Optics Communications 410 (2018) 756–762

Contents lists available at ScienceDirect

Optics Communications

journal homepage: www.elsevier.com/locate/optcom

Large radius of curvature measurement based on the evaluation of interferogram-quality metric in non-null interferometry

Zhongming Yang [a,*], Jiantai Dou [b], Jinyu Du [b,c], Zhishan Gao [b]

[a] School of Information Science & Engineering and Shandong Provincial Key Laboratory of Laser Technology and Application, Shandong University, Jinan 250100, China
[b] School of Electronic and Optical Engineering, Nanjing University of Science and Technology, Xiao Lingwei Road 200, Nanjing, Jiangsu, 210094, China
[c] Institute of Applied Electronics, China Academy of Engineering Physics, Mianyang 621900, China

ARTICLE INFO

Keywords:
Curvature radius
Interferometry
Spherical surface
Testing

ABSTRACT

Non-null interferometry could use to measure the radius of curvature (ROC), we have presented a virtual quadratic Newton rings phase-shifting moiré-fringes measurement method for large ROC measurement (Yang et al., 2016). In this paper, we propose a large ROC measurement method based on the evaluation of the interferogram-quality metric by the non-null interferometer. With the multi-configuration model of the non-null interferometric system in ZEMAX, the retrace errors and the phase introduced by the test surface are reconstructed. The interferogram-quality metric is obtained by the normalized phase-shifted testing Newton rings with the spherical surface model in the non-null interferometric system. The radius curvature of the test spherical surface can be obtained until the minimum of the interferogram-quality metric is found. Simulations and experimental results are verified the feasibility of our proposed method. For a spherical mirror with a ROC of 41,400 mm, the measurement accuracy is better than 0.13%.

1. Introduction

important for applications in laser fusion programs and large optical observing systems. High precision metrology for large ROC is still one of key problem that has considerable influence on the performance of large optical system. Due to the metrology methods for ROC of the optical spherical surface, such as spherometer, laser spherical interferometer and knife-edge tester, have their own limitation on the large ROC measurement, researchers are trying to develop simpler and more accurate metrology techniques suit for spherical surfaces with large ROC [1].

The differential technique for large ROC measurement based on Fizeau interferometer was introduced by Gerchman, based on a cavity to fold the light path, a spherical surface with ROC up to 175 m can be measured [2]. The measurement method based on designed zoom lens was utilized by Cai, combining a Fizeau interferometer, a spherical surface with a ROC of 10 m was being measured [3]. The initial work of the ROC measurement for a spherical surface with a ROC of 10 m used a nested dual-focus zone plate was introduced by Wang in 2008 [4]. In 2014, Wang used a Fresnel zone lenses for the ROC special surfaces measurement, and the measurement range is between several meters and a few hundred meters [5]. In the metrology technique using long trace profiler to measure ROC of spherical surface proposed by Ye, the ROC can be calculated by the full aperture scanning line, and a spherical mirror with 37.108 m can be measured [6]. In 2015, Zhao proposed a measurement technique for the spherical surface with large ROC based on novel differential confocal method and a spherical surface with 15 m can be measured [7–10]. We have proposed a virtual quadratic Newton rings phase-shifting moiré-fringe measurement method (VQNPM) to measure the large ROC for a spherical surface by a non-null interferometer, in which the measurement accuracy is better than 0.18% for a spherical mirror with a ROC of 41.4 m [11]. In our VQNPM method, the measurement accuracy mainly depends on low-pass filter that used to obtain the low-pass filtered moiré fringes.

In this present study, we propose a Newton rings demodulation method based on the evaluation of interferogram-quality metric to measure the large ROC for a spherical surface. With the multi-configuration model of the non-null interferometric system in ZEMAX, the retrace errors and the phase introduced by the air gap between test surface and reference flat are reconstructed. The interferogram-quality metric is calculated by the normalized phase-shifted testing Newton rings with the reconstructed retrace errors and the phase introduced by test spherical surface. An algorithm for minimizing the function is selected

* Corresponding author.
E-mail address: zhongming.yang@sdu.edu.cn (Z. Yang).

https://doi.org/10.1016/j.optcom.2017.11.037
Received 12 September 2017; Received in revised form 10 November 2017; Accepted 13 November 2017

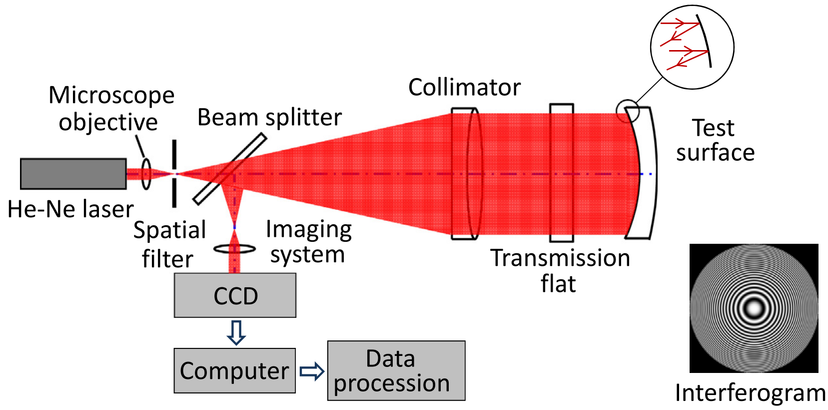

Fig. 1. The non-null interferometric system for ROC measurement.

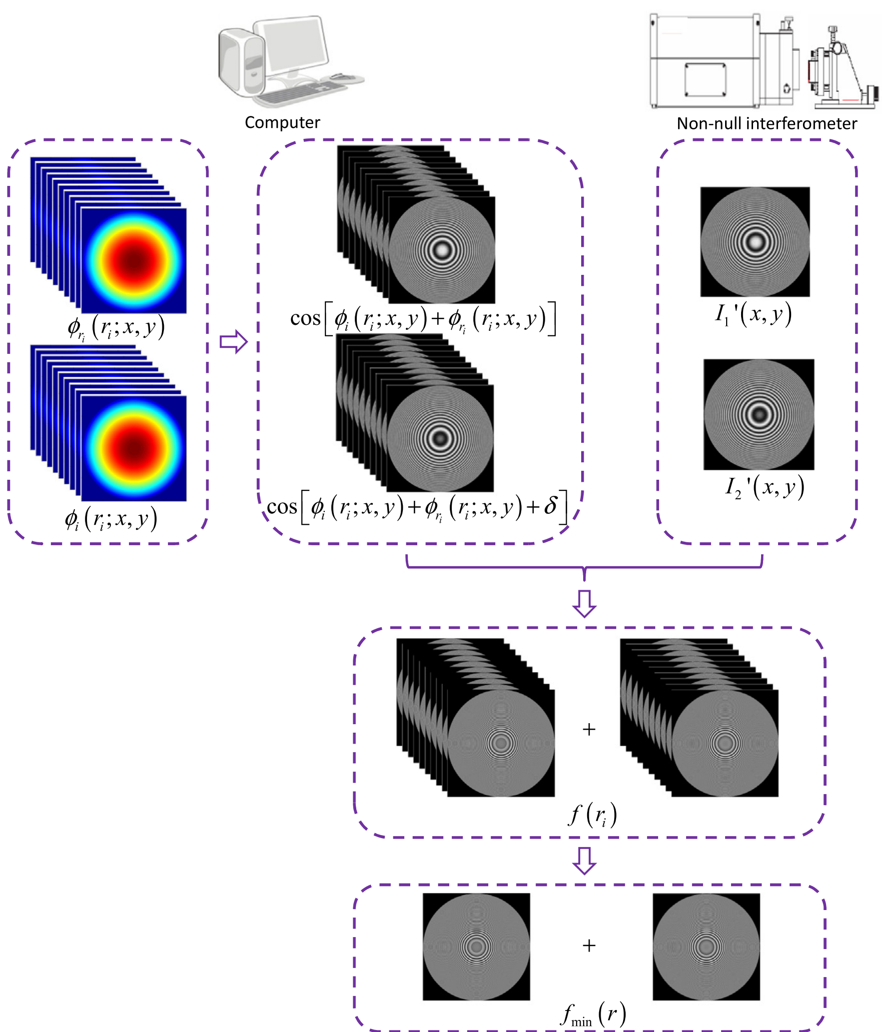

Fig. 2. The process of large ROC measurement based on the interferogram-quality metric.

to seek the radius curvature of the test spherical surface that minimized the interferogram-quality metric. Compared with the virtual quadratic Newton rings phase-shifting moiré-fringes measurement method, our proposed method avoids the retrieve process of wavefront difference data between the testing and standard spherical surface, it gives advantages in computing time and its accuracy [11]. Section 2 presents the theoretical analysis of our proposed large ROC measurement method and the procedure for measurement by the non-null interferometric system. Section 3 shows the simulation of the process of ROC measurement with surface figure error and random error in Newton rings. Section 4 experimentally validates the accuracy and feasibility of our large ROC measurement method. The experiment results are compared with the