J. Vis. Commun. Image R. 59 (2019) 401–406

Contents lists available at ScienceDirect

J. Vis. Commun. Image R.

journal homepage: www.elsevier.com/locate/jvci

The experimental study about laser-induced dizziness effect of medium-wave infrared seeker which based on image processing ☆

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ARTICLE INFO

Article history:
Received 13 November 2018
Revised 23 December 2018
Accepted 24 December 2018
Available online 27 December 2018

Keywords:
Image processing
Laser dizziness interference
Medium wave infrared detector
Photoelectric interference

ABSTRACT

In view of the problem of laser dizzy interference of medium-wave infrared seeker detector in the field of photoelectric confrontation, there is a lack of equidistant distance test to verify the problem. In this paper, a medium-wave infrared seeker for short-range precision guided missile CCD detector was used as the subject, and the 3.8 μm wavelength medium wave laser was used as the laser source to study the calibration of the laser. In the experiment, two locations with a viewing distance of 14.5 km were selected to place the laser and missile seeker detectors respectively. The atmospheric transmittance was estimated using the MODTRAN software based on the meteorological parameters provided by the simple meteorological monitoring tool. Under the different target power density conditions, the simulation of the missile seeker head of the interference of the dizzy effect. By analyzing the interference images in the tracking state, the corresponding qualitative and quantitative dizziness interference results are obtained. After the calculation and analysis, it is considered that the laser energy output from the mid-wave infrared laser is 0.08 mW/m^2 when the power density of the target surface of the detector is 0.08 mW/m^2, respectively, under medium meteorological conditions with a visibility of 0.625. Box cannot lock the original target, there cannot effectively extract the target dizzy effect. The experimental results show that the anti-jamming ability of the anti-jamming capability of the medium-wave infrared precision guidance probe is verified by the photoelectric countermeasure, and it is considered that the dodge power density is smaller when the interference laser wavelength matches the wavelength of the seeker detector. The experimental data can provide theoretical guidance for the inversion and determination of parameters in the study of the medium wave infrared photoelectric countermeasure.
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1. Introduction

Short-range precision-guided weapons have become one of the indispensable weapons and equipment in modern warfare. The range of 10–30 km short-range air, ground-to-air missiles and more anti-interference ability, the system is simple and medium-wave infrared detector as its seeker core device. And the current wave infrared seeker has been able to effectively avoid the aircraft infrared tracer and other interference technology. How to implement effective low cost and high efficiency photoelectric countermeasure interference to such weapons has become a hotspot in this field. In the corresponding interference model building and equipment construction demonstration process requires accurate interference data model, which requires a lot of experimental data and theoretical analysis. At present, the research on the effect of photoelectric countermeasure on weapon interference mainly focuses on theoretical analysis and inner field simulation. This study, which is biased towards theoretical calculation, has some reference value for the actual development of photoelectric countermeasure equipment. However, it has not been verified by practical experiments. It cannot accurately evaluate the interference effect, which is very important for the development of high-value photoelectric countermeasure equipment. Unfavorable [1]. In the current research on the optical interference of the middle waveguide, there is also a problem of re-theoretical simulation of light test, which is related to the complex structure of these experiments, high requirements and difficult to accept the cost. The current domestic photoelectric confrontation is mainly focused on the small and medium power optical interference, in the field of atmospheric transmission, atmospheric turbulence, aiming accuracy,

☆ This article is part of the Special Issue on TIUSM.

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https://doi.org/10.1016/j.jvcir.2018.12.044
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beam jitter and beam divergence angle and other parameters of the interference effect has a greater impact [2]. How to evaluate these parameters and get the corresponding interference model is the focus of this field research. The current low-cost theoretical calculation and simulation analysis can establish the interference model of the medium-wave infrared seeker detector to a certain extent, but some of the parameters in this model need to be corrected by the actual long-distance laser field interference experiment In order to accurately reflect the environmental conditions of a variety of factors for the impact of light detection system interference effects.

In this paper, the process and experimental data of the interference test of the IR probe in the suburb of a city in the north of May 2018 were studied and analyzed. The real photoelectric interference dazzle process and the data image simulated by a kind of medium wave IR head detector are discussed and calculated by scientific and reasonable analysis method, and the requirements of the type of medium wave detector are obtained. The minimum medium-wave laser power and the minimum long-wavelength laser power with out-of-band interference. This paper first summarizes the current research situation in this field, and then discusses the process and some key technologies of the experiment. Finally, the image data of the experiment are analyzed and the corresponding interference power density is calculated.

2. Research status of inflammation effect of wave infrared seeker

Wavelength of 3–5 μm band of the waveguide probe detector is characterized by aircraft, missiles and other engines issued a strong thermal radiation sensitivity, and for the aircraft and the missile skin radiation emitted by the light is in the 8–12 μm long wave infrared Sensitive area of the detector. As the aircraft in the high-speed flight process the engine nozzle will emit a very high stability of the medium-wave radiation, so the wave infrared detector as a seeker to detect the core components have become empty, ground-to-air missiles of choice. At the same time to laser interference as the representative of the photoelectric confrontation is also in the field with the target, at home and abroad for infrared IR detector laser interference research has been carried out for many years, has made a lot of results. For example, Liu Jingmei of the People's Liberation Army 91,404 in 1994, analyzed and calculated the criterion of the use of the non-point source infrared interference and the interference effect, and achieved the quantitative evaluation of the infrared interference effect by the statistical interference success rate [3]. 2017 Changchun University of Technology, Liu Zhijing, who, including the interference of optical interference, including optical interference detection and evaluation of a systematic discussion, given the interference effect detection and Apple basic methods, the establishment of a simulated subject [4]. Zhang Jingyang, etc. of the Air Force Engineering University, in order to determine the interference effect of the pulsed laser on the CCD detector, and to study the interference effect is affected by many factors, the fuzzy evaluation method is used to evaluate the interference effect, and the fuzzy evaluation method is verified as laser interference The rationality of the assessment method [5]. In order to study the key technology of laser weapon against laser precision guidance weapon in complex electromagnetic environment, a series of factors influencing laser interference are analyzed comprehensively. In this paper, The laser energy estimation model of laser effective interference far field photodetector is established by means of theoretical analysis. The study uses the searched literature as the basis of the model [6]. In addition, Changchun Institute of Light, Zhang Laiming, Luoyang Institute of electro-optical equipment at the beginning of the Institute and Naval Aeronautical Engineering Institute of Liu Tingwu et al in the laser irradiation mechanism and interference analysis also carried out a certain study [7–10] The But the analysis found that these studies focus on the theoretical analysis of laser interference or laboratory simulation of the field simulation. These theories have a certain value, but in engineering applications can not be completely based on these theoretical analyses as a reference, in the calculation of laser power, light aperture, interference mode and other parameters need more direct and reliable data [11–22]. Through the literature search, it is found that there are few researches on the field of laser interference in China, which is due to the fact that photoelectric confrontation is a new field, and there are few units in this field that are more in-depth, and on the other hand, Research requires a lot of human and material resources to participate in the general study is difficult to organize this test. Even if the corresponding tests were organized, the results of the interference glare parameters for the medium wave infrared seeker detector were not available due to the test objectives and conditions. In the field test of the mid-wave laser interfering medium-wave infrared detector referred to in Ref. [1], although the corresponding interference threshold is also obtained, since the missile leader does not lock the target in the test, Under the test conditions to verify the interference effect, so the interference effect can only be directly from the interference image to judge. This has a certain access to the actual working condition of the seeker. In addition, since the power of the mid-wave infrared laser is difficult to be high, and the power of the long-wave infrared laser can be high, it is possible to interfere with the mid-wave infrared seeker detector with a long-wave infrared laser beam What kind of power density can meet the requirements of the test are discussed in this paper need to solve the problem.

3. Test principle and process

First of all, the parameters of the main device involved in the test analysis, the device parameters are as follows:

1. Medium wave infrared seeker detector parameters: Brand FLIR; sensitive center wavelength 3.8 μm; CCD pixel number 320 × 256;
2. Medium-wave laser parameters: brand domestic self-study; peak power 15 W; center wavelength 3.8 μm; laser light emitted the initial divergence angle 15 mrad;
3. Camera lens parameters: lens long focal length 384 mm, short focal length 153 mm, caliber 220 mm, monolithic decay film decay rate of 70%;
4. Laser detector parameters: Brand OPHIR; range 250 W; resolution 10 mW; detection of sensitive wavelengths 1–15 μm.

The purpose of the probe installation on the lens during the test is to better simulate the guiding effect of the seeker. The field of view of the waveguide missile is based on the distance from the target and the specific tracking algorithm. If the seeker's lens field is too large or too small will affect the leader of the attack target search and tracking. Therefore, this test chooses an optical system similar to the current short-range combat missile parameter as the lens of the infrared detector. The test chose 14.5 km of sight distance on both sides of the placement of the laser and the detector. Short-range empty, ground-to-air infrared guided missile guidance device more than 10–15 km began to function. For airborne photoelectric combat equipment, the infrared alarm and other passive detection means can only be found within 20 km of missile targets, and in addition to the size of the precision guided missiles smaller, if the distance between the missile and then use the photoelectric interference Will lose the best time, so in a dozen kilometers away on the missile seeker on the wave infrared detector interference is a more feasible distance. In addition, the domestic application of high-power laser damage in the field of photoelectric confrontation has not yet been applied. This is due to the technical difficulty of miniaturization of high-power lasers in this application, focusing on long-distance focus focusing and atmospheric compensation. Therefore, laser interference is the current domestic photoelectric countermeasure in the field of research and application of the main content. In this paper, the laser interference and dizzy of the waveguide infrared guided missile are analyzed and studied in this background. Fig. 1 shows the test schematic.

In the figure, the IR laser is a medium wave or long wave laser, 1 is a medium wave or a long wave expanding system, 2 is an output laser beam after beam expansion, 3 is a real time monitoring laser detector, 4 is a semi inverse system, 5 is a laser The final outgoing laser beam, 6 is the atmospheric medium with a distance of 14.5 km, 7 is the seeker detector protection window, 8 is a certain type of medium-wave infrared laser detector with lens, 9 is with the image processing function detection Display system.

Before performing the interference test, first manually adjust the direction of the outgoing laser beam of the laser and the optical axis of the detector lens in parallel. In this process, the appropriate beam expansion system is selected, and the energy of the laser output laser is monitored in real time by the semi-semi-circular mirror, thus improving the accuracy of the output laser power in the experiment. As the beam and the detector are required to start the work of the adjustment process, in order to protect the detector is not accidental damage, need to be placed in front of the detector lens or a number of pieces of attenuation film. It is also necessary to determine the transmittance and reflectance of the semi-reciprocal system before the interference test is carried out, and the outgoing laser power is accurately calculated from the monitoring power through the detector. In addition, the transmittance of the front attenuator of the lens also needs to be measured. In the measurement process need to medium-wave lasers and long-wave laser output of specific wavelength laser were measured. In the laser jamming experiment, atmospheric interference is one of the most important influencing factors. Therefore, it is necessary to judge the effect of the interference experiment on the specific atmospheric visibility index. In order to simplify the experimental process, the atmospheric permeability values were obtained by the model calculation in the experiment, and the local temperature and humidity parameters required in the model were provided by the local meteorological tools.

During the test, the medium-wave lasers and the long-wave lasers were placed side by side and were lighted at shorter intervals. This is due to the same atmospheric conditions, respectively, on the wave and long-wave laser beam interference effects are comparable. In the experiment, the difference in the transmittance of the air in different wavelengths was observed in the same time period. In order to fully verify the interference effect of the laser on the probe of the seeker detector, in addition to the intuitive judgment of the interference image as described in Document 1, the three most commonly used tracking algorithms are embedded in the image processing center, edge and correlation, By tracking the cross box in the three algorithms under the interference phenomenon to determine the detector interference dizzy effect. In different laser band input and different tracking algorithm conditions, the laser energy increases from small to large, until there is a significant interference effect. Combined with the detector after the interference tracking image changes and the corresponding power index, target power density, the overall transmittance values were calculated and analyzed.

4. Test results and analysis

In order to accurately assess the effect of the interference will be carried out for several days of the experiment to select one of the records for analysis. The beam magnification of the beam after the beam is 18 mrad, and the spot area on the magnification of 14.5 km is S, and the value can be calculated by Eq. (1).

$$S = \pi r^2 = \pi(Ltg(\alpha))^2 = 3.14(14,500 \times tg(9\,\text{mrad}))^2 = 52,920\,\text{m}^2 \tag{1}$$

where r is the radius of the beam spot, L is the straight distance between the spot and the laser, and is the half divergence angle of the laser.

After accurate measurement, it was found that the transmittance of the semi-reverse semipermeable system for long-wave laser and medium-wave laser was 92%, the reflectance was 5% and the absorption rate was 3%. Since the output power of the laser always fluctuates, it is calculated by taking the average of multiple measurements. By accurately measuring the energy f of the reflected laser, the emission laser power density λ at this time can be calculated using Eq. (2).

$$\lambda = \frac{P}{S} = \frac{\frac{f \times 92\% \times \gamma}{5\%}}{52,920} = 0.00033 f\gamma \tag{2}$$

The atmospheric transmittance r is estimated by software and the weather parameters of the day. In order to compare the interference effect, the test values of the two laser bands were compared to set the same laser divergence angle, integration time and attenuation number. According to some meteorological parameters and empirical formula, the atmospheric transmittance estimate for the day of the test is 0.625. For simplicity analysis, the test data discussed in this paper are from the same day, so the atmospheric transmittance of 0.625 can be calculated as the reference value. The laser power density λ converted to the target position of the medium wave infrared detector is $2.1 \times 10 - 4f$.

Fig. 2 shows the image of the building where the laser is located when the laser does not output the medium wave infrared seeker detector. Fig. 3 for the medium-wave laser output laser is not in the tracking state of the interference glare image. Fig. 4 for the relevant tracking state of the medium-wave laser output power is small when the interference glare image. Fig. 5 for the relevant tracking

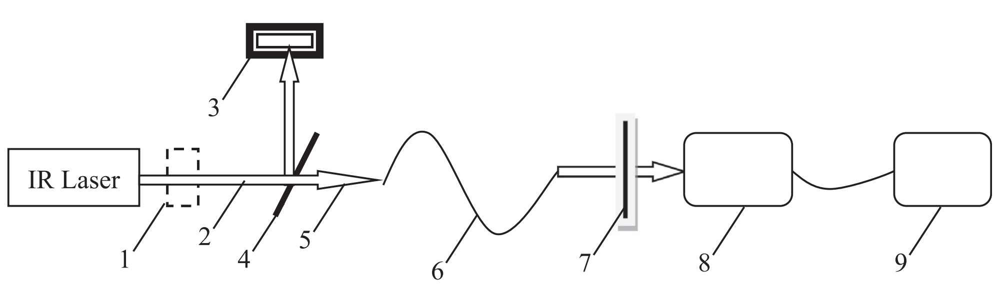

Fig. 1. The experiment light sketch.

Fig. 2. The following and locking when none laser exporting.

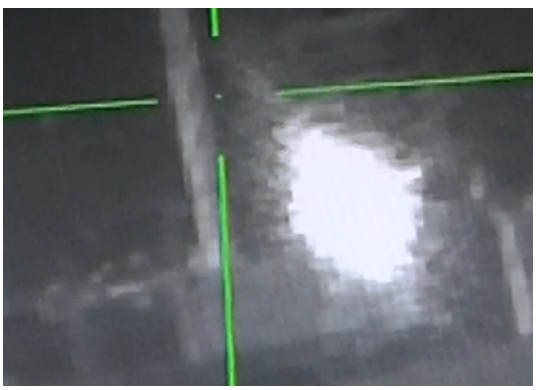

Fig. 3. The mid-infrared disturbing when none following.

Fig. 4. The wave power is small when tracking lock.

state of the medium-wave laser output power caused by large tracking loss of the target when the interference glare image. Fig. 6 for the center of gravity tracking state of the long-wave laser output power caused by large tracking loss of the target when the interference glare image.

The following analysis of the critical state of the test. When the laser does not have the power output, the tracking effect is basically the same under the center of gravity, edge, and related tracking algorithm, which can completely lock the target with high radiation in the field of view. When the detector lens is slightly shaking, the tracking frame can always lock the target. When the laser power reaches a certain value, The pixels cause permanent damage, but the power density at the time of damage is difficult to calculate by the naked eye. In the medium-wave laser from

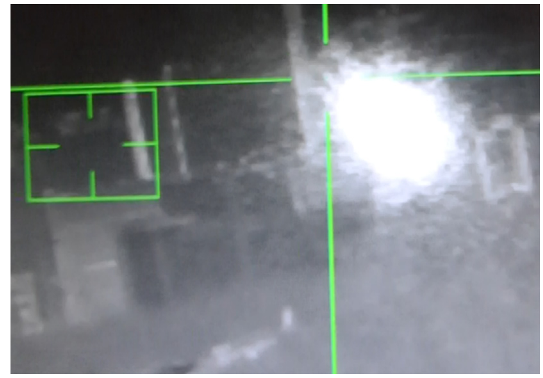

Fig. 5. The wave power exceeds the threshold when tracking the loss of the target.

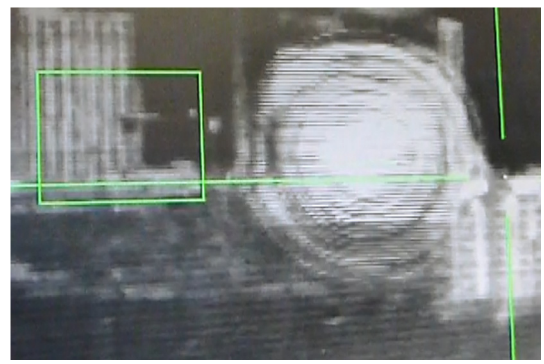

Fig. 6. The lost aim when long-infrared laser power exceed threshold.

small to large output medium-wave laser power will find the detector on the laser spot gradually become larger and stronger. If the three tracking algorithms are loaded into the image during this process, it is found that the tracking frame always locks the position of the output laser as the target when the laser power (medium wave or long wave) is less than a certain value (the laser power is greater than the lens Other target radiation in the field). Shaking the detector lens in azimuth or pitch direction does not affect the tracking of the system (the target is always in the field of view). It can be seen that if the interference laser power is less than the interference threshold of the detector, it will not only interfere with the detector, but will directly cause the seeker to lock the laser emission source. In this case, if the laser interference system on the high-value aircraft, but will make the missile directly locked laser source. If the laser jamming system is placed on the side of the ground target, when the interference laser is weak, the missile seeker can directly ignore the target and lock the exit laser position, thus effectively protecting the target. When the power density at the target surface of the missile seeker detector reaches or exceeds a certain value (the mid-wave laser power density is 0.08 mW/m^2 and the long-wave laser power density is 0.43 mw/m^2), the tracking frame is emitted by the original locked laser Source or other high radiation target position is directly deflected to a random position without locking the original target position. It can be considered that in this state, the interference of the laser for the detector to achieve a dizzy effect. In addition to the three tracking state of the threshold test results found that the results are basically the same. In this state, the output power of the long-wave laser and the medium-wave laser output port is 37.8 W and 6.93 W respectively. It can be seen that the interference energy of the long-wave laser to the mid-wave detection is much greater than the interference threshold energy of the wavelength-matched medium-wave laser. In the experiment, only three tracking algorithms were simply loaded in the image processing of the medium wave infrared detector without any filtering and anti-jamming measures. In the practical application of the missile-guided attack target, anti-jamming is usually carried out, and other wavelengths of laser are difficult to enter the middle waveguide detector for the time window. Therefore, it can be considered that the long-wave laser is difficult to achieve the dizzy effect compared with the medium wave laser in the interference of the medium wave detector.

The atmospheric condition of the day is medium transmittance condition, and when the laser output power reaches 6.93 W and the long wave reaches 37.8 W, it can realize the glare interference to the detector system. Therefore, it can be considered that the laser wave with smaller power Energy can be effective for medium-wave infrared seeker detectors to achieve effective interference. In addition, the long focal length condition of the lead head barrel is practically used in practice, because the infrared seeker detector will increase the focal length as much as possible to improve the detection distance and reduce the field of view, so the actual enemy The field of view of the pilot optical system is smaller than the field of view of the camera in the test, so it can be considered that this power can be achieved at 14.5 km away from the effective interference of the medium wave infrared seeker. As the actual medium-wave missile seeker probe search and tracking process may use a variable field of view, and may take some anti-jamming measures, such as when the energy reaches a certain value automatically reduce the window shutter, so the actual interference caused Dizziness threshold and test results may have a certain access.

5. Conclusion

In this paper, the distance from the laser dizzy disturbance of a short distance medium wave infrared missile seeker detector is 14.5 km. Respectively, to the medium-wave laser and long-wave laser output of the laser to detect the interference, by determining whether the tracking box to lock the original target to determine whether the interference is successful, resulting in different wavelength interference conditions under the glare threshold. It can be considered that the effective interference to the medium wave detector can be achieved under the condition of smaller power output. Because of the large error in the atmospheric transmittance obtained by MODTRAN atmospheric transmittance calculation software, the power density value at the lens of the mid-wave infrared camera is only valuable. In the next step, it is necessary to test the laser interference of the medium wave infrared missile seeker with anti-jamming measures, so as to provide reference for the demonstration of the actual photoelectric countermeasure device. The more far-reaching significance of this paper is to use this experimental method to carry out further experiments to get more interference data under the conditions, through the inversion of the data can be established more suitable for our environment more accurate atmospheric permeability calculation model And the interference effect evaluation model.

Declarations

Ethical Approval and Consent to participate: Approved.
Consent for publication: Approved.
Availability of supporting data: We can provide the data.

Competing interests

These no potential competing interests in our paper. And all authors have seen the manuscript and approved to submit to your journal. We confirm that the content of the manuscript has not been published or submitted for publication elsewhere.

Author's contributions

All authors take part in the discussion of the work described in this paper. The author Zhaobing Chen wrote the first version of the paper, The author Kui Shi and Ning Chen did part experiments of the paper, Long Shi, Xinyu Zhuang, Jiaqi Zhou, Yushuai Zhang, Hongqi Wang, Xingyang Liu and Guannan Li revised the paper in different version of the paper, respectively.

The contributions of the proposed work are mainly in two aspects:

(1) This paper creatively proposes an evaluation method of outfield laser jamming test based on image processing. The method uses the image of the interfered photoelectric detection system as the calibration basis, and realizes the quantitative calibration of the external interference of the mid-wave infrared laser.
(2) The interference effect and interference threshold of mid-wave infrared laser are quantitatively checked by outfield equal-proportion laser countermeasure test, and the results are calibrated. It is the first time in China to adopt the method of mid-wave infrared laser outfield test.

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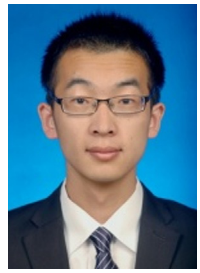

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