Compact Laser Designators (LDs) for Mini Unmanned Aerial Vehicles (UAVs) and Handheld Targeting Systems

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Defense Systems Information Analysis Center

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Introduction

Laser target ranging and designation systems provide accurate target acquisition. Once a target has been acquired and located, laser designation can be used to accurately guide laser-guided munition (LGM) to the target. LDs are commonly used onboard airborne platforms, ground platforms, and by dismounted soldiers using handheld or tripod-mounted LDs.

A laser acquisition system:

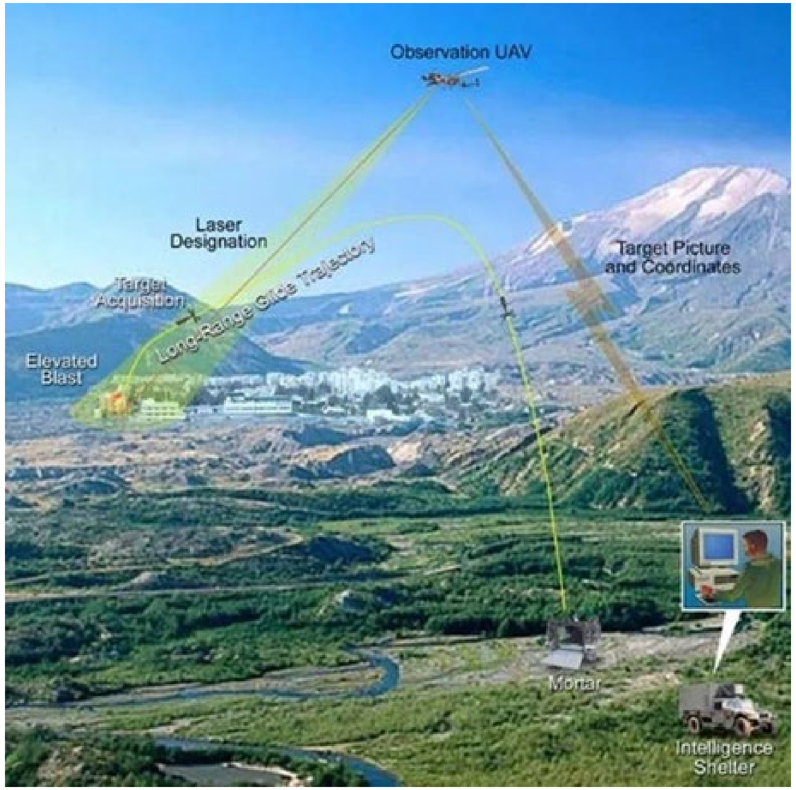
- Acquires targets and provides accurate target coordinates to Global Positioning System (GPS) weapons.
- Homes in on LD energy reflected from the designated target during the terminal interval of flight.

The laser acquisition system consists of:

- Laser rangefinder
- GPS
- Inertial Navigation System

Laser designators can designate tactical targets at ranges between 1 and 10 km based on their power, beam divergence, and atmospheric conditions. Typical performance envelopes:

- 10-30 mJ; weight 0.1-0.3 kg; range 1-3 km
- 50-100 mJ; weight 0.5-1 kg; range 5-10 km



Common Characteristics and Limitations

- **Pulse repetition frequency (PRF) codes of laser designators and laser acquisition devices must be synchronized with LGM's seeker head in accordance with North Atlantic Treaty Organization (NATO) Standardization Agreement (STANAG) 3733 standard.**

- **The field of view of reflected LD energy must overlap with the LGM flight envelope to enable continuous visibility of reflected LD energy throughout LGM flight duration.**

- **Laser designators must be lasing in a timely sequence with the LGM or laser acquisition device.**

- **Military-grade laser designators are emitting pulse trains at a 1064-nm wavelength, not visible to the human eye. A high frame rate short-wave infrared imaging sensor or high sensitivity/high frame rate, complementary metal oxide semiconductor near-infrared sensor is needed to "see" the LD spot on the target.**

Laser Characteristics and Limitations

Laser designators must comply with NATO STANAG 3733 standard for pulse codes. The code defines specific PRF structure of emitted pulses, compatible with LGM missile seekers detection electronics.

LD key performance parameters:

- **Output energy (mJ)**
- **Beam divergence (µrad)**
- **Beam jitter (µrad)**

High output energy, narrow beam divergence, and low beam jitter would increase overall LD range.

Poor atmospheric transmission conditions will reduce LD range due to high absorption and scattering of laser energy in the atmospheric path.

System Characteristics and Limitations

- **LDs are typically packaged in a targeting pod or a gimbaled payload that contains imaging sensors nested on a stabilized optical bench.**

- **Heat dissipation design is required to release excess heat generated during target designation.**

- **LD operation requires "laser off" periods between designation intervals to prevent laser overheating.**

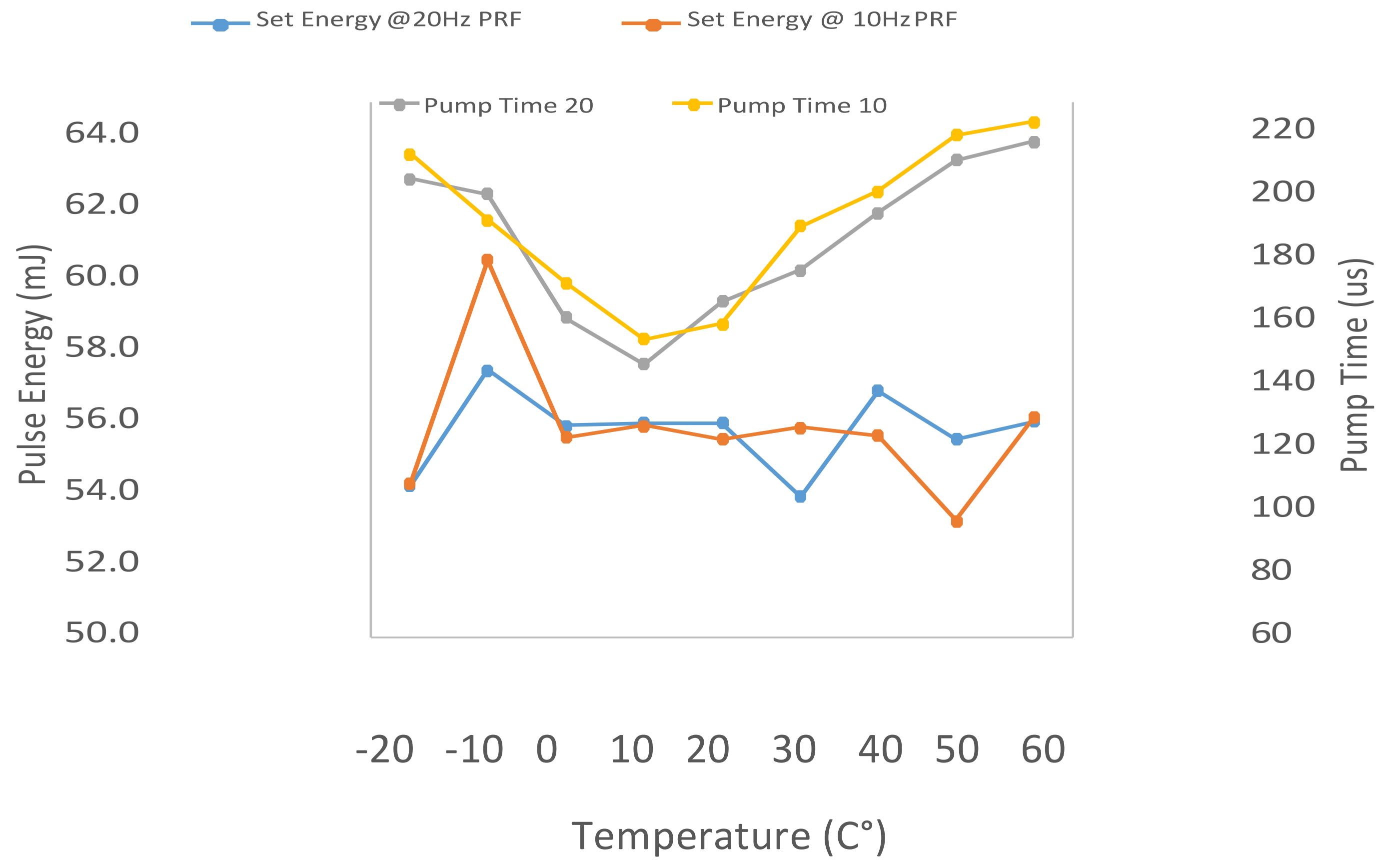
  – Typical duty cycle is 20% (e.g., 1 minute "laser on" followed by 4 minutes "laser off"), limiting continuous laser designation for multiple LGMs.

Key Performance Parameters (KPPs)

Parameter	LD Performance
Wavelength	1064 nm
Output Energy	10-30 mJ
Beam Divergence	50-1000 µrad
Pulse Width (FWHM)	20 ns
Pulse PRF Code	Bands I and II defined by NATO STANAG 3733
Pulse-to-Pulse Stability	4 µs
Duty Cycle @ 20 Hz	1 min continuous/4 min OFF period
Beam Jitter	<50-100 µrad (<10% of beam divergence)
Pulse-to-Pulse Energy Stability	<10% in any 100 pulses <10% consecutive pulses

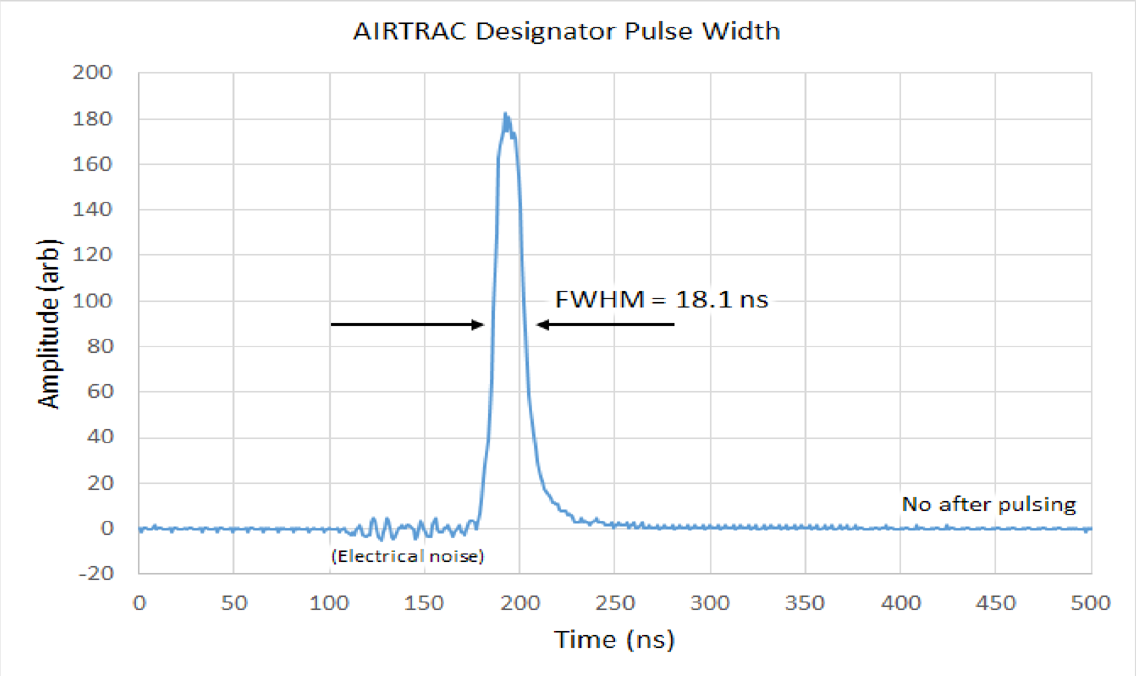
Laser Designator KPPs

Military-grade laser designators must generate stable pulse energy over a wide temperature range for all required PRF codes for effective target designation.



Laser Designator KPPs

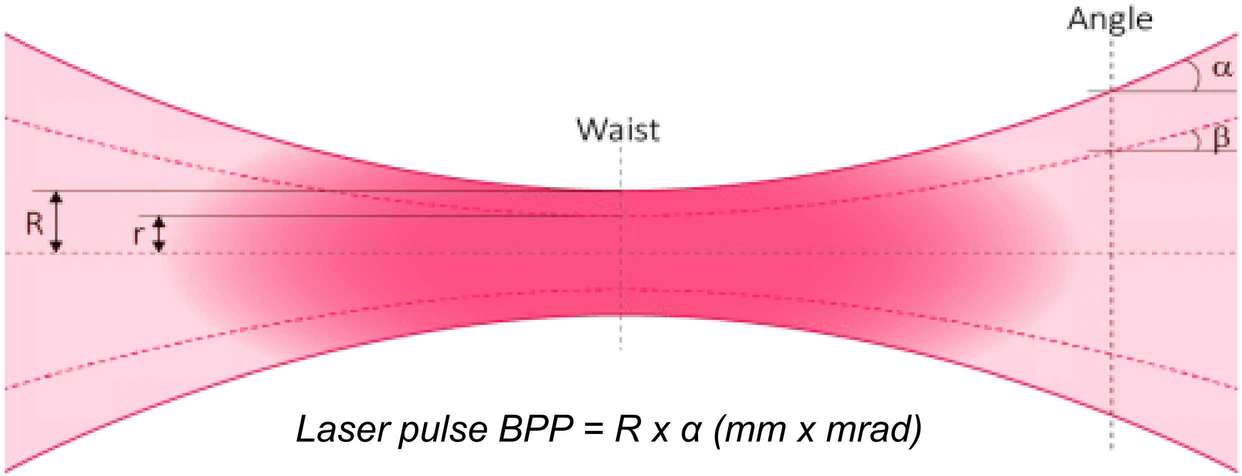
Military laser designators should have a pulse width between 10 and 25 ns for effective and efficient target designation.



Laser Designator KPPs

Beam parameter product (BPP) quantifies the quality of the laser beam and how well it can focus. It is the product of:

- The laser beam far field half divergence angle (α)
- The beam radius at its narrowest spot or beam waist (R)
  - The beam waist R is defined as the beam radius that contains 95% of encircled laser energy.



Laser pulse BPP = R x α (mm x mrad)

For example, a laser designator with BPP = 2 and beam waist of 4 mm expanded to 20 mm by a 5X optical beam expander will produce a total output beam angle 2α = 200 µrad.

Laser Designator KPPs

- Laser ½ total beam divergence β can be derived from the following:
  - The laser ½ output beam angle (α)
  - Beam internal root mean square (RMS) jitter (σ)
  - Payload gimbal residual RMS jitter (j)
  - β is calculated using the root sum square $\beta = \sqrt{(\alpha^2 + \sigma^2 + j^2)}$
- For example, the total ½ beam divergence β = 144 μrad calculated using beam angle α = 100, beam jitter σ = 25 μrad, and payload gimbal residual jitter j = 100 μrad.
- In this case, the total beam divergence 2β = 288 μrad. The LD spot size will be
  - 28.8 cm at 1 km
  - 2.88 m at 10 km
- This LD beam will be contained within a standard NATO target within the critical dimension of 2.3 m at 1 km but will spill over the same target at 10 km. It will be fully contained within the target at an 8-km range.

Laser Designator KPPs

Laser designation range performance can be estimated using EDR95, a simplified laser designation performance model. Assumptions include:

- Clear atmospheric visibility (23 km) (not limiting the reflected laser energy detected by the missile seeker).
- Target position is perpendicular to the laser transmitter.
- Collocated laser transmitter and receiver.

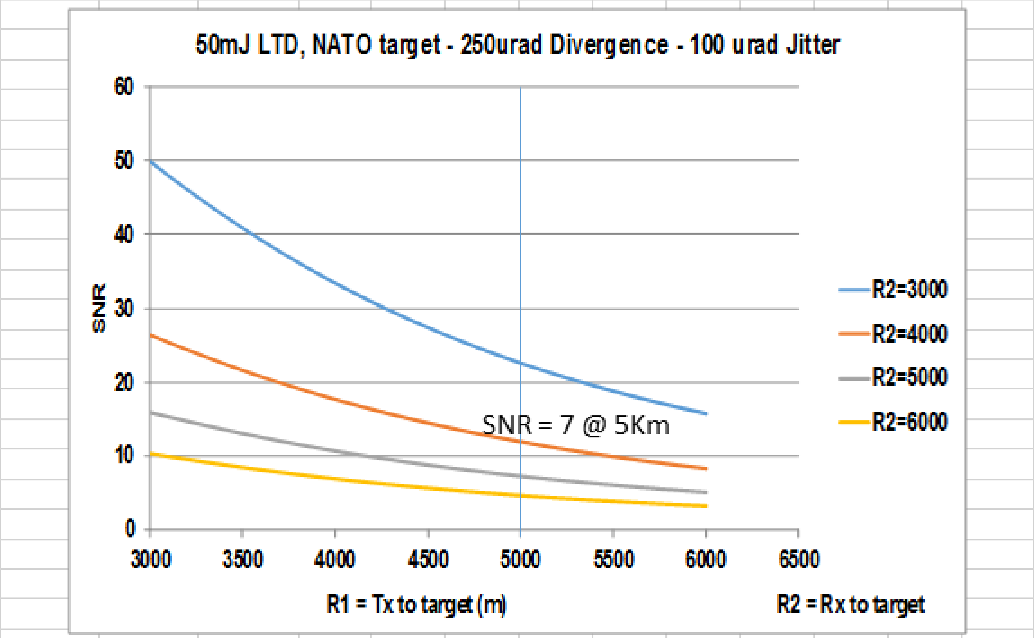
Total Beam Divergence (µRad)	Residual Motion (µRad)	Target Size (m)	EDR95 (Km)
200	0	2.3	11.9
200	20	2.3	9.7
200	40	2.3	7.3
200	60	2.3	5.8
200	80	2.3	4.7
200	100	2.3	4.0
500	0	2.3	4.8
500	20	2.3	4.6
500	40	2.3	4.1
500	60	2.3	3.7
500	80	2.3	3.3
500	100	2.3	2.9
1000	0	2.3	2.4
1000	20	2.3	2.4
1000	40	2.3	2.3
1000	60	2.3	2.2
1000	80	2.3	2.1
1000	100	2.3	1.9

Laser beam divergence, residual motion, and target size significantly impact overall designation range.

Laser Designator KPPs

- **Lock On Before Launch (LOBL)** - Weapon operator receives an indication of sufficient laser power to lock the LGM on a safe trajectory toward the target prior to launch.
- **Lock On After Launch (LOAL)** - Weapon operator releases the LGM from a safe standoff range, and the LGM seeker receives a laser designator code during flight.

In order to provide reliable laser designation throughout a missile flight, it is necessary to maintain a signal-to-noise ratio (SNR) of at least 7:1 at the missile seeker detector throughout the flight.



Range performance estimation for a 50-mJ laser with 250 μrad beam divergence and 100 μrad residual jitter operating in LOBL mode

Growing Market for LDs

The global military laser designator market is anticipated to reach $3.6B by 2027 and expand at a stable compound annual growth rate (CAGR) of 8% worldwide.

- CAGR of 4.3% in North America between 2019 and 2027, according to a new research report published by Transparency Market Research titled "Military Laser Designator Market – Global Industry Analysis, Size, Share, Growth, Trends, and Forecast."
- The market in Asia Pacific is likely to expand at a rapid CAGR of 8.6% during the forecast period.
- In terms of revenue, Europe will account for a significant share of the global military laser designator market during this period.

Laser Designator KPPs

With the presence of several major players, the global military laser designator market is fragmented. Leading military laser designator manufacturers include BAE Systems Plc, Elbit Systems Ltd., FLIR Systems Inc., L3Harris Technologies Inc., Leonardo-DRS, Northrop Grumman Corp., Rheinmetall AG, Safran SA, Thales Group, United Technologies Corp., and Arete Inc.

Miniature laser designators with <50 mJ are under development by ELBIT, Northrop Grumman, and L3 for lightweight UAV payloads and handheld devices.

Laser Designator Comparison

Manufacturer	Model No	Wavelength (LD,LRF)	Size L x W x H (mm)	Weight (gr)	Pulse Output (mJ)	Power Consumption (W)	Beam Div. (urad)
FLIR	MLR/TM-10K	1.064/1.535		1000	50	25	350
L3-ALST	MLD	1.064	145 x 78 x 78	818	80	40	300
Arete	Airtrac	1.064	117 x 43 x 43	680	70	25	250
Cilas	AlaDem - R 180	1.064	170x 65x 45	1500	80	65	200