A New Test Method of Optical-Axis Parallelism for Three-Meter Reflex Light-Tube

Zhang Yaoyu　Li Min

(*Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences, Changchun, Jilin* 130033, *China*)

Abstract　Reflex light-tubes are widely used in optoelectronic measuring systems such as in ships, vehicles and so on. To make the optical path reflex in altitude direction and keep the incident light parallel to the emergent light in azimuth transmission, the reflex light-tubes are needed, which finally ensures precision transmission of the azimuth reference. The flat mirror method and the mercury method are used to test the optical-axis parallelism of reflex light-tubes shorter than 1 m, however when the methods are applied to reflex light-tubes longer than 3 m, the accuracy required cannot be reached. A new test method of optical-axis parallelism for three-meter reflex light-tube is introduced and it is well suited for testing the parallelization of reflex light-tubes more than 3 m.

Key words　measurement; reflex light-tube; optical-axis parallelism; azimuth reference

OCIS codes　120.1008; 120.4630; 230.1150

3 m 长折转光管光轴平行性检测新方法

张尧禹　李　岷

(中国科学院长春光学精密机械与物理研究所，吉林 长春 130033)

摘要　折转光管广泛应用于舰船、车载等光电测量系统中，在方位基准传递过程中，光路在高度上产生折转，入射光与出射光在方位上保证相互平行，从而实现方位基准的保精度传递。对于长度小于 1 m 的折转光管多采用平面镜法或水银盘法检测其光轴平行性，但对于长度大于 3 m 的折转光管，采用上两种检测方法则不能满足其精度指标要求。为此，提出了对于 3 m 长度的折转光管光轴平行性检测的一种新方法，此方法适用于长度大于 3 m 的折转光管光轴平行性的检测。

关键词　测量；折转光管；光轴平行性；方位基准

中图分类号　TN206　　**文献标识码**　A　　**doi**: 10.3788/LOP49.121205

1　Introduction

Reflex light-tube is an important part of optical path transmission in optoelectronic measuring systems such as ships, vehicles and so on. In a vehiclular optoelectronic measuring system, the reference light transmitted to the prism should be measured accurately through the reflex light-tube for the purpose of achieving the transmission of azimuth reference[1~4]. In a longitudinal orientation collimation system of ship, there is a difference in height between the photoelectric collimator and the reference reflecting mirror. It means that a reflex light-tube is also needed to achieve the transmission of the azimuth reference[5].

The reflex light-tube translates the parallel light to some distance in plumb-plane or horizontal plane and transmits the light to another plane. Meanwhile the light propagation direction remains, which refers to that the incident light parallel to the emergent light.

As this characteristic of reflex light-tubes is widely applied to azimuth measuring systems, quite high parallelism of reflex light-tubes′ axis is required[6]. For the purpose of testing long reflex light-tubes accurately as well as meeting the accuracy requirements, a new test method is proposed[7].

收稿日期：2012-06-10；收到修改稿日期：2012-07-11；网络出版日期：2012-11-02

作者简介：张尧禹(1973—)，男，研究员，博士生导师，主要从事靶场设备、瞄准系统、跟踪系统等方面的研究。

E-mail: zhangyaoyu1973@sina.com

2 Conventional test methods for reflex light-tube

Generally, two main test methods, namely the flat mirror method and the mercury method, are applied to short reflex light-tubes[8]. Fig.1 shows the flat mirror method.

Firstly, a 0.2″ autocollimator is aligned to the reflecting mirror for collimating. The reading of the autocollimator′s azimuth (α_0) and pitching (λ_0) are recorded.

The reflex light-tube is placed between the 0.2″ autocollimator and the reflecting mirror, and then the parallel beam from the collimator transmits to the flat mirror via mirror 1 and mirror 2 in the reflex light-tube. At last, the collimator is collimated to the mirror image by fine tuning of its azimuth and pitching knob. The values of azimuth (α_1) and pitching (λ_1) are recorded. $\Delta\alpha$ and $\Delta\lambda$ are the errors of azimuth and pitching, respectively. So the parallelism errors of these two optical axes are defined as

$$\Delta\alpha = (\alpha_1 - \alpha_0)/2, \quad (1)$$

$$\Delta\lambda = (\lambda_1 - \lambda_0)/2. \quad (2)$$

As to the mercury method, it can be seen from Fig.2 that the test principle is the same as that of the flat mirror method.

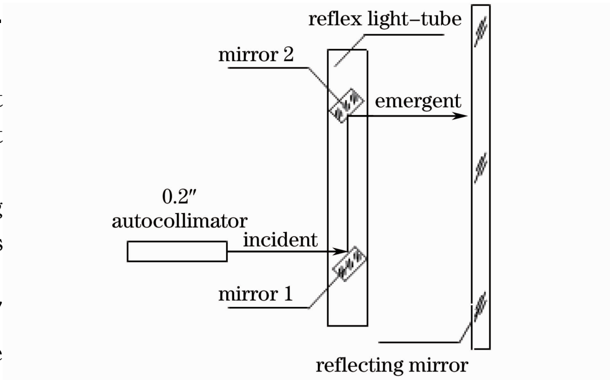

Fig.1 Flat mirror method

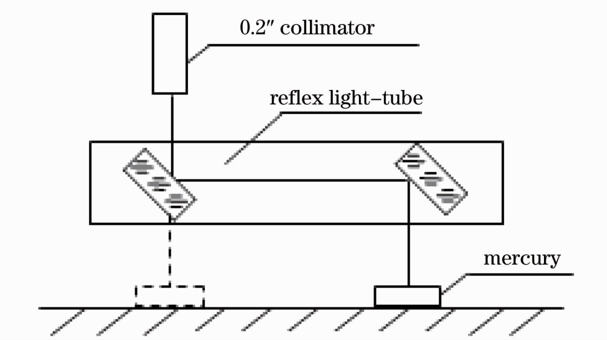

Fig.2 Mercury method

3 A new test method for long reflex light-tubes

Due to the size of long reflex light-tubes, the application of the flat mirror method is limited by size of the mirror. And at present, large-aperture mirrors are expensive and difficult to install or adjust[9~12]. However, the mercury method may produce aiming errors[13~15], due to the long span which weakens the energy transmisson. So a new test method of optical-axis′ parallelism is required, as shown in Fig.3.

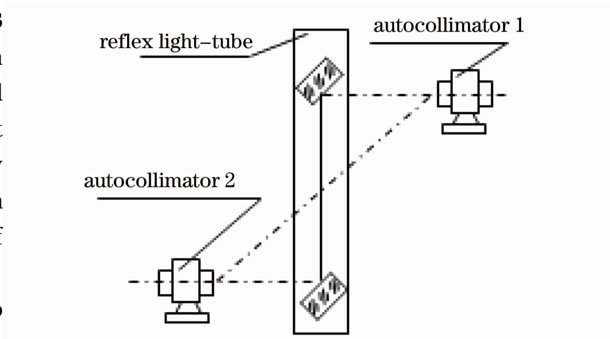

Fig.3 New method

Firstly, the autocollimator 1 and 2 should be leveled to make sure the optical-axis in the same vertical plane. The autocollimators are collimated with each other, and the reading of autocollimator 1 (α_0 as the azimuth and λ_0 as the pitching) and that of autocollimator 2 (α_1 as the azimuth and λ_1 as the pitching) are recorded.

The reflex light-tube is placed between the autocollimators to make sure the optical axis is in the same vertical-plane with them. The azimuth of autocollimator 2 is kept, and the pitch angle stays zero. Autocollimator 2 is collimated to autocollimator 1 through the reflex light-tube. The reading of autocollimator 1 (α_0' as the azimuth and λ_0' as the pitching) and that of autocollimator 2 (α_1' as the azimuth and λ_1' as the pitching) are recorded. Hence the parallelism errors of these two optical axes is as follows:

$$\Delta\alpha' = \alpha_0' - \alpha_0, \quad (3)$$

$$\Delta\lambda' = |\lambda_0' - \lambda_0| - |\lambda_1' - \lambda_1|. \quad (4)$$

4 Experiment and Results

The autocollimators used in the experiment are 0.5″-degree Leica. While a three-meter reflex light-tube is tested, the leveling accuracy reaches 0.5″ and the autocollimators are collimated to the light tube well, as shown in Fig.3. The optical axis of the reflex light-tube is in the same vertical plane with the autocollimators. The readings of autocollimator 1 and that of autocollimator 2 are recorded, hence the parallelism errors of the two optical axes can be calculated. As a result, the parallelism errors of the light-tube′s optical axis are 3″ in azimuth and 10″ in pitching, which meets the mission requirements.

There are two advantages when two theodolites are used as a substitute of the reflecting mirrors. On the one hand, the method is suitable for testing reflex light-tubes of any size. On the other hand, the 0.5″ Leica autocollimator with good precision is also easy to manipulate and adjust.

5 Conclusion

Lots of experiments indicate that the new method, which measure the parallelism error of the reflex light-tube′s optical axis, performs well in precision. The accuracy of measurement results is proved to meet the requirements and the method is practicable. In short, the test method of optical-axis′ parallelism mentioned in this paper is well suited for long reflex light-tubes.

References

1 Zhang Yaoyu, Zhang Minghui, Qiao Yanfeng. High-precision noncontact position measuring system [J]. *Optics and Precision Engineering*, 2002, **10**(1): 41～44

张尧禹，张明慧，乔彦峰. 一种高精度非接触位置测量系统[J]. 光学 精密工程，2002，**10**(1)：41～44

2 Zhang Minghui, Zhang Yaoyu, Qiao Yanfeng. Study on vehicle twin-photoelectrical pointing system [J]. *Opto-Electronic Engineering*, 2004, **31**(7): 18～23

张明慧，张尧禹，乔彦峰. 车载双联光电瞄准系统的研究[J]. 光电工程，2004，**31**(7)：18～23

3 Xu Wei, Zhang Minghui, Zhang Yaoyu. Trajectory measuring array system [J]. *Optics and Precision Engineering*, 2001, **9**(4): 339～343

徐 卫，张明慧，张尧禹. 阵列式弹道测量系统[J]. 光学 精密工程，2001，**9**(4)：339～343

4 Du Junfeng, Li Zhengzhou. Analysis of the axial accuracy of the GD-220 photoelectric theodolite [J]. *Optics and Precision Engineering*, 2002, **10**(4): 416～419

杜俊峰，李正周. GD-220 光电经纬仪轴系的精度分析[J]. 光学 精密工程，2002，**10**(4)：416～419

5 Tang Zhengzong, Liang Jin, Xiao Zhenzhong *et al*.. Digital image correlation system for three-dimensional deformation measurement [J]. *Optics and Precision Engineering*, 2010, **18**(10): 2244～2253

唐正宗，梁 晋，肖振中 等. 用于三维变形测量的数字图像相关系统[J]. 光学 精密工程，2010，**18**(10)：2244～2253

6 Zheng Hong, Shi Qingsong. Study and application of a dig axis measuring method with laser collimation [J]. *Opto-Electronic Engineering*, 2002, **29**(4): 28～31

郑 洪，施青松. 激光瞄准大轴半径测量方法的研究与应用[J]. 光电工程，2002，**29**(4)：28～31

7 Zhang Qiang. Reflex light-tube in azimuth pointing system of missile[J]. *J. Appl. Opt.*, 2008, **29**(4): 512～517

张 强. 方位瞄准系统中折转光管的应用研究[J]. 应用光学，2008，**29**(4)：512～517

8 Wang Jiaqi. Integrated Design for Optical Instruments [M]. Changchun: Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences, 1998

王家骐. 光学仪器总体设计[M]. 长春:长春光学精密机械与物理研究所，1998

9 He Xu, Wu Guodong, Han Bing. Study of large-diameter long focal length collimator assemble technical [J]. *Optical Technique*, 2009, **35**(5): 781～784

何 煦，吴国栋，韩 冰. 大口径长焦距平行光管装调技术研究[J]. 光学技术，2009，**35**(5)：781～784

10 Song Shumei, Chen Ya, Lü Xuefeng *et al*.. Study on a big aperture lightweight aspheric mirror manufacture [J]. *Optical Technique*, 2005, **31**(2): 246～251

宋淑梅，陈 亚，吕学峰 等. 大口径轻质非球面反射镜制造技术研究[J]. 光学技术，2005，**31**(2)：246～251

11 You Rui, Wang Jing, Wang Wen′ge *et al*.. Adjustment and error analysis of the large mirror of test system [J]. *J. Changchun University of Science and Technology (Natural Science Edition)*, 2008, **31**(3): 20～23

尤 锐，王 晶，王文革 等. 大口径测量系统主反射镜装调及精度分析[J]. 长春理工大学学报(自然科学版)，2008，**31**(3)：20～23

12 Ma Chuntao, Luo Hongxin, Wang Jie *et al*.. Surface error measurement of plane mirrors based on oblique incidence [J]. *Laser & Optoelectronics Progress*, 2011, **48**(7): 071201

马春桃，罗红心，王 劼 等. 斜入射法检测平面反射镜的面形误差[J]. 激光与光电子学进展，2011，**48**(7)：071201

13 Li Zeng, Wu Zhiyong, Tong Gang *et al*.. Pointing error correction for vehicular platform theodolite [J]. *Optics and Precision Engineering*, 2010, **18**(4): 921～927

李 增，吴志勇，佟 刚 等. 车载经纬仪的静态指向误差补偿[J]. 光学 精密工程，2010，**18**(4)：921～927

14 Wang Tao, Song Liwei. Measurement error correction of vehicular theodolite [J]. *Chinese J. Scientific Instrument*, 2012, **2**(2): 469～473

王　涛，宋立维. 车载经纬仪的测量误差修正[J]. 仪器仪表学报，2012，**2**(2)：469～473

15 Gao Ce, Qiao Yanfeng. Real-time error-correction-method for photoelectrical theodolite [J]. *Optics and Precision Engineering*, 2007, **16**(4): 846～851

高　策，乔彦峰. 光电经纬仪测量误差的实时修正[J]. 光学 精密工程，2007，**15**(6)：846～851