Towards the automatization of the Foucault knife-edge quantitative test

G. Rodríguez[a], J. Villa[a], G. Martínez[b], I. de la Rosa[a] and R. Ivanov[c]

[a]Unidad Académica de Ingeniería Eléctrica, Universidad Autónoma de Zacatecas, Av. Ramón López Velarde 801, Zacatecas 98000, Mexico;
[b]Centro de Investigaciones en Óptica, A.C., Loma del Bosque 115, Col. Lomas del Campestre, Guanajuato 37150, Mexico;
[c]Unidad Académica de Física, Universidad Autónoma de Zacatecas, Calz. Solidaridad, Esquina Paseo de la Bufa s/n, Zacatecas 98060, Mexico

ABSTRACT

Given the increasing necessity of simple, economical and reliable methods and instruments for performing quality tests of optical surfaces such as mirrors and lenses, in the recent years we resumed the study of the long forgotten Foucault knife-edge test from the point of view of the physical optics, ultimately achieving a closed mathematical expression that directly relates the knife-edge position along the displacement paraxial axis with the observable irradiance pattern, which later allowed us to propose a quantitative methodology for estimating the wavefront error of an aspherical mirror with precision akin to interferometry.

In this work, we present a further improved digital image processing algorithm in which the sigmoidal cost-function for calculating the transient slope-point of each associated intensity-illumination profile is replaced for a simplified version of it, thus making the whole process of estimating the wavefront gradient remarkably more stable and efficient, at the same time, the Fourier based algorithm employed for gradient integration has been replaced as well for a regularized quadratic cost-function that allows a considerably easier introduction of the region of interest (ROI) of the function, which solved by means of a linear gradient conjugate method largely increases the overall accuracy and efficiency of the algorithm.

This revised approach of our methodology can be easily implemented and handled by most single-board microcontrollers in the market, hence enabling the implementation of a full-integrated automatized test apparatus, opening a realistic path for even the proposal of a stand-alone optical mirror analyzer prototype.

Keywords: Optical testing, Surface measurements

1. INTRODUCTION

During the 20th century the optical shop techniques from the Schlieren family proved to be extremely useful for the quality testing of optical surfaces such as mirrors and lenses.[1] Particularly, the knife-edge Foucault test became the natural choice for the craftsman and technicians of the time given its inherent simplicity and remarkably straightforwardness.[2] However, the steady advancement of the technology in the optical field largely contributed to the progressive abandon of these qualitative methodologies based in the rather subjective comparison of intensity images in favor of far more accurate and stable quantitative procedures such as interferometry, which also implied a considerable increment both in the complexity and overall cost of quality surface testing nonetheless.[3,4]

With these drawbacks in mind, in 2014 we resumed the study of the long forgotten Foucault test, this time from the more complete point of view of the physical theory, which would eventually allow us to directly relate the gradient of the wavefront error with the paraxial displacement (perpendicular to the optical axis) of the

Further author information: (Send correspondence to J. Villa)
J. Villa: E-mail: jvillah@uaz.edu.mx, Telephone: +52 492 124 3672
G. Rodríguez: E-mail: icegustavoadolfo@gmail.com, Telephone: +52 478 105 2971

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