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 2012, 20(6) 1225-1232 ISSN: 1004-924X CN: 22-1198/TH

现代应用光学

凹面光栅衍射效率测试仪精度分析和优化

寇婕婷[1,2], 吴娜[1,2], 巴音贺希格[1], 唐玉国[1], 齐向东[1], 于宏柱[1]

1. 中国科学院 长春光学精密机械与物理研究所,吉林 长春 130033;
2. 中国科学院 研究生院,北京 100049

摘要： 分析和优化了凹面光栅衍射效率自动测试仪的测量精度,以提高凹面光栅相对衍射效率测量结果的准确性。根据凹面光栅相对衍射效率测量原理,对凹面光栅出射光谱增宽、衍射光束截面变化、光源辐射亮度的控制和测量波长同步精度等影响测量准确性的因素进行分析,给出了必要的运算关系式。采用回归分析等数学方法,基于大量实验数据建立了测量结果的优化公式,并将该公式编入测量程序,实现了在测量结束的同时自动优化测量结果。实验表明,经过优化后的测量值更加准确,与相对衍射效率理论值的偏差均在±2.5%以内,有效提高了仪器的测量精度。该方法操作简单,无需添加或改动仪器的任何部件,可满足仪器实时性强、测量准确的要求。

关键词： 凹面光栅 衍射效率 精度分析 结果优化

Precision analysis and optimization on diffraction efficiency instrument for concave gratings

KOU Jie-ting[1,2], WU Na[1,2], Bayanheshig[1], TANG Yu-guo[1], QI Xiang-dong[1], YU Hong-zhu[1]

1. Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences, Changchun 130033, China;
2. Graduate University of Chinese Academy of Sciences, Beijing 100039, China

Abstract: This paper analyzes the measuring results of a diffraction efficiency measuring instrument for concave gratings to improve the measuring accuracy of relative diffractive efficiency. According to the testing theory of diffraction efficiency of concave gratings, the effects of the spectral broadening of exit beam for the concave grating, section changing of diffraction beam, control of light source radiation luminance and the synchronization precision of testing wavelength on the measuring accuracy were analyzed, and several kinds of necessary equations were given. Based on regression analysis and a large number of experiment data, an optimization equation was established and programmed into a testing programming to correct automatically the test results. Experiments indicate that the tested results are correct and more precise, and the difference between optimization value and theoretical one is less than? 2.5%, which improves the testing precision effectively. This method is simpler operation, not to change the components of the instrument, and can satisfy the test requirements in strong real-time and higher precision.

Keywords: concave grating diffraction efficiency precision analysis result optimization

收稿日期 2011-12-10 修回日期 2012-03-04 网络版发布日期 2012-06-10

基金项目:

国家自然科学基金资助项目(No.60478043);"十一五"国家科技支撑计划重大项目(No.2006BAK03A02);中国科学院重大科研装备研制资助项目(No.YZ200804);吉林省科技发展计划资助项目(No.20070523、20086013);吉林省重大科技攻关项目(No.09ZDGG005);长春市应用技术研究计划资助项目(No.08YJ07)。

通讯作者: 寇婕婷

作者简介:

作者Email:

参考文献：

[1] 孔鹏,巴音贺希格,李文昊,等. 双光栅平场全息凹面光栅光谱仪的优化设计[J]. 光学学报,2011,31(2):0205001 KONG P, BAYANHESHIG, LI W H, *et al*.. Optimization of double-grating flat-field holographic concave grating spectrographs [J]. *Acta Optica Sinica, 2011,31(2): 0205001*. (in Chinese)
[2] 卢启鹏,马磊,彭忠琦. 变包含角平面光栅单色器扫描转角精度的检测[J]. 光学 精密工程,2010,18(7):1548-1553. LU Q P, MA L, PENG ZH Q. Rotation angle-accuarcy measurement of scanning mechanism in variable included angle plane grating monochromator [J]. *Opt. Precision Eng.*, 2010,18(7):1548-1553. (in Chinese)
[3] 王玲芳,温志渝,向贤毅. 近红外微型光谱仪光学系统设计与模拟[J]. 光谱学与光谱分析,2009,29(6):1721-1725. WANG L F, WEN Z Y, XIANG X Y. Design and simulation of the NIR micro-spectrometer optical system [J]. *Spectroscopy and Spectral Analysis, 2009,*29(6):1721-1725.(in Chinese)
[4] 唐玉国,陈少杰,巴音贺希格,等. 中阶梯光栅光谱仪谱图还原与波长标定[J]. 光学 精密工程,2010,18(10):2130-2136. TANG Y G, CHEN SH J, BAYANHESHIG, *et al*.. Spectral reducing of cross-dispersed echelle spectrograph and its wavelength calibration [J]. *Opt. Precision Eng.*,2010,18(10):2130-2136. (in Chinese)
[5] 皮道锐,黄元申,张大伟,等. 宽光谱平像场全息凹面光栅的优化研究[J]. 物理学报,2010,59(2):1009-1016. PI D R, HUANG Y SH, ZHANG D W, *et al*.. Optimization of the flat-field holographic concave grating in wide spectral range [J]. *Acta Physica Sinica, 2010,*59(2):1009-1016.(in Chinese)
[6] 寇婕婷,巴音贺希格,唐玉国,等. 平面光栅效率仪测量过程分析与结果修正[J]. 光学学报,2011, 已录用. KOU J T, BAYANHESHIG, TANG Y G, *et al*.. Analysis of testing process and result revising on the instrument for plane grating diffraction efficiency [J]. *Acta Optica Sinica,* 2011, paper adopted. (in Chinese)
[7] 张善文,巴音贺希格. 宽波段金属光栅设计中闪耀波长对光栅异常的补偿效应[J]. 光学 精密工程,2009,17(5):990-1000. ZHANG SH W, BAYANHESHIG. Compensating effect of blazed wavelength to grating anomalies in design of broadband metallic

diffraction gratings [J]. *Opt. Precision Eng.*, 2009,17(5):990-1000. (in Chinese)
[8] 巴音贺希格,朱洪春. 基于槽型函数拟合的刻划光栅衍射特性分析方法[J]. 物理学报,2007,56(7):3893-3899. BAYANHESHIG, ZHU H CH. Analytical method of the diffraction characteristic of ruled grating based on profile fitting function [J]. *Acta Physica Sinica, 2007,*56(7):3893-3899. (in Chinese)
[9] ZIMMER F, HEBERER A,SANDNER TH, *et al*.. Investigation and characterization of high-efficient NIR-scanning gratings used in NIR-micro-spectrometer [J]. *SPIE*, 2007, 6466: 646605.
[10] NAOYUKI TAMURA, GRAHAM J. MURRAY, RAY M. SHARPLES, *et al*.. Measurement of throughput variation across a large format volume-phase holographic grating [J]. *Optics Express, 2008,13(11):4125-4133*.
[11] 巴音贺希格.衍射光栅色散理论与光栅设计、制作和检验方法研究 . 北京: 中国科学院, 2004. BAYANHESHIG. *The Study On the Dispersion Theory, Design, Manufacture , and Efficiency Test of Diffraction Gratings* . Beijing: Graduate University of Chinese Academy of Sciences, 2004. (in Chinese)
[12] 吴国安.光谱仪器设计[M]. 北京:科学出版社,1978. WU G A. *Design of Optical Spectrometer*[M]. Beijing, Science Press, 1978. (in Chinese)
[13] 李全臣,蒋月娟. 光谱仪器原理[M]. 北京:北京理工大学出版社,1999. LI Q CH, JIANG Y J. *The Theory of Spectrometer*[M]. Beijing, Beijing Institute of Technology Press, 1999. (in Chinese)
[14] 王生怀,陈育荣,王淑珍,等. 三维精密位移系统的设计[J]. 光学 精密工程,2010,18(1):175-182. WANG SH H, CHEN Y R, WANG SH ZH. Design of 3D precision displacement system [J]. *Opt. Precision Eng.*, 2010, 18(1):175-182. (in Chinese)
[15] 费业泰.误差理论与数据处理[M]. 北京:机械工业出版社,1999. FEI Y T. *Error Theory and Data Processing*[M]. Beijing: China Machine Press, 1999. (in Chinese)
[16] 凌树森. 实验数据的统计处理和误差分析—回归分析[J]. 理化检验物理分册,2001,37(6):271-276. LING S S. The statistical treatment and error analysis of experiment data-regression analysis[J]. *Physical Testing, 2001,37(6):271-276*.(in Chinese)
[17] 朱洪春,巴音贺希格. 紫外刻划光栅母版及二代版衍射特性的模拟和分析[J]. 光学学报,2007,27(7):1151-1155. ZHU H CH, BAYANHESHIG. Analysis and simulation of diffraction characteristics of the ultraviolet ruled grating master and the second duplicate [J]. *Acta Optica Sinica,* 2007,27(7):1151-1155. (in Chinese)

本刊中的类似文章

1．谭鑫 沈晨 吴娜 张方程 巴音贺希格.基于解析分区法设计闪耀全息凹面光栅[J]. 光学精密工程, 2013,21(9): 2303-2308

2．薛庆生 王淑荣 于向阳.大相对孔径宽波段Dyson光谱成像系统[J]. 光学精密工程, 2013,21(10): 2535-2542

3．于国权 郭劲 李岩 王建军 崔爽.激光角度欺骗干扰内场仿真系统精度分析[J]. 光学精密工程, 2013,21(10): 2610-2616

4．吴娜, 谭鑫, 巴音贺希格, 唐玉国.闪耀全息光栅离子束刻蚀工艺模拟及实验验证[J]. 光学精密工程, 2012,20(9): 1904-1912

5．王显军.光电轴角编码器细分信号误差及精度分析[J]. 光学精密工程, 2012,20(2): 379-386

6．许杰, 蒋山平, 杨林华, 肖大舟, 张景川.卫星结构件常压热变形的数字摄影测量[J]. 光学精密工程, 2012,20(12): 2667-2673

7．李延伟, 远国勤.面阵彩色航空遥感相机前向像移补偿机构精度分析[J]. 光学精密工程, 2012,20(11): 2439-2443

8．唐玉国, 何淼, 崔继承, 巴音贺希格, 陈少杰.用于红外晶体双折射测量的单1/4波片法[J]. 光学精密工程, 2012,20(10): 2176-2183

9．霍雷, 曾晓东.激光外差干涉中声光器件的非均匀声场特性[J]. 光学精密工程, 2011,19(10): 2386-2392

10．谭 鑫, 李文昊, 巴音贺希格, 齐向东.紫外全息闪耀光栅的制作[J]. 光学精密工程, 2010,18(7): 1536-1542

11．孙莹,，万秋华，王树洁，佘容红，卢欣然，梁立辉,.航天级光电编码器的信号处理系统设计[J]. 光学精密工程, 2010,18(5): 1182-1187

12．王书新, 李景林, 刘磊, 齐光, 任建岳.大尺寸焦平面空间相机调焦机构的精度分析[J]. 光学精密工程, 2010,18(10): 2239-2243

13．许杰,汪逸群.高集成度新型摆镜驱动模块的研制[J]. 光学精密工程, 2009,17(12): 2997-3000

14．陈洁;柳龙华;刘刚;田扬超.X射线成像波带片及制作[J]. 光学精密工程, 2007,15(12): 1894-1899

15．巴音贺希格;高键翔;齐向东.机械刻划长焦距凹面金属光栅的研制[J]. 光学精密工程, 2006,14(3): 391-395