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Long-Range Laser Rangefinding Beyond 10 km

Technology, applications, market direction and the role of eye-safe 1.54 µm Er:glass transmitters

Technical white paper | October 2026

A system-level assessment for defense and aerospace decision-makers, OEM developers and integrators evaluating long-range electro-optical sensing, wide-area coastal surveillance, airborne payloads and emerging space applications.

Executive takeaway

For >10 km direct time-of-flight ranging, maximum distance is not a laser specification by itself. It is a link-budget result determined by pulse energy, pulse width, transmitter divergence, receiver aperture and detector sensitivity, target size/reflectivity, alignment, processing and the atmosphere. The strongest commercial trend is toward compact, eye-safe 1.5 µm-class modules that combine long reach with low SWaP and OEM-ready interfaces.

Technology-supplier perspective

OPTOGAMA develops 1.54 µm passively Q-switched Er:glass transmitters and related optical engineering capabilities that may support long-range rangefinder architectures. Released data identify KAUKAS 3 as a >3 mJ source for energy-focused designs and RANGER as a compact >1.5 mJ, 5–10 Hz source where update rate and integration volume are important. These parameters describe the transmitter only. Achievable range must be determined at system level from the complete optical, electronic, target and atmospheric configuration.

1. Why the 10+ km regime is different

A pulsed laser rangefinder measures round-trip time of flight. Conceptually, $R = c\Delta t/2$. At long range, however, timing is usually not the hardest problem: obtaining a sufficiently strong and distinguishable return is. The optical signal spreads geometrically, suffers two-way atmospheric attenuation, competes with solar/background radiation and detector noise, and may only partially illuminate the target.

- Pulse energy and peak power determine the energy launched toward the target and the strength of a single-shot return.
- Beam divergence controls how much of that energy remains on the target. At 10 km, 0.5 mrad corresponds to a roughly 5 mrad? No: using the small-angle approximation, the beam diameter contribution from full-angle divergence is about 5 m at 10 km. This simple geometry illustrates why collimation matters as much as source energy.
- Receiver aperture, optical throughput, narrowband filtering and InGaAs/APD detector performance set how efficiently weak 1.5 µm returns are captured.
- Atmospheric visibility, aerosols, fog, rain and target reflectivity can dominate the link budget. Range therefore has to be quoted with explicit target and visibility conditions.

Scientific literature supports the architecture. An IEEE-reported eye-safe rangefinder reached distances up to 10 km using a 1 mJ Yb:Er:glass source and an InGaAs avalanche photodiode. A 2022 SPIE transmitter paper reported a compact 1535 nm passively Q-switched Er–Yb:glass laser operating at 1–8 Hz, 4.5 ns pulse width and >250 kW peak power. Published Er:glass reviews identify the 1.53–1.56 µm region as attractive because of eye-safety, atmospheric transparency and compatibility with room-temperature Ge/InGaAs detectors.

2. System architecture for long-range direct ToF

Subsystem	Function	What matters at >10 km
Er:glass transmitter	Generate short 1.54 µm pulse	mJ-class pulse energy, ns pulse width, stability, trigger behavior
Beam expander / collimator	Reduce far-field spot	Low divergence, boresight stability, aperture, optical quality
Transmit/receive alignment	Keep FOV and beam overlapped	Thermo-mechanical stability and calibration
Receiver telescope	Collect weak return	Clear aperture, throughput, stray-light control
Spectral filter	Suppress background	Bandwidth, angle sensitivity, transmission at laser wavelength
InGaAs / APD receiver	Convert return to electrical signal	Sensitivity, noise, gain, recovery, dynamic range
Timing & processing	Estimate distance	Thresholding, gating, multi-target logic, false-alarm control
Housing & thermal design	Maintain calibration	Shock/vibration, temperature, humidity, contamination

A useful design discipline is to treat pulse energy and divergence as a coupled quantity. Increasing energy helps only if enough of it hits the target and the receiver can discriminate the return. Conversely, very low divergence can reduce acquisition margin for small or rapidly moving targets. Optimal divergence is therefore application-specific.

3. Why 1.54 µm Er:glass is important

The scientific and commercial evidence converges on three advantages: eye-safety at approximately 1.5 µm compared with retinal-hazard near-IR wavelengths, efficient detection with InGaAs technology, and useful atmospheric transmission. This does not make every 1535 nm implementation automatically Class 1: accessible-emission classification applies to the complete product and operating conditions, not wavelength alone.

For OEM systems, diode-pumped passively Q-switched Er:glass also offers a compact route to short nanosecond, mJ-class pulses. The market shows this architecture from transmitter level through complete modules: Jenoptik states that its ELEM family uses 1.54 µm Er:glass and ranges non-cooperative targets up to 60 km depending on model; current Asian OEM offerings advertise 12–20 km-class complete 1535 nm modules with roughly 0.3 mrad beam divergence and explicit target/visibility conditions.

4. Applications

Application	Why >10 km matters	System priorities
Long-range EO/IR observation	Adds precise distance to identification/observation	Range probability, boresight, compact integration, environmental stability
Wide-area coastal and maritime surveillance	Supports ranging to vessels, shoreline objects and navigation-relevant features across large observation sectors	Marine visibility, haze, sea clutter, platform stabilization, geolocation accuracy and track continuity
Airborne / UAV payloads	Standoff measurement from moving platforms	SWaP, vibration, divergence, fast updates
Defense target-location and sensor-fusion systems	Provides range input for observation, cueing, geolocation and multi-sensor correlation	Low latency, false-alarm control, boresight retention, cybersecurity and rules for human authorization
Surveying / industrial remote measurement	Remote non-contact distance to structures/terrain	Accuracy, target reflectivity, eye safety
Space / landing / proximity sensing	Vacuum removes atmospheric loss but qualification dominates	Radiation/thermal-vacuum design, reliability, heritage, receiver link budget

For aerospace and space programs, application potential must not be confused with qualification. Long-range ranging architectures can support descent, landing, proximity and platform-navigation functions, but radiation tolerance, thermal-vacuum behavior, contamination control, reliability, redundancy and mission assurance require program-specific verification. Available released OPTOGAMA information does not confirm space qualification of the evaluated standard transmitters.

4.1 Decision criteria for defense, aerospace and coastal-surveillance programs

- Mission effectiveness: define target classes, required instrumented range, range probability, update rate, accuracy, false-alarm tolerance and day/night operating cases before selecting the transmitter.
- Coastal surveillance: model humidity, aerosol loading, haze, sea-surface background and moving-platform effects. A clear-weather maximum range is not an adequate basis for operational coverage planning.
- Defense integration: evaluate boresight stability, shock and vibration, electromagnetic compatibility, cybersecurity, timing interfaces, multi-target logic and export-control constraints at system level.
- Airborne and spaceborne use: allocate mass, power, thermal rejection, alignment stability and qualification evidence early. Standard commercial performance does not demonstrate mission qualification.
- Acquisition and lifecycle: require a controlled configuration, acceptance-test definition, obsolescence approach, repair strategy and supply-continuity plan. Compare suppliers using the same target, atmosphere and probability-of-detection assumptions.

5. Current market and trends

The market is moving toward eye-safe wavelengths, lower SWaP, tighter integration and higher levels of module completeness. A 2026 third-party market study estimates the eye-safe LRF module market at USD 544.2 million in 2025 and USD 1.1 billion by 2035, corresponding to a stated 7.5% CAGR. It identifies defense modernization, laser-safety adoption and unmanned or autonomous platforms as growth drivers. Such market models are directional

estimates rather than audited industry totals and should not be used alone for investment or procurement decisions.

Market signal	Evidence	Implication for OEM laser suppliers
1535 nm becoming mainstream	Market reports and broad product availability	Compete on SWaP, stability, integration and supply, not wavelength alone
Longer range in smaller modules	Public complete-module specifications extend from 10 km-class systems to substantially longer ranges under stated conditions	Transmitter must support tighter, thermally stable beam delivery
Unmanned/airborne integration	Market reports cite UAV/autonomous demand	Weight, power, interfaces and vibration become purchase criteria
Complete solution expectations	Modules integrate TX/RX, timing and interfaces	Laser vendors benefit from collimators, drivers and system engineering
Environmental performance	Products advertise wide temperature/shock ranges	Qualification evidence and configuration control matter commercially

Public product information shows an established international supply base for complete 1.5 µm-class modules, alongside a growing number of lower-cost OEM offerings. To avoid implied endorsement, affiliation or incomplete product-to-product comparison, this paper does not identify or rank individual competing suppliers. For procurement, the meaningful differentiators are verified detection probability under stated conditions, environmental evidence, configuration control, interface maturity, supportability, exportability and supply continuity.

6. OPTOGAMA transmitter fit: KAUKAS versus RANGER

The table below summarizes released product information for two transmitter families that may be considered during system architecture studies. It is not a complete-rangefinder comparison and does not establish achieved range. Controlled datasheet revisions should be confirmed before procurement or publication.

Parameter	KAUKAS 2	KAUKAS 3	RANGER
Wavelength	1534 nm	1534 nm	1534 nm (some newer material: 1533 nm)
Pulse energy	>2 mJ	>3 mJ	>1.5 mJ standard
Pulse duration	<11 ns	<8 ns	<6 ns standard; some current collateral: 6–6.5 ns
Repetition rate	single shot–2 Hz	single shot–1 Hz	5–10 Hz
Beam quality	M^2 <2	M^2 <2	M^2 <2
Beam profile	TEM00	TEM00	TEM00
Laser-head size	61 × 33 × 29.5 mm	61 × 33 × 29.5 mm	current collateral: 61.5 × 30.6 × 20.5 mm
Published use	LIDAR / laser ranging / LIBS	LIDAR / laser ranging / LIBS	LIDAR / laser ranging

6.1 Suitability for >10 km architectures

KAUKAS 3 is the stronger candidate when the design is fundamentally photon-limited and update rate can be low. Its >3 mJ pulse energy provides the largest standard pulse-energy budget among the compared OPTOGAMA Er:glass models. KAUKAS 2 provides an intermediate >2 mJ option.

RANGER is the more natural fit where compact packaging and 5–10 Hz update rate are important. Standard material supports >1.5 mJ, <6 ns, M^2 <2, TEM00 operation and OEM rangefinding use. Newer OPTOGAMA collateral lists a 61.5 × 30.6 × 20.5 mm laser head. A beam-expansion/collimation stage is still required for genuinely long-range operation because the bare-source divergence is not the finished rangefinder divergence.

No complete-system range claim is made in this paper. A defensible range statement requires an approved test report covering target type and reflectivity, visibility, receiver configuration, beam divergence, detection probability, false-alarm criteria and measurement method.

7. Engineering capabilities relevant to complete long-range LRF integration

- Beam delivery: internal R&D material includes a Ranger collimator activity targeting divergence below 0.5 mrad. This is highly relevant to 10+ km links, but the current status and controlled specification require verification before publication.
- LRF electronics/integration: internal R&D material identifies a laser rangefinder and controller work compatible with Ranger and KAUKAS platforms.
- Environmental robustness: recent internal achievement material reports Ranger environmental validation and low-temperature operation; only values already represented in released datasheets should be used publicly until the latest test report is approved.
- System roadmap: a May 2026 internal commercial discussion described a preliminary 10–20 km LRF target, 10 Hz operation and <500 g prototype goal. These were development targets, not released product specifications, and should remain internal unless formally approved.

For program planning, the relevant supplier scope can extend beyond the laser head to the driver, beam expansion and collimation, optomechanics, alignment strategy and test support. The boundary between standard product, configurable subsystem and new development should be defined in the statement of work, together with acceptance evidence and configuration control.

8. Design guidance for selecting the source

Need	Preferred starting point	Reasoning
Maximum single-shot link margin; low update rate acceptable	KAUKAS 3	Highest standard pulse energy (>3 mJ)
Energy-focused design with somewhat higher cadence	KAUKAS 2	>2 mJ with up to 2 Hz
Portable/OEM system needing 5–10 Hz updates	RANGER	Compact head with >1.5 mJ and 5–10 Hz
Complete 10–20+ km instrument	System engineering required	Receiver aperture, APD, optics, divergence, target and atmosphere determine achieved range

The central recommendation is not to advertise “10 km laser” or “20 km laser” at source level. Instead, state the verified transmitter parameters and show how they map into a representative LRF link budget. This is technically stronger and reduces the risk of a range claim being interpreted independently of target and visibility assumptions.

Sources and evidence

Type	Source / relevance
Scientific	IEEE, “Eye safe laser rangefinder for transport safety,” document 9840158. Search abstract reports an ultracompact eye-safe LRF up to 10 km using a 1 mJ Yb:Er:glass laser and InGaAs APD.
Scientific	Vu et al., SPIE Proc. 12273 (2022), “Compact, diode end-pumped, eye-safe laser rangefinder transmitter,” DOI 10.1117/12.2638473.
Scientific	Denker, Galagan & Sverchkov, “Erbium (Er) glass lasers,” Handbook of Solid-State Lasers (2013), DOI 10.1533/9780857097507.2.341.

Market/product	Public European complete-module product literature reviewed for architecture and range-claim conventions. Individual supplier names are omitted to avoid implied comparison or endorsement.
Market	Global Market Insights, Eye-Safe Laser Rangefinder Module Market, published August 2026.
Market	Global Info Research, Global 1535nm Laser Ranging Module Market 2026–2032.
Competitive product	Public 1535 nm OEM-module literature reviewed for market and architecture context. Individual supplier names are omitted to avoid implied comparison or endorsement.
OPTOGAMA approved/product	OPTOGAMA product collateral for KAUKAS 2, KAUKAS 3 and RANGER; current 2026 Optica laser collateral.