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Research on simulated generator of optical target for low light level weapon sight

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ABSTRACT

The environmental adaptability is one of the key factors to evaluate the operational performance of low-light-level sight. In this paper double-integrating-sphere in illumination-mode combined with collimator was adopted to design a simulated generator of infinite target in order to provide four different level light stresses environment needed for detecting the adaptability for low-light-level sight. First of all, for the actual application of the low-light-level sight in aiming and positioning at night and midnight, the illumination at the entrance pupil of the sight was calculated. And then the double-integrating-sphere and collimator were designed in accordance with the illumination. Finally, the output illumination of integrating sphere and simulated generator for infinite target simulation were analyzed and calculated, the results of experiment and measuring showed that the illumination non-uniformity is less than 2%, which can satisfy the application requirements.

1. Introduction

Low-light-level (LLL) night vision is mainly used for aiming and observing at night, which plays an irreplaceable role with its unique value in the operation for every single soldier [1–7]. Meanwhile, the operation efficiency of the sight greatly depends on its reliability which is also the important quality characteristic of the sight. Therefore, it is urgent to concentrate on improving and enhancing the environmental adaptability of the weapons. While the reliability validating system of LLL sight is absolutely necessary for realizing above mentioned functions. Light stress system is one of the important contents of the reliability validating system, which is the key issue of this paper.

As the light stress system, simulated generator of infinite low light level weapon sight target simulation provides low light environment for the sight being measured, its illumination uniformity of emergent light would directly affect the imaging definition and accuracy of the CCD camera system [8,9]. Therefore it is necessary to research the image surface uniformity of imaging system.

2. Components and operational principles of light stress system

The main structure compositions of light stress system as Fig. 1 shows, which are standard A light source, double-integrating-sphere, reticule, collimator and so on. Uniform light was due primarily to the diffuse reflection for heaps of times in the large-integrating-sphere since it was emitted from the standard A light source and illuminated up the reticule of collimator which was strictly placed at its focal plane. The image of the reticule was grabbed by the sight and located in focal plane of its lens, and after overlapped on image of small internal reticule of the sight, the images were acquired by CCD and transferred to backstage computer to be deal and so on. And in the whole process, the illumination of uniform light which was scattered by the integrating sphere had certain attenuation, which might have effect on image plane illumination of the sight reticule.

3. Entrance pupil illumination calculation of LLL weapon sight

Scene brightness under night sky radiation related to illumination of the scenery, which mainly come from night sky radiation on the illuminated surface and reflectance of the objects. On the

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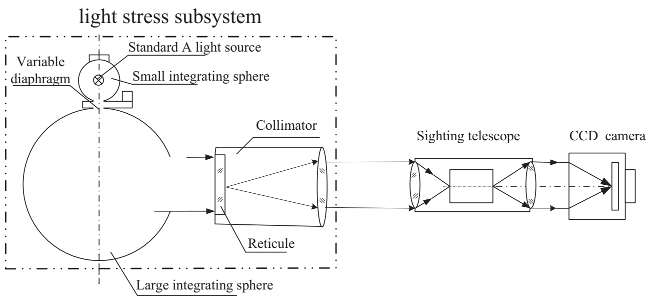

Fig. 1. The principle picture of work system.

Table 1
Illumination at the entrance pupil of sighting telescope under different weather conditions.

Weather status	E/lx	E_{ed}/lx
Heavy cloud and without moonlight	2×10^{-4}	1.1×10^{-6}
Clear and without moonlight	1×10^{-3}	5.4×10^{-6}
Clear and waning moon	2×10^{-2}	1.1×10^{-4}
Clear and full moon	2×10^{-1}	1.1×10^{-3}

presupposition that the target is diffusedly reflective object, flux existence of the target can be expressed as:

$$M = \rho E = \pi L \tag{1}$$

Then scene brightness can be written as:

$$L = \frac{\rho E}{\pi} \tag{2}$$

where E and ρ represent the value of the scene illumination, which is also the illumination of night sky radiation, reflectance of the objects, respectively.

Illumination of the LLL night vision device at its entrance pupil is given by:

$$E_{ed} = \frac{LS}{H^2} = \rho E \tan^2\ \omega \tag{3}$$

where H is the distance between target object and the LLL sight, S is effective illuminated area, and ω is the field angle of sight.

According to requirements of the detection system, the sight was required for pointing, acquiring and tracking at four different weather conditions, including: heavy cloud and without moonlight, clear and without moonlight, clear and waning moon, clear and full moon. Calculated the E_{ed} by formula (3), when the full field of view 2ω is 5°, ρ is 0.7, and the calculation results as shown in Table 1.

4. Design and analysis of collimator and its illumination distribution

The designing optical parameters of collimator as follows: the focal length f is 600 mm, entrance pupil diameter D_0 is 120 mm, the aperture of the exit pupil D_1 is 125 mm, the full field of view $2\omega'$ is 10°. Fig. 2 illustrates the structure diagram of optical system, and Fig. 3 shows the relative illumination of the system.

As seen from Fig. 2, the optical system is constituted by two single lens and a doublet lenses. The transmittance of each lens surface is 98%, so the transmittance of the optical system τ' is 87%. When the visual field reaches the maximum value, the system suffers from illumination attenuation about 0.5%, the illumination non-uniformity is less than 0.3%.

Based on the known illuminations of points on and off axis of the imaging system E' and E'' can be expressed as:

$$E' = \frac{n'^2}{n^2}\tau\pi L_1 \sin^2 U' \tag{4}$$

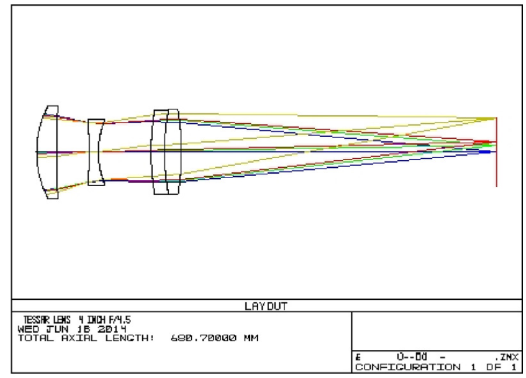

Fig. 2. Structure diagram of optical system.

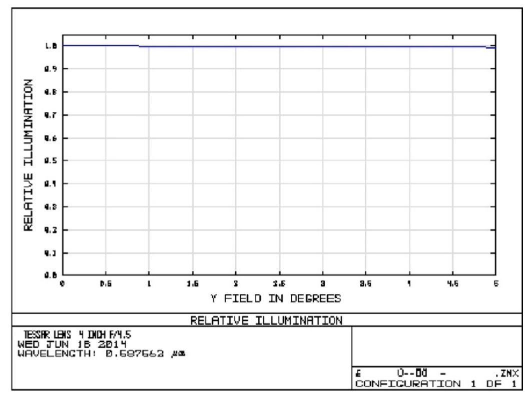

Fig. 3. Relative illumination.

$$E'' = \frac{n'^2}{n^2}\tau\pi L_1 \sin^2\ U' \cos^4\ \omega' = E' \cos^4\ \omega' \tag{5}$$

where n' is refractive index in object space, n is refractive index in image space, τ *is* luminous transmission of optical system, L_1 is brightness value of the object plane, U' is image aperture angle, ω' is field angle.

Further research shows that, the illumination of output light from the simulated generator of optical target is approximately equal to the illumination intensity at entrance pupil of the LLL sight. Target is determined by: Therefore, the illumination intensity at exit pupil of the simulated generator of optical

$$E_c = \frac{\phi_c \cdot \tau'}{S_1} = \frac{M_1 \cdot S_2 \cdot \sin^2\ u \cdot \tau'}{S_1} = E_{ed} \tag{6}$$

The illumination on the imaging plan of the reticule is E_{li}:

$$E_{li} \approx M_1 = \frac{E_c \cdot S_1}{\tau' \cdot S_2 \cdot \sin^2\ u} = \frac{E_{ed} \cdot (D_1/2)^2}{\tau' \cdot (f' \cdot \tan\ \omega')^2 \cdot \sin^2\left[\arctan\left(D_0/2f'\right)\right]} \tag{7}$$

where S_1 is the illuminated area at the exit pupil of the simulated generator of optical target, S_2 is effective area of image plane, ϕ_c is the luminous flux under the range of the field solid angle between the central imaging plane of simulated generator of optical target and the aperture of objective lens. τ' is the transmittance of optical system, M_1 is luminous emittance, u is aperture angle. The integrating sphere light source was designed on the basis of the illumination at the reticule, which was able to satisfy the requirements of the sight.