Infrared Physics & Technology 69 (2015) 179–183

Contents lists available at ScienceDirect

Infrared Physics & Technology

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

A study of relationship between laser intensity and scanning frequency in MEMS scanning system

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HIGHLIGHTS

- We established a MEMS scanning interferometer system.
- Analyzed the relationship between MEMS scanning device scanning frequency and the received laser intensity.
- Simulated the periodic variation of laser intensity in different MEMS scanning frequency.
- Using MEMS scanning interferometer system get the periodic variation of laser intensity in different MEMS scanning frequency.
- Analyzed some special cases appeared in MEMS vibration.

ARTICLE INFO

Article history:
Received 28 December 2014
Available online 14 February 2015

Keywords:
MEMS
Interference
Intensity
Frequency

ABSTRACT

The periodic variation of laser intensity in MEMS scanning interferometer system is one of the most important factors which influence the interferometer performance. In this paper, we analyzed the relationship between MEMS scanning device scanning frequency and the received laser intensity, by simulation and experiment, get the conclusion of that: in MEMS scanning interferometer system, the slow axis vibration frequency of MEMS scanning device determines the received laser intensity.

1. Introduction

Since Michelson invented interferometer in 1881 [1], interference technique has become high and new technology which attracts the whole world's attention in a short time. Especially with the progress in laser, optical fiber technology and electronic technology, the technique of interferometer total system has become fairly mature in the world [2–4]. In 2008, ZhouSi et al. took advantage of interferometry to measure the axial stress of circular film and oval film, and gave distribution images of stresses [5]. In 2009, Hungarian Dirckx et al. invented four-channel heterodyne interferometer measurement system [6]. In 2000, National Institute of Standards and Technology (NIST) developed 1550 nm near infrared heterodyne interferometer which can detect silicon wafer whose diameter is 300 mm. As a real-time optical inspection, heterodyne interferometry [7] gets rid of the bandage of traditional visual photographic methods. By transferring the information of physical quantities to intermediate-frequency electrical signals and demodulating these signals, this technique gets the information of the physical quantities which are to be measured.

With regard to scanning method, laser heterodyne interferometer has developed from the former broad beam scanning, single shot measurement, multi-faced mirror rotation scanning measurement, acousto-optic frequency shifter scanning measurement to recently widely used stepper motor drive scanning measurement and multiple galvanometers scanning measurement. Since the size and type of obstacles which are to be measured develop, common scanning measurements cannot meet the requirements of large range scanning. They have some deficiencies as follows: their scanning range is small; scanning is inhomogeneous; it is not capable of realizing simultaneous uniform scanning in two directions by single device; spatial scanning angle is hard to control; it brings micro vibration which is an external interference factor, thus the improvement of precision of scanning is inhibited; scanning speed is comparatively slow; scanning device is complex, and the cost is high, and the productization is hard to realize. So MEMS galvanometer which is based on MEMS technique attracts people's attention and becomes one of the ideal choices for its small volume, low energy consumption, fast response speed, high integration. So in order to apply this technique, it is necessary to

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http://dx.doi.org/10.1016/j.infrared.2015.01.025
1350-4495/

learn the period of echo light intensity after laser goes through MEMS scanning system.

This paper elaborates on the period of echo light intensity after laser goes through MEMS scanning system. By simulation and experiments, we reach the conclusion that the period of echo light intensity after laser goes through MEMS scanning system is consistent with the vibration frequency of slow axis of MEMS galvanometer.

2. Theoretical analysis

Figs. 1 and 2 are the principle diagram and physical diagram respectively, showing the period of echo light intensity of laser after it goes through MEMS scanning system. In Fig. 1, the angle between the optical axis of quarter-wave plate and incident linearly polarized light is 45°. Thus it ensures that the signal reflected from the mirror can return to the photo-sensitive surface of photodetector.

As Fig. 1 shows, incident light is linearly polarized light. We call it light P, and its light intensity is I. When light P transmits completely through polarization beam splitter and arrives at quarter-wave plate, it becomes circular polarized light. This circular polarized light goes through MEMS galvanometer, then is reflected by the high-reflectance mirror and returned to MEMS galvanometer as signal light. When it goes through quarter-wave plate, circular polarized light becomes linearly polarized light, however, the polarization direction rotates 90°, light P becomes light S. Light S is completely reflected by polarization beam splitter and gets into detector for photovoltaic conversion. At last, oscilloscope shows the relationship between light intensity and time.

Let us suppose that when the angle between laser beam and the normal line of MEMS galvanometer is θ, the reflectivity of light P is R_p, and the reflectivity of light S is R_s. If the light intensity of incident linearly polarized light is I, the light intensity would still be I after the incident light goes through polarization beam splitter and quarter-wave plate. However, the linearly polarized light becomes circular polarized light. Decompose the circular polarized light into light P and light S, the light intensity of light P and light S are I_{10} and I_{20}, respectively. Both the value of I_{10} and I_{20} are 0.5I. As Fig. 3 shows, when MEMS galvanometer does not vibrate, in the direction of slow axis, the angle θ between normal line and incident light is 45°, in the direction of fast axis, the angle between normal line and incident light is 0°.

According to Fresnel formula, the reflectivity of light P and light S can be represented as follows:

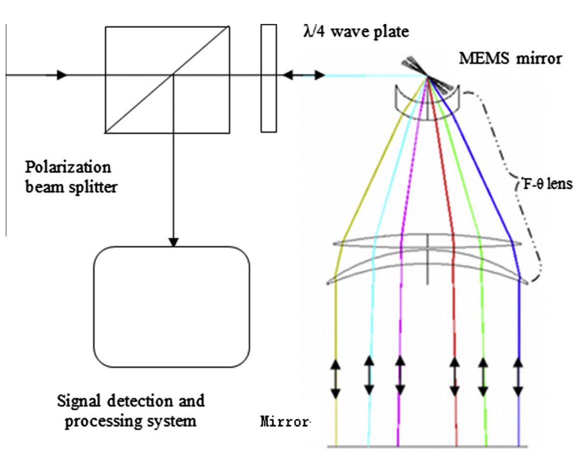

Fig. 1. Scanning principle diagram of MEMS galvanometer.

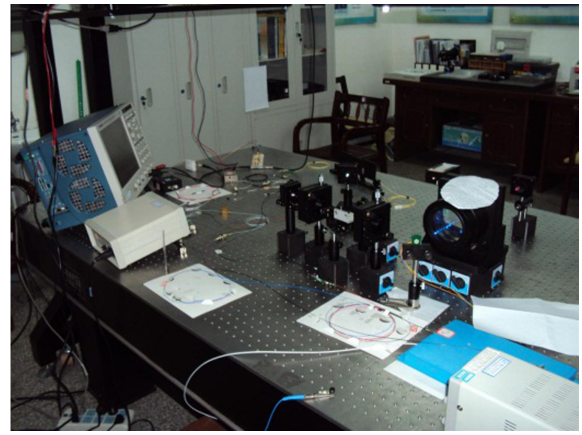

Fig. 2. Physical map of MEMS scanning light path.

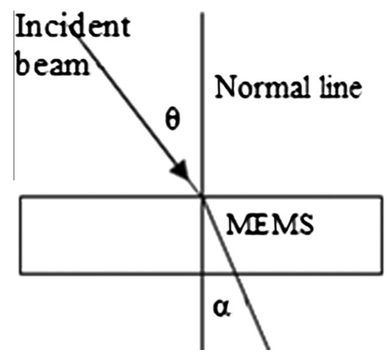

Fig. 3. Diagram of incident light when it is incident on the surface of MEMS galvanometer.

$$R_s = r_s^2 = \frac{\sin^2(\theta-\alpha)}{\sin^2(\theta+\alpha)}, \quad R_p = r_p^2 = \frac{\tan^2(\theta-\alpha)}{\tan^2(\theta+\alpha)}$$

$$\text{Thereinto}, \frac{\sin\theta}{\sin\alpha} = n = 1.6, \text{ that is}, \quad \alpha = \arcsin\frac{\sin\theta}{1.6} \tag{1}$$

The reflectivity of light P and light S can be represented as follows:

$$R_s = \frac{\sin^2(\theta - \arcsin(\sin\theta/1.6))}{\sin^2(\theta + \arcsin(\sin\theta/1.6))},$$
$$R_p = \frac{\tan^2(\theta - \arcsin(\sin\theta/1.6))}{\tan^2(\theta + \arcsin(\sin\theta/1.6))} \tag{2}$$

When light P whose light intensity is I_{10} is reflected by MEMS galvanometer and reflected by high-reflectance mirror, and then reflected by MEMS galvanometer, its light intensity attenuates to I_{11}:

$$I_{11} = I_{10}R_P 0.9 \times 0.96 \times 0.9 R_P = 0.39 I R_P^2 \tag{3}$$

Similarly, the light intensity of light S whose light intensity is I_{20} attenuates to I_{21}:

$$I_{21} = I_{21}R_S 0.9 \times 0.96 \times 0.9 R_S = 0.39 I R_S^2 \tag{4}$$

Light P and light S compose a circular polarized light, and the light intensity of this circular polarized light is I'.

$$I' = I_{11} + I_{21} = 0.5I(R_P^2 + R_S^2)0.9 \times 0.96 \times 0.9$$
$$= 0.39I\left(\frac{\sin^4(\theta - \arcsin\frac{\sin\theta}{1.6})}{\sin^4(\theta + \arcsin\frac{\sin\theta}{1.6})} + \frac{\tan^4(\theta - \arcsin\frac{\sin\theta}{1.6})}{\tan^4(\theta + \arcsin\frac{\sin\theta}{1.6})}\right) \tag{5}$$