LUNI

Universal station for testing laser range finders/designators

a)



b)



Fig. 1. Photo of LUNI test station: a)LUNI120, b)LUNI250

1 Introduction

Laser range finders (LRFs) are one of most important types of electro-optical systems that enable accurate distance measurement to target of interest. LRFs typically operate at a wavelength in spectral band from 800nm to 1700nm: 905nm, 1064nm, 1535nm, 1550nm, 1570nm.

LRFs can be divided into two main groups:

1. Stand-alone devices (small portable devices of optical aperture up to 100mm – typically smaller),
2. Modules of bigger multi-sensor surveillance systems of combined optical aperture up to 250mm or more.

In the first case the LRF usually has an integrated aiming channel. In the second case one of the systems imagers is used as an aiming channel.

Both types of LRFs are of crucial importance in defense, security, search and rescue, industrial or recreational applications.

2 What can be tested?

LRFs can be divided into five groups based on their optical design:

1. Dual channel LRFs with integrated sight – the transmitter and receiver are separate optical channels positioned in close proximity to each other, while the aiming channel is integrated with either the transmitter or receiver channel. The aiming device can be an optical sight, a VIS–NIR camera, or a night-vision device.
2. Dual channel LRFs with a separated aiming channel – aiming channel forms a third optical channel that is positioned in close proximity to either the transmitter or receiver channel.
3. Dual channel LRFs with an external sight – aiming channel forms a third optical channel that is positioned at a significant distance from the transmitter and receiver channels.
4. Dual channel LRFs with thermal imager used as external sight.
5. Single channel LRFs with coaxial optics channel – transmitter and receiver share a single coaxial optical channel. In some configurations, the aiming channel can also integrated into the same optical channel as transmitter and receiver.

All these LRF configurations can be tested using LUNI, although some limitations apply. For single-channel LRFs, detailed drawings of the internal optics are required to design and manufacture the adapters necessary for testing. Detailed drawings are also required for dual-channel LRFs with an external sight located at a significant distance from the transmitter or receiver.

Next, LRFs tested using LUNI can operate at different wavelengths within spectral range from 800nm to 1700nm. Typical calibrated wavelengths include: 905nm, 1064nm, 1535nm, 1550nm and 1570nm.

Further on, LUNI is primarily intended for testing medium- and long-range LRFs, with maximum operational distance measurement range from about 1km to over 40km. However, short range LRFs can also be tested, as LUNI can simulate distances as short as 20m.
LUNI is designed for use under typical laboratory or workshop conditions and is not optimized to be used under extreme field conditions.
The main parameters of LRFs that can be tested, together with the testing conditions are summarized in Table 1.

Table 1. Summary of LRF characteristics and testing conditions

Parameter	Value
Types of tested LRF	Optimized for all types of LRF
CWL of pulsed light source of LRF	905nm, 1060 nm, 1535 nm, 1550 nm, 1570 nm
Diameter of aperture of optics of tested LRF	< 120 mm in case of LUNI120 < 250 mm in case of LUNI250 Diameter of collimators aperture should overlap transmitter, receiver, and at least partially aiming channels of the LRF.
Range of tested LRF	Optimized for testing medium/long range LRFs but short range LRFs can also be tested: simulated distance from 20m to 40km (option 98km)
Environmental conditions	Typical laboratory/workshop conditions

2.1 Testing laser designators

LUNI test station can also be used for testing laser designators. These devices can typically be treated as high-power transmitters with a design very similar to that of transmitters used by LRFs. The same parameters used to characterize transmitters of LRFs are also applicable for characterization of laser designators. Therefore, the following section focuses excusively on testing of LRFs.

3 What is LUNI?

LUNI is a quasi universal station capable of testing virtually of LRFs available on market including both stand-alone portable devices and LRF modules integrated into larger multi-sensor surveillance systems. It enables the measurement of design and performance parameters of LRFs, provides accurate measurement of beam divergence angle and supports optimal alignment of the LRF channels (transmitter, receiver, aiming). LUNI is the most advanced station for testing LRFs that offers ultra expanded testing capabilities for testing and characterization of LRFs.

4 Test capabilities

LUNI has been developed as a quasi universal station suitable for R&D projects, factory quality control, acceptance testing and maintenance testing of almost all types of LRF offered on the market.
LUNI test station enables comprehensive testing of LRFs under laboratory conditions significantly reducing the need for frequent, costly and time consuming field tests, however supplementary field testing is still recommended.. The station enables measurements of transmitter radiometric parameters, transmitter imaging parameters, receiver/performance parameters, and boresight errors.
Test capabilities of LUNI test station are shown in Tables 2-5 on next page.

Table 2. Test capabilities of LUNI in configuration A

No	Parameter	Measurement range	Measurement uncertainty
	Transmitter parameters of tested LRFs		
1	Pulse energy	10nJ to 200 mJ	10%
2	Pulse width	4-600 ns	5% or 1ns
3	Pulse peak power	1W to 10 MW	10%
4	Pulse Repetition Frequency	0.1 Hz to 20 kHz	0.01%
5	Pulse coding	Yes (customer is expected to define type of coding used)	-
6	Missing pulse	Yes	-
7	Divergence Angle*	Up to 10 mrad	Up to 50%
	Receiver parameters of tested LRFs		
8	Receiver sensitivity	0.1 nW/cm² to 1μW/cm²	10%
9	Reflected pulse width	10-500 ns	5% or 1ns
	Performance parametersof tested LRFs		
10	Operational range	20 – 40000 m (option 98km)	0.5 m
11	Distance discrimination	Up to three echos with regulated distance difference: 20 – 6 000 m*	0.5 m
12	Relative Extinction Ratio	At least 0.1 dB – 60 dB (for target at 500 m distance)	1dB
13	Absolute Extinction Ratio	At least 100 dB -160 dB	1dB
	Boresight paramers		
14	Alignment error between transmitter of LRF and internal optical sight	Up to 20 mrad	0.1mrad**
15	Alignment error transmitter to external thermal imager/VIS-NIR camera	Up to 20 mrad	0.1 mrad
16	Boresight of transmitter relative to receiver***	Yes	50% of receiver FOV

*Minimum achievable distance is dependent on the selected pulse width
**Depends on magnification of aiming channel
*** Attention: very slow, non convenient measurement and aligning

Table 3. Test capabilities of LUNI-B test station

No	Parameter	Measurement range	Measurement uncertainty
1	Divergence Angle	Up to 10 mrad	0.1 mrad

Table 4. Test capabilities LUNI-C test station

No	Parameter	Measurement range	Measurement resolution	Measurement uncertainty
1	Alignment error between transmitter and receiver of tested LRF	Up to 10 mrad	0.1 mrad	0.1 mrad or 10% of receiver FOV
2	Field of view	Up to 10 mrad	0.1 mrad	0.5mrad or 25% of FOV

Table 5. Test capabilities LUNI-D test station

No	Parameter	Measurement range	Measurement resolution	Measurement uncertainty
1	Alignment error between transmitter and receiver of tested LRF	Up to 10 mrad	0.05 mrad	0.1 mrad or 10% of receiver FOV
2	Field of view	Up to 5 mrad	0.05 mrad	0.1 mrad or 5 of FOV

5 How is LUNI station bulit?

LUNI is a modular station that can operate in four different configurations, that differ in test capabilities:

A) Calibrated receiver/transmitter,
B) High dynamic SWIR camera,
C) Multi-emitter transmitter,
D) Boresight dual sensor camera.

Changing between configurations requires manual exchange (adding/removing) of selected system blocks. Configuration A is the most important and forms the base version of LUNI. Configurations B, C and D are optional and extend the testing capabilities of the station.

Configuration A

In configuration A, LUNI simulates a target of variable size located at a variable distance. Depending on the test being performed, the simulated target operates either as calibrated receiver (when testing transmitter of LRF) or calibrated transmitter (when testing receiver of LRF). The user aims tested LRF at the simulated target and to shoots.

Configuration A enables measurement of virtually all important radiometric, temporal and performance parameters of LRFs, including:

1. Transmitter radiometric and temporal tests: pulse energy, pulse peak power, pulse time width, pulse frequency, coding, missing pulses
2. Receiver tests: receiver sensitivity, FOV
3. Overall LRF performance tests: distance measurement, distance discrimination, extinction ratio (ER), and operational range. The last two parameters can be measured for up to five angular sizes of simulated target.

An internal boresight camera also enables visualization of the LRF transmitter laser spot and measurement of its angular position and dimensions. Therefore both spatial and boresight tests can be carried out, including:

1. Transmitter spatial tests: transmitter beam divergence angle,
2. Boresight errors: 1) transmitter to aiming channel (angle between transmitter axis and aiming channel axis), 2) transmitter to receiver (angle between transmitter axis and receiver axis).

However, there are two drawbacks of configuration A:

1. Limited accuracy of transmitter divergence angle measurement using laser sensing cards. The laser sensing cards are perfect for boresight tests but enable only rough measurement of divergence angle,
2. Time consuming and inconvenient measurements of receiver FOV and transmitter to receiver boresight error. Measurement is carried out by precise rotation of tested LRF and repeated shooting at simulated target using pulses of variable intensity. The objective is to find angular position of LRF at which receiver achieves highest sensitivity – reaction to pulses of lowest detectable power. Since the operator does not initially know the direction or magnitude of the angular offset between the receiver axis and the pulsed optical source, a relatively long series of measurements may be required to determine the optimum angular position of the LRF.

In summary, transmitter beam divergence angle, receiver FOV and boresight errors can be measured using configuration A but this method is not recommended. Configurations B, C and D eliminate these drawbacks.

Configuration B

Configuration B enables fast and accurate measurement of the spatial distribution of light intensity of laser beam emitted by the LRF transmitter located at optical infinity. Based on that divergence angle of transmitter can be calculated. In this configuration LUNI operates as a special SWIR camera of ultra high dynamic (over 10^{10}) capable of capturing pulses emitted by both high power monopulse LRF (peak power over 1MW) and pulses emitted by multi pulse LRF (peak power as low as 1W) without blurring.

Configuration C

Configuration C enables fast user friendly measurement of boresight error between receiver axis and transmitter axis and facilitates fast alignment of these channels. In this configuration the stations project an image of a square emitter composed of four smaller square emitters. Each small emitter simulates target located at a different distance. By observing the distance indicated by LRF, the user can immediately identify which emitter is seen by the receiver and what direction to rotate LRF to achieve optimal position. The boresight accuracy is the same as in configuration A, with vastly increased comfort and measurement time reduced by over 10 times.

Configuration D

Configuration D enables even faster measurement of boresight error between receiver axis and transmitter axis compared to configuration C by using visual boresight method. In configuration D, LUNI uses special L2CAM dual camera that generates fusion of two images: 1) detector in receiver channel, 2) image of laser spot at collimator focal plane. Therefore even after one shot user already knows what the boresight error between receiver axis and transmitter axis is and how to rotate receiver (or transmitter) to correct the error. However, there is also a significant drawback of configuration D: L2CAM dual camera must be located directly in front of the receiver of tested LRF and at relatively short distance (below 100mm) from the receiver optics. This arrangement limits the free space around the LRF and may

restrict access to its mechanical adjustment elements. This can be inconvenient when the alignment procedure requires direct access to these elements while the LRF remains installed on the test station.

6 List of blocks of LUNI station

LUNI is a modular station built from following blocks:

Configuration A

1. CDT12100HR off-axis reflective collimator or CDT25200HR off-axis reflective collimator;
2. LOR optical receiver;
3. LOPG optical pulse generator;
4. Additional modules:
   4.1. AH attenuator holder;
   4.2. LSC set of laser sensing cards;
   4.3. OTR optical trigger;
   4.4. XNASB angular stage;
   4.5. HEC camera;
   4.6. BRL internal boresight camera (integrated with CDT);
   4.7. SOA set of optical attenuator;
5. Laptop;
6. Software control package;
7. Software measurement package.

Configuration B

Additional blocks:

1. LSR10 laser beam profiler

Configuration C

Additional blocks:

1. LATRA boresight module

Configuration D

Additional blocks:

1. L2CAM dual camera
2. OMB camera holder

Attention: Inframet delivers XNASB angular stage for rotation of small stand alone LRFs. It is assumed that tested multi sensor or gimbal systems are equipped with mechanism enabling precise rotation of LRF in such block. If not then Inframet can deliver optional angular platform for such systems.

7 Versions of LUNI station

The primary division of LUNI station is according to criterion of diameter of optical beam that can be projected/or received by the test station. In detail, LUNI is divided into two types:

1. LUNI120,
2. LUNI250.

From design perspective the difference is mainly in reflective collimator used as image projector/laser beam receiver. LUNI120 uses CDT12100 collimator of 120mm aperture and 1000mm focal length while LUNI250 uses CDT25200 collimator of 250mm aperture and 2000mm focal length. This difference is most visible as LUNI120 is much smaller than LUNI250. There are also minor differences in a series of other system components as LUNI250 uses blocks of larger size.

The rule for the collimator is that collimator aperture must be equal to or larger than the diameter of circle that overlaps optics of transmitter, optics of receiver and significant part of aiming channel. This rule is easily fulfilled by LUNI120 in case of stand alone portable LRFs and is also fulfilled in case of great majority of LRFs used in multi sensor gimbal systems. However, it should be noted that in the latter case it is sometimes needed to regulate position of LUNI120 relative to big multi-sensor system to achieve situation when CDT12100 collimator overlaps apertures of optics of LRF. Further on, there are cases of multi-sensor systems where distance from transmitter/receiver to aiming channel is significant and then LUNI250 is strictly required. Bigger station is also needed when customers want avoid necessity of regulation of position of collimator relative to LRF used in big multi-sensor systems at different locations (center, left, right, up, down).

To summarize, Inframet can deliver two types of LUNI stations: LUNI120 and LUNI250. If tests are limited to stand alone LRFs or LRFs used in small gimbal multi sensor systems then LUNI120 is recommended. However, if LRFs are used in big multi sensor gimbal systems then LUNI250 is recommended.

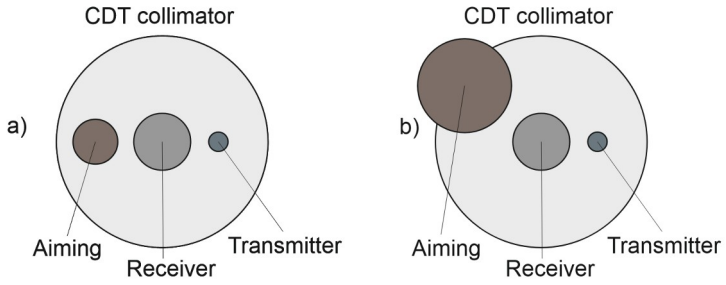


Fig. 2. CDT collimator and tested LRFs: a) collimator overlapping optical apertures of all sensors; b) collimator partially overlapping optical apertures of sensors of LRF.

7.1 Station code

This solution lets potential customer select optimal version of the station. However, it should be noted that the more advanced version and the station the more expensive it is.

1. LUNI-A – basic version of LUNI that can work in configuration A
2. LUNI-AB – can work in configuration A and configuration B,
3. LUNI-AC – can work in configuration A and configuration C,
4. LUNI-ABC – can work in configuration A, configuration B and configuration C.
5. LUNI-ABCD – can work in configuration A, configuration B, configuration C and configuration D.

8 Optional solutions

There is a series of options that help to operate LUNI station:

1. Additional adapters to enable testing of single channel LRFs built using using coaxial optics solution. Coaxial LRF are rarely met on market but sometimes it is needed to test such LRFs.
2. Electrical triggering of emitter block in LUNI station (enables distance simulation for receiver of tested LRF without necessity of shooting the transmitter – increases safety and easiness of such tests)
3. AT optical table optimized for LUNI station, recommeded sizes are AT822/AT830 – Other sizes available on request.
4. Maximal simulated distance is increased to 98km from typical level 40km.
5. Inframet can deliver optional computer programs to calculate:
   1) Maximal operational range of laser designator at simulated work conditions (target size, target reflectivity, weather conditions, day level target illumination, laser designator parameters),
   2) Maximal operational range of laser range finder at simulated work conditions (target size, target reflectivity, weather conditions, parameters of LRF)
6. BORIM boresight autocollimator enables alignment of optical axis (LOS) of imager (thermal imager or VIS-NIR camera) with reference front wall of the imager (axis is perpendicular to the front wall). It is achieved using special ABT target located inside the collimator that emits laser beam to be reflected by small mirror attached to imager reference flat wall. Then it is possible to boresight LRF transmitter to the aiming camera, achieving situation where transmitter is perpendicular to the reference plane. It should be noted that such boresight of LOS of imager to a reference mechanical plane is needed only in case of special thermal sights having such reference wall (Catherine Thales).

Coding: Number of selected option should be added to the station code. LUNI-A-124 means that LUNI-A station with options 1,2 and 4 is to be delivered.

9 Summary

LRFs are of crucial importance in defense, security, search and rescue, industrial or recreational applications. If LRF fails then big multi-sensor imaging/laser systems are almost useless. Therefore expended testing of LRFs is critically needed. LUNI is an universal station for expanded testing and boresight of laser ranger finders offered at international market. It offers measurement of virtually all parameters and boresight errors of LRFs. The station is particularly suitable for RD projects, manufacturing quality control or for acceptance tests. LUNI station is characterized by high ration of test capabilities (number of measured parameters) to price.

Version 2.2

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