Advanced Man-Portable Test Systems for Characterization of UUTs with Laser Range Finder/Designator Capabilities

Paul Bryant[a*], Brian Rich[a], Jack Grigor[a], Jim McKechnie[a], Jay James[a], Steve McHugh[a], Rich Raney[b]

[a]Santa Barbara Infrared, Inc., 30 S. Calle Cesar Chavez, Suite D, Santa Barbara, CA 93103
[b]The Boeing Company, P.O. Box 516, St. Louis, MO 63166

ABSTRACT

This paper presents the latest developments in instrumentation for military laser range-finder/designator (LRF/D) test and evaluation. SBIR has completed development of two new laser test modules designed to support a wide range of laser measurements including range accuracy and receiver sensitivity, pulse energy and temporal characteristics, beam spatial/angular characteristics, and VIS/IR to laser co-boresighting. The new Laser Energy Module (LEM) provides automated, variable attenuation of UUT laser energy, and performs measurement of beam amplitude and temporal characteristics. The new Laser/Boresight Module (LBM) supports range simulation and receiver sensitivity measurement, performs UUT laser beam analysis (divergence, satellite beams, etc), and supports high-accuracy co-boresighting of VIS, IR, and laser UUT subsystems. The LBM includes a three-color, fiber-coupled laser source (1064, 1540, and 1570 nm), a sophisticated fiber-optic module (FOM) for output energy amplitude modulation, a 1-2 µm SWIR camera, and a variety of advanced triggering and range simulation functions.

Keywords: EO test & calibration, laser range finder/designator, laser receiver, laser transmitter, MEMS, variable optical attenuator.

1. INTRODUCTION

The new LEM and LBM subsystems incorporate a wide range of functionality in support of testing of laser range finder/designators with wavelengths of 1064, 1540, 1570, and 1910 nm. Both modules have been developed by SBIR in support of the Man-Portable Electro-Optical Test System (MPETS) program, under the guidance of the US Navy and The Boeing Company.

The general-purpose nature of the MPETS system prompted the conception of a highly flexible laser testing capability to provide maximum compatibility with existing Test Program Sets (TPSs). Due to the large number of supported UUTs and the correspondingly broad laser UUT performance envelope (pulse energy, beam diameter, and divergence ranges), a concept was developed in which attenuation and pulse energy/temporal measurement was performed in front of the main optics (i.e. – between the collimator and UUT). Remaining functions provided by the laser camera, multi-color laser source, and combined VIS/IR/laser target were partitioned into a backend module, placing these critical focal plane components at collimator focus.

In this partitioned approach, the LEM supports laser transmitter energy, pulse amplitude, pulse period stability, pulse rate, and pulse width measurements – while providing a very large range of adjustable beam attenuation. The LBM supports VIS/IR/laser co-boresight operations, and adds the ability to measure additional transmitter parameters such as beam divergence and satellite beams. A calibrated multi-color laser source within the LBM also allows the user to measure UUT receiver sensitivity, range accuracy, field-of-view, and automatic gain control/time program gain

* paul@sbir.com; (805) 965-3669; http://www.sbir.com

(AGC/TPG). Coupled with IRWindows™, a fully automated setup, execution, data collection and results analysis capability is provided.

2. MODULAR SOLUTION

The modular approach described above required that the LBM installation be repeatable at collimator focus before each test. It also required that the LEM be easily installable and removal between the collimator and UUT apertures to support the different IR, VIS, and laser tests. To address this need, our modular approach includes a Kinematic Universal Test Interface (KUTI), which provides an optical/mechanical/electrical module attachment scheme with no external cables. KUTI uses a manual lever to engage/disengage the backend module from the collimator, and is incorporated into the LBM as well as other non-laser modules such as the Precision Target Module (PTM) and Modulated Source Module (MSM). LEM installation/removal is facilitated by a hinge mount and blind-mate electronic connector on the UUT interface plate.

Figure 1 shows the MPETS system configured with the LEM installed on the UUT mount, and the LBM attached to the main collimator module using KUTI.

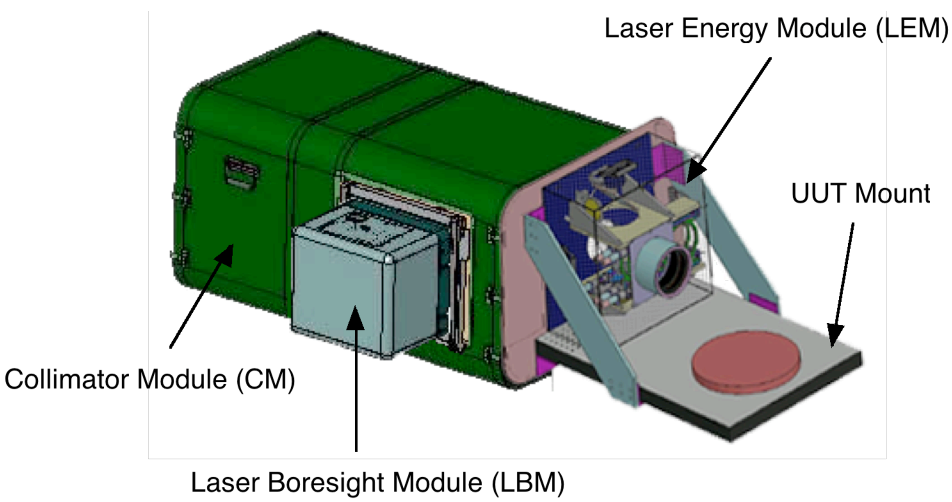

Figure 1 – MPETS Optical System Configured for Laser Testing with LEM and LBM

3. LASER ENERGY MODULE (LEM)

The LEM supports laser transmitter energy, pulse amplitude, pulse period stability, pulse rate, and pulse width measurements, using a variety of advanced custom components and COTS measurement devices. The LEM also provides an extremely large range of adjustable attenuation and – in conjunction with the system controller – an auto-attenuation control system to optimize measurement accuracy and prevent damage to sensitive optical and electronic components. The functionality of the LEM is illustrated in Figure 2.

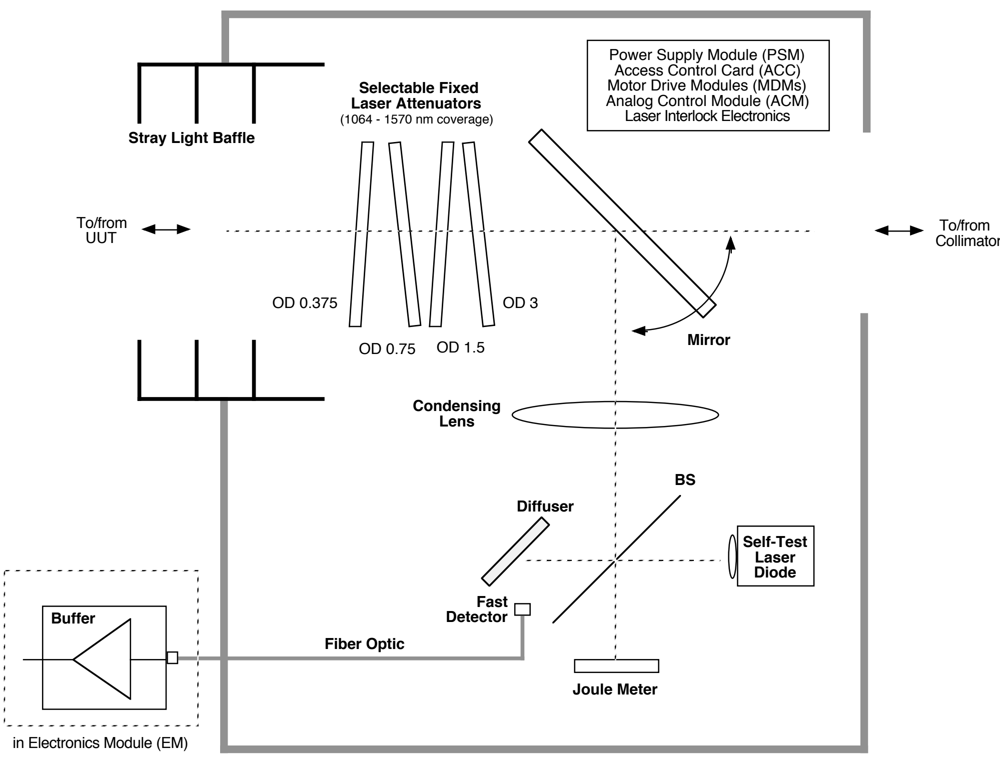

Figure 2 – LEM Functional Architecture

As shown in figure 2, the LEM includes an integral stray light baffle and selectable optical density (OD) filters near the aperture. The baffle is optimized for ultra-low backscatter between 900 and 2000 nm, and rated for very high incident power levels in order to survive exposure to direct UUT laser output during setup and alignment. Annular baffles of a specially selected material provide a robust optical solution, and unique machined profiling minimizes edge diffraction effects. The four discrete OD filters provide optical densities of 3.0, 1.5, 0.75, and 0.375 – for a total attenuation of more than OD 5.5 – and are individually actuated by software-controlled linear slide mechanisms. During system operation, the control software uses per-UUT pulse energy and divergence information to automatically set the OD stages to protect the system and provide high measurement accuracy for the various tests.

After passing through the entrance baffle and selectable ODs, input laser energy is directed by a flip mirror to either (a) the LEM measurement section or (b) the main collimator optics and backend module(s). For measurement of pulse amplitude and temporal characteristics, the mirror directs input energy to a condensing lens and a pyroelectric joule meter/fast detector/fiber combination – optically combined using a 50/50 beam splitter. The joule meter reports pulse energy to the system controller, and the fast detector/fiber provides a temporal representation of the UUT pulse to a high-performance digitizer in the MPETS Electronics Module (EM). A self-test source in the backend of the LEM allows the system to automatically verify that the joule meter and fast detector/fiber components are functioning, as a part of the MPETS built-in test (BIT) implementation. The LEM supports the measurements and UUT performance envelopes listed in Tables 1a and 1b.

PARAMETER	*RANGE*
Laser Wavelengths	1064 nm 1540 nm 1570 nm
Pulse Period Stability	50-1000 ms
Pulse Amplitude	Per input range
Pulse Energy	30-1000 mJ (1064 nm)
	4-120 mJ (15XX nm)
Pulse Energy (avg)	up to 2048 pulses
Pulse Width	3-30 ns
Polarization	Orientation-independent

Table 1a – LEM Performance Specifications

PARAMETER	*VALUE*	*CONDITION*
Laser Aperture	1-5 inch diameter	-
Angle of Regard	10 mrad (max)	-
Pulse Energy	30-1000 mJ	(1064 nm)
	4-120 mJ	(15XX nm)
Beam Divergence	80-1000 μrad	-
Pulse Repetition Frequency	8-20 Hz	-

Table 1b – UUT Laser Transmitter Performance Envelope Supported by LEM

Figure 3 shows the LEM as a cutaway view in its stand-alone hardware configuration, and attached to the MPETS UUT mount. Visible in the cutaway view are the stray light baffle, OD mechanisms, flip mirror, condensing lens, beam splitter, and measurement components.

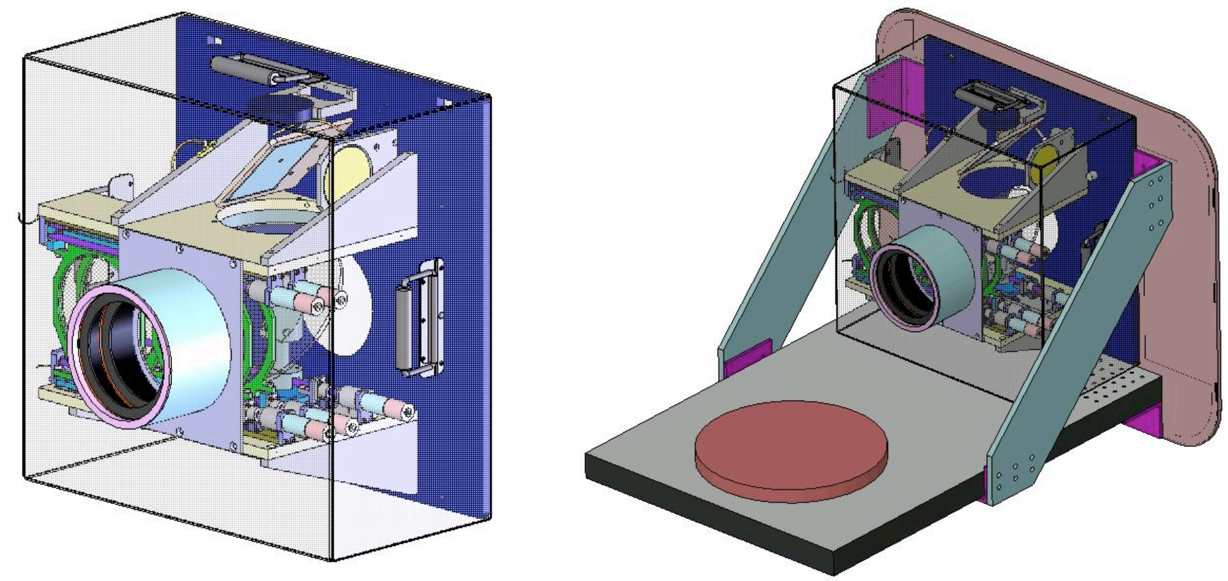

Figure 3 – LEM Hardware Architecture (left) and LEM Installed onto MPETS UUT Mount (right)

4. LASER/BORESIGHT MODULE (LBM)

The LBM supports VIS/IR/laser co-boresight operations, and allows the user to measure LRF/D transmitter parameters such as beam divergence and satellite beams. An advanced fiber-couple multi-color laser source assembly within the LBM allows the user to provide accurately calibrated pulsed laser stimulus for measurement of UUT receiver sensitivity, range accuracy, field-of-view, and automatic gain control/time program gain (AGC/TPG). The LBM offers an unprecedented level of timing flexibility in the laser source, allowing the user to simulate a very wide range of target range, intensity, pulse width, and first/last pulse options.

After passing through the LEM and collimator modules, UUT laser energy enters the LBM through a broadband window. The window minimizes contamination of optical surfaces near focus, thereby reducing the likelihood of particle-induced damage under UUT illumination conditions. As illustrated in Figure 4, the LBM uses two beam splitters to direct incoming and outgoing energy between a combined VIS/IR/laser boresight target, a triggering sphere, and an optimized SWIR laser camera.

The combined boresight target provides simultaneous VIS, IR, and laser stimulus for alignment of multi-sensor platforms. The target is heated and front illuminated to provide VIS and IR output, and produces laser energy from a fiber/ferrule assembly located at the target center. The integrating sphere is used to trigger both the SWIR camera and the fast digital timing electronics, which control the pulsed lasers and range simulation timing circuits. The SWIR camera assembly includes two CVFs (OD 0-4, each) for optimization of laser spot intensity during boresight and divergence measurement – plus a custom spectral filter to optimize the response ratio between 1064 and 1910 nm light, during multi-laser boresight operations.

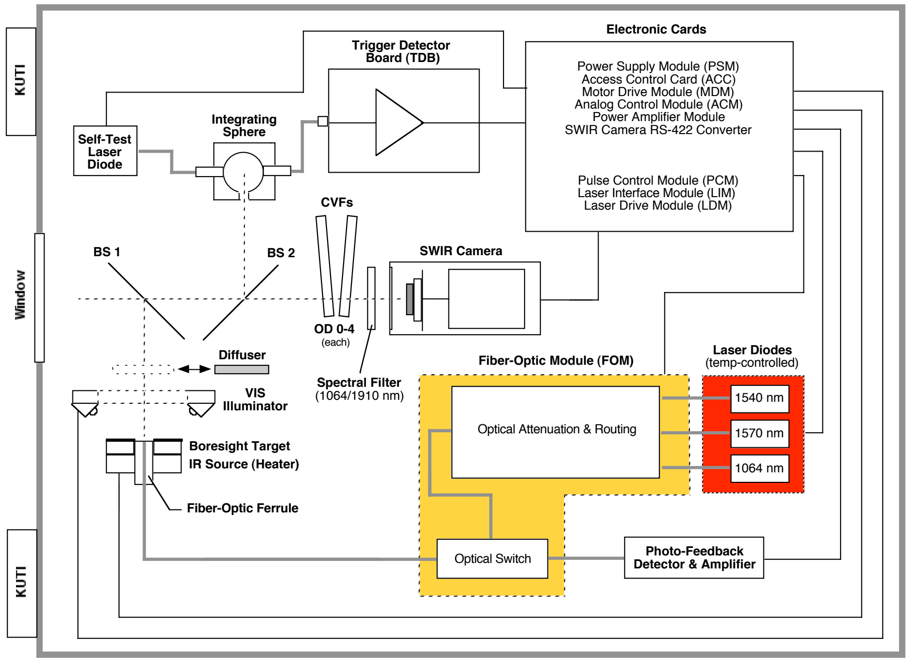

Figure 4 – LBM Functional Architecture

To generate pulsed laser output stimulus and perform all critical range timing functions, the LBM includes SBIR's second-generation laser pulse control module (LPCM) and laser diode drive module (LDDM) electronics, an improved fiber-optic module (FOM), and three discrete, temperature-controlled laser diode sources. The 1064, 1540, and 1570 nm laser diodes are pulsed at a constant drive current to maximize calibration stability and minimize drift. The FOM includes a variety of sophisticated fiber-optic signal routing and attenuation components, easily supporting the required 40 dB modulated output range. LBM specs and supported UUT parameter space are summarized in Tables 2a and 2b.

PARAMETER	*RANGE*
Incoming Wavelengths	1064 nm 1540/1570 nm 1910 nm
Beam Divergence	80-4000 μrad
Beam Alignment	-
Multiple Laser Boresight	Between all bands
Beam Profile	Capture & display
Range Simulation	25-150,000 m
Output Power Density	0.1-1000 nW/cm^2
Output Bandwidth	5 nm (1064 nm)
	10 nm (15XX nm)
Output Pulse Width	10-2560 ns
Last Pulse Delay	60-2000 ns
Polarization	Orientation-independent

Table 2a – LBM Performance Specifications

PARAMETER	*VALUE*
Receiver Sensitivity	0.1-1000 nW/cm^2
Range Gate	20 m to 60 km
Field-of-View	0.2º-2º
Wavelength	1064 nm 1540 nm 1570 nm
Aperture	0.2-5.0 in
FOV Coincidence	Laser within UUT FOV
Aperture Configurations	Coaxial, separate

Table 2b – UUT Laser Receiver Performance Envelope Supported by LBM

For UUT receiver and range testing, the LBM pulsed laser output may be precisely controlled to optimize the simulated return energy for the device under evaluation. The LBM supports simulated ranges between 25 – 150,000 m, and is capable of providing return amplitudes between 0.1 – 1000 nW/cm^{2}at the aperture of a 55-inch collimator. Pulse width is variable between 10 and 2560 ns, and a variety of first/last pulse control parameters are provided – as illustrated in Figure 5.

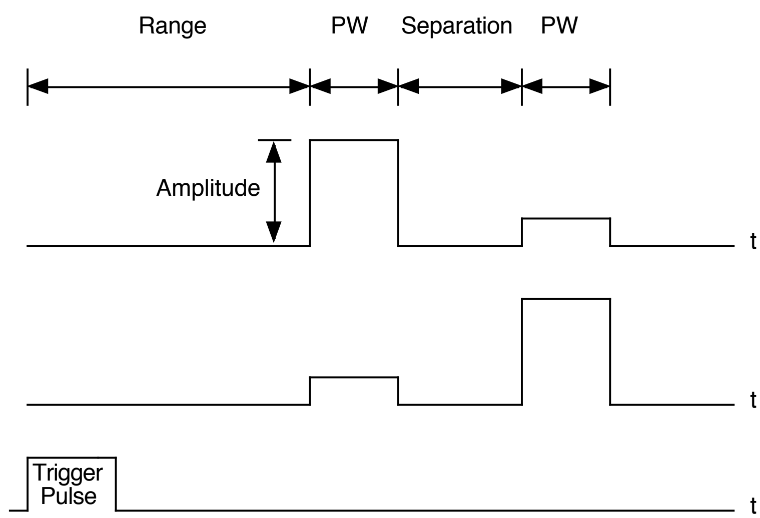

Figure 5 – LBM Pulsed Laser Output Waveform Parameters

The LBM hardware architecture is shown in Figure 6. The front face includes the optical window, blind-mate electrical connector, and kinematic mount points for connection to the collimator via KUTI.

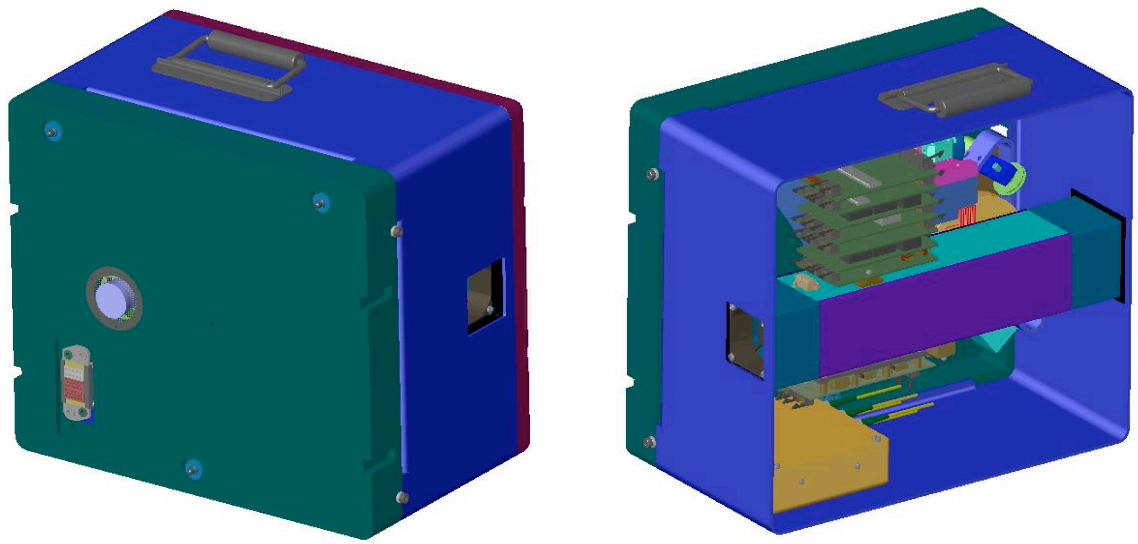

Figure 6 – LBM Hardware Architecture

This front plate configuration is by definition the same for each MPETS module utilizing the KUTI mount. In this way, the system includes an advanced means of quickly and easily reconfiguring for different tests, while minimizing the use of external cables – which are traditionally the weak link in terms of any electronic system's reliability.

SUMMARY

SBIR has developed two new laser measurement instruments, each incorporating novel solutions for test and evaluation of a wide range of different LRF/D systems. Both LEM and LBM strongly leverage SBIR's prior work in this area, and offer unprecedented flexibility for range simulation. The LEM and LBM work together within a modular EO test suite to support all key laser transmitter and receiver measurements for current and emerging UUTs, and provide maximum compatibility with and transportability between existing TPSs.

ACKNOWLEDGMENTS

The authors would like to acknowledge the support of the Navy/NAVAIR MPETS program office and the multi-service MPETS technical team for its ongoing direction and collaboration.