光学精密工程
OPTICS AND PRECISION ENGINEERING
核心期刊
主管：中国科学院
主办：中国科学院长春光学精密机械与物理研究所
中国仪器仪表学会
主编：曹健林

光学精密工程 2013, 21(3) 652-663 ISSN: 1004-924X CN: 22-1198/TH

微纳技术与精密机械

中频波面的旋转平移法干涉绝对检验

袁群,高志山,张聪旸,成金龙,朱波

南京理工大学 电子工程与光电技术学院

摘要： 基于Zernike多项式拟合的传统干涉绝对检验方法由于平滑了波面和丢失了中频成分，仅可以实现面形误差的绝对检验。本文提出利用旋转平移法来实现中频波面的干涉绝对检验。将被测波面分解成旋转对称成分和旋转非对称成分，通过N次旋转被测件，求解波面中的旋转非对称成分；通过平移被测件实现伪剪切，求解波面中的旋转对称成分。与传统绝对检验方法相比，该方法既能够恢复整个波面，又不需要对整个波面进行Zernike多项式拟合；由于仅对旋转对称成分用偶次多项式进行提取，提升了计算速度，降低了拟合误差，保留了中频成分,数值仿真显示其比传统方法优越，测量精度可达到1 nm rms。在ZYGO干涉仪上完成了平面元件的干涉绝对检验测量。采用改变伪剪切比和更换标准镜两种方案，分别实现了实验数据的自比对；将测试结果与经典三面互检法得到的水平和垂直方向的一维轮廓数据进行比对，验证了旋转平移法的准确性。

关键词： 干涉术 绝对检验 波纹度 旋转 平移

Absolute interferometric testing of mid-spatial frequency wavefront by rotation and displacement technique

QUAN Qun,GAO Zhi-shan,ZHANG Cong-yang,CHENG Jin-long,ZHU Bo

Institute of Electrical Engineering & Photoelectric Technology

Abstract: Traditional absolute interferometric testing methods are all based on Zernike’s polynomial fitting of tested wavefront, where the wavefront is smoothed and the mid-frequency element is lost, so they can only get the real figure of test optics. This paper adopts the rotation and displacement technique to the absolute interferometric testing of mid-frequency wavefront. The real wavefront of the test optic is separated into a rotationally symmetric component and a rotationally asymmetric component. The rotationally asymmetric component is determined by rotating the test optics for N times, while the rotationally symmetric component is determined by the pseudo shearing data through displacing the test optics. As compared with traditional absolute interferometric testing methods, there is no need to fit the wavefront of test optics with Zernike’s polynomials and can preserve whole wavefront with the proposed method. Because the rotationally symmetric component is retrieved using the even polynomials, the computation speed is enhanced and the fitting error is reduced with the mid-frequency element retained. The numerical simulation shows that the proposed method has much superiority than the traditional method and can achieve the nanometer accuracy. An experimental measurement for a flat surface is carried on with a ZYGO interferometer. The self-comparison of the experimental data is implemented by changing the pseudo shearing ratio and substituting the standard lens and the experimental data is also compared with the horizontal and vertical profiles derived from three-flat testing. Obtained results prove the accuracy of the rotation and displacement technique.

Keywords: interferometry absolute testing waviness rotation displacement

收稿日期 2012-08-24 修回日期 2012-11-15 网络版发布日期 2013-03-20

基金项目:

国家自然科学基金项目;教育部博士学科专项科研基金;中国科学院光学系统先进制造技术重点实验室基金

通讯作者: 袁群

作者简介: 袁群(1986-)，男，江苏扬州人，博士研究生，2008年于南京理工大学获得学士学位,主要从事光干涉测量方面的研究。

作者Email: karmen86913@126.com

参考文献:

[1]DECK L, EVANS C. High performance Fizeau and scanning white-light interferometers for mid-spatial frequency optical testing of free-form optics [J]. SPIE, 2005, 5921: 59210A. [2]FREISCHLAD K. Interferometer for optical waviness and figure testing [J]. SPIE, 1997, 3098: 53-61. [3]SCHULZ G, SCHWIDER J. Precise measurement of planeness [J]. Appl. Opt., 1967, 6(6): 1077-1084. [4]SCHULZ G, SCHWIDER J, HILLER C, et al.. Establishing an optical flatness standard [J]. Appl. Opt., 1971, 10(4): 929-934. [5]FRITZ B S. Absolute calibration of an optical flat [J]. Opt. Eng., 1984, 23(4): 379-383. [6]AI C, WYANT J C. Absolute testing of flatness decomposed to even and odd functions [J]. SPIE, 1992, 1776: 73-83. [7]KLAUS R， FREISCHLAD. Absolute interferometric testing based on reconstruction of rotational shear [J]. Appl. Opt., 2001, 40(10): 1637-1648. [8]XU CH, CHEN L, YIN J Y. Method for absolute flatness measurement of optical surfaces [J]. Appl. Opt., 2009, 48(13): 2536-2541. [9]GRIESMANN U. Three-flat test solutions based on simple mirror symmetry [J]. Appl. Opt., 2006, 45(23): 5856-5865. [10]徐洋,唐锋,王向朝,等.平面面形绝对检验技术测量误差分析[J]. 中国激光, 2011, 38(10): 1008009. XU Y, TANG F, WANG X ZH, et al.. Measurement error analysis of absolute flatness test [J]. Chinese Journal of Lasers, 2011, 38(10): 1008009. (in Chinese) [11]MALACARA. Optical Shop Testing [M]. 3rd ed. Canada: John Wiley & Sons，Inc.，Publication，2007：538. [12]OTAKI K, YAMAMOTO T, FUKUDA Y, et al.. Accuracy evaluation of the point diffraction interferometer for extreme ultraviolet lithography aspheric mirror [J]. J. Vac. Sci. Technol. B. 2002, 20(1): 295-300. [13]OTAKI K, OTA K, NISHIYAMA I, et al.. Development of the point diffraction interferometer for extreme ultraviolet lithography: design, fabrication, and evaluation [J]. J. Vac. Sci. Technol. B. 2002,

20(6): 2449-2457. [14]宋伟红,伍凡,侯溪,等. 基于平移旋转的球面绝对检验检测技术仿真分析[J]. 强激光与粒子束, 2011, 23(12): 3229-3234. SONG W H, WU F, HOU X, et al.. Simulation analysis on absolute testing of spherical surfaces with shift-rotation method [J]. High Power Laser and Particle Beams, 2011, 23(12): 3229-3234.(in Chinese)

本刊中的类似文章

1. 周远 鲁亚飞 黑沫 熊飞湍 李凯 范大鹏.旋转双棱镜光束指向的反向解析解[J]. 光学精密工程, 2013,21(7): 1693-1700

2. 周远 鲁亚飞 黑沫 熊飞湍 李凯 范大鹏.旋转双棱镜光束指向解析解[J]. 光学精密工程, 2013,21(6): 1373-1379

3. 荆君涛 刘运凤 李占杰 饶小双.旋转超声磨削加工中影响磨具寿命的结构参数优化[J]. 光学精密工程, 2013,21(4): 972-979

4. 温建明 马继杰 曾平 张忠华 阚君武 程光明.压电旋转驱动器制作及性能测试[J]. 光学精密工程, 2013,21(1): 131-136

5. 刘运凤, 荆君涛, 李占杰.旋转超声磨削加工中刀具结合剂类型与加工性能的关系[J]. 光学精密工程, 2012,20(9): 2021-2028

6. 杨德兴, 许增奇, 姜宏振, 付永辉, 王骏, 邵兆申, 赵建林.利用数字全息干涉术测量电路板的连续弯曲形变[J]. 光学精密工程, 2012,(8): 1789-1795

7. 于旭东, 王宇, 张鹏飞, 谢元平, 汤建勋, 龙兴武.单轴旋转惯导系统中陀螺漂移的精确校准[J]. 光学精密工程, 2012,20(6): 1201-1207

8. 贾大功, 武立强, 马彩缤, 张红霞, 张以谟.剪切散斑干涉术中剪切量的测量[J]. 光学精密工程, 2012,20(2): 226-232

9. 武颖丽, 吴振森.旋转粗糙圆柱的激光散射功率谱分析[J]. 光学精密工程, 2012,20(12): 2654-2660

10. 龚学鹏, 李明哲, 卢启鹏, 彭忠琦.基于多点调形原理的旋转曲面连续成形[J]. 光学精密工程, 2012,20(1): 117-123

11. 朱齐丹, 李科, 蔡成涛, 程甘霖.采用改进的尺度不变特征变换算法计算物体旋转角度[J]. 光学精密工程, 2011,19(7): 1669-1676

12. 杨李茗, 叶海仙.大口径大曲率半径光学元件的高精度检测[J]. 光学精密工程, 2011,19(6): 1207-1212

13. 孙韶春, 石庚辰.旋转式微发电机的设计与制造[J]. 光学精密工程, 2011,19(6): 1306-1312

14. 李保磊, 张耀军.X射线CT系统投影旋转中心的测量[J]. 光学精密工程, 2011,19(5): 967-971

15. 孙慧贤, 张玉华, 罗飞路.局部Walsh谱描述图像纹理特征的旋转不变性[J]. 光学精密工程, 2010,18(8): 1886-1895
