The new RIEGL® LMS-Q780 long-range airborne laser scanner makes use of a powerful laser source, multiple-time-around (MTA) processing, echo digitization and waveform analysis. This combination allows the operation at varying flight altitudes and is therefore ideally suited for aerial survey of complex terrain.

The RIEGL LMS-Q780 gives access to detailed target parameters by digitizing the echo signal online during data acquisition, and subsequent off-line waveform analysis. This method is especially valuable when dealing with difficult tasks, such as canopy height investigation or target classification. Multiple-time-around processing allows the utilization of target echo signals which have been detected out of the unambiguity range between two successive laser pulses. In post-processing the correct allocation of ambiguous echo ranges is accomplished by using RIANALYZE in combination with the associated plugin RIMTA.

The operational parameters of the RIEGL LMS-Q780 can be configured to cover a wide field of applications. Comprehensive interface features support smooth integration of the instrument into a complete airborne scanning system.

The instrument makes use of the time-of-flight distance measurement principle of infrared nanosecond pulses. Fast opto-mechanical beam scanning provides absolutely linear, unidirectional and parallel scan lines. The instrument is extremely rugged, therefore ideally suited for the installation on aircraft. Also, it is compact and lightweight enough to be installed in small twin- or single-engine planes, helicopters or UAVs. The instrument needs only one power supply and GPS timing signals to provide online monitoring data while logging the precisely time-stamped and digitized echo signal data to the rugged RIEGL Data Recorder.

Applications:

**Full Laser Power:**
- Wide Area / High Altitude Mapping
- Topography & Mining
- Glacier & Snowfield Mapping

**Reduced Laser Power:**
- City Modeling
- Mapping of Lakesides & River Banks
- Agriculture & Forestry
- Corridor Mapping

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www.riegl.com
### Range Measurement Performance

#### Full Laser Power

<table>
<thead>
<tr>
<th>Laser Power Level</th>
<th>Laser Pulse Repetition Rate (PRR)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100 kHz</td>
</tr>
<tr>
<td></td>
<td>200 kHz</td>
</tr>
<tr>
<td></td>
<td>300 kHz</td>
</tr>
<tr>
<td></td>
<td>400 kHz</td>
</tr>
<tr>
<td>Max. Measuring Range [^1]^ [^2]^ [^3]^</td>
<td></td>
</tr>
<tr>
<td>natural targets $\rho \geq 20%$</td>
<td>4100 m</td>
</tr>
<tr>
<td>natural targets $\rho \geq 60%$</td>
<td>3500 m</td>
</tr>
<tr>
<td>Max. Operating Flight Altitude Above Ground Level (AGL) [^2]^ [^3]^</td>
<td></td>
</tr>
<tr>
<td>4700 m</td>
<td>15500 ft</td>
</tr>
<tr>
<td>1500 m</td>
<td>1200 m</td>
</tr>
</tbody>
</table>

\[^1\] The following conditions are assumed:  
- target is larger than the footprint of the laser beam  
- average ambient brightness  
- visibility 40 km  
- perpendicular angle of incidence  
- ambiguity resolved by multiple-time-around processing  
- reflectivity $\rho \geq 60\%$, max. scan angle 60°, additional roll angle $\pm 5^\circ$  
- in bright sunlight the operational range may be considerably shorter and the operational flight altitude may be considerably lower than under an overcast sky.

\[^2\] Nominal Ocular Hazard Distance, based upon MPE according to IEC60825-1:2007, for single scan line.

\[^3\] Extended Nominal Ocular Hazard Distance, based upon MPE according to IEC60825-1:2007, viewing a single scan line.

### Reduced Laser Power

<table>
<thead>
<tr>
<th>Laser Power Level</th>
<th>Laser Pulse Repetition Rate (PRR)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>400 kHz</td>
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<tr>
<td></td>
<td>400 kHz</td>
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<tr>
<td></td>
<td>400 kHz</td>
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<tr>
<td></td>
<td>400 kHz</td>
</tr>
<tr>
<td>Max. Measuring Range [^4]^ [^5]^ [^6]^</td>
<td></td>
</tr>
<tr>
<td>natural targets $\rho \geq 20%$</td>
<td>2100 m</td>
</tr>
<tr>
<td>natural targets $\rho \geq 60%$</td>
<td>3200 m</td>
</tr>
<tr>
<td>Max. Operating Flight Altitude Above Ground Level (AGL) [^6]^ [^7]^ [^8]^</td>
<td></td>
</tr>
<tr>
<td>2600 m</td>
<td>1950 m</td>
</tr>
<tr>
<td>8600 ft</td>
<td>6400 ft</td>
</tr>
<tr>
<td>NOHD [^5]^</td>
<td>70 m</td>
</tr>
<tr>
<td>ENOHD [^5]^</td>
<td>560 m</td>
</tr>
</tbody>
</table>

\[^4\] The following conditions are assumed:  
- target is larger than the footprint of the laser beam  
- average ambient brightness  
- visibility 40 km  
- perpendicular angle of incidence  
- ambiguity resolved by multiple-time-around processing  
- reflectivity $\rho \geq 60\%$, max. scan angle 60°, additional roll angle $\pm 5^\circ$  
- in bright sunlight the operational range may be considerably shorter and the operational flight altitude may be considerably lower than under an overcast sky.

\[^5\] Nominal Ocular Hazard Distance, based upon MPE according to IEC60825-1:2007, viewing a single scan line.

\[^6\] Extended Nominal Ocular Hazard Distance, based upon MPE according to IEC60825-1:2007, viewing a single scan line.

### Scanning Performance

- Angular Step Width $\Delta \theta$ \[^9\]^  
- Angle Measurement Resolution
- Scan Sync

### Intensity Measurement

- For each echo signal, high-resolution 16-bit intensity information is provided which can be used for target discrimination and/or identification/classification.

\[^9\] Angle between consecutive laser shots, user adjustable.

**Technical Data to be continued at page 7**
The waveform digitization feature of the RIEGL LMS-Q780 enables the user to extract most comprehensive information from the echo signals. Figure 1 illustrates a measurement situation where 3 laser measurements are taken on different types of targets. The red pulses symbolize the laser signals travelling towards the target with the speed of light. When the signal interacts with the diffusely reflecting target surface, a fraction of the transmitted signal is reflected towards the laser instrument, indicated by the blue signals.

In situation 1, the laser pulse hits the canopy first and causes three distinct echo pulses. A fraction of the laser pulse also hits the ground giving rise to another echo pulse. In situation 2, the laser beam is reflected from a flat surface at a small angle of incidence yielding an extended echo pulse width. In situation 3, the pulse is simply reflected by a flat surface at perpendicular incidence resulting in one single echo pulse with a shape identical to the transmitted laser pulse.

The upper line of the acquisition diagram shows the analog signals: the first (red) pulse relates to a fraction of the laser transmitter pulse, and the next 3 (blue) pulses correspond to the reflections by the branches of the tree; the last pulse corresponds to the ground reflection.

This analog echo signal is sampled at constant time intervals (middle line) and is, in the following, analog-to-digital converted, resulting in a digital data stream (bottom line of the acquisition section). This data stream is stored in the RIEGL Data Recorder for subsequent off-line post processing, where the echo signals can be perfectly reconstructed and analyzed in detail to precisely derive target distance, pulse shape as an indicator for target type, and other parameters.

Based upon RIEGL’s long-standing expertise and experience in designing, manufacturing and marketing digitizing laser rangefinders for challenging industrial and surveying applications, and due to the careful design of the analog and digital front-end electronics, the LMS-Q780 records the complete information of the echo signal over a wide dynamic range. Thus, in post-processing the signal can be perfectly reconstructed and analyzed in detail to precisely derive target distance, target type, and other parameters.
In time-of-flight laser ranging a maximum unambiguous measurement range exists which is defined by the measurement repetition rate and the speed of light. When scanning at a pulse repetition rate of, e.g., 400 kHz, measurement ranges above approx. 375 m are ambiguous caused by an effect known as "Multiple-Time-Around" (MTA). In such case target echoes received may not be associated with their preceding laser pulses emitted any longer (MTA-zone 1), but have to be associated with their last but one (MTA-zone 2), or even last but two laser pulses emitted (MTA-zone 3), in order to determine the true measurement range.

Figure 3 gives an impression of ALS data where each single echo of a scan line is associated with each of its last four preceding laser shots emitted. Each single echo is represented by a measurement range calculated in MTA zone 1, 2, 3 and 4 respectively, but only one of the four realizations represents the true point cloud model of the scanned earth surface. The chosen example shows scan data correctly allocated in MTA zone 2, where the earth surface appears more or less flat in contrast to the typical spatial characteristics of incorrectly calculated ambiguous ranges in MTA zones 1, 3 and 4.

The RIEGL LMS-Q780 is capable of acquiring echo signals which arrive after a delay of more than one pulse repetition interval, thus allowing range measurements beyond the maximum unambiguous measurement range. Unique techniques in high-speed signal processing and a novel modulation scheme applied to the train of emitted laser pulses permit range measurements without any perceivable gaps at any distance within the instrument’s maximum measurement range. The specific modulation scheme applied to the train of emitted laser pulses avoids a total loss of data at the transitions between MTA-zones and retains range measurement at approximately half the point density.

The correct resolution of ambiguous echo ranges is accomplished using RIANALYZE in combination with the associated plugin RiMTA, which does not require any further user interaction, and maintains fast processing speed for mass data production.
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
- Scan angle: 60°
- Roll angle: ±5°

**Definition of the Spatial Sampling Frequency:**

The Spatial Sampling Frequency is the reciprocal of the 95th percentile of the distribution function of the maximum distances between neighboring scan points. When considering any individual scan point, the probability to find its most distant neighbor within the reciprocal of the Spatial Sampling Frequency is 95%.

Assumptions for calculation of the Covered Area per Time:

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

**Measurement Range & Point Density RIEGL LMS-Q780**

### PRR = 300 kHz, laser power level 100%

- **Example:** LMS-Q780 at 300,000 pulses/sec, laser power level 100%
  - Altitude: 5700 ft AGL
  - Speed: 80 kn
  - Results:
    - Point Density ~ 4 pts/m²

- **Example:** LMS-Q780 at 200,000 pulses/sec, laser power level 100%
  - Altitude: 4000 ft AGL
  - Speed: 70 kn
  - Results:
    - Point Density ~ 1.6 pts/m²

- **Example:** LMS-Q780 at 100,000 pulses/sec, laser power level 100%
  - Altitude: 3000 ft AGL
  - Speed: 60 kn
  - Results:
    - Point Density ~ 0.6 pts/m²

### PRR = 200 kHz, laser power level 100%

- **Example:** LMS-Q780 at 200,000 pulses/sec, laser power level 100%
  - Altitude: 5700 ft AGL
  - Speed: 80 kn
  - Results:
    - Spatial Sampling Frequency ~ 0.53 pts/m
    - Covered Area per Time ~ 530 km²/h

- **Example:** LMS-Q780 at 100,000 pulses/sec, laser power level 100%
  - Altitude: 4500 ft AGL
  - Speed: 70 kn
  - Results:
    - Spatial Sampling Frequency ~ 1.35 pts/m
    - Covered Area per Time ~ 230 km²/h
**Measurement Range & Point Density RIEGL LMS-Q780**

**PRR = 400 kHz, laser power level 100%**

Example: LMS-Q780 at 400,000 pulses/sec; laser power level 100%
Altitude = 2700 ft AGL, Speed = 85 kn
Results: Point Density ~ 8.4 pts/m²
Spatial Sampling Frequency ~ 1.6 pts/m
Covered Area per Time ~ 140 km²/h

**PRR = 400 kHz, laser power level 50%**

Example: LMS-Q780 at 400,000 pulses/sec; laser power level 50%
Altitude = 2500 ft AGL, Speed = 70 kn
Results: Point Density ~ 8.4 pts/m²
Spatial Sampling Frequency ~ 1.9 pts/m
Covered Area per Time ~ 95 km²/h

**PRR = 400 kHz, laser power level 25%**

Example: LMS-Q780 at 400,000 pulses/sec; laser power level 25%
Altitude = 2500 ft AGL, Speed = 70 kn
Results: Point Density ~ 5.8 pts/m²
Spatial Sampling Frequency ~ 1.6 pts/m
Covered Area per Time ~ 140 km²/h

The following conditions are assumed for the Operating Flight Altitude AGL:
- target size
- 20% overlap of neighboring flight strips
- This overlap covers a roll angle of ±5° or a reduction of flight altitude AGL of 20%.

Assumptions for calculation of the Covered Area per Time:
- 20% overlap of neighboring flight strips. This overlap covers a roll angle of ±5° or a reduction of flight altitude AGL of 20%.

**Definition of the Spatial Sampling Frequency**
- The Spatial Sampling Frequency is the reciprocal of the 95th percentile of the distribution function of the maximum distances between neighboring scan points. When considering any individual scan point, the probability to find its most distant neighbor within the reciprocal of the Spatial Sampling Frequency is 95%.
Example: LMS-Q780 at 400,000 pulses/sec, laser power level 12%  
Altitude = 1200 ft AGL, Speed = 80 kn  
Point Density ~ 24.7 pts/m²

Example: LMS-Q780 at 400,000 pulses/sec, laser power level 6%  
Altitude = 850 ft AGL, Speed = 60 kn  
Point Density ~ 15.3 pts/m²

The following conditions are assumed for the Operating Flight Altitude AGL:
- target size = laser footprint
- roll angle ±5°
- average ambient brightness
- scanner roll angle ±5°

Assumptions for calculation of the Covered Area per Time:
- 20% overlap of neighboring flight strips. This overlap covers a roll angle of ±5° or a reduction of flight altitude AGL of 20%.

Some technical data are:
- Power Supply: 18 - 32 V DC / approx. 7 A @ 24 VDC
- Main Dimensions (L x W x H): 480 x 212 x 279 mm / approx. 20 kg
- Protection Class: IP54
- Operating Flight Altitude: 0 ft to 1200 ft AGL / 0 m to 365 m
- Temperature Range: -5°C to +40°C (operation) / -10°C to +50°C (storage)
- Mounting: Steel thread inserts on both sides of the laser scanner, rigidly connected to the inner structure of the scanning mechanism
Dimensional Drawings RIEGL LMS-Q780

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