

Antiaircraft Missile Stimulator for Countermeasure Development



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Abstract

An electro-optical-mechanical stimulator has been designed, built and tested by the Naval Research Laboratory (NRL), and is being used to develop countermeasures against infrared-seeking anti-aircraft missiles. It consists of an elevated static-target optic bench integrated with a rotary optic bench. The elevated bench generates an aircraft signature at two wavelengths or an aircraft with a laser countermeasure. The rotary optic can be used to generate two independently controlled, two wavelength sources. Sources can be deployed flares, an aircraft target or a combination of the two. This configuration provides a temporally controlled dual wavelength aircraft optic signature as well as temporal and intensity control of two dual wavelength flares. This produces a realistic test environment in which missile seekers can track an aircraft while flare countermeasures can be evaluated.

The elevated sources are projected onto a tripod-mounted folding mirror which then integrates the beam into the optics of the rotary bench. After integration in the rotary plane, the target beam propagates through two large combiners and onto the seeker aperture. The addition of two moving flares is controlled by a workstation on the table that rotates during operations. Flares are generated on opposite sides of the rotary table. Each flare has both wavelengths fiber coupled from diode lasers. These wavelengths are projected via a 2" beam combiner into an 8" OAP. After combination of the two wavelengths, each flare beam is projected into 12" beam combiners, and folded into the optic axis of the seeker. A calibration radiometer is positioned to control the optic signatures before each test. This calibration allows temporal control the flare intensity independent of its spatial position relative to the aircraft.

1.0 Introduction

The anti-aircraft (AA) missile challenge to naval aviation is undergoing a continuing upgrade and becoming more sophisticated. Algorithms utilized by infrared-seeking AA missiles are evolving into complex discriminators that are increasingly difficult to counter. The dimensions that these discriminators work in include spectral, temporal, spatial and kinematics:

- Spectral in that multiband evaluation allows a rejection of decoys based on divergence from an aircraft signature
- Temporal in that the history of intensity fluctuations is remembered to reject intensity variations that do not correlate to aircraft performance
- Spatial in that the movement of additional sources within the missile FOV are evaluated to reject trajectories that conform to traditional flares
- Kinematics in that the turning accelerations are accounted in aerial combat maneuvering.

The countermeasure response to such sophisticated infrared AA missile discrimination has been limited by the historical application of decoy flares. These flares are typically at a higher color temperature than aircraft, and deploy by simple release into the aircraft jet stream. In modern countermeasure concepts, flares are deployed in a smart manner with adjustments and adaptations designed to overcome the complex discriminators in advanced AA missiles. The spectral dimension is approached via designer chemoluminescence that shifts the color temperature to mimic that of aircraft. The temporal dimension is approached by controlling the intensity profile of both the applied countermeasure (laser jammers and flares) and the aircraft. The spatial dimension is approached with the application of advanced designs that incorporate vectored propulsion that control both direction and speed of flare separation from the aircraft. The kinematic dimension is approached with the generation of air combat maneuvers used in conjunction with countermeasures to enhance the probability of decoy.

2.0 Countermeasure Test Environment

The test environment used to develop advance countermeasures against infrared seeking missiles requires missile stimulation sources that mimic the aircraft target, laser countermeasures, and multiple flares. The test environment must be realistic wherein missile seekers can track an aircraft while countermeasures can be evaluated under kinematic variable conditions. This has been achieved at the IRCM Techniques Laboratory of the Naval Research Laboratory.

The essential improvement in test facilities of this kind is the ability to embed large jammer lasers in aircraft target signatures while multiple flares are being deployed. Jammer lasers can be selected from a list of sophisticated lasers operating in either CW or pulse modes. Additionally, multi-spectral stimulation is achieved allowing wavelength ratio control, all within a low cost facility and operating umbrella. Low cost is realized through open loop testing affording snapshots in the engagement sequence. This provides low cost testing and analysis that focuses on time sequenced, missile vulnerabilities.

The floor plan of the stimulator is diagramed in Figure 1 that shows 1) an elevated optical bench for generating the aircraft target and laser countermeasures and 2) a rotating optical table upon which the missile seeker is placed. This floor plan includes the integration of six laser sources that are temporally controlled.

Stimulator Floor Plan

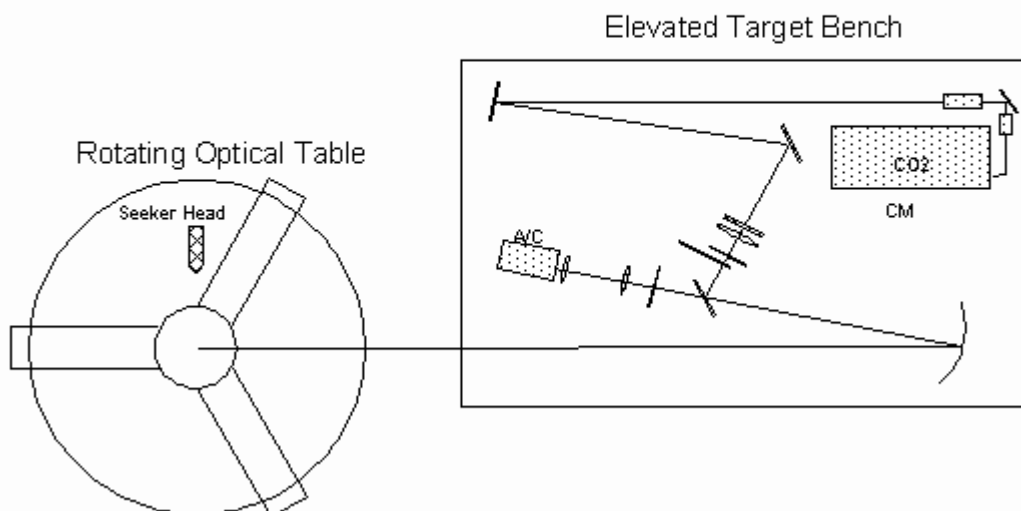


Figure 1.

The elevated bench generates either an aircraft signature at two wavelengths or an aircraft with a operative laser countermeasure. The rotary optic bench generates two independently controlled, double wavelength flare sources along with kinematic stimulation of the missile seeker. Figure 2 are photographs of the rotary optic table on the left and the elevated optic bench on the right. Integration of the elevated bench with the lower rotary table is achieved with a beam transfer from the 25" Off Axis Parabolic (OAP) from the elevated bench to a 12" mirror suspended on the Optic Tripod over the rotary table. The two wavelength IR sources on the elevated target optic bench are separately controlled to emulate an aircraft in two wavelengths, or an aircraft with a laser countermeasure As shown in Figure 3.

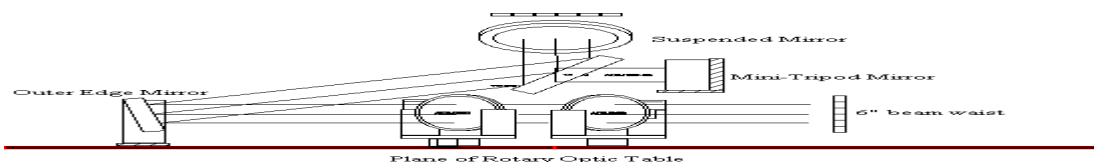


Figure 2.



Figure 3.

The projection mechanism for the aircraft target is diagramed in Figure 4. The beam generated in the elevated optic bench is transferred to the mirror suspended by the overhead tripod. The beam folds down to the mirror that is mounted on a mini-tripod seated on the rotary optic table but not in the plane of the rotation. The beam is then transferred to the mirror located on the outer edge of the plane where it finally is bent into the optic plane. The beam proceeds through two large combiners, where the flare sources are introduced, and then propagates to present a six inch beam to the missile seeker. This arrangement for the beam directing mirror is shown from two opposing directions in Figure 5.



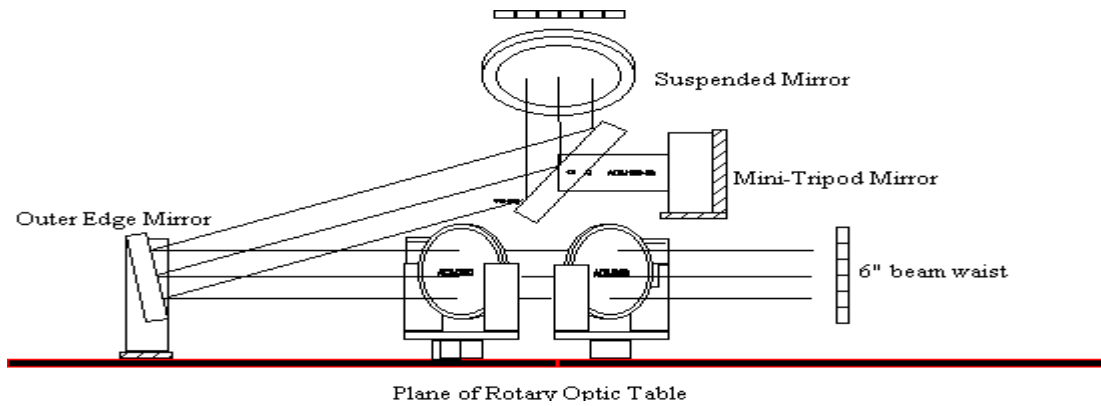


Figure 4.

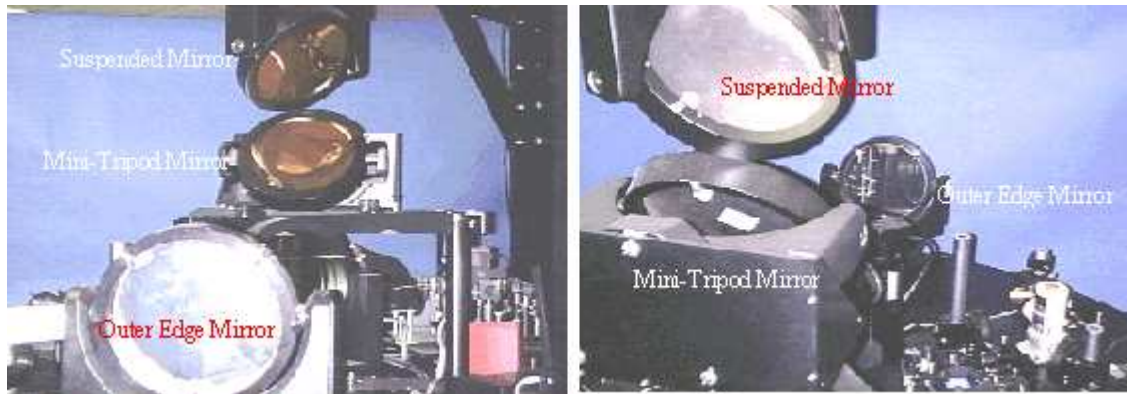
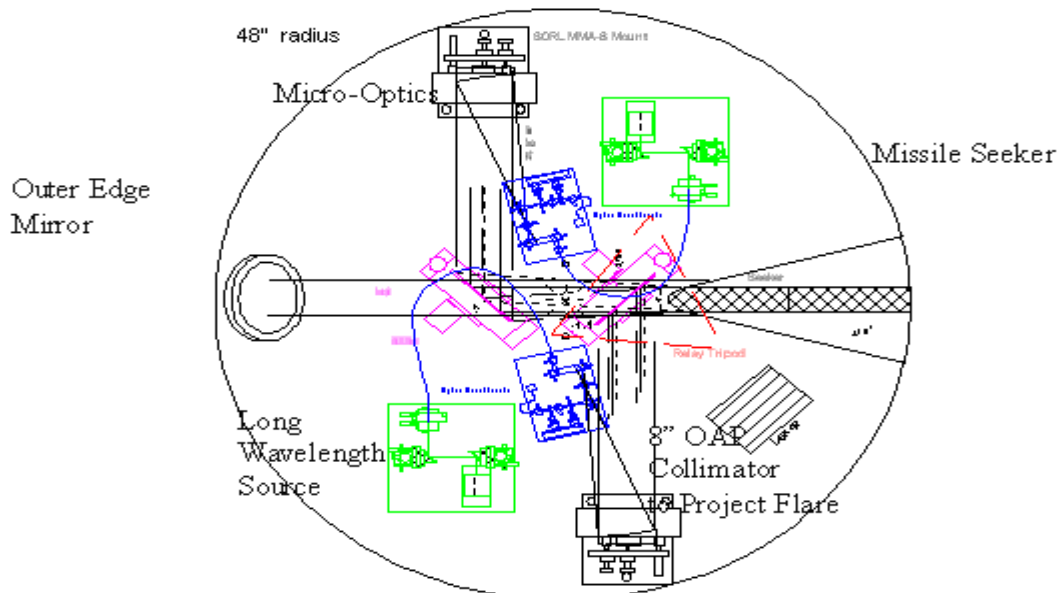


Figure 5.

The diagram of the rotary table is shown in Figure 6 where the beam enters into the plane at the left with the outer edge mirror. The beam propagates straight across the table in the horizontal dimension and into the missile seeker. Two flares are introduced into this beam in mechanisms drawn in the vertical axis as shown. These flares are comprised of a long wavelength source breadboard, a micro-optic breadboard including a short wavelength source and a small combiner for both wavelengths, an 8" off axis parabolic collimator, and a large beam combiner in the aircraft beam. Pictures of this are shown in Figure 7 where in the seeker's place is shown a calibration radiometer at the left. A missile seeker is shown at the right with one of the flare stimulators in the background.



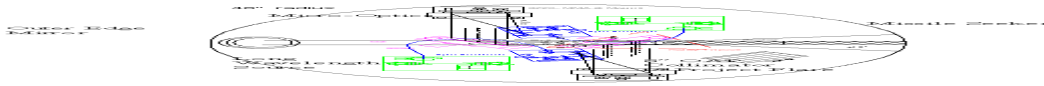


Figure 6.



Figure 7.

Figure 8 shows how the target-beam folding optics steer the beam from left at top center, to right foreground, and across the middle of the table to the left background. The addition of two moving flares is controlled by a workstation on the right that rotates during operations.



Figure 8.

Flares are generated on opposite sides of the rotary table. At left of Figure 9, the shorter wavelength is generated on a micro-optic breadboard and projected via a 1" beam combiner into a 8" OAP. The longer wavelength is generated on a standard breadboard as shown on the left in the Figure.

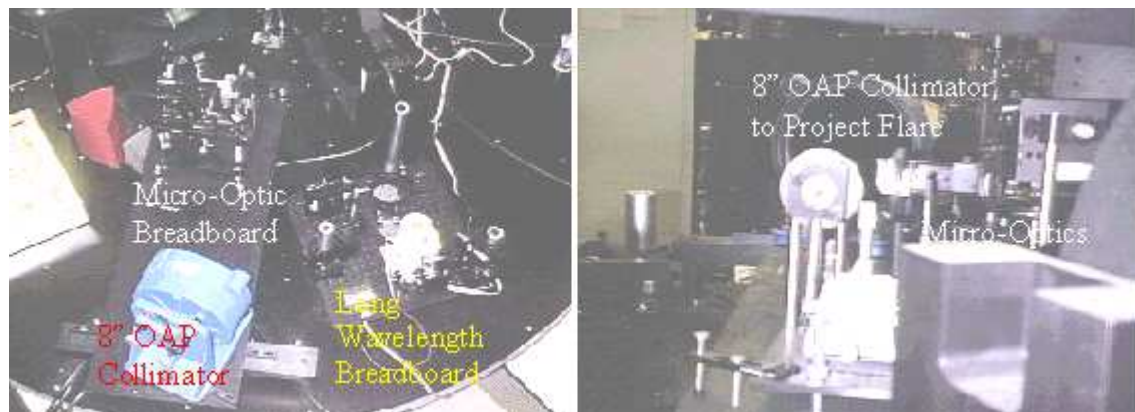


Figure 9.

The micro-optic breadboard (shown on left in Figure 10) supports the short wavelength optics and combiner. The mode stabilizer for the short wavelength fiber optics is the triangular object on the left. The regular breadboard (on right of figure) supports the long wavelength optics and laser, transferring the beam via an additional fiber optic.

After combination of the two wavelengths, the flare beam is projected into one of the two 12" beam combiners, and folded into the optic axis of the seeker as shown in Figure 11. The seeker view is shown (at right of the figure) with the calibration radiometer in place.



Figure 10.



Figure 11.

3.0 Resultant Presentation and Future Development

The result of all this beam manipulation is a simulation of an advanced countermeasure deployed at great range, and shown in Figure 12 from a video clip. The simulation begins during the initial phase of the missile engagement of the aircraft which is shown as the distant infrared object. The aircraft is moving to the left as the viewer sees the image.

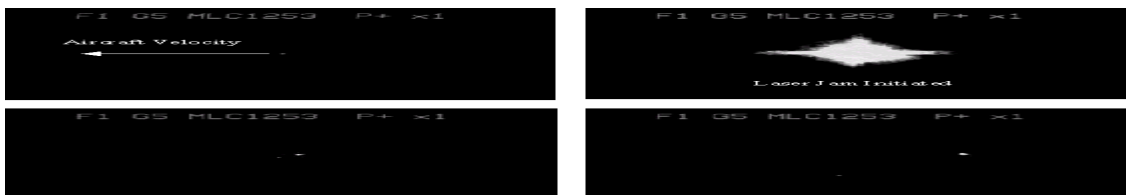




Figure 12.

The progression of the action is you read, from top left to right then down. In the simulation, the laser jammer is initiated at the outset of the countermeasure response. Two flares are simultaneously launched while the laser is emitting in a pulsed fashion. One flare is a conventional type that falls behind the aircraft. It is the brighter one in this case. The second flare is an advanced propelled model that moves slightly forward of nadir.

The dynamic images of the flares suffer from both beam spatial irregularities of the diode laser sources and an irregular drive response. The spatial manifestations are typical of high multi-mode profiles dominated by complex diffraction effects. The radiant output that is non-linear, discontinuous, and mode variant as a function of the drive voltage. Thus the chosen flare trajectories must be compensated for local spatial modulations by training the system to recognize and compensate for these variations. This is done by a calibration procedure that employs a 7 mm diameter InSb detector in the focal plane of a two inch diameter, aberration corrected lens. This lens performs with excellent response over a 10° FOV. The whole process is controlled by calibration software that varies the drive voltage according to the image position in the missile FOV.

In the near future, the stimulator will be upgraded to include the two dimensional representation of the target aircraft. This will allow the simulation of the end game, and will address the unique capabilities of seekers that employ focal plane arrays with advanced correlation algorithms. Such a capability will be integrated with the existing long range simulation to render a complete test scenario from missile launch to intercept.