SWIR Multimode Tracking (MMT) Developments at SUI

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ABSTRACT

The value proposition for Short-Wave Infrared (SWIR) includes capabilities beyond standard passive, low-noise imaging. Sensors Unlimited Inc. (SUI), a Raytheon Technologies Company, has expanded its multi-mode tracking (MMT) portfolio with the development of two new solutions, each of which offers laser range finding (LRF) capability. The SWIR Pocket Scope-MMT (SPS-MMT) sets the gold standard for asynchronous laser pulse detection (ALPD) and low-noise passive imaging, internally dubbed MMT, in a SWIR hand-held solution. SUI's expanded portfolio now includes a variant of that product with an embedded LRF so that the warfighter can simultaneously, image, track and decode any laser designators, and determine the distance to any targets in the same scene of interest. Additionally, SUI has developed an HD version of that capability set. Performance results of each solution will be described herein.

Keywords: SWIR, MMT, ALPD, LRF, SPS-MMT, 640MMT, 1280MMT, ToF

1. INTRODUCTION

Laser range finders (LRFs) are versatile devices with applications spanning commercial and military sectors. The importance of LRFs stems from their unparalleled ability to measure distances to targets precisely. In commercial applications, they aid in tasks such as land surveying, construction layout, and outdoor sports, revolutionizing industries reliant on accurate distance measurements. In military contexts, laser range finders are indispensable for target acquisition, artillery fire control, and reconnaissance, providing critical information for effective decision-making and mission success. Their importance lies in their ability to enhance situational awareness, improve accuracy in targeting, and streamline operational workflows, ultimately contributing to increased efficiency, safety, and success in a wide range of activities, from everyday tasks to high-stakes military operations.

Laser range finders are composed of optics, electronics, and supporting signal processing technologies. At the forefront is the laser emitter, which generates a precise beam of light used to measure distances. Detectors, typically PIN photodiode or avalanche photodiode (APD) based arrays, capture the reflected laser light. Advanced optics, including lenses and mirrors, focus and direct the laser beam for accurate targeting and imaging. Signal processing algorithms analyze the time-of-flight (ToF) or phase shift of the laser pulse to calculate the distance to the target with exceptional accuracy.

The SWIR optical band is important for laser range finders due to its ability to penetrate obscurants like smoke, fog, and haze better than visible or other infrared wavelengths. This allows for enhanced imaging capabilities even in challenging environmental conditions, making SWIR ideal for both day and night operations. This capability translates to improved situational awareness and target identification for both commercial and military applications. Lasers operating in the SWIR spectrum are eye-safe, enabling safe illumination of human targets[1].

In 2019 SUI introduced its SPS-MMT into its product portfolio. The SPS-MMT is the expansion of SUI's handheld pocket scope product line to include SUI's 640MMT ROIC technology, which facilitates asynchronous laser pulse detection (ALPD) at every pixel location. SUI continues to invest in this area and develop technologies to address continued calls for innovations improving situational awareness and reducing SWaP. The following text is structured in the following fashion. Section 2 reviews current state-of-the-art (SOA) technology and introduces SUI's SHIELD and 1280JDSX-MMT solutions. Section 3 offers performance results of these solutions, while Section 4 offers conclusions.

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Infrared Technology and Applications L, edited by Gabor F. Fulop, Michael H. MacDougal,
David Z. Ting, Masafumi Kimata, Proc. of SPIE Vol. 13046, 1304606 ·
© 2024 SPIE · 0277-786X · doi: 10.1117/12.3013845

2. TECHNOLOGY OVERVIEW

LRF Parameters

The salient performance parameters of LRFs are the following:

- Range: The maximum distance over which the laser range finder can accurately measure distances to targets.
- Ranging Accuracy: The degree of precision in distance measurements, crucial for ensuring effective targeting and engagement.
- Resolution: The level of detail and clarity in the imaging provided by the range finder, affecting target identification.
- Speed: The time taken to acquire and calculate distance measurements, influencing operational efficiency.

SUI SHIELD Solution

Figure 1. SHIELD System, M1 Lens Configuration

SUI introduces an LRF-based solution that combines an external eye-safe LRF module to SUI's SPS-MMT handheld in a single handheld package. This solution includes all the features of SUI's SPS-MMT handheld with the addition of integrated LRF data presented on the Graphical User Interface (GUI). Like the SPS-MMT, the SHIELD unit can track and decode up to 3 pulsed laser sources (rangefinders or laser target designators/markers with NATO PRF codes). User-selectable colored highlights for all pulsed laser sources ensure the warfighter can visually verify the LRF has acquired the target of interest. The addition of LFR data on the GUI enhances the warfighters situational awareness by combining imaging, laser decoding, and range finding in the same scene.

The SHIELD system is produced with a factory boresight, aligning the external LRF to the LRF reticle on the GUI. In addition to the fixed LRF reticle, the system has a user adjustable reticle.

The end user interface for SHIELD is consistent with SUI's SPS-MMT. The modular lens interface allows for interchangeable options compatible with other SUI lenses. The button layout and bindings are consistent with SPS-MMT. The GUI has all the same features and menus with the addition of LRF-specific selections and data. The handheld design is versatile and can be tripod, or rail-mounted.

SUI 1280JDSX-MMT Solution

Figure 2. 1280JDSX-MMT System, L1 Lens Configuration

1280JDSX-MMT further integrates LRF capability into SUI's products with the addition of an embedding LRF receiver. The 1280JDSX-MMT includes an external laser emitter coupled with a 1280x1024 image resolution and 640x512 ALPD resolution sensor in a single system. This approach allows SUI control of the salient performance parameters: range, ranging accuracy, resolution, and speed. The embedded LRF receiver enables the ToF range finder capability in conjunction with the laser emitter.

The integrated laser is produced with a fixed factory boresight. The boresight is aligned and set to the center group of LRF pixels. With this approach, the operator aims the system at a target of interest. Upon decoding the LRF spot, the system will display a target reticle at the center of the spot. The target reticle provides additional confirmation to the user that the intended target has been measured. In conjunction with tracking and decoding of up to three laser pulse sources, each with their own user-selectable colored highlights, the user is provided with greater situational awareness in the same field of view.

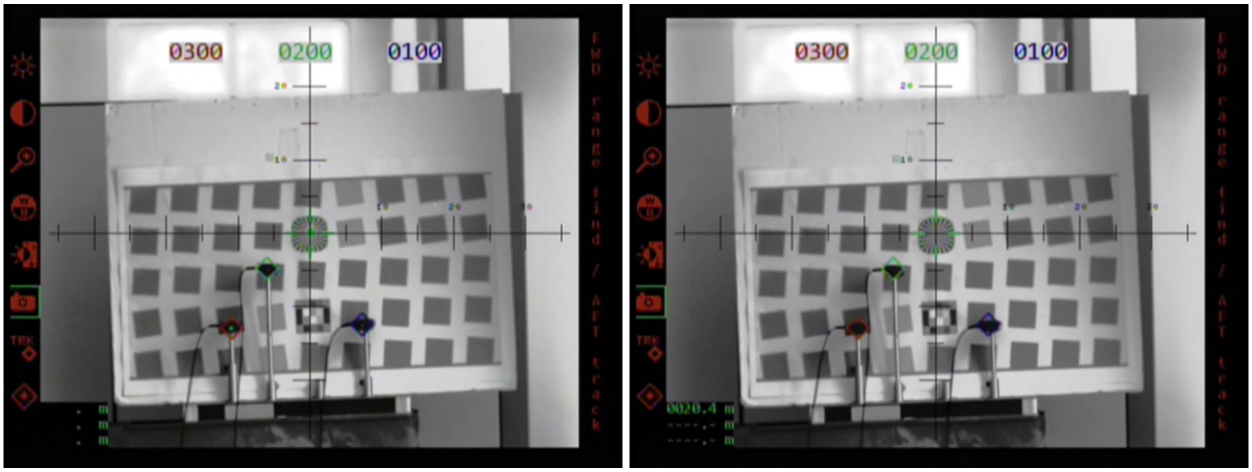
The JDSX-MMT end user interface utilizes a direct threaded lens compatible with SUI lens offerings. Video output is provided via a standard Camera Link video and data communication protocol. The JDSX-MMT also has a secondary dedicated serial communication port for laser spot location and code data for up to three unique laser spots[2].

3. PERFORMANCE RESULTS

SUI SHIELD Performance

The SHILED LRF function is demonstrated through indoor testing and an outdoor example. The following results highlight the LRF and MMT capabilities in the same area of interest.

For the indoor testing, 3 Multi-Laser Pulse Simulator (MLPS) units with SWIR light sources are used to simulate laser spot locations. The MLPS pulses are detected and located with colored diamonds and the related pulse codes are displayed at the top of the GUI. Additionally, the LRF laser spot is shown to be aligned to the green LRF reticle and the measured distance data is displayed on the GUI. The image in Figure 3(a) captures the LRF laser spot location, while the Figure 3(b) image shows the resulting LRF measurement data displayed on the bottom left of the GUI. In each image the MMT capability continues to track the 3 MLPS pulses.



(a) (b)

Figure 3. SHIELD Indoor LRF Testing

Outdoor use of the SHILED unit performs similarly to the indoor testing results. MMT laser spot detection and LRF measurements operate at an extended range. Like the indoor testing, pulse detection and decoding are highlighted with overlaid symbols and the decoded pulse values are shown in corresponding color to the symbols. In this example, SWIR laser sources are used instead of MLPS units. LRF measurement data is similarly displayed on the GUI. Figure 4 shows an example outdoor scene utilizing the MMT and LRF capabilities of the SHIELD unit.

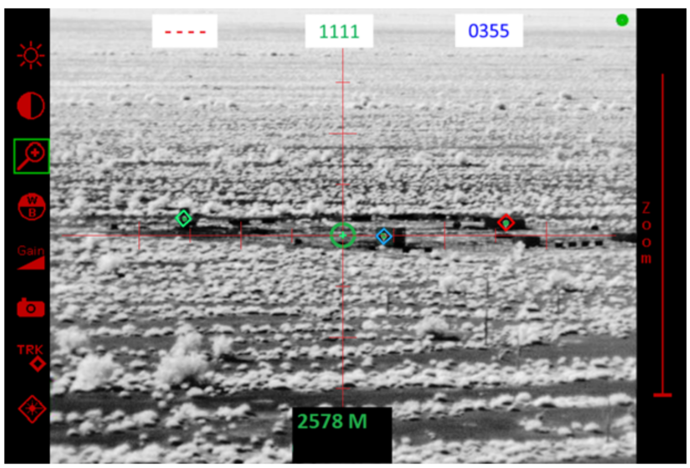


Figure 4. SHIELD Outdoor LRF Testing Example[3]

SUI 1280JDSX-MMT Performance

The following testing illustrates the capabilities of the embedded LRF receiver and ToF performance in indoor and outdoor environments.

To utilize the benefits of the target reticle, the reticle is aligned with the laser spot. In Figure 5(a) the integrated SWIR laser is generating a spot shown on the target. Additionally, the target reticle is seen on the right-hand side of the image, not aligned with the laser spot. When aligned the reticle is centered on the detected laser spot. Figure 5(b) shows the target reticle aligned to the location of the laser spot shown in Figure 5(a). Once the reticle is aligned the end user will have visual confirmation in addition to the laser spot to confirm the intended target has been measured.

(a) (b)

Figure 5. 1280JDSX-MMT TOF Reticle Acquisition

With an aligned reticle, ToF measurements were taken using the same indoor target from Figure 5. ToF measurements involve triggering the integrated SWIR laser and detecting the laser spot on the embedded receiver. 5 ToF pulses were triggered and received in this test and the resulting measurement data is displayed on the top of Figure 6.

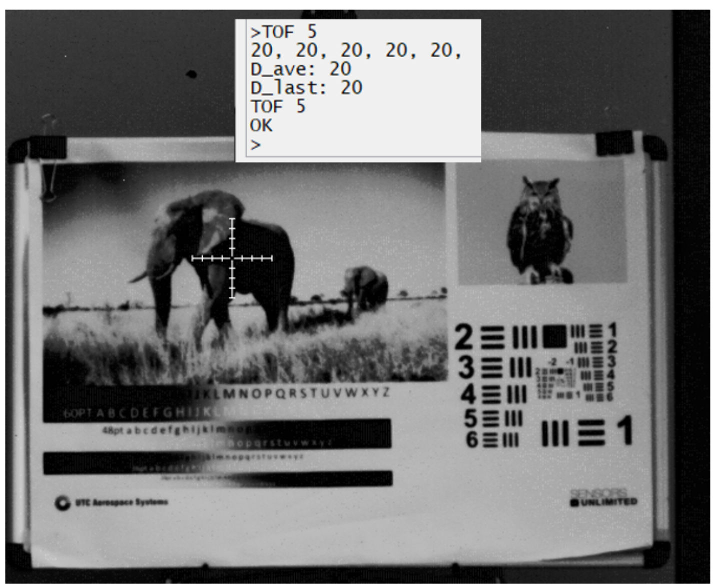


Figure 6. 1280JDSX-MMT Indoor TOF Measurement

To extend the range of the 1280JDSX-MMT ToF testing, an outdoor range and target were utilized. The selected range is shown in Figure 7(b). The outdoor testing procedure included boresighting the integrated laser, alignment of the target reticle, and triggering ToF pulses. ToF measurements were recorded over 7 testing runs and the resulting range calculations are displayed in Figure 7(a).

Run #	Time, PM	Thresh	ToF Count	Range, m
1	316	44	751	378.4
2	318	46	751	378.4
3	319	46	750	377.8
4	320	44	749	377.3
5	345	41	751	378.4
6	346	41	751	378.4
7	347	42	752	378.9

Range, m	
Mean	StDev
378.2	0.49

(a)

(b)

Figure 7. 1280JDSX-MMT Outdoor TOF Measurement

Next Steps

The next steps for SHIELD include improving range without sacrificing SWAP-C, incorporating a 1280MMT sensor, and user accessible boresight adjustments to allow greater versatility to the warfighter mission.

The next steps for 1280JDSX-MMT include improved resolution, reduced pixel pitch, increase in range by improving the signal to noise ratio, and an increase in the Technical Readiness Level (TRL) for the design. 1280JDSX-MMT will utilize enhancements in laser selection and SWAP-C opportunities to greater serve the warfighter in a wider variety of missions.

4. CONCLUSIONS

In summary, laser range finders are valuable tools with diverse applications in both commercial and military settings. The SWIR band offers distinct advantages in challenging environments, and ongoing research and development efforts aim to enhance their performance and versatility for future applications. In this work, SUI presented two LRF-based solutions, SHIELD and 1280JDSX-MMT. SHIELD adds an external LRF module to SUI's SPS-MMT handheld, while 1280JDSX-MMT offers an embedded LRF receiver in an 1280x1024 and 640x512, imaging and ALPD resolutions, respectively. SUI continues to explore opportunities for further SWAP-C reductions in its LRF-based systems while continuing to improve performance to facilitate easier integration into a host of platforms including unmanned aerial vehicles (UAVs) and wearable devices. Ongoing research and development activities at SUI focus on developing advanced technologies, including multi-band IR imaging and ALPD, and artificial intelligence (AI) algorithms, to enhance the capabilities of SUI's laser range finders, improving accuracy and target recognition, and providing more comprehensive situational awareness and target identification capabilities.

ACKNOWLEDGEMENTS

The authors would like the thank the SUI team members, both current and past, who although not listed here, provided indispensable efforts to bring the technologies presented here to fruition.

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