Lightweight UAV Laser Scanner with Online Waveform Processing

RIEGL VUX®-1UAV

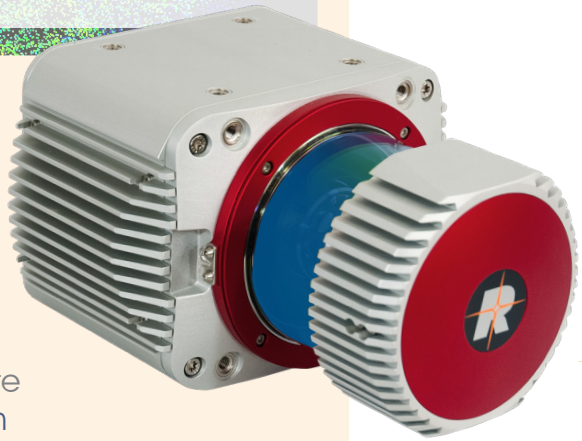
- *10 mm survey-grade accuracy*
- *scan speed up to 200 scans / second*
- *measurement rate up to 500,000 meas./sec (@ 550 kHz PRR & 330° FOV)*
- *operating flight altitude more than 1,000 ft*
- *field of view up to 330° for practically unrestricted data acquisition*
- *regular point pattern, perfectly 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 professional UAS / UAV / RPAS*
- *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-1UAV is a very lightweight and compact laser scanner, meeting the challenges of emerging survey solutions by UAS/UAV/RPAS both in measurement performance as well as in system integration. With regard to the specific constraints and flight characteristics of the UAS, the *RIEGL* VUX-1UAV 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-1UAV 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

- *Agriculture & Forestry*
- *Archaeology and Cultural Heritage Documentation*
- *Corridor Mapping: Power Line, Railway Track, and Pipeline Inspection*
- *Topography in Open-Cast Mining*
- *Construction-Site Monitoring*
- *Surveying of Urban Environments*
- *Resources Management*



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.

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*	*300 kHz*	*380 kHz*	*550 kHz* *full power*	*550 kHz* *reduced power* [2]
Max. Measuring Range [3] [4]							
natural targets ρ ≥ 20 %	550 m	400 m	280 m	230 m	200 m	170 m	85 m
natural targets ρ ≥ 60 %	920 m	660 m	480 m	400 m	350 m	300 m	150 m
natural targets ρ ≥ 80 %	1050 m	760 m	550 m	450 m	400 m	340 m	170 m
Max. Operating Flight Altitude AGL [1] [5]							
@ ρ ≥ 20 %	350 m (1150 ft)	250 m (820 ft)	180 m (590 ft)	150 m (490 ft)	130 m (430 ft)	110 m (360 ft)	55 m (180 ft)
@ ρ ≥ 60 %	590 m (1940 ft)	420 m (1380 ft)	310 m (1020 ft)	260 m (850 ft)	230 m (760 ft)	190 m (620 ft)	100 m (330 ft)
Max. Number of Targets per Pulse up to [6]	15	15	13	9	7	4	4

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	3 m
Accuracy [7] [9]	10 mm
Precision [8] [9]	5 mm
Laser Pulse Repetition Rate [1] [10]	up to 550 kHz
Max. Effective Measurement Rate [1]	up to 500 000 meas./sec. (@ 550 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 $1/e^2$ 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) [12]
Scan Speed (selectable)	10 - 200 revolutions per second, equivalent to 10 - 200 scans/sec
Angular Step Width Δ ϑ (selectable) between consecutive laser shots	0.006° ≤ 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 RS-232 interface for data string with GNSS-time information, TTL input for 1PPS synchronization pulse
Internal Data Storage	1 TByte SSD
Memory Card Slot [13]	for CFAST® [14] memory card 120 GByte (can be upgraded to 256 GByte)
External Camera	TTL input/output
External GNSS Antenna	SMA connector

12) upgrade to 360° FOV (optional)
13) applies to IMU APX-20 UAV only
14) CFast is a registered trademark of CompactFlash Association

General Technical Data

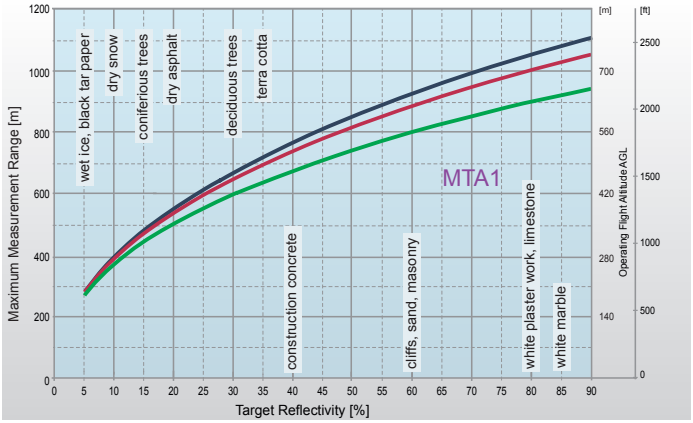
Power Supply Input Voltage / Consumption [15]	11 - 34 V DC / typ. 60 W
Main Dimensions [15]	
VUX-1UAV without / with Cooling Fan	227 x 180 x 125 mm / 227 x 209 x 129 mm
Weight [15]	
VUX-1UAV without / with Cooling Fan	approx. 3.5 kg / approx. 3.75 kg
Humidity	max. 80 % non condensing @ 31°C
Protection 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 [16]	-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

15) without external IMU/GNSS, cooling fan not in operation
16) 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 (included in the scope of delivery) has to be used.

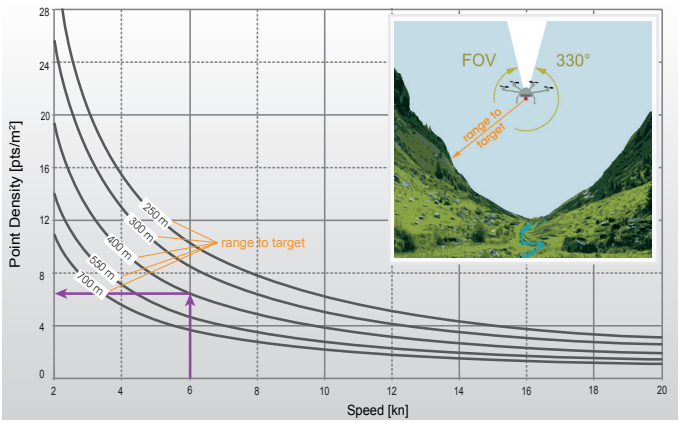
PRR = 50 kHz



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

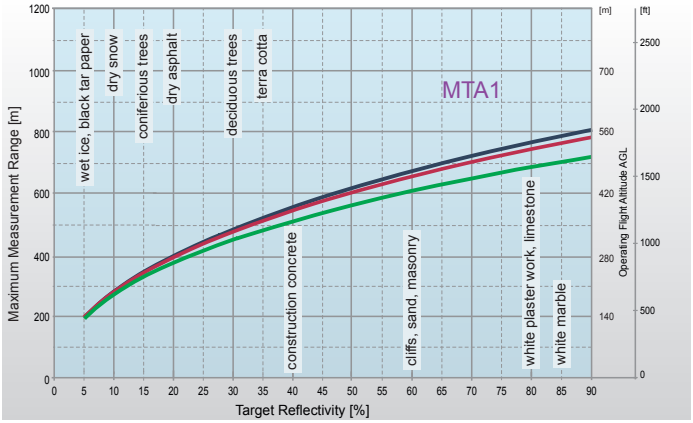
@ visibility 23 km
@ visibility 15 km
@ visibility 8 km

PRR = 50 kHz



Example: VUX-1UAV at 50,000 pulses/second
range to target = 400 m, speed = 6 kn
Resulting Point Density ~ 6.5 pts/m²

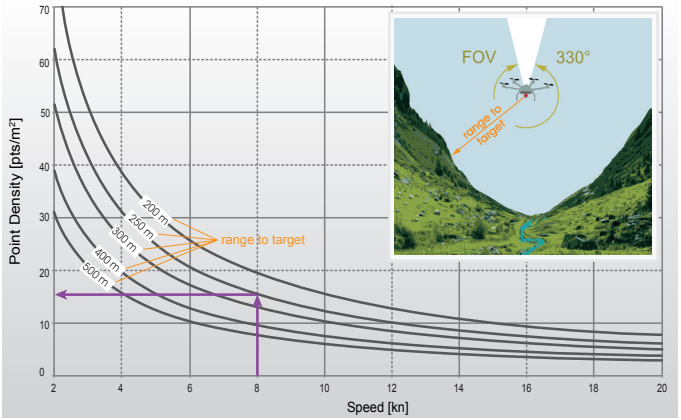
PRR = 100 kHz



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

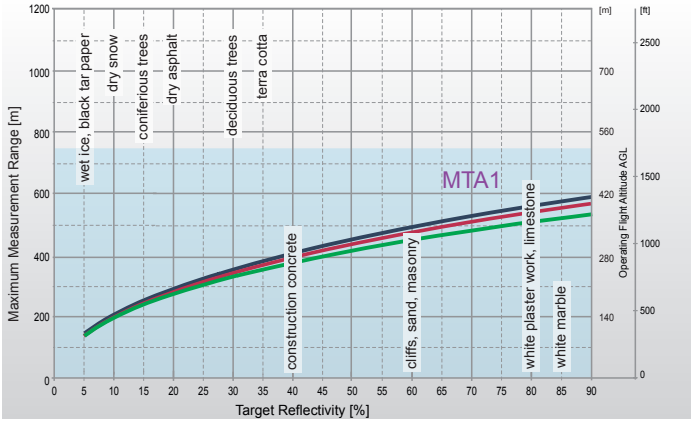
@ visibility 23 km
@ visibility 15 km
@ visibility 8 km

PRR = 100 kHz



Example: VUX-1UAV at 100,000 pulses/second
range to target = 250 m, speed = 8 kn
Resulting Point Density ~ 15.5 pts/m²

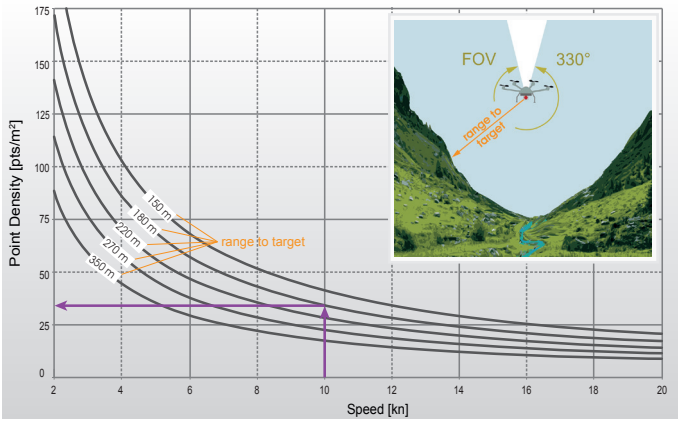
PRR = 200 kHz



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

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

PRR = 200 kHz

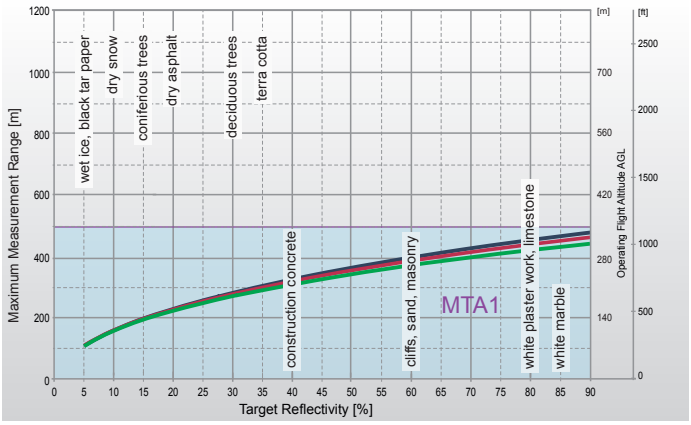


Example: VUX-1UAV at 200,000 pulses/second
range to target = 180 m, speed = 10 kn
Resulting Point Density ~ 34 pts/m²

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°

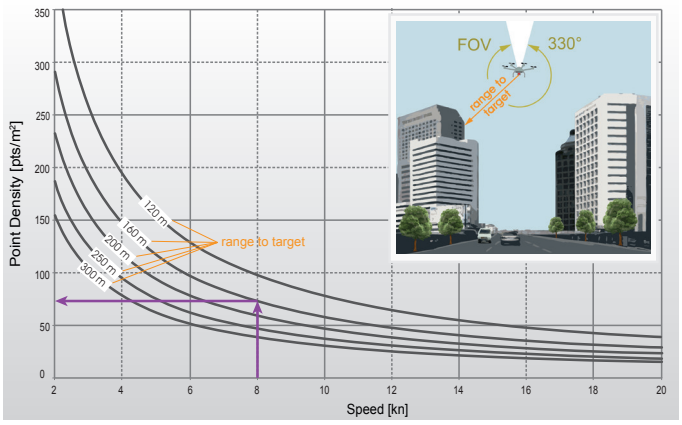
PRR = 300 kHz



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

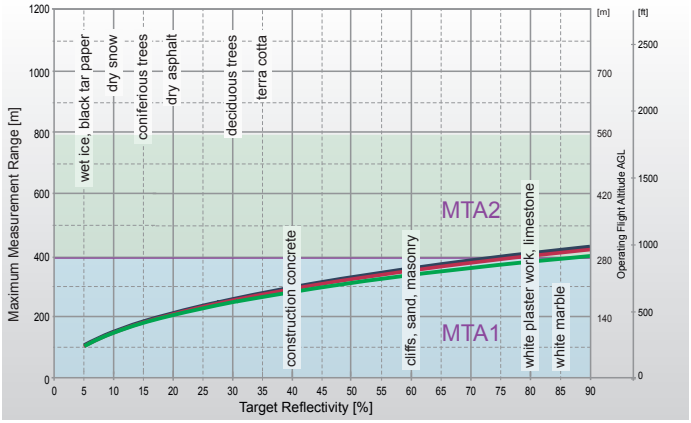
@ visibility 23 km
@ visibility 15 km
@ visibility 8 km

PRR = 300 kHz



Example: VUX-1UAV at 300,000 pulses/second
range to target = 160 m, speed = 8 kn
Resulting Point Density ~ 72 pts/m²

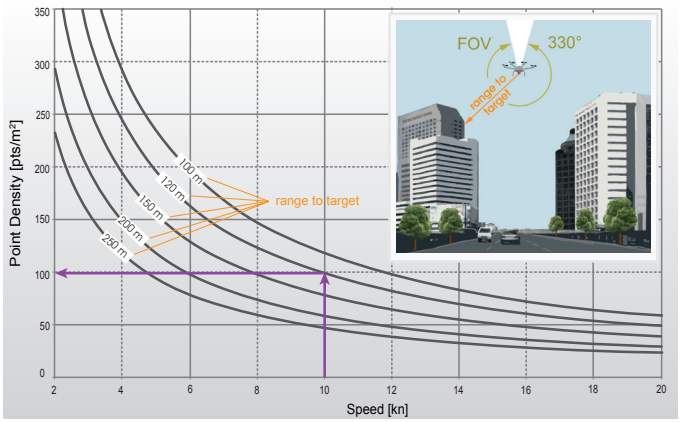
PRR = 380 kHz



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

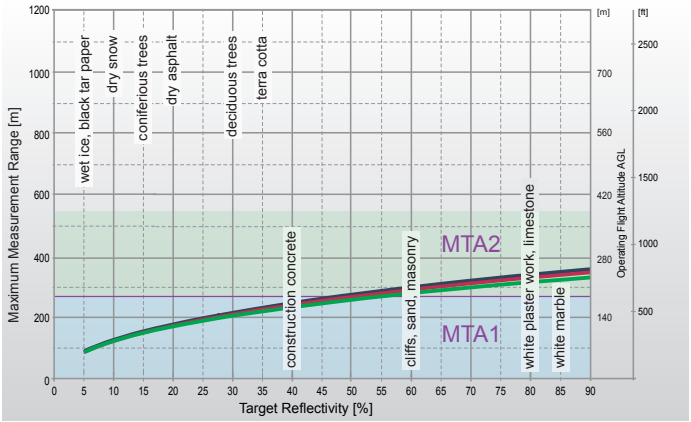
@ visibility 23 km
@ visibility 15 km
@ visibility 8 km

PRR = 380 kHz



Example: VUX-1UAV at 380,000 pulses/second
range to target = 120 m, speed = 10 kn
Resulting Point Density ~ 95 pts/m²

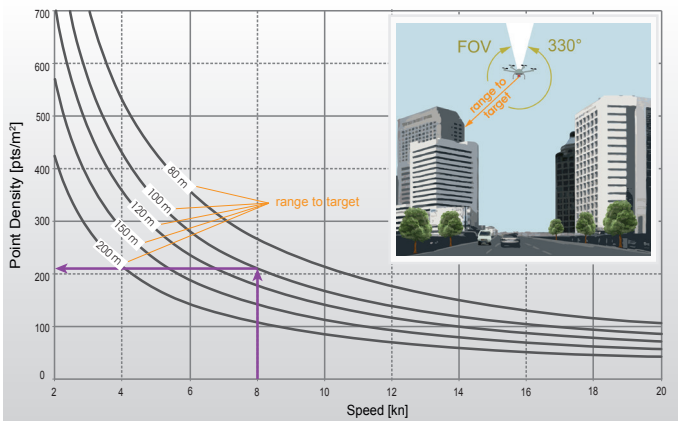
PRR = 550 kHz



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 = 550 kHz



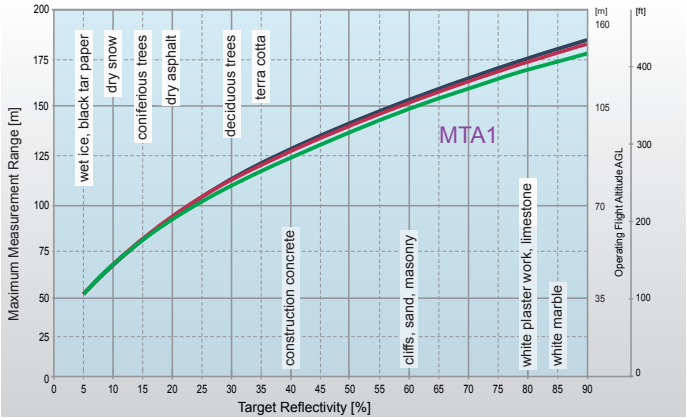
Example: VUX-1UAV at 550,000 pulses/second
range to target = 100 m, speed = 8 kn
Resulting Point Density ~ 210 pts/m²

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®-1UAV

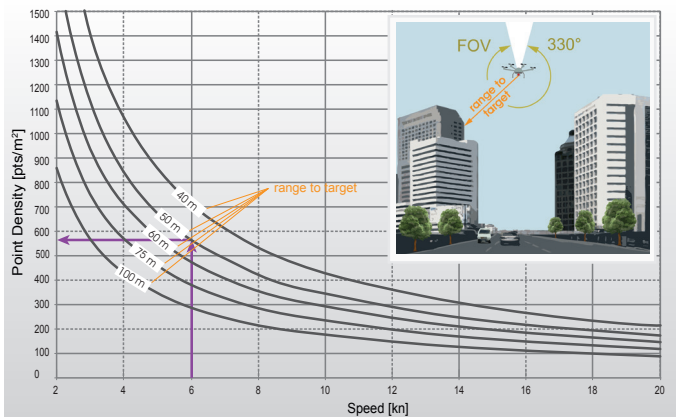
PRR = 550 kHz reduced power



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

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

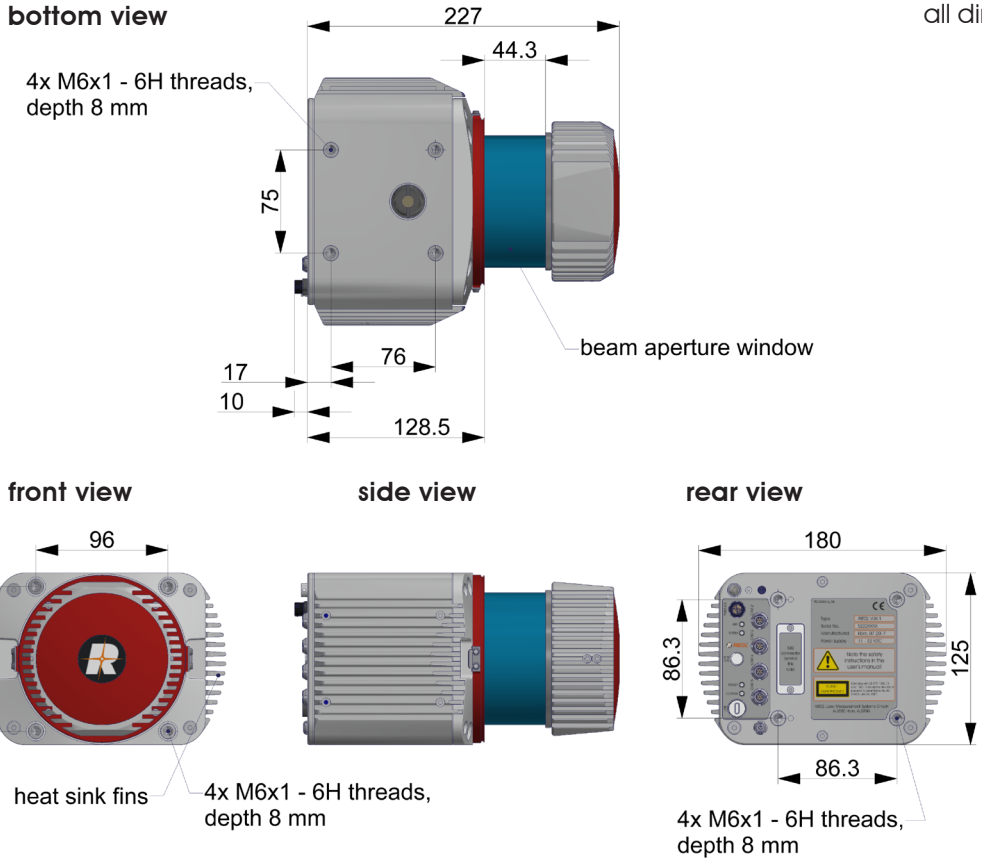
PRR = 550 kHz reduced power



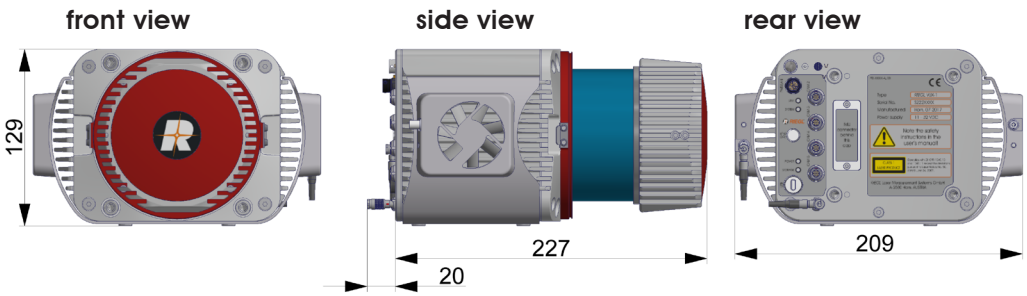
Example: VUX-1UAV at 550,000 pulses/second reduced power
range to target = 50 m, speed = 6 kn
Resulting Point Density ~ 570 pts/m²

Dimensional Drawings *RIEGL* VUX®-1UAV

all dimensions in mm



RIEGL VUX®-1UAV with Cooling Fan Device



RIEGL VUX®-1UAV Additional Equipment and Integration

Cooling Fan

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

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

Additional Equipment for *RIEGL* VUX-1UAV

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-1UAV. The cooling fan can be mounted either on the top side or on the bottom side of the *RIEGL* VUX-1UAV 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-1UAV from mechanical damage and soiling, a protective cap is provided to cover the upper part of the instrument during transport and storage.

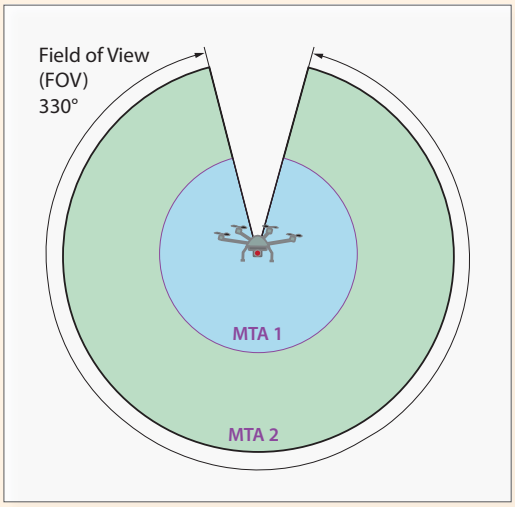
Options for *RIEGL* VUX-1UAV Integration

RIEGL provides user-friendly, application- and installation-oriented solutions for integration of the VUX-1UAV 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-1UAV, an IMU/GNSS unit and a dedicated control unit.
- **RiCOPTER**
  Ready to fly remotely piloted aircraft system with *RIEGL* VUX-SYS integrated
- ***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

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-1UAV 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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