JAVI

Boresight of small multi-sensor imaging&laser systems

Fig. 1. JAVI150 boresight system

1 Introduction

Boresight is a process to align optical axis of single system or several optical or electro-optical systems with a certain reference optical axis or mechanical axis. Boresight is particularly critical in case of multi-sensor electro-optical surveillance systems built from a series of systems like thermal imager, VIS/NIR camera, SWIR camera, laser range finder, laser pointer. The aim of boresight of such imaging/laser systems is to achieve situation when optical axis of both imagers (line of sights) and laser systems (laser beams) are parallel.

2 What is JAVI?

JAVI is system that have been developed to support boresight of short/medium range multi-sensor surveillance systems built from a series of EO imaging/laser systems (thermal imager, VNIR camera, SWIR camera, laser range finder, laser pointer). Such EO systems are relatively small (total aperture of all sensors is below 200mm). Example application: surveillance EO systems used by drones.

3 How JAVI works?

JAVI works as an image projector that projects into direction of tested UUT two types of images: 1)image of reference cross target irradiated by broadband VIS-LWIR radiation source and seen by all types of EO imagers sensitive in part of this range, 2)image of a beam tested laser at simulated optical infinity created by irradiated laser sensing cards. Analysis of images of the reference target and images of laser spots enables determination of alignment errors (angle between two optical axis) between different two sensors (imagers/imager, imager/laser or laser/laser).

JAVI can works in two modes of boresight of EO systems: 1)subjective, 2)objective. In first mode alignment errors are estimated subjectively by human: checking if aiming mark of all imagers indicate center of the reference target and every laser spot. In the second mode, image generated by imagers are captured, analysed and measurement of alignment errors is determined by software.

4 Boresight/test capabilities

JAVI enables boresight of short/medium range multi-sensor surveillance systems built from a set of small EO imaging/laser systems of total aperture below 200mm (circle diameter that overlaps optics of all sensors must be below or equal 200mm).

In detail, JAVI enables measurement of alignment errors between optical axis of multi-sensor EO systems built from up to five types of EO systems:

1. thermal imager (LWIR thermal imager, MWIR thermal imager)
2. VNIR camera (VIS color camera, LLTV camera, monochromatic VNIR camera)
3. SWIR imager (typical SWIR imager, broadband VIS-SWIR imager, longwave SWIR imager),
4. LRF/designator (multi pulse LRF operating at 910nm band, multi pulse LRF operating at 1550nm band, mono pulse LRF/designator operating at 1060nm band, mono pulse LRF/designator operating at 1060nm band),
5. laser pointer (NIR pointer, SWIR pointer).

Practically it means that can be used to determine ten types of alignment errors: TI/VNIR, TI/SWIR, VNIR/SWIR, TI/LRF, VNIR/LRF, SWIR/LRF, TI/pointer, VNIR/pointer, SWIR/pointer, LRF/pointer. In detail, not all these errors are measured directly – some can be calculated when majority of alignment errors are measured.

It should be also noticed that measurement of ten alignment errors is possible only for case of most advanced EO systems built using five imaging/laser sensors. In case of most typical EO system (TI, VNIR, LRF) this number of errors decreases to three: TI/VNIR, TI/LRF, VNIR/LRF.

Measurement of boresight errors is the main application of JAVI. However, it can be also used for checking infinity focusing.

5 Measurement accuracy

Alignment errors of tested multi sensor EO system are measured by analysis of images generated by imagers used by tested EO system. Therefore the alignment errors depends on quality of such images (noisiness, blurring) and decisions of human operator of the software. However, in some simplification it can be said that alignment errors are approximately equal to angular size of single pixel of image of tested imager used for calculations.

6 How JAVI is built?

JAVI is a modular system built from a series of blocks. In case of most advanced version the blocks are:

1. CJV series off axis reflective collimator (modified one mirror version of typical CDT collimators – it works as projector of images of target/sensing card located at its focal plane);
2. CB25 color blackbody (radiation source that works at the same time as typical blackbody and VIS-NIR light source (optional SWIR light source);
3. CCB25 electrical controller of CB25 color blackbody;
4. MRW-25-6 motorized rotary wheel for automatic exchange of sensing cards or targets;
5. LSC set of laser sensing cards (the cards show a point illuminated by transmitter of LRF, laser designator or by laser pointer). The list of LSC cards and its work principles can be found in Table 1
6. Set of two multi-hole protection plates SPROT (protection of LRF receivers and human operators against laser light reflected by interio of CJV collimator)- manufactured according to customer drawings;
7. SOA set of optical attenuators and mounting holders to protect LSC cards against laser pulses of too high pulse energy. Use or SOA attenuator is recommended in case of monopulse lasers of ultra high pulse energy but is not strictly needed;
8. PC set;
9. frame grabber cards (type of frame grabber depends on image video standard of tested imagers);
10. BOR computer program. This program carries analysis of images from from tested imager and calculates alignment errors.

7 Set of laser sensing cards

LSC set of laser sensing cards are tools used in JAVI to to show a part of the card illuminated by laser (transmitter of LRF, laser designator or by laser pointer) when the card is located at collimator focal plane. The cards are critical for boresight of lasers.

As can be seen in Tabel 1 there are two main types of sensing cards:

1. converters of SWIR laser pulsed light into non-SWIR radiation (VIS light or thermal radiation)
2. photo recorder (laser spot burns spot image).

Cards of the first type generate transient image of laser spot as long as they are irradiated by laser. Cards of the second type burns image visible even when no laser light.

All types of laser sensing cards can be used for boresight using subjective or objective work mode. However, type II cards are more convenient for subjective mode (image is recorded).

Attention:

When there are too many recorded laser spots on type II card then it should be replaced to a new one. It is estimated that such change should be done when number of recorded laser spots is about 100 spots. Inframet offers typically 100 MON/MOG cards that should be enough to record 10 000 laser shots.

Table 1. Properties ofLSC set of laser sensing cards

Card code	Work principle	Optimized for boresight	Number of cards
TEG	high sensitivity converter of SWIR laser pulsed light into thermal radiation	All lasers to TI	1
FOS	high sensitivity converter of SWIR laser light into visible light	Multipulse LRFs to VIS	1
MON	Photo recorder (laser spot burns spot image)	Monopulse LRF to VIS	100
MOG	Sensitive photo recorder (laser spot burns spot image)	Low pulse energy monopulse LRF to VIS	20
MOS	medium sensitivity converter of SWIR laser light into visible light	Monopulse LRF to VIS	1
MOX	Ultra high durability converter of SWIR laser light into visible light	Ultra high pulse energy monopulse LRF to VIS	1
ILU	Diffuse uniform reflector of low/high reflectivity	Laser pointers to NIR/VIS	2

8 Computerization of JAVI

Computerized version of JAVI (PC set, frame grabber, image analysis software) is needed to enable objective measurement of alignment errors (objective work mode). Computerized JAVI can capture video sequence, find proper frame and determine precisely location of laser spot at laser sensing card. It is highly recommended even for teams that use often subjective mode of work (visual checking if laser spot is created at point indicated by aiming mark) due to higher boresight accuracy, and ability of recording measurement results.

9 Safety of operation of JAVI

JAVI system does not emit laser light. However it can reflect a portion of light emitted by tested laser that can be dangerous. Therefore operator should always wear protection glasses and pass proper laser safety training.

Inframet proposes to install at collimator output one of several multi-hole protection plates SPROT. These are simple metal plates having holes of the same diameter and location as optics of tested system and coated using low reflectivity paint. There is no hole for receiver optics of LRF or receiver is only partially open. In this way both the receiver and human operator are protected against laser light reflected by interior of JAVI collimator.

Inframet delivers typically up to three multi-hole protection plates under condition the customer deliver drawing of tested EO system. Anyway, manufacturing of multi-hole protection plates is easy and such plates can be also made by customer.

10 Versions of JAVI

JAVI test systems are modular test systems that can be delivered in form of different versions of different configurations, boresight capabilities and price. The basic division of JAVI series system is based on output aperture of the collimator (Table 2). Higher collimator aperture means larger collimator.

Table 2. Division of JAVI series systems based on the collimator aperture

System aperture code	Collimator output aperture [mm]	Collimator focal length [mm]	Collimator code
JAVI 120	120	1000	CJV12100
JAVI 150	150	1200	CJV15120
JAVI 200	200	1600	CJV20160

The basic rule for choosing proper collimator is that collimator aperture should be bigger than total aperture of optics of tested EO system.

JAVI can be further divided depending on boresight/test capabilities that are described using three digit code (Table 3).

Table 3. Digit code of basic versions of JAVI station

	A	B	C	D
No	**Imagers**	**LRFs**	**Laser pointers**	**Work mode/ computerization**
1	TI/VNIR	No	No	Only subjective mode. No computerization.
2	Additionally SWIR	Multipulse LRF	Typical	Two modes: subjective and objective. PC with one frame grabber and boresight software. Accepted one standard of video image.
3		Additionally typical mono-pulse LRF/designators	Ultra high power	As in D2 but two standards of video image used by tested imagers are accepted.
4		lasers of ultra high pulse energy		As in D3 but three standards of video image used by tested imagers are accepted.

A1: JAVI enables measurement of aligning error between LOS of two imagers: TI (LWIR or MWIR) and VNIR camera.
A2: Additionally SWIR imagers can be aligned.
The difference between A1 and A2 is in spectral band of CB25 color blackbody.

B1: No LRFs/designators to be aligned.
B2: Multipulse LRF can be aligned.
B3: As in B2 but additionally typical mono-pulse LRF/designators
B4: As in B3 but mono-pulse LRF/designators of ultra high pulse energy can be tested.
Difference between B1/B2/B3 is in number of laser sensing cards.

C1: No laser pointers.
C2: Typical pointers of power up to 5W can be aligned.
C3: As in C2 but additionally pointers of ultra high power up to 30W can be aligned.
Difference between C1/C2/C3 is in number and type of cards for testing pointers.
Attention: It is assumed that one of imagers of tested EO system is sensitive to laser pointer.

D1: Only subjective mode. Boresight errors are subjectively evaluated by human. No computerization.
D2: JAVI can be used working two modes: subjective and objective. PC with frame grabber and boresight software. Accepted one standard of video image generated by tested imagers. The standard to be chosen from list: analog video, Camera Link, GigE, LVDS, HD-SDI/DVI/HDMI, HD-TVI/HD-CVI, CoaXPress, USB2.0, USB3.0, Ethernet, USB2.0, USB3.0, Ethernet standards
D3: As in D2 but number of two video standards is increased to two.
D4: As in D3 but number of two video standards is increased to three.
Difference between D1/D2/D3/D4 is in number of frame grabbers and test software that enables to capture and analyze video generated by tested imagers.

Exemplary code JAVI 150-1322:

- aperture 150mm,
- boresighted imagers TI/VNIR,
- boresighted lasers: multipulse LRFs, typical monopulse LRFs/designators,
- boresighted lasers: typical laser pointers,
- computerized system equipped with frame grabber and boresight support software that accept imagers generating video image in one of video standards.

11 Why JAVI?

JAVI is a system optimized for boresight of small/medium EO imaging/laser systems. It offers ability to boresight of virtually every EO imaging/laser system of total aperture below about 200mm including EO systems equipped with high power mono-pulse LRF/LD due to special design of collimators. Technically it is a perfect fit for EO systems used by small drones or similar applications.

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Economical advantage of JAVI is significantly lower price comparing to MS series systems for testing/boresight of similar EO imaging/laser systems. It should be also noted that JAVI test system is characterized by the absence of a dead collimator aperture (comparing to standard boresight systems like JT/JIMS series stations.

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