LTIR

System for testing and boresight thermal infrared lasers

a) b)

Fig. 1.LTIR test/boresight system: a)photo, b) exemplary measured spatial intensity profile

1 Basic information

Infrared lasers operating in long wavelength spectral range (thermal infrared) from about 2 µm to 15 µm have found a series of both civilian and military applications. These lasers are longwave SWIR lasers operating at wavelengths over 2µm, MWIR lasers - 3-6µm, and LWIR lasers - 6-15µm. Such lasers are used in directional infrared countermeasure systems (DIRCM), atmospheric pollution detection systems, laser radars (LIDARs), or in remote detection systems do detect chemical/biological agents. In all these applications it is of critical importance to optimize design of the laser (sometimes set of several lasers working at different wavelengths) to achieve low divergence angle of emitted total laser beam at optical infinity, to know precisely relative angular intensity of the total laser beam (to calculate beam divergence angle), and to know angular direction of emitted laser beam relative to optical axis of a reference aiming device (laser pointer, thermal imager, VIS-SWIR camera) or to laser reference mechanical axis. It is highly desirable to know also temporal variations of total power, and temporal variations of beam spatial intensity. Sometimes it is needed also to check focusing and resolution of aiming imaging device (thermal imager or VIS-NIR camera).

Thermal infrared laser systems offered on the market vary a lot due to different laser parameters (wavelength, mean power, divergence angle, number of laser modules) or due to different aiming concept (1-no aiming device at all, 2- VIS-NIR laser pointer having the same optical axis as the tested thermal laser, 3-tested laser integrated with an aiming imager).

LTIR is a professional system for testing/boresight thermal infrared lasers. This system enables high accuracy testing/boresight of virtually all thermal infrared lasers offered on the market. This universality/high accuracy has been achieved due to special design that differ much comparing to other simpler methods.

2 LTIR design

LTIR is a modular system built from a series of modules:

1. CDT15150 reflective off axis collimator (option bigger CDT20200 collimator),
2. MWR8 rotary wheel
3. Set of uniform targets (different reflectivity),
4. Set of aiming targets (different shape)
5. DNCB color blackbody
6. Infra214 high dynamic broadband thermal imager,
7. BRL2 VIS-NIR camera,
8. MFS4 motorized filter slider
9. Set of spectral filters
10. Analog frame grabber
11. PC set
12. BOL software (analysis of captured images of laser spot)
13. LTIR Control software for control of MRW wheel and MFS4 filter slider.

Modules 1-5 form an image projector capable to project images of two types of targets: 1)uniform targets (to be irradiated by tested thermal laser or optional aiming laser pointer.

Modules 6-7 are two imagers responsible to capture image of the uniform target irradiated by: module 6- tested thermal laser, module 7 – optional aiming laser pointer. In detail, module 6 is an unique high dynamic broadband thermal imager sensitive in SWIR-LWIR spectral band. Module 7 is a rather typical VIS-NIR camera sensitive to typical laser pointers.

Modules 8-9 enable change of spectral band of Infra214 broadband imager (useful when tested laser systems emits at wavelengths in different spectral bands and attenuation of one wavelength is needed).
Modules 10-13 form a computing system responsible for analysis of images generated by the modules 6-7.

Both imagers (modules no 6-7), and spectral modules (no 8-9) are located inside the CDT collimator. Modules 2-5 are connected to CDT collimator. Therefore from external view LTIR is basically the collimator system and PC set. It should be also noted that the targets and filters can be remotely changed via software.

LTIR can perform three different tasks:

1. Measurement of spatial intensity of beam of tested laser at optical intensity (including calculation of divergence angle,
2. Boresight of tested thermal laser with a reference aiming laser (typically laser pointer operating at VIS-NIR band) – useful for a case of laser system having VIS-NIR laser pointer as aiming device,
3. Boresight of tested thermal laser with a reference aiming imager (thermal imager, VIS-NIR camera, SWIR imager) - useful for a case of laser system having aiming imager.

Attention: Boresight task: zeroing of angle between laser beam of tested laser and optical axis of the aiming device.

The first task is to be done by a system composed from modules 1,2, 3, 6, 9-13. Modules no 4,5, 7,8,9 – not needed. In this configuration LTIR is capable to:

1. project image of an uniform target located at collimator infinity to be irradiated by tested thermal infrared laser (uniform target located at collimator focal plane),
2. capture image of laser spot of tested laser shooting to the target defined at previous point using a high dynamic broadband imager sensitive in SWIR-LWIR spectral range (Infra214 imager).

The second task is to be done by a system composed using all modules for task one and additional module no 7. The latter module is needed to capture image of spot created by laser pointer on the uniform target. Later the BOL software can calculate angular distance between center of spots created by tested thermal infrared laser and aiming laser pointer.

The third task is to be done by a system composed using all modules for task one and additional modules no 4-5. The latter modules are needed to create image of aiming mark (typically cross) to be seen by aiming imager. Other targets (like four bar target) can be used to check focusing/resolution of this imager, too.

When aiming target is seen by the aiming imager then the imager is to be regulated until its aiming mark overlaps on center of the aiming target. After this tested laser can shoot. Now, software calculates angular distance between position of the aiming target and the laser spot.

3 Test capabilities

LTIR enables directly following capabilities:

1. Measurement of 2D spatial profile of laser beam at optical infinity,
2. Boresight of tested thermal laser with a reference aiming laser (typically laser pointer operating at VIS-NIR band),
3. Boresight of tested thermal laser with a reference aiming imager (thermal imager, VIS-NIR camera, SWIR imager).

However, indirect test/boresight capabilties are wider:

1. Calculation of divergence angle of the lasers using two different definitions (1- spot diameter determine by relative intensity criterion, 2- spot diameter determine by relative power criterion),
2. Design optimization of tested thermal laser in order to achieve optimal focusing at optical infinity (situation when divergence angle is minimal)
3. Checking infinity focusing/resolution of an aiming imager.
4. Aligning of several thermal infrared lasers (situation when all laser beams are parallel)
5. Optional measurement of temporal stability of beam of tested laser.

Any laser system (thermal infrared laser and aiming device) having total aperture below active aperture of CDT collimator used by LTIR system can be tested.

Attention: Beam quality parameter M^2

M^2 or Beam Propagation Ratio, is a value that indicates how close a laser is to being a single mode TEM00 beam, which in turn determines how small a beam waist can be focused. For the perfect Gaussian TEM00 condition the M^2 equals 1. M^2 cannot be determined from a single beam profile measurement.

The ISO/DIS 11146 standard requires that M^2 be calculated from a series of profile measurements at different distances. LTIR does not enable direct measurement of M^2 parameter because it makes possible only to measure laser beam profile at a single distance: optical infinity. It means that LTIR cannot measure M^2 and cannot deliver information to compare tested divergent laser to a perfect laser. However, LTIR delivers precision information about laser beam intensity at optical infinity – the intended distance of targeted long range thermal lasers. Therefore, information delivered by LTIR is fully satisfactory for final testing and boresight long range lasers to be used in atmospheric pollution detection systems, laser radars (LIDARs), remote systems to detect explosives, in chemical warfare agents, or in directional infrared countermeasure systems (DIRCM). M^2 parameter is not needed to evaluate final performance of long range lasers to be used in earlier mentioned applications.

Next, big advantage of LTIR is that it can test virtually all long range thermal range lasers offered on market. Design of LTIR could be modified to enable measurement of M^2 but this universality should be sacrificed. These are reasons why M^2 parameter is not on list of parameters measured by LTIR system.

4 Technical specifications

Table 1.

No	Parameter/feature	Value
	Parameters of tested thermal infrared lasers	
1	Overall aperture	Optics of both lasers and optional aiming device imager should be at least partially be within a semimoon of diameter 150mm
2	Types of lasers	Both continuous and pulsed
3	Wavelengths	Any wavelength in spectral band 2 µm to 14µm
4	Max divergence angle	20 mrad
5	Min divergence angle	0.2 mrad
6	Resolution of measurement of divergence angle	0.06 mrad
	Continuous lasers	
7	Max acceptable power of beam	100 W
8	Max acceptable ratio of laser mean power and divergence angle	10 W/mrad
9	Minimal acceptable ratio of laser mean power and divergence angle	10 mW/mrad
	Pulsed lasers	
10	Max acceptable pulse energy	2 mJ
11	Max acceptable ratio of pulse energy and divergence angle	200 uJ/mrad
12	Max acceptable ratio of laser mean power and divergence angle	10 W/mrad
13	Minimal acceptable ratio of laser mean power and divergence angle	10 mW/mrad
14	PRF range	From DC to 100 kHz
	Parameters of aiming laser pointer	
15	Wavelength	Any wavelength in spectral band 500 nm to 1100nm
16	Max acceptable ratio of laser mean power and divergence angle	100 mW/mrad
17	Minimal acceptable ratio of laser mean power and divergence angle	1 mW/mrad
	Parameters of aiming imager	
18	Maximal NETD of aiming thermal imager	200mK

19	Maximal sensitivity of aiming VIS-NIR camera	50 lx
20	Maximal sensitivity of aiming SWIR camera	10 mW/m^2
	Other parameters	
21	Work temperature	+5C to +35C
22	Storage temperature	-5C to 45C
23	Humidity	Up to 85% (non condensing)
24	Dimensions	About 200x250x1350 mm
25	Mass	About 35 kg

5 Versions

LTIR is a modular system can be delivered in form of slightly different versions. The first main criterion is aperture of the CDT collimator used by the LTIR systems. There are two versions: LTIR150 based on CDT15150 collimator of 150mm aperture or LTIR200 based on CDT20200 collimator of 200mm aperture.

Collimator aperture is only one of a series of technical parameters that should be determined to optimize LTIR system for required applications. We need also to determine:

1. Spectral band of Infra thermal imager (location of wavelengths of tested lasers),
2. Tools to support boresight to an aiming laser pointer (BRL2 camera),
3. Tools to support boresight to reference imager (DNCB color blackbody, aiming targets, modified software)
4. Tools to modify spectral band of Infra thermal imager (filter slider and filters).

Therefore collimator aperture code and four letter code are use to describe precisely version of LTIR systems.

Table 2. Definition of the ten letter code used to describe versions of LTIR test system

	1	2	3	4
Code	Location of wavelengths of tested laser	Tools to support boresight to an aiming laser pointer	Tools to support boresight to reference imager	Tools to modify spectral band
A	2-5um	No	No	No
B	2-14um	Yes	Yes	Yes

The code LTIR150 ABBA means system based on collimator of 150mm aperture and having such features:

1. capable to test thermal infrared laser that emit light at spectral band from 2um to 5um,
2. having earlier defined tools for to support boresight to aiming laser pointer,
3. having earlier defined tools for to support boresight to reference imager,
4. no tools to regulate spectral band of Infra214 imager.

6 Options

Inframet can deliver optional XNAS15 manual angular stage for precision positioning of tested laser.

7 Why LTIR is special?

Measurement of divergence angle of thermal infrared lasers looks apparently easy because there are many laser beam profilers offered on the market. Therefore it looks that it is enough to put such profiler at focal plane of a reflective collimator, capture image of laser spot and measurement is done. However, practically situation is not so easy. Almost all laser beam profilers are sensitive up to about 1100nm, few up to 1600nm. Laser beam profilers sensitive at longer wavelengths in SWIR, MWIR and LWIR are rare. Anyway they need additional attenuators to be used for testing thermal infrared lasers, especially for testing lasers used in directional infrared countermeasure systems (DIRCM).

Another tempting solution is to use thermal imager to capture image of laser spot. However, special customized imagers are needed to cover required broadband spectral band from 2um to about 14um. Additionally such thermal imagers cannot withstand work with high power laser like typical thermal infrared lasers.

Further on, rough aligning and measurement of divergence angle of thermal range lasers can be also done using liquid crystal cards located at collimator focal plane working as imaging sensors. These cards change color when irradiated by such lasers. However, this method is inherently non accurate particularly during measurement of divergence angle. Liquid crystal cards are also characterized by low dynamic and are not useful for testing lasers of unknown intensity.

Finally, LTIR is not a single tool to support testing thermal infrared lasers that makes user responsible to built ad hoc a complete test system. LTIR is a complete test system optimized for testing/boresight of thermal infrared lasers.

All these reasons make LTIR system the best and unique solution on the world market for testing/boresight of thermal infrared lasers.

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CONTACT:

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