34{,}5\ s$$

Maximum emission duration to consider is the time base 0,25 s (<T_2) which is used to calculate N = 335·0,25 = 84. The factor C_5 becomes

$$C_5 = 84^{-0{,}25} = 0{,}330; \text{for } t_p > T_i, \alpha > \alpha_{max}, N \leq 625$$

For a pulse train, average pulse energy:

$$AEL_3 = 0{,}330 \cdot 331 \cdot 10^{-6} = 109\ \mu J$$

For this case and class 3R the minimum AEL is 109 µJ. Measured value is 17,4 µJ.

2) The eye is relaxed (accommodated to infinity) and the *AEL* is calculated at the closest point of human access (257 mm). Radiation will form a scanned line on the retina, where the spot is of the angular size θ = 1,7 mrad, given by the beam divergence angle. The relation between spot size and scan length gives a scan factor

$$k_{scan} = \frac{t_p \cdot \omega_{rot}}{\theta} = \frac{t_p \cdot f_{rot} \cdot 2\pi}{\theta} = \frac{14{,}8 \cdot 10^{-6} \cdot 335 \cdot 2\pi}{1{,}7 \cdot 10^{-3}} = 18{,}3$$

The angular subtense of the apparent source for the spot on the retina is also given by the divergence, α = 1,7 mrad.

The factor C_6 is

$$C_6 = k_{scan} \frac{\alpha}{\alpha_{min}} = 18{,}3 \cdot \frac{1{,}7}{1{,}5} = 20{,}8$$

For a single pulse:

$$AEL_{1nE} = 3{,}5 \cdot 10^{-3} \cdot (14{,}8 \cdot 10^{-6})^{0{,}75} \cdot 20{,}8 = 17{,}4\ \mu J$$

For a pulse train, average power over the emission duration (T = 0,25 s):

$$AEL_{2nT} = 5{,}0 \cdot 10^{-3} \cdot 20{,}8 = 104\ mW$$

For a pulse train, C_5 = 1 when the pulse duration is 14,8 µs and α < 5 mrad. The result for the pulse train is the same as for a single pulse.

For this case and class 3R the minimum AEL is 17,4 µJ. Measured value is 17,4 µJ.

3) The eye is focused on the scanning element and the *AEL* is calculated at the distance where the pulse width equals the breakpoint 5 µs. The distance was found by measurement to be 762 mm from the scanning vertex.

The angular subtense of the apparent source is

$$\alpha = \frac{14{,}0}{762} = 18{,}4 \text{ mrad}$$

The maximum angular subtense is

$$\alpha_{\max} = 5 \text{ mrad; for } t < 625 \text{ µ}s$$

The angle of acceptance γ shall be limited to α_{max}, which gives a correction factor κ for C_6 equal to

$$\kappa = \frac{\alpha^2}{{\alpha_{\max}}^2}$$

The factor C_6 is

$$C_6 = \kappa \frac{\alpha_{\max}}{\alpha_{\min}} = \frac{\alpha^2}{\alpha_{\min} \cdot \alpha_{\max}} = \frac{18{,}4^2}{5 \cdot 1{,}5} = 45{,}0$$

For a single pulse:

$$AEL_{1nE} = 3{,}5 \cdot 10^{-3} \cdot (5{,}0 \cdot 10^{-6})^{0{,}75} \cdot 45{,}0 = 16{,}7 \text{ µJ}$$

For a pulse train, average power over the emission duration (T = 0,25 s):

$$AEL_{2nT} = 5{,}0 \cdot 10^{-3} \cdot 45{,}0 = 225 \text{ mW}$$

For a pulse train, C_5 = 1 when the pulse width is 5 µs and the time base is 0,25 s. The result for the pulse train is the same as for a single pulse.

For this case and class 3R the minimum AEL is 16,7 µJ. Measured value is 5,05 µJ.

4) The eye is focused on the scanning element and the *AEL* is calculated at the distance where C_6 becomes equal to 1. The pulse width was measured to 0,497 µs.

At a distance $Z = M$

$$Z = \frac{d}{\alpha} = \frac{14{,}0}{1{,}5 \cdot 10^{-3}} = 9330 \text{ mm}$$

The factor C_6 becomes

$$C_6 = \frac{1{,}5}{1{,}5} = 1$$

For a single pulse:

$$AEL_{1E} = 3{,}8 \cdot 10^{-7} \text{ J}$$

For a pulse train, average power over the emission duration:

$$AEL_{2m} = 5{,}0 \text{ mW}$$

For a pulse train, C_5 = 1 when the pulse width is <5 µs and the time base is 0,25 s. The result for the pulse train is the same as for a single pulse.

For this case and class 3R the minimum AEL is 0,38 µJ. Measured value is 0,32 µJ.

The product is classified as Class 3R according to EN IEC 60825-1:2014

Reasonably foreseeable single fault conditions:

The following single faults have been identified;

- Laser drive current increases to higher than the set value.
  The driver circuitry has internal control of current and voltage, preventing higher output current than programmed.

- Scanning speed is reduced, causing higher exposure;
  The scanning speed is continuously monitored by a photodiode and the laser output is stopped if the speed is reduced. The lowest attainable scanning speed was checked and reported in report MTt7P06092-2. The scanning speed reduction does not affect the classification in a significant way.

There are no optical components which act to significantly limit the radiation output power.

No single faults which can lead to the product falling into a higher class have been identified.

The above calculation applies for exposure to one line. Top-emission exposure may result in a case where the eye is exposed to radiation from all eight folding mirrors. The result is that the pulse repetition rate is increased eight-fold. However, since the most restrictive condition is exposure to a single pulse, such an exposure will not result in a lower *MPE*.

Critical components information					
Object / part No.	**Manufacturer/ trademark**	**Type / model**	**Technical data**	**Standard**	**Mark(s) of conformity[1)]**
Laser source					
Red	SwissLas	OEM Module	1 000 mW	–	
Green	SwissLas	OEM Module	800 mW	–	
Blue	SwissLas	OEM Module	1 300 mW	–	
Supplementary information: [1)] Provided evidence ensures the agreed level of compliance. See OD-CB2039.					

List of test equipment used:					
Clause	**Measurement / testing**	**Testing / measuring equipment / material used, (Equipment ID)**	**Inv. No.**	**Last Calibration date**	**Calibration due date**
5.4.2	Laser radiation	Oscilloscope Keysight DSA90804A	BX70821	2020-04-16	2022-04-16
5.4.2	Laser radiation	Radiometer UDT 350 (no. 35469) Integrating sphere (2500)	500638 500229	2019-05-27	2021-05-27
5.4.2	Laser radiation	Photodetector	BX43660	2021-05-18	At use
5.4.2	Laser radiation	Aperture ∅7,0 mm	901721	2018-12-21	2021-12-21
5.4.2	Laser radiation	Current amplifier DHPCA-100	BX82958	2020-01-01	2022-01-01
5.4.2	Laser radiation	Spectrometer Avantes AvaSpec-2048	603160	2020-01-01	2022-01-01
5.4.2	Laser radiation	Distance Leica Disto L3	900793	2019-01-04	2021-01-04
Note: A completed list of used test equipment shall be provided in the Test Reports when a Manufacturer Testing Laboratory according to TMP/CTF stage 1 or WMT/CTF stage 2 procedure has been used.					