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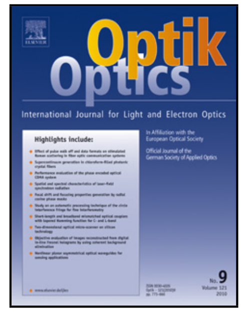


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# Quality of a Gaussian beam diffracted by a concave non-spherical grating

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(Dated:)

we examine the propagation of a complex-source-point spherical wave via a concave non-spherical grating. First we trace the paraxial paths of a chief ray propagating from a complex source point through the system to complex image points of different orders. Then we represent the wave function of the light in terms of Seidel-type aberrations, while the terms of up to fourth order in aperture variables are taken into account. Based on the derived formula, we also evaluate the quality of a Gaussian beam degraded by the system. We show how the beam qualities in the sagittal and tangential sections are influenced by the conic constant (or the aspheric coefficient of fourth order) and the positions of source and stop.

Keywords: Complex-source-point, Gaussian beam, Quality factor, Seidel aberration, Diffraction grating

## I. INTRODUCTION

It is well-known that a Gaussian beam is equivalent paraxially to a spherical wave with a center at a complex location[1] and the sum of all the higher order corrections to the paraxial Gaussian beam is also reduced to the so-called complex-source-point spherical wave (CSPSW) [2]. Recently we have taken advantage of the CSPSW to analyze the quality of a Gaussian beam passing through a rotationally symmetric system which involves any combination of refracting (or reflecting) surfaces[3], zone plates[4], and graded-index lenses[5]. In an earlier work[6], we have also investigted the evolution of the CSPSW through a grating spectrometer that is made up of a convex spherical grating and two concave mirrors, and we have then evaluated the degradation in the quality of a Gaussian beam due to aberration of the system. However, diffraction gratings are sometimes made on non-spherical substrates[7]. The quality of a Gaussian beam degraded by non-spherical gratings has not been analyzed yet.

In this article we examine the propagation of a CSPSW through a concave grating spectrometer, in which the grating is ruled on a concave non-spherical mirror of metal. We allow an aperture stop to be displaced from the grating surface along the optical axis. First we trace the paraxial paths of a chief ray propagating from a complex source point through the system to complex image points of different orders. Then we represent the wave function of the light in terms of Seidel-type aberrations[8], while the terms of up to fourth order in aperture variables are taken into account. Based on the derived formula, we also evaluate the quality of a Gaussian beam degraded by the system. We show how the quality factors of the beam in the sagittal and tangential sections are influenced by the conic constant (or the aspheric coefficient of fourth order) and the positions of source and stop.

## II. A COMPLEX-SOURCE-POINT SPHERICAL WAVE REFLECTED BY A CONCAVE NON-SPHERICAL GRATING

Figure 1 shows the setup of a concave grating spectrometer, in which the grating is ruled on a concave non-spherical mirror of metal. $V$ is the vertex of the grating surface to be taken as the origin of a coordinate system. $C$ is the center of curvature of the surface near $V$. The $x$ and $y$ axes are in the plane tangent to the surface at $V$ and the $z$ axis is directed to the point behind the surface. The grating lines are parallel to the $x$ axis and equally spaced with a period of $p$ along the $y$ axis. The aperture stop may be displaced from the grating surface along the $z$ axis. In the case of a standard type of non-spherical surface that is rotationally symmetric with respect to the $z$-axis, the surface sag is represented as

$$z \simeq \frac{x^2+y^2}{2R} + \left(\frac{\alpha+1}{8R^3}+\beta\right)\left(x^2+y^2\right)^2, \qquad (1)$$

up to fourth order in the transverse coordinates $x$ and $y$[7], where $R$ is the radius of curvature at the vertex of the surface, $\alpha$ is the conic constant, and $\beta$ is the aspheric coefficient of fourth order. $R$ is positive (or negative) in sign when $C$ is located on the right (or left)-hand side of the surface. If $\beta$ is zero, the surface reduces to a pure conic. The type of conic depends upon the value of the conic constant: $\alpha < -1$ (hyperboloid), $\alpha = -1$ (paraboloid), $-1 < \alpha < 0$ (ellipsoid with the major axis placed along the $z$-axis), $\alpha = 0$ (sphere), and $\alpha > 0$ (ellipsoid with the minor axis placed along the $z$-axis). If $\alpha = 0$, the surface is the fourth order deformation to a sphere.

A chief ray of light, passing through the center of the stop, propagates from a source point $O$ to another point $P$ on the grating surface. The ray of light, after being reflected at $P$, arrives at several image points $O'_l$ corresponding to a finite number of diffracted orders. The local coordinates of $O$ and $O'_l$ are assumed to be of $(0, y_0 + ib_0 \sin u_0, z_0 + ib_0 \cos u_0)$ and