Lightweight Airborne Laser Scanner with Online Waveform Processing

RIEGL VUX®-1LR

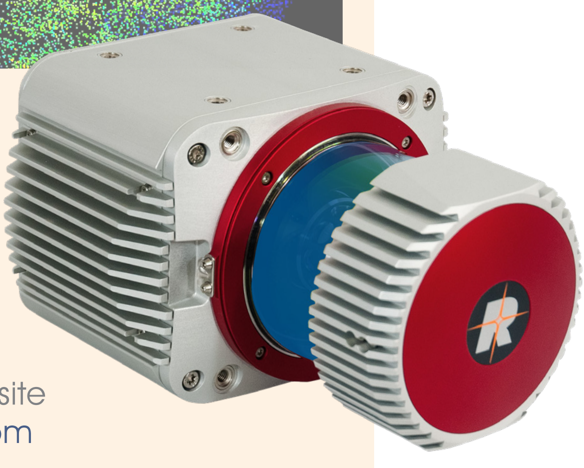
- *15 mm survey-grade accuracy*
- *scan speed up to 200 scans / second*
- *measurement rate up to 750,000 meas./sec*
- *operating flight altitude more than 1,700 ft*
- *field of view up to 330° for practically unrestricted data acquisition*
- *regular point pattern, perfectly parallel scan lines*
- *cutting edge RIEGL technology providing:*
  - *echo signal digitization*
  - *online waveform processing*
  - *multiple-time-around processing*
- *multiple target capability - practically unlimited number of target echoes*
- *compact (227x180x125 mm), lightweight (3.5 kg), and rugged*
- *easily mountable to helicopters, gyrocopters, and other small manned aircrafts*
- *mechanical and electrical interface for IMU mounting*
- *electrical interfaces for GPS data string and Sync Pulse (1PPS)*
- *LAN-TCP/IP interface*
- *internal data storage on Solid State Disc SSD, 1 TByte*

The *RIEGL* VUX-1LR is a very lightweight and compact laser scanner, meeting the challenges of airborne laser scanning by helicopter, gyrocopter, and other small aircraft both in measurement performance as well as in system integration. With regard to the specific constraints and flight characteristics, the *RIEGL* VUX-1LR is designed to be mounted in any orientation and even under limited weight and space conditions. Modest in power consumption, the instrument requires only a single power supply. The entire data set of an acquisition campaign is stored onto an internal 1 TByte SSD and/or provided as real-time line scan data via the integrated LAN-TCP/IP interface.

The *RIEGL* VUX-1LR provides highspeed data acquisition using a narrow infrared laser beam and a fast line scanning mechanism. High-accuracy laser ranging is based on *RIEGL*´s unique echo digitization and online waveform processing, which enables achieving superior measurement results even under adverse atmospheric conditions, and the evaluation of multiple target echoes. The scanning mechanism is based on an extremely fast rotating mirror, which provides fully linear, unidirectional and parallel scan lines, resulting in excellent regular point pattern.

Typical applications include

- *Corridor Mapping: Power Line, Railway Track and Pipeline Inspection*
- *Topography in Open-Cast Mining*
- *Terrain and Canyon Mapping*
- *Surveying of Urban Environments*
- *Archeology and Cultural Heritage Documentation*
- *Agriculture & Forestry*
- *Resources Management*
- *Rapid Response in Small Scale Surveying (Collision Investigation, Risk Prevention)*



visit our website
www.riegl.com

RIEGL®
LASER MEASUREMENT SYSTEMS

Laser Product Classification	Class 1 Laser Product according to IEC 60825-1:2014 The following clause applies for instruments delivered into the United States: Complies with 21 CFR 1040.10 and 1040.11 except for conformance with IEC 60825-1 Ed.3., as described in Laser Notice No. 56, dated May 8, 2019.

CLASS 1
LASER PRODUCT

Range Measurement Performance

Measuring Principle	time of flight measurement, echo signal digitization, online waveform processing, multiple-time-around-processing

Laser Pulse Repetition Rate PRR [1]	*50 kHz*	*100 kHz*	*200 kHz*	*400 kHz*	*600 kHz*	*820 kHz*	
						full power	*reduced power* [2]
Max. Measuring Range [3] [4]							
natural targets ρ ≥ 20 %	820 m	600 m	430 m	300 m	250 m	215 m	110 m
natural targets ρ ≥ 60 %	1350 m	1000 m	720 m	520 m	430 m	370 m	180 m
natural targets ρ ≥ 80 %	1540 m	1130 m	820 m	600 m	500 m	430 m	220 m
Max. Operating Flight Altitude AGL [1] [5]							
@ ρ ≥ 20 %	530 m (1740 ft)	380 m (1250 ft)	270 m (880 ft)	190 m (620 ft)	160 m (520 ft)	140 m (460 ft)	70 m (230 ft)
@ ρ ≥ 60 %	870 m (2850 ft)	640 m (2100 ft)	460 m (1510 ft)	330 m (1080 ft)	280 m (920 ft)	240 m (790 ft)	120 m (390 ft)
Max. Number of Targets per Pulse [6]	15	15	15	14	8	6	6

1) Rounded values.
2) Laser power optimized (reduced) for measurements of short ranges with high pulse repetition rate.
3) Typical values for average conditions. Maximum range is specified for flat targets with size in excess of the laser beam diameter, perpendicular angle of incidence, and for atmospheric visibility of 23 km. In bright sunlight, the max. range is shorter than under overcast sky.
4) Ambiguity to be resolved by post-processing with RiMTA software.
5) Flat terrain assumed, scan angle ±45° FOV.
6) If more than one target is hit, the total laser transmitter power is split and, accordingly, the achieveable range is reduced.

Minimum Range	5 m
Accuracy [7] [9]	15 mm
Precision [8] [9]	10 mm
Laser Pulse Repetition Rate [1] [10]	up to 820 kHz
Max. Effective Measurement Rate [1]	up to 750 000 meas./sec. (@ 820 kHz PRR & 330° FOV)
Echo Signal Intensity	for each echo signal, high-resolution 16 bit intensity information is provided
Laser Wavelength	near infrared
Laser Beam Divergence	0.5 mrad [11]
Laser Beam Footprint (Gaussian Beam Definition)	50 mm @ 100 m, 250 mm @ 500 m, 500 mm @ 1000 m

7) Accuracy is the degree of conformity of a measured quantity to its actual (true) value.
8) Precision, also called reproducibility or repeatability, is the degree to which further measurements show the same result.
9) One sigma @ 150 m range under *RIEGL* test conditions.
10) User selectable.
11) Measured at the 1/e² points. 0.50 mrad corresponds to an increase of 50 mm of beam diameter per 100 m distance.

Scanner Performance

Scanning Mechanism	rotating mirror
Field of View (selectable)	up to 330° (full range measurement performance)
Scan Speed (selectable)	10 - 200 revolutions per second, equivalent to 10 - 200 scans/sec
Angular Step Width Δ ϑ (selectable) between consecutive laser shots	0.004° ≤ Δ ϑ ≤ 1.5°
Angle Measurement Resolution	0.001°
Internal Sync Timer	for real-time synchronized time stamping of scan data
Scan Sync (optional)	scanner rotation synchronization

Data Interfaces

Configuration	LAN 10/100/1000 Mbit/sec
Scan Data Output	LAN 10/100/1000 Mbit/sec or USB 2.0
GNSS Interface	Serial RS232 interface for data string with GNSS-time information, TTL input for 1PPS synchronization pulse
Internal Data Storage	1 TByte SSD
External Camera	TTL input/output
External GNSS Antenna	SMA connector

General Technical Data

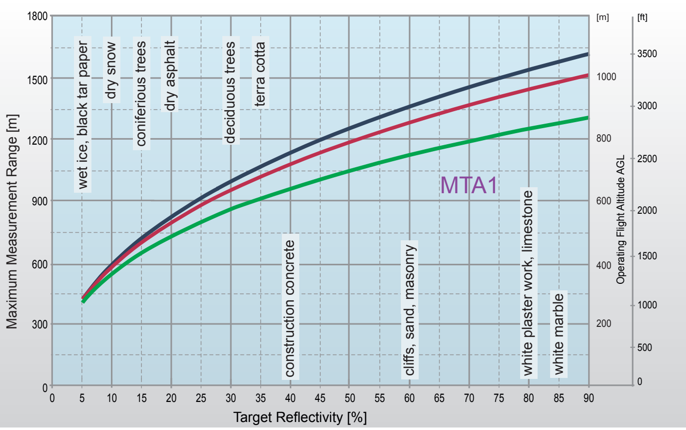
Power Supply Input Voltage / Consumption [12]	11 - 34 V DC / typ. 65 W
Main Dimensions [12]	
VUX-1UAV without / with Cooling Fan	227 x 180 x 125 mm / 227 x 209 x 129 mm
Weight [12]	
VUX-1UAV without / with Cooling Fan	approx. 3.5 kg / approx. 3.75 kg
Humidity	max. 80 % non condensing @ 31°C
Protection Class	IP64, dust and splash-proof
Max. Flight Altitude (operating / not operating)	16 500 ft (5 000 m) above MSL / 18 000 ft (5 500 m) above MSL
Temperature Range [13]	-10°C up to +40°C (operation) / -20°C up to +50°C (storage)

Optional Components (integrated)

Embedded GNSS-Inertial System	high performance multi-channel, multi-band GNSS receiver, solid-state MEMS IMU

12) without external IMU/GNSS, cooling fan device not in operation
13) The instrument requires air convection with a minimum flow rate of 5 m/s for continuous operation at +15 °C and above. If the necessary flow rate cannot be provided by the moving platform, the cooling fan device (included in the scope of delivery) has to be used.

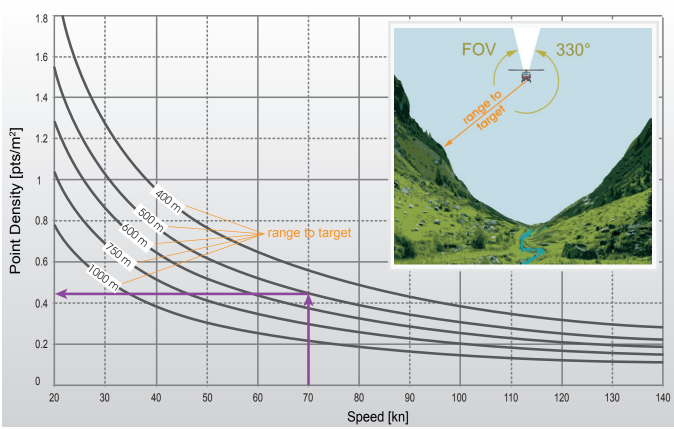
PRR = 50 kHz



MTA1: no ambiguity / one transmitted pulse „in the air"

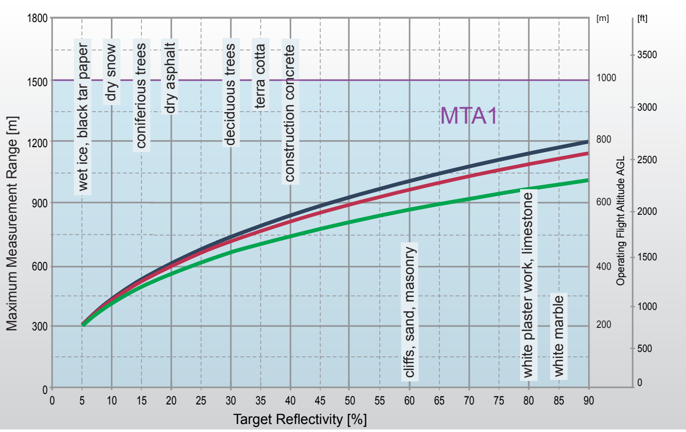
@ visibility 23 km
@ visibility 15 km
@ visibility 8 km

PRR = 50 kHz



Example: VUX-1LR at 50,000 pulses/second
range to target = 500 m, speed = 70 kn
Resulting Point Density ~ 0.44 pts/m²

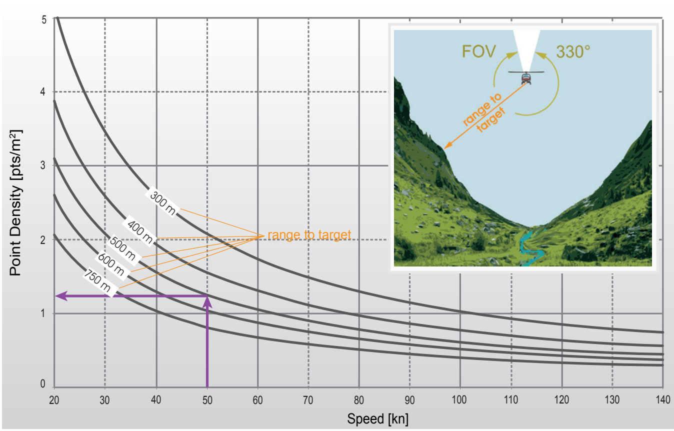
PRR = 100 kHz



MTA1: no ambiguity / one transmitted pulse „in the air"

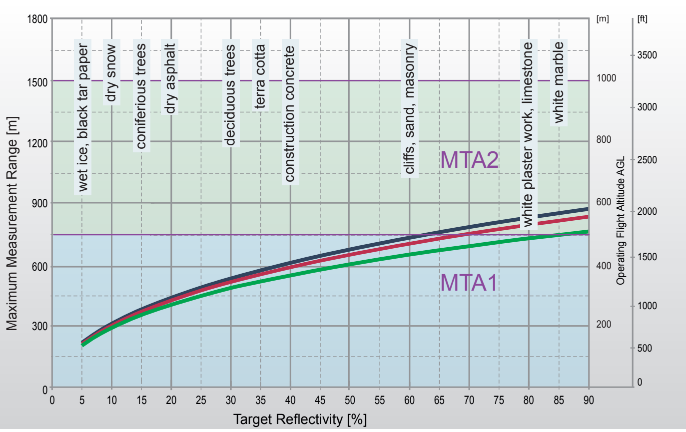
@ visibility 23 km
@ visibility 15 km
@ visibility 8 km

PRR = 100 kHz



Example: VUX-1LR at 100,000 pulses/second
range to target = 500 m, speed = 50 kn
Resulting Point Density ~ 1.2 pts/m²

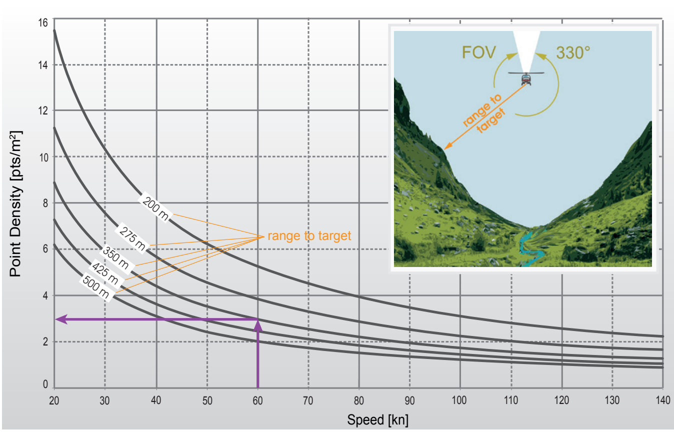
PRR = 200 kHz



MTA1: no ambiguity / one transmitted pulse „in the air"
MTA2: two transmitted pulses „in the air"

@ visibility 23 km
@ visibility 15 km
@ visibility 8 km

PRR = 200 kHz

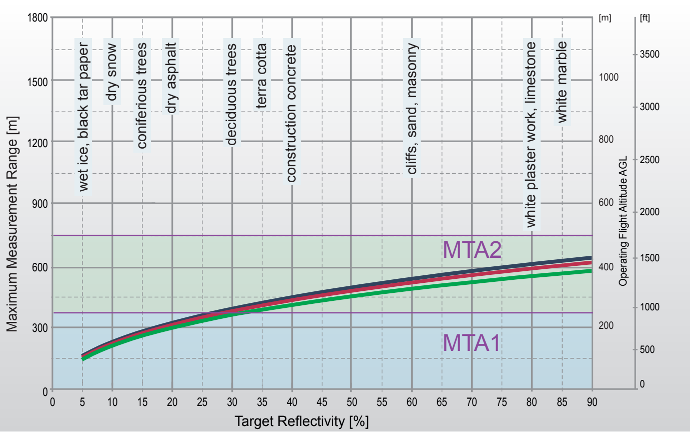


Example: VUX-1LR at 200,000 pulses/second
range to target = 350 m, speed = 60 kn
Resulting Point Density ~ 3.0 pts/m²

The following conditions are assumed for the Operating Flight Altitude AGL

- ambiguity resolved by multiple-time-around (MTA) processing & flight planning
- target size ≥ laser footprint
- average ambient brightness
- operating flight altitude given at a FOV of ±45°

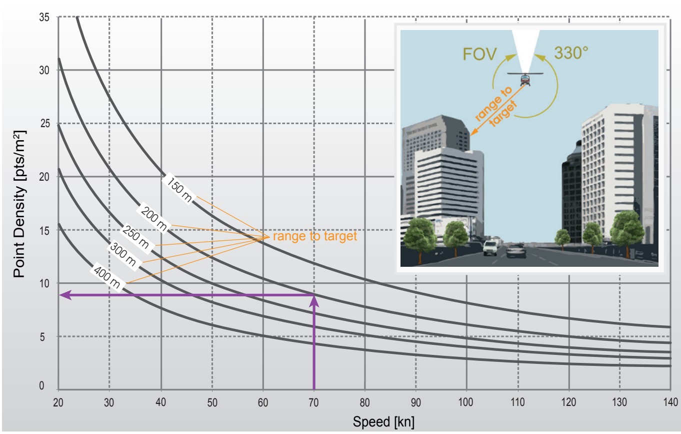
PRR = 400 kHz



MTA1: no ambiguity / one transmitted pulse „in the air"
MTA2: two transmitted pulses „in the air"

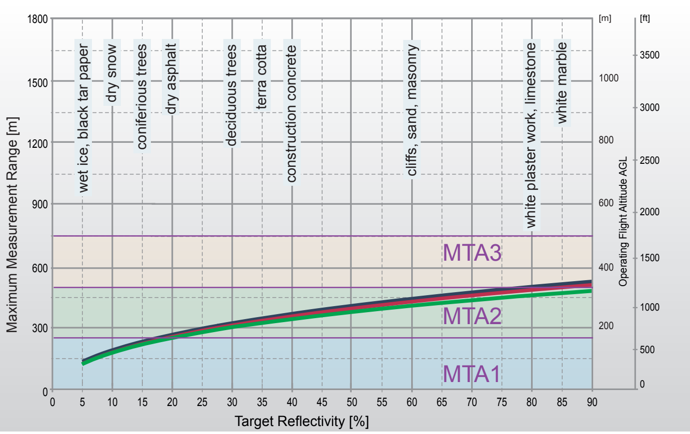
@ visibility 23 km
@ visibility 15 km
@ visibility 8 km

PRR = 400 kHz



Example: VUX-1LR at 400,000 pulses/second
range to target = 200 m, speed = 70 kn
Resulting Point Density ~ 8.8 pts/m²

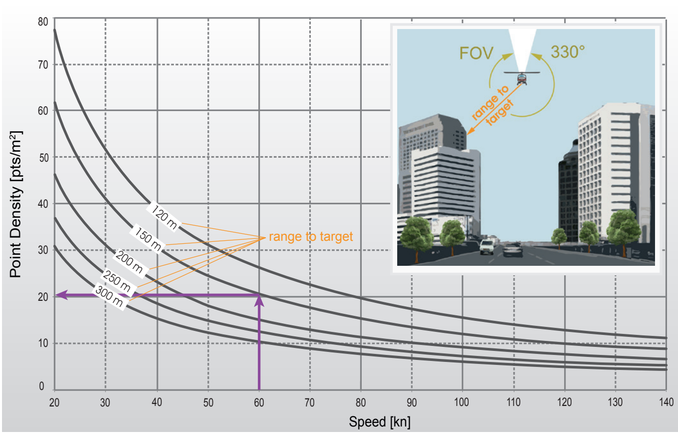
PRR = 600 kHz



MTA1: no ambiguity / one transmitted pulse „in the air"
MTA2: two transmitted pulses „in the air"
MTA3: three transmitted pulses „in the air"

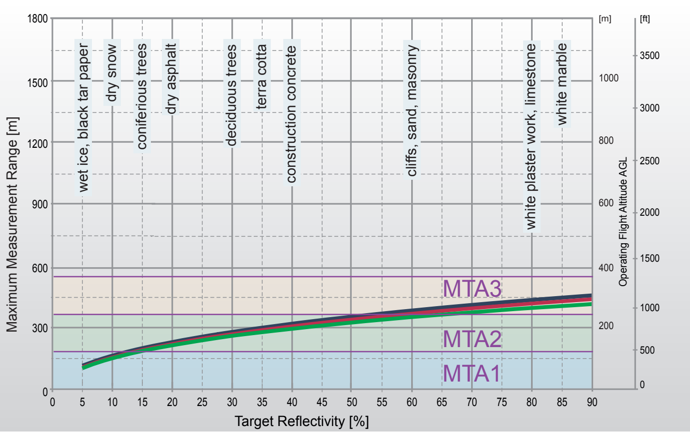
@ visibility 23 km
@ visibility 15 km
@ visibility 8 km

PRR = 600 kHz



Example: VUX-1LR at 600,000 pulses/second
range to target = 150 m, speed = 60 kn
Resulting Point Density ~ 21 pts/m²

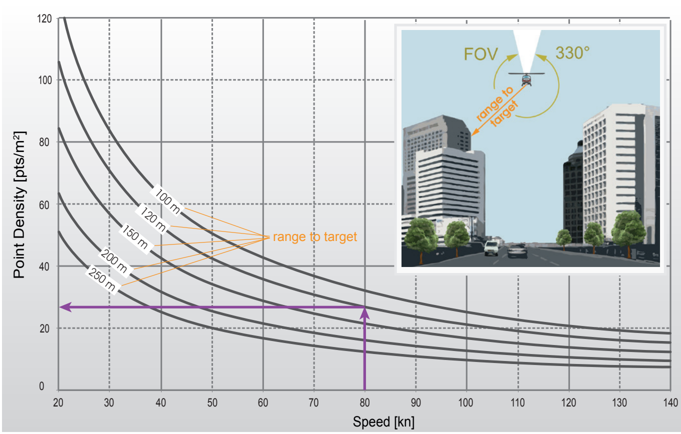
PRR = 820 kHz



MTA1: no ambiguity / one transmitted pulse „in the air"
MTA2: two transmitted pulses „in the air"
MTA3: three transmitted pulses „in the air"

@ visibility 23 km
@ visibility 15 km
@ visibility 8 km

PRR = 820 kHz

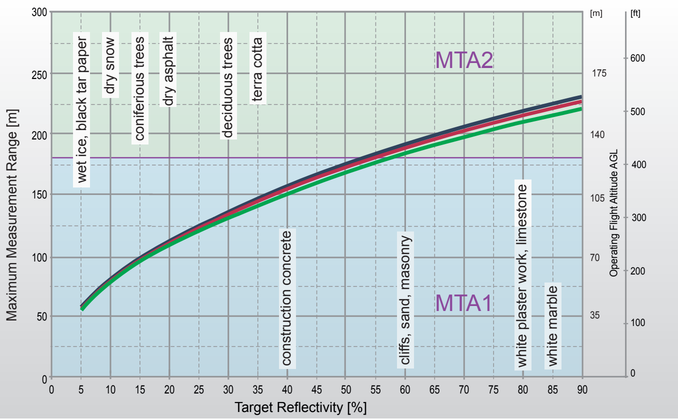


Example: VUX-1LR at 820,000 pulses/second
range to target = 120 m, speed = 80 kn
Resulting Point Density ~ 26 pts/m²

The following conditions are assumed for the Operating Flight Altitude AGL
- ambiguity resolved by multiple-time-around (MTA) processing & flight planning
- target size ≥ laser footprint
- average ambient brightness
- operating flight altitude given at a FOV of ±45°

Maximum Measurement Range & Point Density *RIEGL* VUX®-1LR

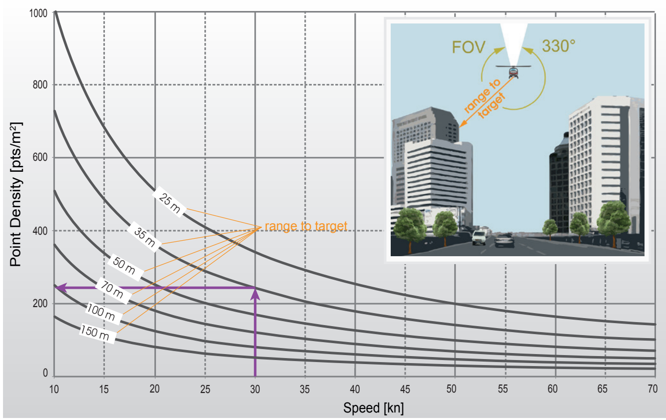
PRR = 820 kHz reduced power



MTA1: no ambiguity / one transmitted pulse „in the air"
MTA2: two transmitted pulses „in the air"

@ visibility 23 km
@ visibility 15 km
@ visibility 8 km

PRR = 820 kHz reduced power

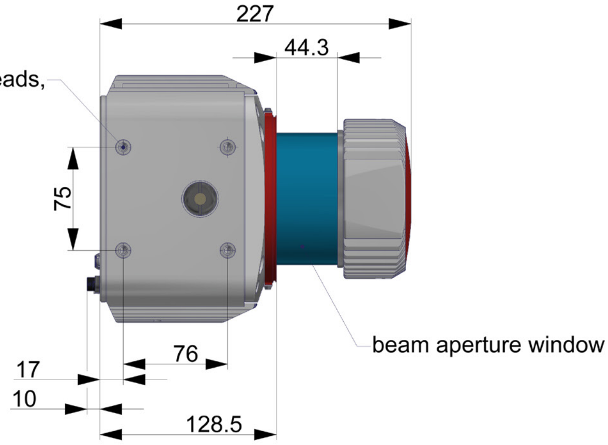


Example: VUX-1LR at 820,000 pulses/second reduced range to target = 35 m, speed = 30 kn
Resulting Point Density ~ 240 pts/m²

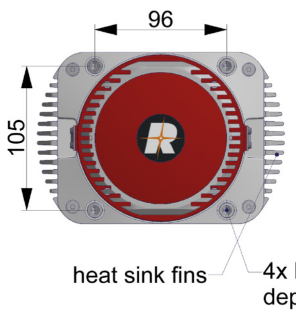
Dimensional Drawings *RIEGL* VUX®-1LR

all dimensions in mm

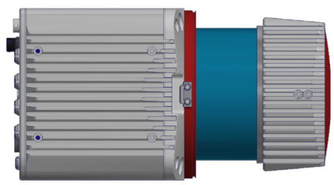
bottom view



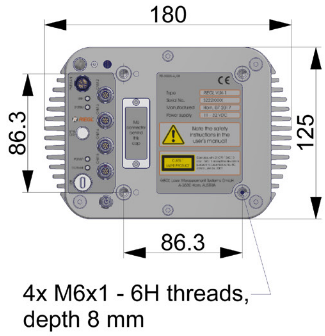
front view



side view

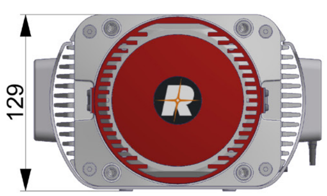


rear view

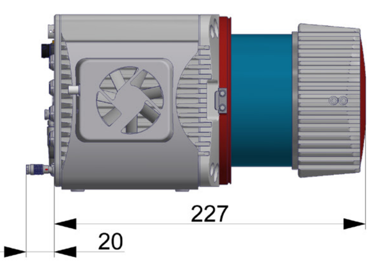


RIEGL VUX®-1LR with Cooling Fan Device

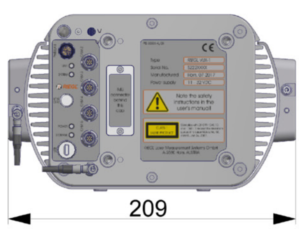
front view



side view



rear view



RIEGL VUX®-1LR Additional Equipment and Integration

Cooling Fan

***RIEGL* VUX-1LR with Protective Cap**

***RIEGL* VUX-1LR with external IMU-Sensor** (*RIEGL* VUX-SYS)

Additional Equipment for *RIEGL* VUX-1LR

Cooling Fan

Lightweight structure with two axial fans providing forced air convection for applications where sufficient natural air flow cannot be guaranteed. Power supply is provided via a connector on the rear side of the *RIEGL* VUX-1LR. The cooling fan can be mounted either on the top side or on the bottom side of the *RIEGL* VUX-1LR and is included in the scanner's scope of delivery.

The cooling fan has to be mounted whenever the environmental conditions/ temperatures require (see "temperature range" on page 2 of this data sheet).

Protective Cap

To shield the glass tube of the *RIEGL* VUX-1LR from mechanical damage and soiling, a protective cap is provided to cover the upper part of the instrument during transport and storage.

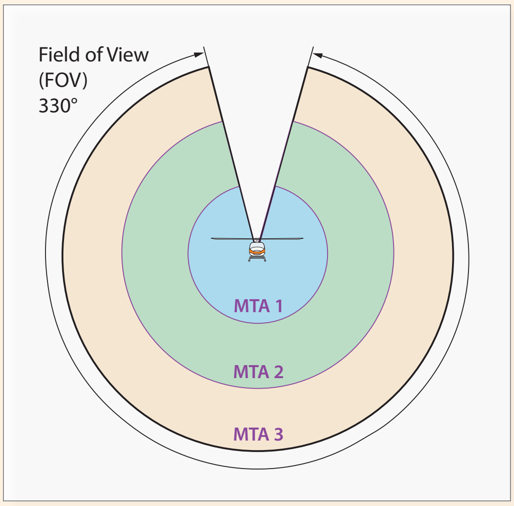
Options for *RIEGL* VUX-1LR Integration

RIEGL provides user-friendly, application- and installation-oriented solutions for integration of the VUX-1LR LiDAR sensor:

- ***RIEGL* VUX-SYS**
  Complete airborne laser scanning system for flexible use in UAS/UAV/RPAS, helicopter, gyrocopter and ultra-light aircraft installations comprising the *RIEGL* VUX-1LR, an IMU/GNSS unit and a dedicated control unit.
- ***RIEGL* VP-1**
  Small and lightweight pod with integrated *RIEGL* VUX-SYS to be mounted on standard hard points and typical camera mounts of manned helicopters
- **RiCOPTER**
  Ready to fly remotely piloted aircraft system with *RIEGL* VUX-SYS integrated

Details to be found on the relevant datasheets and infosheets.

Multiple-Time-Around Data Acquisition and Processing



In time-of-flight laser ranging a maximum unambiguous measurement range exists, which is defined by the laser pulse repetition rate and the speed of light. In case the echo signal of an emitted laser pulse arrives later than the emission of the subsequently emitted laser pulse, the range result becomes ambiguous - an effect known as **„Multiple-Time-Around" (MTA)**.

The *RIEGL* VUX-1LR allows ranging beyond the maximum unambiguous measurement range using a sophisticated modulation scheme applied to the train of emitted laser pulses. The dedicated post-processing software RiMTA provides algorithms for multiple-time-around processing, which automatically assign definite range results to the correct MTA zones without any further user interaction required.

RIEGL LASER MEASUREMENT SYSTEMS

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