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信息科学

基于全相位谱分析的傅里叶望远镜外场实验数据处理

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摘要： 为了提高傅里叶望远镜(FT)的成像质量,实现对运动目标的高分辨率成像,研究了能抑制由声光移频器移频误差、光学器件偏差及信号采样截断等产生的频谱泄漏且能实时计算信号频率的数据处理方法。首先,采用全相位预处理技术对外场静态目标的采样信号进行处理;通过搜索算法得到每束干涉光的整点频率最大值。然后,基于apFFT谱分析时移相位差校正法计算每束干涉光的真实频率。最后,对非整点频率解调,采用5点最小二乘拟合方法,得到目标的傅里叶分量信息。实验结果表明:与传统方法相比,本文提出的数据处理方法得到的重构图像的斯托里尔比(Strehl)相应提高了3%。另外,本文方法对频谱泄漏的抑制能力更强;对静态目标实验数据进行处理后,重构图像质量有一定的提升;该方法也为运动目标的成像数据处理提供了参考。

关键词： 傅里叶望远镜 全相位谱分析 频率校正 图像重构 数据处理

Field experiment data processing of Fourier telescopy based on all phase spectrum analysis

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Abstract: To improve the imaging quality of a Fourier Telescopy(FT) and to implement the high-resolution imaging for moving targets, the data processing methods to inhibit the spectral leakage generated by the frequency shift error from an acousto-optic frequency shifter, the bias of an optical device and truncating signals were researched and how to calculate the signal frequency in real time was given. Firstly, an all phase spectrum analysis technology was used to process sampling signals of a static target and a search algorithm was taken to capture the maximum frequency value of each interferometric beam. Then, the actual frequencies of any two beams were calculated by an all phase time shift phase difference correcting spectrum method. Finally, the frequency deviation and demodulated target's Fourier information were obtained and the demodulation frequency of the non-whole point was estimated by the least square fitting. The results show that the Strehl ratio of reconstructed image by proposed method is increased by 3% as compared with that of traditional methods. Furthermore, the new method has a higher inhibiting ability for spectral leakage, better reconstructed image, and it can provide the reference for data processing of moving targets.

Keywords: Fourier telescopy all phase spectrum analysis frequency correction image reconstruction data processing

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参考文献：

[1] 王海涛, 周必方. 光学综合孔径干涉成像技术 [J]. 光学 精密工程,2002,10(5):434-442. WANG H T, ZHU B F. Optical synthesis aperture interference image technology [J]. *Opt. Precision Eng.*,2002,10(5):434-442.(in Chinese) [2] HOLMES R B,MA S,BHOWMIK A,*et al.*. Analysis and simulation of a synthetic aperture technique for imaging through a turbulent medium [J].*OSA,1996,13(2):351-364.* [3] BRINKLEY T J,SANDLER D. Effect of atmospheric turbulence and jitter on fourier telescopy imaging systems [J].*SPIE,1999,3815:42-47.* [4] KENNETH R, MACDONALDA, JAMES K,*et al.*. An experimental demonstration of Fourier telescopy[J]. *SPIE,*1999,3815:23-29. [5] CUELLAR L E, JAMES S,JUSTIN C.Laboratory and field experimental demonstration of a Fourier telescopy imaging system[J].*SPIE, 2005,5896(D):1-14.* [6] LOUIS C E, JUSTIN C, JAMES M, *et al.*.Laboratory demonstration of a multiple beam Fourier telescopy imaging system[J].*SPIE,*2008,7094 (G):1-12. [7] 董磊,刘欣悦,王建立. 实验室环境内傅里叶望远镜技术的实现[J]. 光学 精密工程,2008,16(6):999-1002. DONG L, LIU X Y, WANG J L. The realization of Fourier telescope technology in laboratory [J]. *Opt. Precision Eng.*,2008, 16(6):999-1002.(in Chinese) [8] 王小伟,黎全,王雁桂,等. 傅里叶望远术中的相位闭合分析及其仿真[J]. 国防科技大学学报,2009,31(1):38-42. WANG X W, LI Q, WANG Y G,*et al.*. Analysis and simulation on phase closure of Fourier telescopy [J]. *Journal of National University of Defense Technoloy,*2009,31(1): 38-42.(in Chinese) [9] 陆长明,王建军,高昕,等. 傅里叶望远镜原理及改进研究[J]. 飞行器测控学报,2010,29(2):17-20. LU CH M,WANG J J,GAO X,*et al.*. A study on the theory of Fourier telescope and it improvement [J].*Journal of Spacecraft TT&C Technology,2010,29(2):17-20.*(in Chinese) [10] 刘欣悦,董磊,王建立. 稀疏采样傅里叶望远镜成像[J]. 光学 精密工程,2010,18(3):521-527. LIU X Y, DONG L, WANG J L. Fourier telescopy imaging via sparse sampling[J]. *Opt. Precision Eng.*,2010,18(3):521-527.(in Chinese) [11] 张炎,杨春平,郭晶,等. 实验室中傅里叶望远术频谱抽取方式[J]. 强激光与粒

子束,2011,23(3):571-575. ZHANG Y,YANG CH P,GUO J,*et al*.. Spectrum extraction mode for Fourier telescopy in laboratory[J].*High Power Laser and Particle Beams,2011,* 23(3):571-575.(in Chinese) [12] 陈卫,黎全,王雁桂. 基于全相位谱分析的傅里叶望远术目标重构[J]. 光学学报,2011,30(12):3443-3446. CHEN W,LI Q,WANG Y G. Object reconstruction of Fourier telescopy based on all phase spectrum analysis[J]. *Acta Optica Sinica,2011,30(12):3443-3446.*(in Chinese) [13] 王兆华,黄翔东. 数字信号全相位谱分析与滤波技术[M]. 北京:电子工业出版社, 2009:1- 71. WANG ZH H, HUANG X D. *All Phase Spectrum Analysis and Filter of Digital Signal*[M]. Beijing: Publishing House of Electronics Industry, 2009:1-71.(in Chinese) [14] 黄翔东,王兆华. 全相位时移相位差频谱校正法[J]. 天津大学学报,2008,41(7):815-820. HUANG X D, WANG ZH H. All phase time shift phase difference correcting spectrum method [J]. *Journal of Tianjin University, 2008, 41(7)*:815-820.(in Chinese) [15] 陈卫,黎全,王雁桂. 傅里叶望远术成像系统的实验研究[J]. 光学学报,2011,31(3),0311001:1-6. CHEN W,LI Q,WANG Y G. Experimental research of Fourier telescopy imaging system [J]. *Acta Optica Sinica, 2011,31(3), 0311001:1-6.*(in Chinese) [16] 董磊,刘欣悦,林旭东,等. 傅立叶望远镜外场实验性能改进和结果分析[J]. 光学学报,2012,32(2):0201004. DONG L,LIU X Y,LIN X D,*et al.*.Improvement of performance and analysis of results of field experiments of Fourier telescopy[J]. *Acta Optica Sinica,*2012,32(2):0201004.(in Chinese)