

Dual Channel Waveform Processing Airborne LiDAR Scanning System for High Point Density Mapping and Ultra-Wide Area Mapping

RIEGL VQ-1560 III-S

- **high pulse repetition rates of up to 4.4 MHz**
- **up to 2.93 million measurements per second on the ground**
- **best point distribution for optimum target sampling**
- **atmospheric clutter suppression**
- **multiple target capability**
- **online waveform processing and full waveform data recording**
- **increased sample block lengths**
- **on-board graphical user interface for easy access to primary scanner parameters**
- **integrated inertial measurement unit and GNSS receiver**
- **prepared for the integration of up to two high resolution RGB/NIR cameras**
- **optimized for interfacing with typical hatches and stabilized platforms**
- **detachable handgrips for facilitated handling**

The VQ-1560III-S is the latest successor in the proven **RIEGL** dual channel laser scanning system series, suitable for a wide field of applications – from high-point density wide area mapping to ultra-high resolution city mapping or corridor mapping.

The well-established “cross-fire” scan pattern – with two scan lines rotated against each other – enables a forward and backward view to the edges of the swath and a nadir view in the middle of the swath.

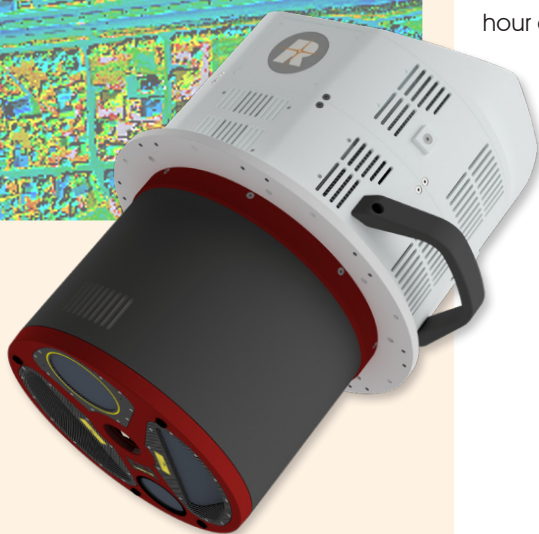
High pulse repetition rates of up to 4.4 MHz enable operational flying altitudes of up to 1,600 m AGL, or up to 3,900 m AGL at a pulse repetition rate of 560 kHz (all values given for 20% target reflectance). Laser pulse repetition rates can be fine-tuned in 12-kHz-steps, which enables subtle optimization of acquisition parameters in order to meet specific project requirements.

Online-waveform processing and full-waveform processing capabilities are standard methods for target detection. Scan data and camera images are stored on removable hard disks that can be accessed directly on the device, eliminating the need for an external data recorder. A high-performance IMU/GNSS unit and one or two optional high resolution RGB/NIR cameras are seamlessly integrated in the compact and user-friendly designed housing. The standardized mounting flange fits typical hatches or gyro-stabilized leveling mounts for maintaining optimum point distribution.

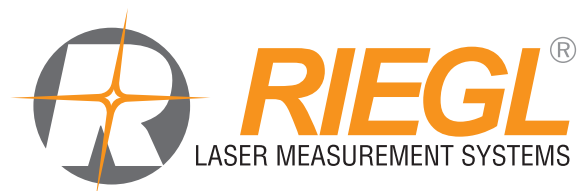
Both, the scan pattern and its wide operational range make the instrument one of the most versatile airborne laser scanners on the market today. It is perfectly suited for any kind of application – from ultra-dense corridor mapping from low altitudes, over high resolution city mapping with minimum shadowing effects in narrow street canyons, to large-scale wide area mapping at utmost efficiency of up to 1,130 km² per hour at a density of 4 points per square meter.

Applications:

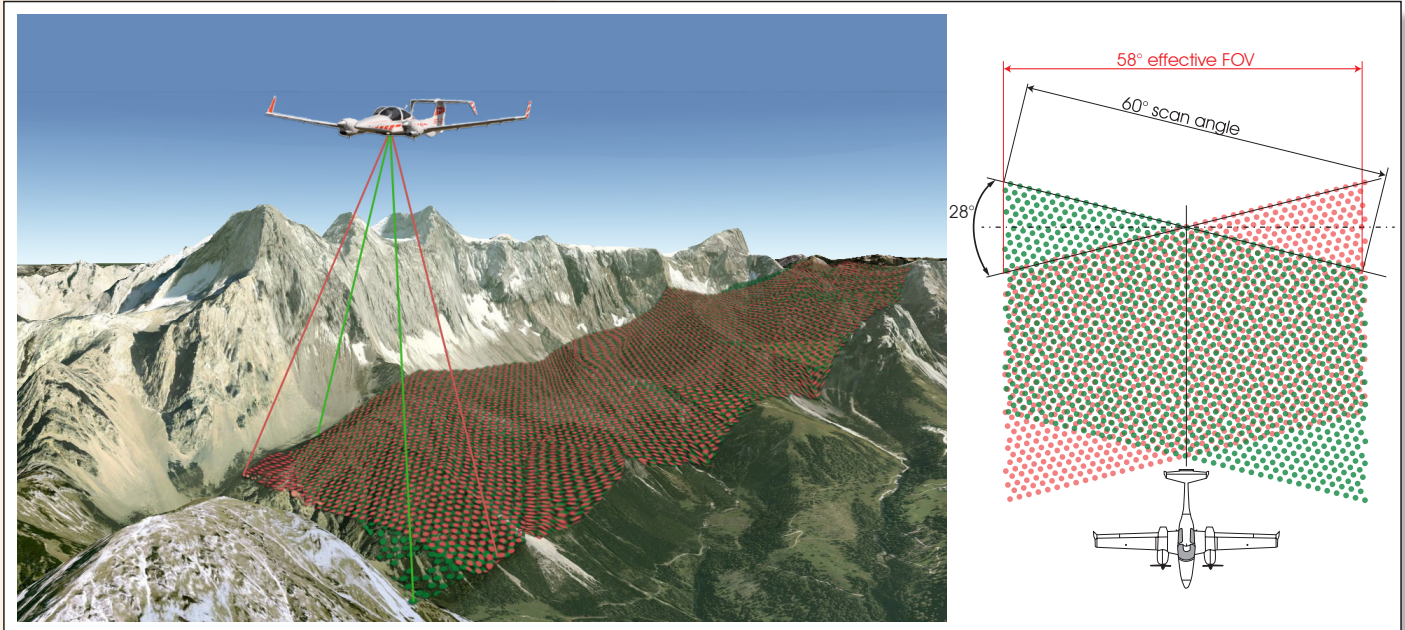
- **Ultra Wide Area / High Altitude Mapping**
- **Ultra-High Point Density Mapping**
- **Mapping of Complex Urban Environments**
- **Glacier & Snowfield Mapping**
- **City Modeling**
- **Mapping of Lakesides & River Banks**
- **Agriculture & Forestry**
- **Corridor Mapping**



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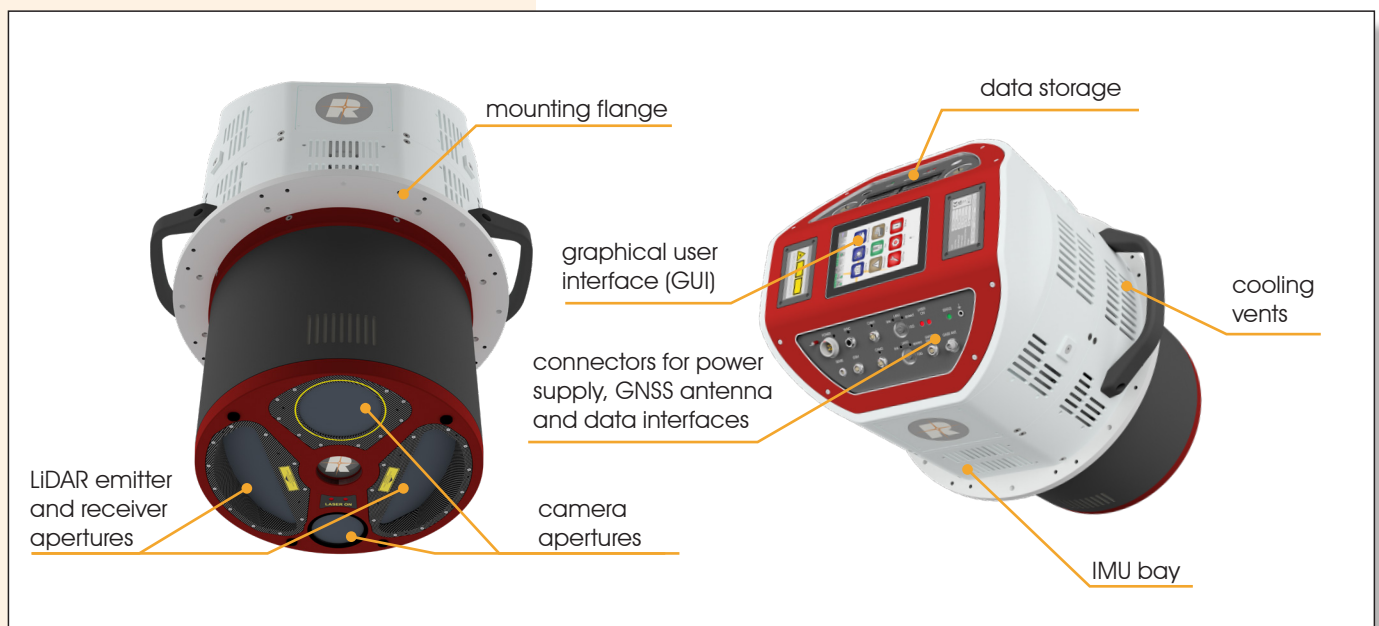
RIEGL VQ-1560 III-S Dense Scan Pattern and Wide Effective Swath Width

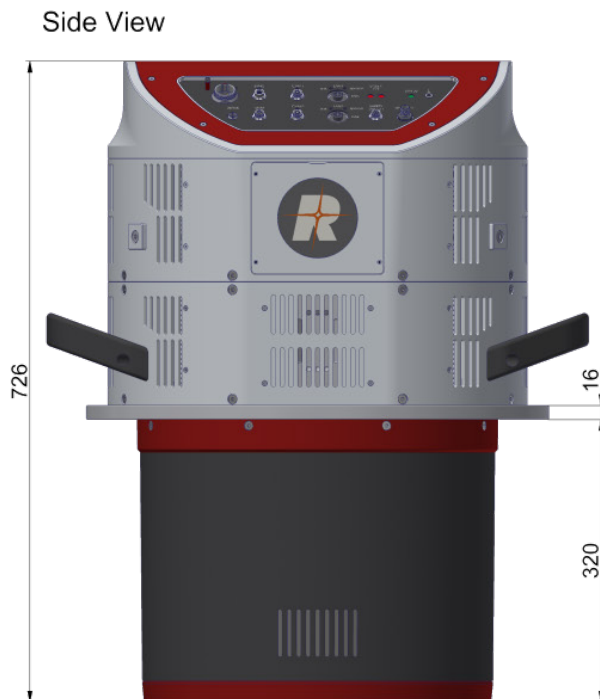
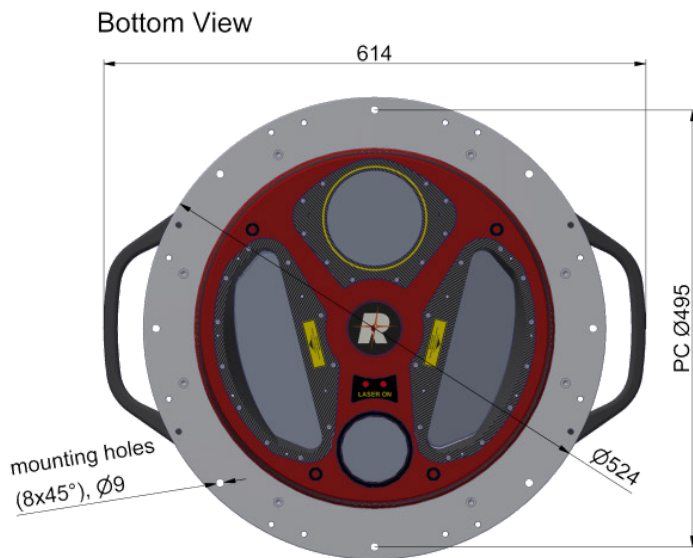


Each channel delivers straight parallel scan lines. The scan lines of the two channels are tilted against each other by 28 degrees providing an optimum distribution of the measurements on the ground invariant to changes in terrain height.

Tilt Angle of Scan Lines	$\pm 14^\circ$
Forward/Backward Scan Angle in Non-Nadir Direction	$\pm 8^\circ$ at the edge

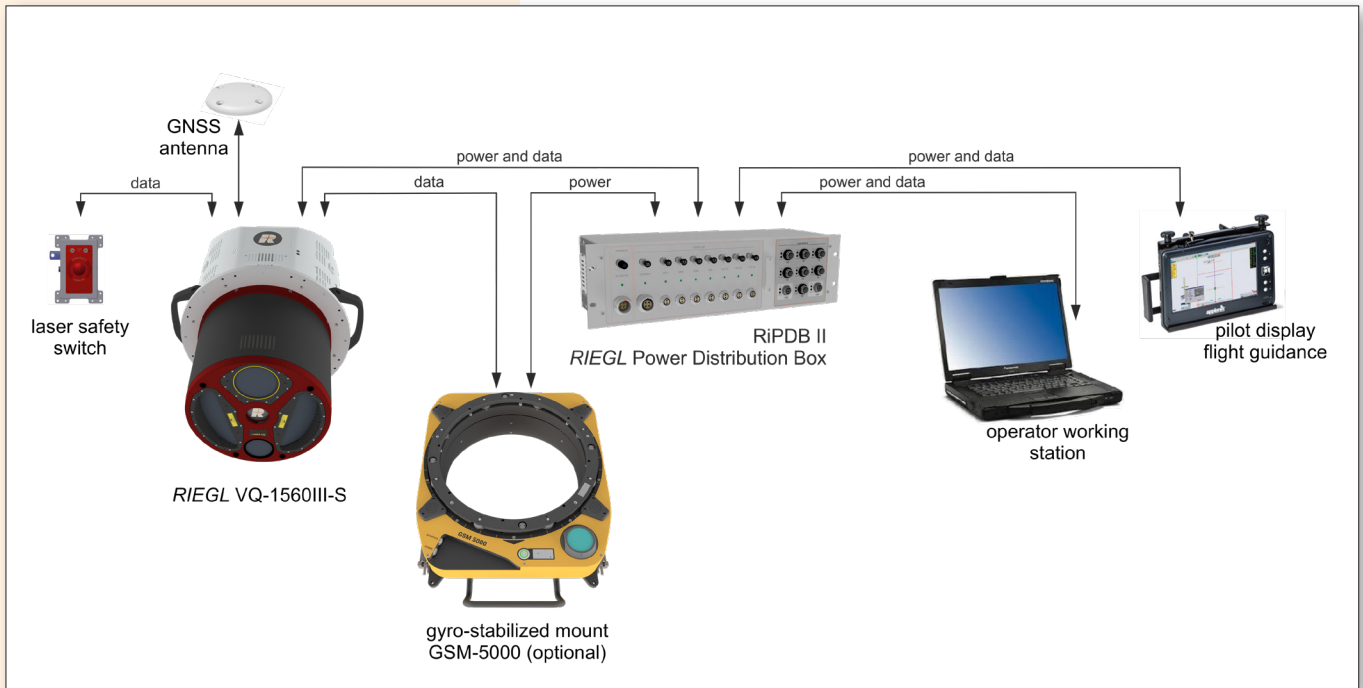
RIEGL VQ-1560 III-S Elements of Function and Operation



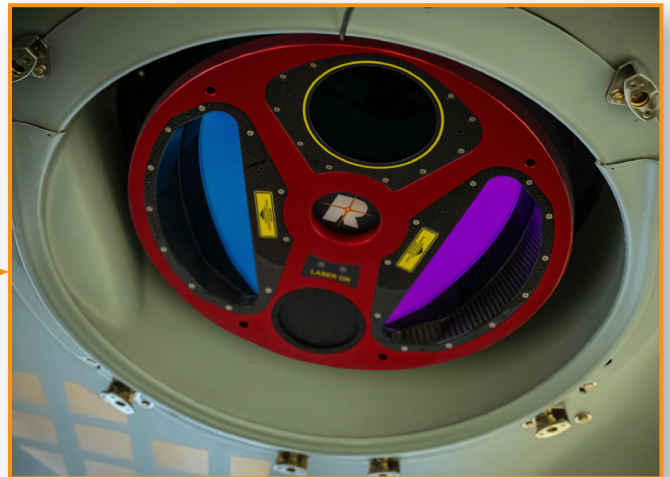


dimensions in mm

RIEGL VQ-1560 III-S System Components



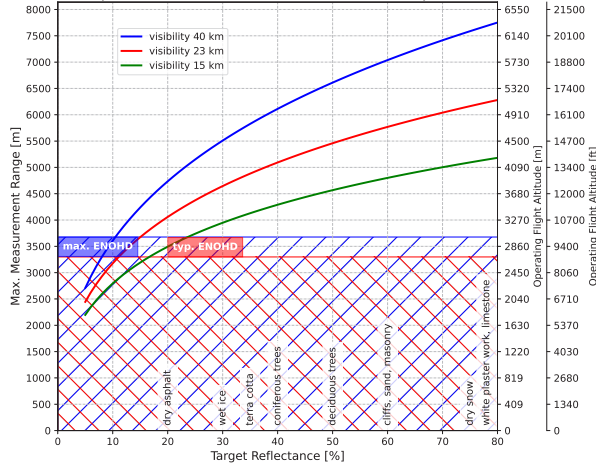
A minimum number of system components and external cabling is required for an easy and quick installation on aircraft.



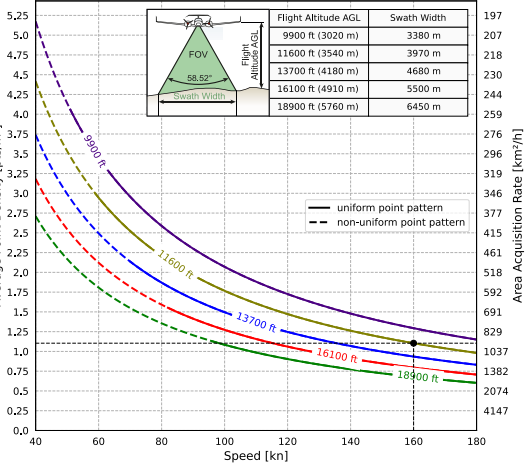
RIEGL VQ-1560 III-S installed in Diamond Aircraft DA62 Survey Star

Measurement Range & Point Density RIEGL VQ-1560 III-S

Laser Pulse Repetition Rate = 2x270kHz, laser power level 100%

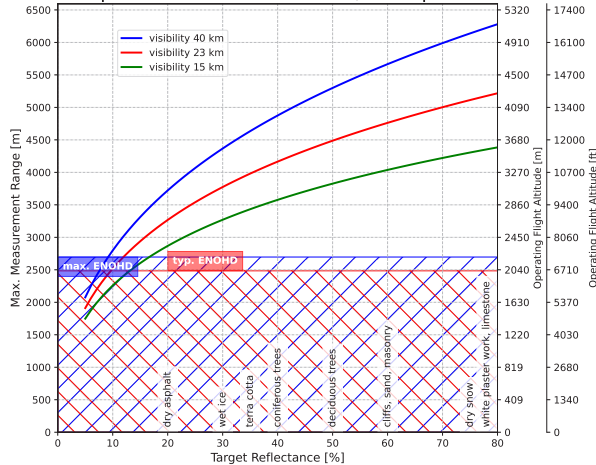


Example: VQ-1560 III-S at 2 x 270,000 pulses/sec, laser power level 100%
Altitude 11,600 ft AGL, Speed 160 kn

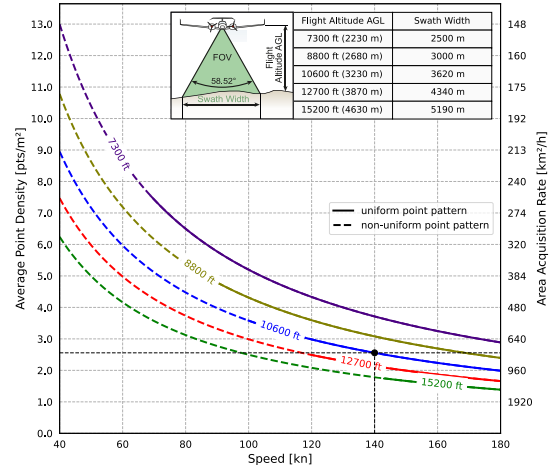


Results: Point Density ~ 1.1 pts/m²
Area Acquisition Rate ~ 939 km²/h

Laser Pulse Repetition Rate = 2x500kHz, laser power level 100%

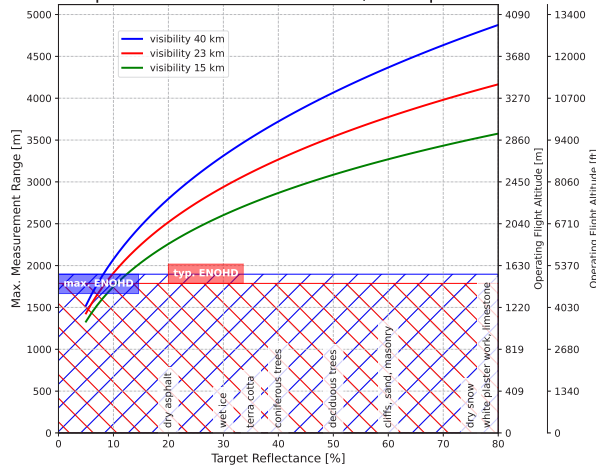


Example: VQ-1560 III-S at 2 x 500,000 pulses/sec, laser power level 100%
Altitude 10,600 ft AGL, Speed 140 kn

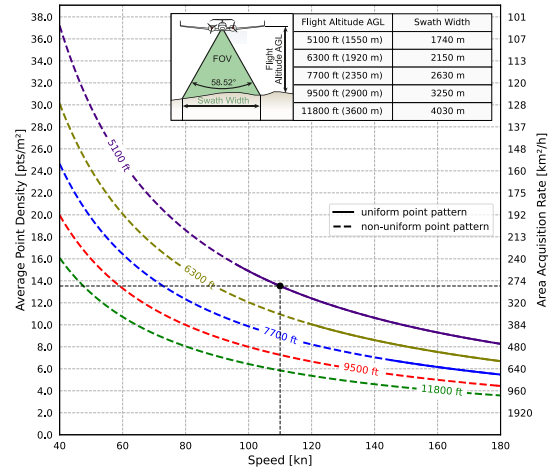


Results: Point Density ~ 2.56 pts/m²
Area Acquisition Rate ~ 751 km²/h

Laser Pulse Repetition Rate = 2x1000kHz, laser power level 100%



Example: VQ-1560 III-S at 2 x 1,000,000 pulses/sec, laser power level 100%
Altitude 5,100 ft AGL, Speed 110 kn



Results: Point Density ~ 13.53 pts/m²
Area Acquisition Rate ~ 284 km²/h

The following conditions are assumed for the Operating Flight Altitude AGL

- ambiguity resolved by multiple-time-around (MTA) processing
- target size ≥ laser footprint
- effective FOV 58°
- average ambient brightness
- roll angle ±5°

Assumptions for calculation of the Area Acquisition Rate

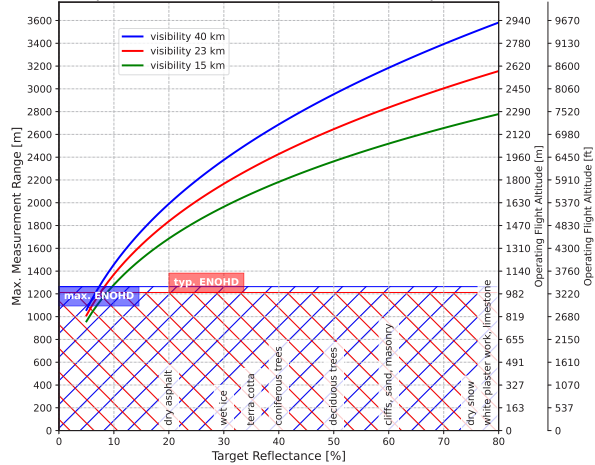
- 20% overlap of neighboring flight strips. This overlap covers a roll angle of ±5° or a reduction of flight altitude AGL of 20%.

Typical ENOHD

- Calculated under assumption of an angular step width of 0.012° and an aircraft speed higher than 10kn.

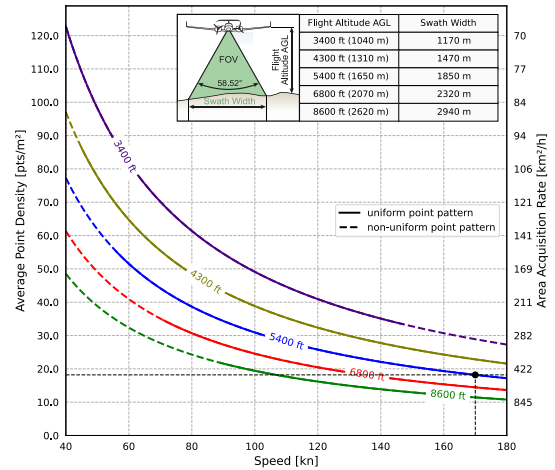
Measurement Range & Point Density *RIEGL* VQ-1560 III-S

Laser Pulse Repetition Rate = 2x2200kHz, laser power level 100%

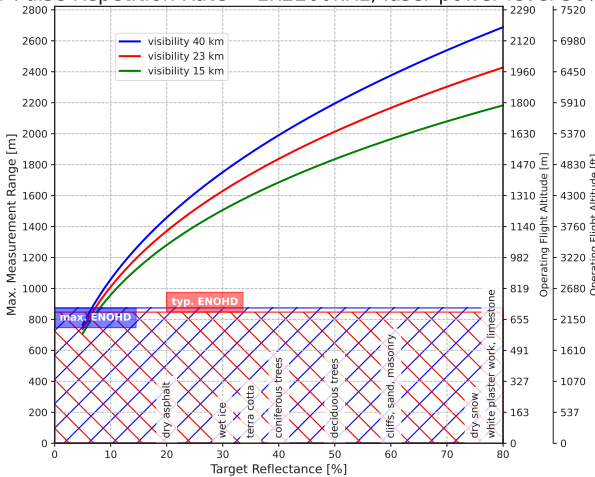


Example: VQ-1560 III-S at 2 x 2,200,000 pulses/sec, laser power level 100%
Altitude 5,400 ft AGL, Speed 170 kn

Results: Point Density ~ 18.19 pts/m²
Area Acquisition Rate ~ 464 km²/h

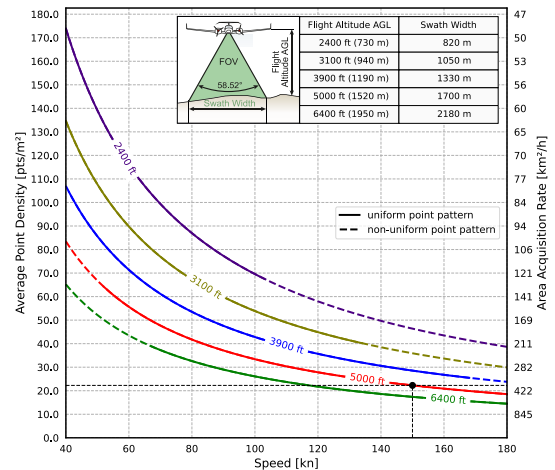


Laser Pulse Repetition Rate = 2x2200kHz, laser power level 50%

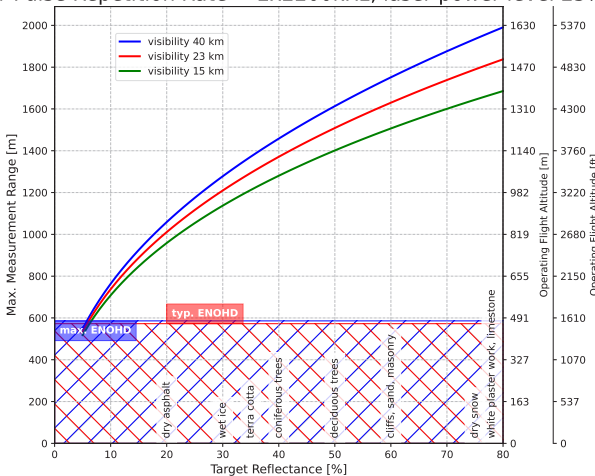


Example: VQ-1560 III-S at 2 x 2,200,000 pulses/sec, laser power level 50%
Altitude 5,000 ft AGL, Speed 150 kn

Results: Point Density ~ 22.26 pts/m²
Area Acquisition Rate ~ 379 km²/h

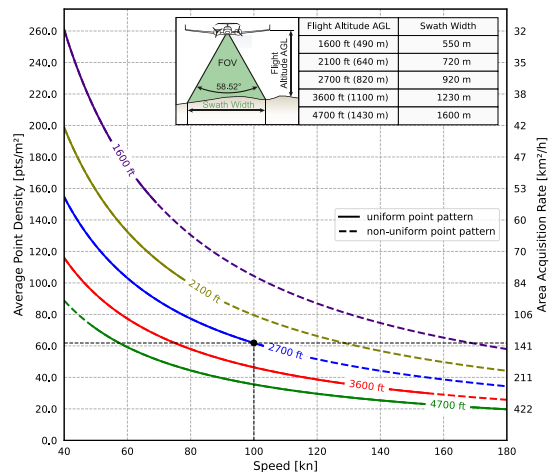


Laser Pulse Repetition Rate = 2x2200kHz, laser power level 25%



Example: VQ-1560 III-S at 2 x 2,200,000 pulses/sec, laser power level 25%
Altitude 2,700 ft AGL, Speed 100 kn

Results: Point Density ~ 61.84 pts/m²
Area Acquisition Rate ~ 137 km²/h



The following conditions are assumed for the Operating Flight Altitude AGL

- ambiguity resolved by multiple-time-around (MTA) processing
- target size ≥ laser footprint
- effective FOV 58°
- average ambient brightness
- roll angle ±5°

Assumptions for calculation of the Area Acquisition Rate

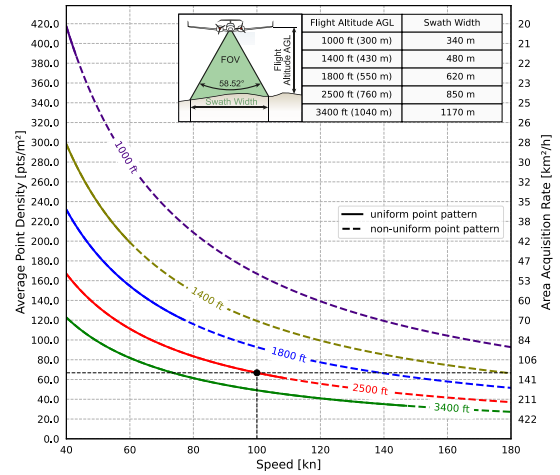
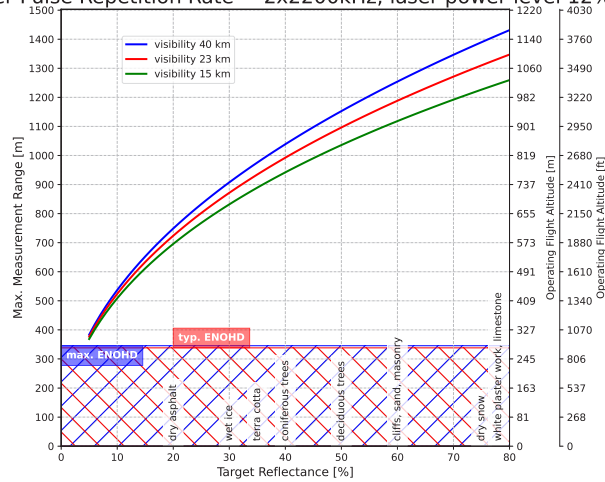
- 20% overlap of neighboring flight strips. This overlap covers a roll angle of ±5° or a reduction of flight altitude AGL of 20%.

Typical ENOHD

- Calculated under assumption of an angular step width of 0.012° and an aircraft speed higher than 10kn.

Measurement Range & Point Density RIEGL VQ-1560 III-S

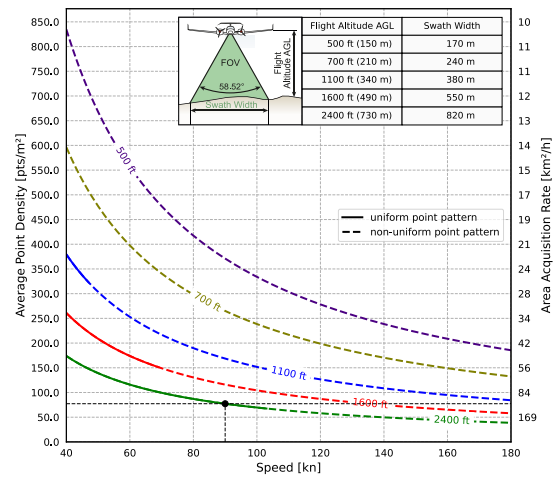
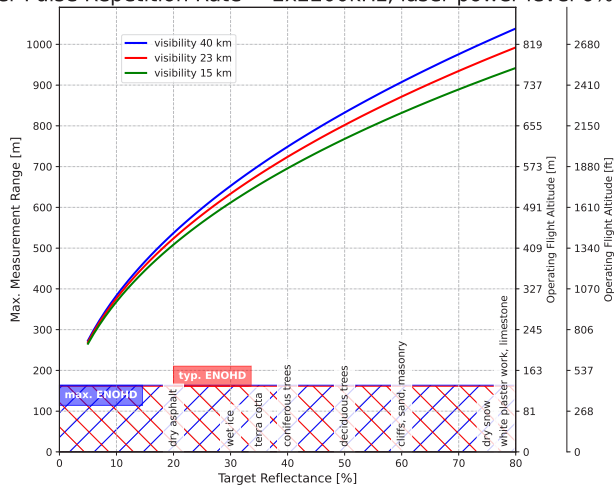
Laser Pulse Repetition Rate = 2x2200kHz, laser power level 12%



Example: VQ-1560 III-S at 2 x 2,200,000 pulses/sec, laser power level 12%
Altitude 2,500 ft AGL, Speed 100 kn

Results: Point Density ~ 66.79 pts/m²
Area Acquisition Rate ~ 126 km²/h

Laser Pulse Repetition Rate = 2x2200kHz, laser power level 6%



Example: VQ-1560 III-S at 2 x 2,200,000 pulses/sec, laser power level 6%
Altitude 2,400 ft AGL, Speed 90 kn

Results: Point Density ~ 77.3 pts/m²
Area Acquisition Rate ~ 109 km²/h

The following conditions are assumed for the Operating Flight Altitude AGL

- ambiguity resolved by multiple-time-around (MTA) processing
- target size $\geq$ laser footprint
- effective FOV 58°
- average ambient brightness
- roll angle $\pm 5^\circ$

Typical ENOHD

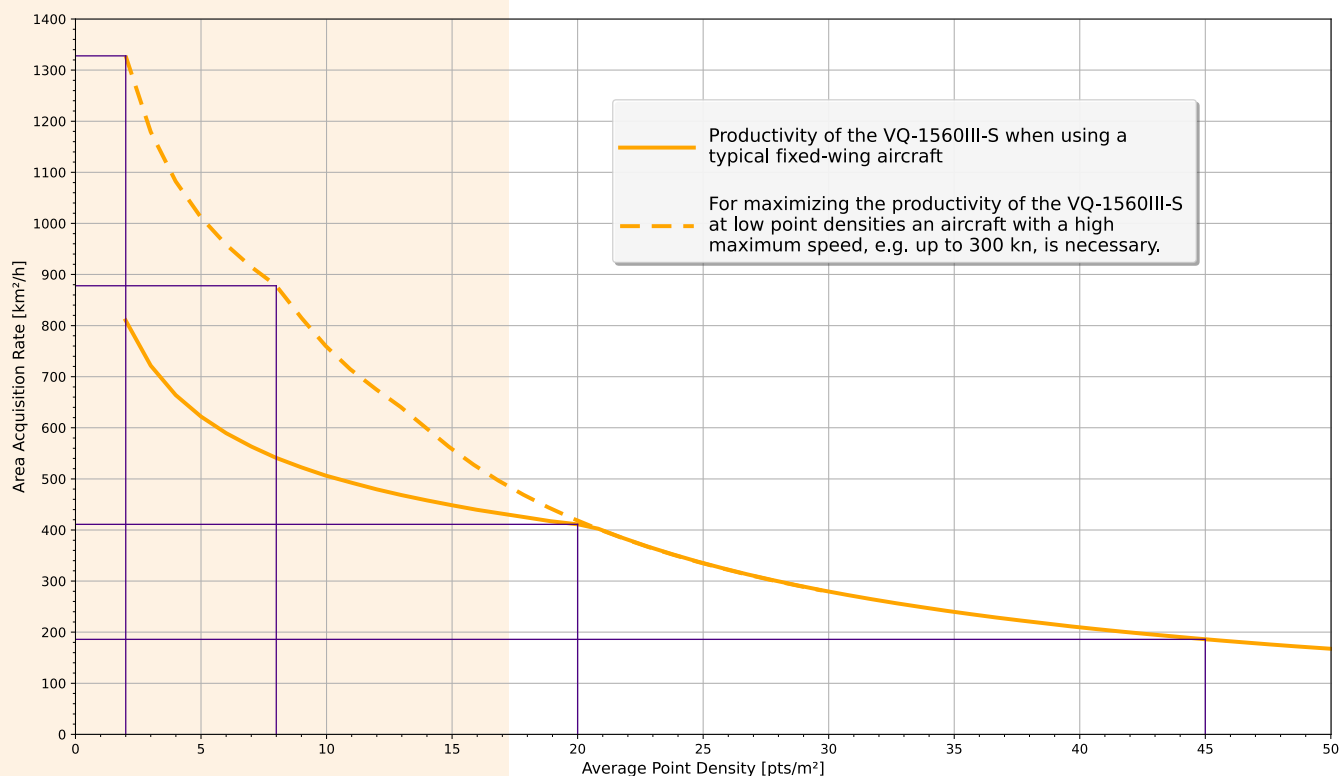
- Calculated under assumption of an angular step width of 0.012° and an aircraft speed higher than 10kn.

Assumptions for calculation of the Area Acquisition Rate

- 20% overlap of neighboring flight strips. This overlap covers a roll angle of $\pm 5^\circ$ or a reduction of flight altitude AGL of 20%.

RIEGL VQ-1560 III-S Productivity

The RIEGL VQ-1560 III-S Waveform Processing Airborne LiDAR Mapping System offers highest productivity.



Examples ¹⁾

Average Point Density	2 pts/m ²	8 pts/m ²	20 pts/m ²	45 pts/m ²
Flight Altitude	8750 ft 2670 m	5790 ft 1760 m	5410 ft 1650 m	3730 ft 1140 m
Ground Speed	300 kn	300 kn	150 kn	99 kn
Swath Width	2990 m	1980 m	1850 m	1270 m
Productivity	1328 km ² /h	878 km ² /h	411 km ² /h	186 km ² /h
eff. Measurement Rate ²⁾	922,000 meas./sec	2,440,000 meas./sec	2,835,000 meas./sec	2,909,000 meas./sec
Camera GSD ^{3) 4)}	200 mm	133 mm	124 mm	85 mm
Camera Trigger Intervall ⁴⁾	5.5 sec	3.7 sec	6.9 sec	7.2 sec

1) calculated for 20% target reflectivity and 20% stripe overlap

2) The target detection rate is equal to the measurement rate for terrains offering only one target per laser pulse but may be much higher for vegetated areas.

3) Ground Sampling Distance

4) calculated for a 150 MPixel CMOS camera with a FOV of 56.2° x 43.7° and 60% image overlap in flight direction (endlap)

Laser Product Classification

Class 3B Laser Product according to IEC60825-1:2014
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.
The instrument must be used only in combination with the appropriate laser safety box.



Range Measurement Performance

as a function of laser power setting, PRR, and target reflectivity

Laser Power Level	100%			
Laser Pulse Repetition Rate (PRR) ¹⁾	2 x 270 kHz	2 x 500 kHz	2 x 1000 kHz	2 x 2200 kHz
Max. Measuring Range ^{2) 3) 4)}				
natural targets $\rho \geq 20\%$	4740 m	3720 m	2800 m	1990 m
natural targets $\rho \geq 60\%$	7040 m	5670 m	4370 m	3180 m
Max. Operating Flight Altitude ^{2) 5)} (AGL) ⁶⁾				
natural targets $\rho \geq 20\%$	3880 m 12750 ft	3050 m 10000 ft	2290 m 7500 ft	1630 m 5350 ft
natural targets $\rho \geq 60\%$	5770 m 18900 ft	4640 m 15250 ft	3580 m 11750 ft	2610 m 8550 ft
NOHD ^{7) 9)}	421 m (414 m ¹⁰⁾)	309 m (305 m ¹⁰⁾)	217 m (215 m ¹⁰⁾)	143 m (142 m ¹⁰⁾)
ENOHD ^{8) 9)}	3012 m (2702 m ¹⁰⁾)	2209 m (2035 m ¹⁰⁾)	1554 m (1464 m ¹⁰⁾)	1035 m (993 m ¹⁰⁾)
Number of Targets per Laser Pulse up to ¹¹⁾	31	31	15	7
Sample block length up to ¹²⁾	244 m	132 m	66 m	30 m

Laser Power Level	50%	25%	12%	6%
Laser Pulse Repetition Rate (PRR) ¹⁾	2 x 2200 kHz	2 x 2200 kHz	2 x 2200 kHz	2 x 2200 kHz
Max. Measuring Range ^{2) 3) 4)}				
natural targets $\rho \geq 20\%$	1460 m	1060 m	750 m	540 m
natural targets $\rho \geq 60\%$	2380 m	1750 m	1250 m	910 m
Max. Operating Flight Altitude ^{2) 5)} (AGL) ⁶⁾				
natural targets $\rho \geq 20\%$	1190 m 3900 ft	870 m 2850 ft	610 m 2000 ft	440 m 1450 ft
natural targets $\rho \geq 60\%$	1950 m 6400 ft	1430 m 4700 ft	1030 m 3350 ft	740 m 2450 ft
NOHD ^{7) 9)}	97 m (97 m ¹⁰⁾)	63 m (63 m ¹⁰⁾)	34 m (34 m ¹⁰⁾)	19 m (19 m ¹⁰⁾)
ENOHD ^{8) 9)}	716 m (694 m ¹⁰⁾)	480 m (469 m ¹⁰⁾)	283 m (277 m ¹⁰⁾)	134 m (132 m ¹⁰⁾)
Number of Targets per Laser Pulse up to ¹¹⁾	7	7	7	7
Sample block length up to ¹²⁾	30 m	30 m	30 m	30 m

¹⁾ rounded average PRR
²⁾ Typical values for average conditions and average ambient brightness; in bright sunlight the operational range may be considerably shorter and the operational flight altitude may be considerably lower than under an overcast sky.
³⁾ The 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 40 km. Range ambiguities have to be resolved by multiple-time-around processing.
⁴⁾ If the laser beam hits, in part, more than one target, the laser's pulse power is split accordingly. Thus, the achievable range is reduced.
⁵⁾ Typical values for max. effective FOV 60°, additional roll angle up to $\pm 5^\circ$
⁶⁾ Above Ground Level
⁷⁾ Nominal Ocular Hazard Distance, based upon MPE according to IEC 60825-1:2014, for single line condition
⁸⁾ Extended Nominal Ocular Hazard Distance, based upon MPE according to IEC 60825-1:2014, for single line condition
⁹⁾ NOHD and ENOHD have been calculated for a typical angular step width of 0.013° (which means non-overlapping laser footprints), and an aircraft speed higher than 10 kn. NOHD and ENOHD increase when using overlapping laser footprints which may be intended e.g. for power line mapping.
¹⁰⁾ The atmospheric attenuation of the laser beam is taken into account assuming standard clear conditions with a visibility of 23.5 km.
¹¹⁾ when using online waveform processing
¹²⁾ when using full waveform recording

Minimum Range ¹³⁾

Accuracy ^{14) 15)} / Precision ^{15) 16)}

Laser Pulse Repetition Rate

Effective Measurement Rate

Echo Signal Intensity

Laser Wavelength

Laser Beam Divergence

100 m

15 mm / 10 mm

2 x 270 kHz up to 2 x 2200 kHz, selectable in steps of less than 1 %

up to 2 x 1.47 MHz @ 60° scan angle

provided for each echo signal

near infrared

typ. 0.17 mrad @ 1/e ¹⁷⁾, typ. 0.23 mrad @ 1/e² ¹⁸⁾

¹³⁾ Limitation for range measurement capability, does not consider laser safety issues! The minimum range for valid reflectivity values is 250 m.

¹⁴⁾ Accuracy is the degree of conformity of a measured quantity to its actual (true) value.

¹⁵⁾ Standard deviation one sigma @ 250 m range under *RIEGL* test conditions.

¹⁶⁾ Precision, also called reproducibility or repeatability, is the degree to which further measurements show the same result.

¹⁷⁾ Measured at the 1/e points. 0.17 mrad correspond to an increase of 17 cm of beam diameter per 1000 m distance.

¹⁸⁾ Measured at the 1/e² points. 0.23 mrad correspond to an increase of 23 cm of beam diameter per 1000 m distance.

Scanner Performance

Scanning Mechanism
Scan Pattern
Tilt Angle of Scan Lines
Forward/ Backward Scan Angle
in Non-Nadir Direction
Scan Angle Range
Total Scan Rate
Angular Step Width $\Delta\theta$
Angle Measurement Resolution

rotating polygon mirror
parallel scan lines per channel, crossed scan lines between channels
 $\pm 14^\circ = 28^\circ$

 $\pm 8^\circ$ at the edges
 60° total per channel, resulting in an effective FOV of 58°
 $40^{1)} - 600$ lines/sec
 $0.006^\circ \leq \Delta\theta \leq 0.100^\circ$ ^{2) 3)}
 0.001°

1) The minimum scan rate depends on the selected laser PRR.

2) The minimum angular step width depends on the selected laser PRR.

3) The maximum angular step width is limited by the maximum scan rate.

Data Interfaces

Configuration
Scan Data Output
Synchronization

LAN 10/100/1000/2500/5000/10000 MBit/s)
LAN 10/100/1000/2500/5000/10000 MBit/s)
Serial RS-232 interface, TTL input for 1 pps synchronization pulse,
accepts different data formats for GNSS-time information
2 connectors for power, RS-232, pps, trigger, exposure
2x U.2 SSD, up to 15.36 TByte each

Camera Interface
Removable Storage Device

General Technical Data

Power Supply / Power Consumption

20 - 32 V DC / typ. 500 W
max. 750 W, depending on integrated optional components
 $\varnothing$ 524 mm x 726 mm (without flange mounted carrying handles)
approx. 65 kg without any camera but including a typical IMU/GNSS unit
approx. 70 kg with optional components
IP54 ⁴⁾
18500 ft (5600 m) above MSL ⁵⁾ / 18500 ft (5600 m) above MSL
-5 °C up to +35 °C / -10 °C up to +50 °C

Main Dimensions (flange diameter x height)
Weight

Protection Class
Max. Flight Altitude operating / not operating
Temperature Range operation / storage

4) Housing below the mounting flange

5) Mean Sea Level

Recommended IMU/GNSS System ^{6) 7)}

IMU Accuracy ⁸⁾
Roll, Pitch
Heading
IMU Sampling Rate
Position Accuracy (typ.)

0.0025°
 0.005°
200 Hz
0.05 m - 0.1 m

6) The recommended IMU is listed neither in the European Export Control List (i.e. Annex 1 of Regulation (EU) No. 2021/821 nor in the Canadian Export Control List. Detailed information on certain cases will be provided on request.

7) The RIEGL VQ-1560 III-S laser scanning system supports different IMU/GNSS Systems, details on request.
8) one sigma values, no GNSS outages, post-processed with base station data

Optional Components VQ-1560 III-S

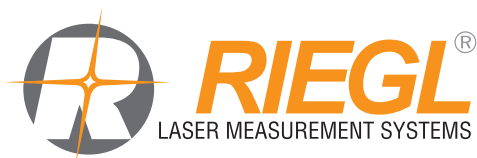
Primary Camera

Sensor Resolution
Sensor Dimensions (diagonal)
Focal Length of Camera Lens
Field of View (FOV)
Data Storage

RGB
e.g. 150 MPixel CMOS
66.7 mm (medium format)
50 mm
approx. $54.6^\circ \times 42.3^\circ$
1x U.2 SSD, up to 15.36 TByte each

Secondary Camera

Different camera types including thermal or NIR cameras can be integrated, details on request.



RIEGL Laser Measurement Systems GmbH, Headquarters
RIEGL USA Inc., Headquarters North America

RIEGL Japan Ltd.
RIEGL China Ltd.
RIEGL Australia Pty Ltd.
RIEGL Canada Inc.
RIEGL UK Ltd.

RIEGL Asia Pacific Ltd.
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