LDIR

Station for measurement of divergence angle of lasers

Fig. 1. Photo of LDIR150 test station

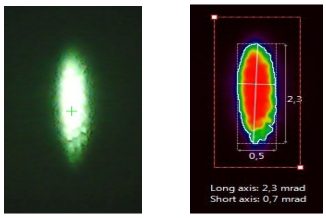

Fig. 2. Photo of laser beam spot recorded using LSR10 laser beam profiler

1 Introduction

Divergence angle is one of most important parameters of popular laser systems like laser range finders, laser designators, laser pointers. The beam divergence of a laser beam is an measure how beam diameter increases with distance (approximately equal to ration of diameter of laser spot at collimator focal plane to collimator focal length). Measurement of divergence angle of laser pointers (CW lasers) is relatively easy using low cost commercially available tools (laser profillers). However, measurement of divergence angle of high power pulsed lasers used in long range LRFs/designators is a technical challenge. Typical InGaAs cameras generate blurred images of spots created by such lasers due to ultra high peak power (over 1 MW) of pulses emitted by such pulsed lasers. Other types of laser profillers fail to deliver accurate measurement results, too.

2 What is LDIR?

LDIR is a test station optimized to enable measurement of divergence angle of laser range finders laser designators, laser pointers. It can be also used to do boresight of tested laser to another laser or to imager (VIS-NIR camers, thermal imager).

LDIR is fusion of simplified versions of two Inframet test stations: 1)LUNI for expanded testing laser ranger finders, 2)LIP for expanded testing of laser pointers/illuminators. In detail, LUNI enables measurement of a long series of parameters of LRFs in situation when sometimes only measurement of divergence angle is needed. Further on, LIP enables measurement of divergence angle of laser pointers/illuminators up to about 200mrad in situation when typically are tested laser pointers of divergence angle up to 2 mrad. Finally, it is also a common situation when it is needed to align optical axis of LRF to laser pointer. Therefore LDIR can be treated as economic solution for measurement of divergence angle of laser range finders laser designators, laser pointers that can replace need for use of LUNI and LIP stations.

3 How LDIR is built?

LDIR is a modular system built from a series of block: CDT off axis reflective collimator,BRL2 laser profilometer (located inside the CDT collimator), LSR10 laser profilometer, LPC set of laser cards, XNAS angular stage (not presented on the photo), laptop, BOR software.

LDIR is built using a concept of high dynamic imaging laser receiver of spectral band from about 500nm to about 1600nm. User is expected to locate tested laser at exit of the CDT collimator, aim to a target and shoot. LDIR station is to generate image of a laser spot created at collimator focal plane. Test software is to analyse captured image of the laser spot and to calculate divergence angle.

BRL2 laser profilometer is of similar design to typical laser profilometers offered on market based on silicon image sensor sensitive up to about 1000nm. The real challenge is LSR10 laser profilometer due to its ultra high dynamic and spectral band up to about 1600nm.

LPC is a set of four reflective laser photosensing cards (TEG, FOS, FOL, ILU) that are used to create image of laser spot visible to BRL2 laser profilometer.

LDIR is built in a way that can withstand tests of high pulse energy lasers without need to install attenuator filters at collimator output. It is a sharp contrast to typical test systems that are damaged if user forgot to install such attenuator filters at proper position.

4 Positioning of tested laser relative to the collimator

Tested laser (with or without aiming device) is to be located at output of the CDT collimator. Different scenarios of positioning of the laser and aiming device (VIS-NIR camera, thermal imager, optical telescope) relative to collimator aperture are possible:

A) Collimator aperture overlaps fully both laser and aiming device,
B) Collimator aperture overlaps fully laser and partially overlaps aiming device,
C) Collimator aperture overlaps fully laser but do not overlaps aiming device,
D) Collimator aperture is so small that it cannot fully overlaps optics of the laser.

The recommended situation is mode A when both collimator aperture overlaps both laser and aiming device located at collimator output. Then user can see the point to be irradiated and the laser can be easily aligned to position when the laser beam is to hit area analysed by one of the laser profillers. Mode B is also acceptable but collimator should overlaps at least 50% of optics of the aiming device to allow generation of clear image from the aiming device.

Mode C is not convenient for user because the user needs to shoot blindly laser and correct angular position of the laser until the laser beam hits proper place but still tests of the laser can be done. Anyway it is often a case when tested laser has no aiming device at all.

Mode D is not acceptable. Low accuracy measurement results are possible. Reflections of laser beam from collimator parts can be danger for the user.

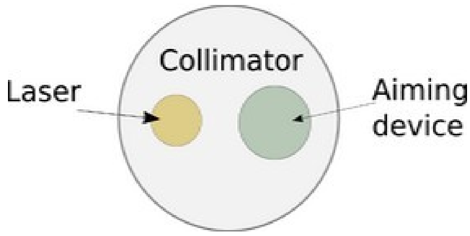

Fig. 3. Exemplary situation when collimator aperture overlaps both laser and aiming device (mode A)

5 Modes of work

LDIR works using two different laser profilometers capable to analyse laser spot created at collimator focal plane:

1. Imaging sensor no 2: BRL2 laser profilometer (ultra high dynamic VIS-NIR camera). Active analysis area: at least 30x30mm.
2. Imaging sensor no 1: LSR10 laser profilometer (ultra high dynamic SWIR imager). Active analysis area: at least 10x10mm.

In case 1 the BRL2 laser profilometer is to create image of laser spot created on an exchangeable laser card. In case 2 the LSR10 laser profilometer is to create laser spot at input plane of this device.

It should be noted that BRL2 laser profilometer has bigger active analysis area. It means that it is easier to adjust angular position of tested laser to hit active analysis area of BRL2 profilometer than to hit area of LSR10 profilometer. Further on, it is possible to expand spectral sensitivity range of this profilometer by use of LPC laser cards. The latter cards can convert SWIR light from tested LRFs/designator to visible light that can be detected by BRL2 profilometer.

Due to these features following tasks can be carries out using BRL2 laser profilometer with LPC laser cards and LSR10 profilometer:

1. BRL2 laser profilometer with reflecting laser card (ILU card): detection and potentially precision measurement of divergence angle of laser pointers that emit light in VIS-NIR spectral band. This mode can be also used for testing low cost multipulse LRFs that operate at 900-1000nm.
2. BRL2 laser profilometer with converting laser card (FOS,FOL, or TEG cards): detection of laser spots created by typical medium/long range monopulse/multi pulse lasers (LRFs/designators) that emit light in SWIR spectral range (1060nm and 1550nm band)
3. LSR10 laser profilometer - precision measurement of divergence angle of monopulse/multi pulse lasers (LRFs/designators) that emit light in SWIR spectral range (1060nm and 1550nm band).

6 Versions

LDIR can be delivered in a series of versions depending on aperture of the CDT reflective collimator. Bigger aperture gives ability to test laser system having bigger optics or to test laser system having aiming device located at longer distance. However, collimator of bigger aperture is also a collimator of longer focal length that means smaller angular size of active area analysed by the laser profilometers of the LDIR system.

Inframet offer LDIR150 built using CDT15120HR collimator of 150mm aperture and 1200mm focal length as the recommended universal solution. Almost all medium/long range LRFs/designators/pointers offered on the market can be tested. Other popular solutions are LDIR110 (aperture 100mm and focal length 1000mm) or LDIR200 (aperture 200mm and focal length 2000mm).

7 Positioning of tested laser

Before LDIR can be used for measurement of divergence angle/boresight of tested laser the user must do proper positioning of tested laser relative to the collimator.
There are two types of positioning:

1. Planar positioning
2. Angular positioning.

In both cases tested laser is expected to be fixed to XNAS angular stage (part of LDIR system).
During planar positioning user is expected to move manually the XNAS stage with fixed laser to achieve situation when collimator aperture overlaps optics of tested laser and its aiming device.
During angular positioning user is expected to rotate the tested laser fixed to XNAS stage until the aiming device points exactly the center of FOV of BRL2 laser profilometer. Image of the center point is projected by the collimator and can be seen by the aiming device.
It there is not aiming device then user is expected to rotate XNAS stage with tested laser and shoots blindly until laser spot is detected in FOV of BRL2 profilometer. Then he should correct angular position of the laser to achieve situation when laser beam hits exactly the center of FOV of BRL2 laser profilometer.
It is assumed that after this stage the tested laser is aligned properly and its beam hit center of FOV of both laser profilometers (center of laser sensing cards).

8 Basic measurement rules

Measurement of divergence angle is the main task of LDIR system. Simplified measurement procedures as below:

8.1.1 Measurement of divergence angle of laser pointer

1. LDIR150 is switched into BRL2 mode
2. Tested pointer shoots to direction of center of ILU reflective card.
3. BRL2 creates image of laser spot
4. LBOR software calculates divergence angle of the pointer.

8.1.2 Measurement of divergence angle of mono pulse LRF

1. LDIR is switched into LSR10 imaging mode
2. User shoots tested LRF/designator.
3. LSR10 creates image of laser spot
4. LBOR software calculates divergence angle of the LRF.

8.1.3 Measurement of divergence angle of multi pulse LRF

The same as in previous case (the difference is that measurement is made at different attenuation level of LSR10 profilometer.
LDIR can be also used for a set of different boresight tasks:

1. Measurement (potentially zeroing) boresight error between two laser pointers,
2. Measurement (potentially zeroing) boresight error between laser pointer and monopulse/multipulse LRF,
3. Measurement (potentially zeroing) boresight error between laser (any type) and imager (VIS-NIR camera, thermal imager, optical sight).

9 Technical specifications

This section refers to LDIR150 system.
Below are presented minimal technical specifications of most typical LDIR150 system.
Table 1. Basic technical data of LDIR150

Parameter	Value
Input aperture	150mm
Imaging tools	1) BRL2 profilometer, 2)LSR10 profilometer
Spectral sensitivity band of BRL2 profilometer	Depends on sensing card ILU card: 400-1000nm TEG card: 400-1600nm FOS card: 1000-1600nm
Angular size of sensing area in BRL2 mode	25x25mrad
Spectral sensitivity band of LSR profilometer	900-1600nm
Angular size of sensing area in LSR mode	8x8mrad

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Table 2. Test capabilities of for case testing monopulse LRFs/designators

Parameter	Value
Max aperture of transmitter of tested LRF/designator	110mm
Wavelengths of tested laser	In spectral band from 1000nm to 1600nm
Minimal divergence angle	0.05 mrad
Maximal divergence angle	2 mrad
Maximal angular density of average pulse energy of monopulse lasers [1]	2000 mJ/mrad^2
Minimal angular density of pulse energy of monopulsed lasers	0.1 mJ//mrad^2
Resolution of measurement of divergence angle	0.02mrad
Uncertainty of measurement of divergence angle	5% or 0.05mrad

Table 3. Test capabilities of for case of testing multi LRFs/designators

Parameter	Value
Max aperture of transmitter of tested LRF/designator	110mm
Wavelengths of tested laser	In spectral band from 900nm to 1600nm
Maximal divergence angle	4 mrad
Maximal angular density of average power of multipulse lasers [2]	1W//mrad^2
Minimal angular density of average power of multipulse lasers	0.05mW//mrad^2
Resolution of measurement of divergence angle	0.02mrad
Uncertainty of measurement of divergence angle	5% or 0.05mrad

Table 4. Test capabilities of for case of testing laser pointers

Laser pointers	
Wavelengths of tested lasers	In spectral band from 500nm to 1000nm
Maximal divergence angle	Up to 10 mrad – recommended situation up to 20 mrad – acceptable situation
Maximal angular density of power of laser beam pulsed lasers [3]	2W/mrad^2
Minimal angular density of power of laser beam pulsed lasers	0.01W//mrad^2
Resolution of measurement of divergence angle	0.06mrad
Uncertainty of measurement of divergence angle	5% or 0.1mrad

Table 5. Test capabilities of for case of boresight of laser pointers/ LRFs/designators

Parameter	Value
Total aperture of tested laser systems	<150mm
Wavelengths of tested laser	In spectral band from 500nm to 1600nm
Maximal aligning error between two lasers	Two laser spots must be within FOV of BRL2 profilometer: 25x25mrad
Resolution of measurement	0.06mrad
Uncertainty of measurement of divergence angle	5% or 0.1mrad

[1] Ratio of pulse energy to square divergence angle

[2] Ratio of power to square divergence angle

[3] Ratio of power to square of divergence angle

10 Why LDIR is special?

The crucial module of LDIR station is LSR10 laser profilometer and this module makes LDIR special test station.

LSR10 laser beam profiler is an macro imaging system optimized for fast and accurate measurement of divergence angle and boresight errors of laser range finders and laser designators (when located at collimator focal plane). The beam divergence of a laser beam is an measure how beam diameter increases with distance (approximately equal to ration of diameter of laser spot at collimator focal plane to collimator focal length). Boresight error is an angle between axis of laser beam and optical axis of imaging system.

LSR10 enables capturing and visualization of 2D profiles of high intensity laser beams (spots) of laser transmitter operating in SWIR range at wavelengths like 910nm, 1064nm, and 1550nm band. It is built as a imaging macro SWIR camera of ultra high dynamic that is capable to capture non distorted images of laser spots generated by monopulse LRFs/designators.

There are many laser beam profilers offered on international market. However, these typical laser beam profilers based on silicon imaging sensors are optimized for testing lasers operating at visible and near infrared range up to about 1000nm when majority of modern LRFs/designators operates are longer wavelengths in SWIR band.

Next, there are laser profilers built using cameras sensitive in SWIR band (typically InGaAs imaging sensors) that enable fast visualization of beams of SWIR lasers but such profilers perform poorly in case of pulsed lasers that emits short pulses of ultra high peak power (noticeable image blurring effect that increases diameter of measured laser spot) that are typically used in monopulse LRFs/designators.

Finally, there are also profilers that use mechanical scanning methods to measure laser beam profile that potentially enable accurate measurement of divergence of LRFs/designators but measurement procedure requires at least a dozen of laser shots to measure laser beam profile. This long measurement time eliminates such scanning profilers in cases when it is necessary to test multi sensor imaging/laser system built on gyroscopic gimbal platform that is always in some movement and measurement must be done using a single shot.

Due to earlier mentioned situation LSR10 laser beam profiler located at collimator focal plane is a perfect solution for measurement of divergence angle of mono pulse pulse lasers.

Version 1.3

CONTACT:

Tel: +48 22 6668780 Fax: +48 22 3987244 Email: sales@inframet.com