Introduction to Aberrations in Optical Imaging Systems

JOSÉ SASIÁN

CAMBRIDGE

INTRODUCTION TO ABERRATIONS IN OPTICAL IMAGING SYSTEMS

JOSÉ SASIÁN
University of Arizona

CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town,
Singapore, São Paulo, Delhi, Mexico City

Cambridge University Press
The Edinburgh Building, Cambridge CB2 8RU, UK

Published in the United States of America by Cambridge University Press, New York

www.cambridge.org
Information on this title: www.cambridge.org/9781107006331

First published 2013

A catalog record for this publication is available from the British Library

Library of Congress Cataloging in Publication data
Sasián, José M.
Introduction to aberrations in optical imaging systems / José Sasián.
p. cm.
Includes bibliographical references and index.
ISBN 978-1-107-00633-1 (hardback)
1. Aberration. 2. Imaging systems – Image quality. 3. Optical engineering. I. Title.
QC671.S27 2012
621.36′7 – dc23 2012027121

ISBN 978-1-107-00633-1 Hardback

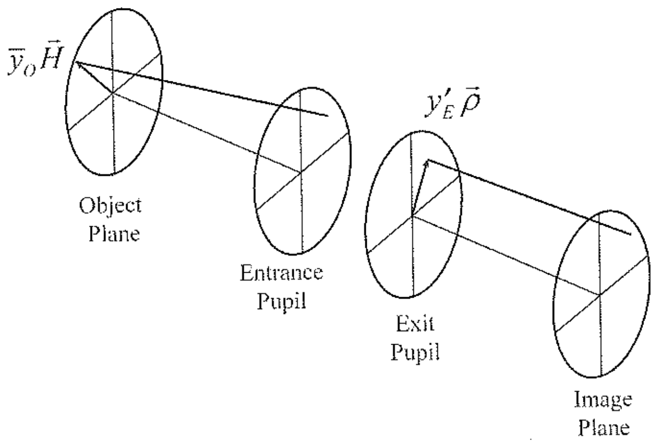

Figure 2.7 The aperture vector (scaled by the marginal ray height y'_E at the exit pupil) and the field vector (scaled by the chief ray height $\bar{y}_O$ at the object plane).

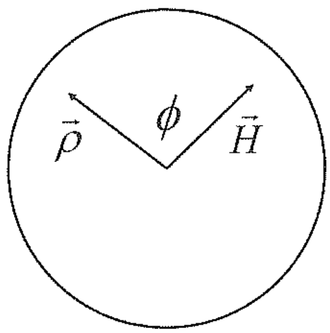

Figure 2.8 The angle ϕ between the field and aperture vectors looking down the optical axis.

The chief ray height in the object plane is $\bar{y}_O$ and the marginal ray height at the exit pupil is y'_E. The magnitude of the aperture vector is ρ, and the magnitude of the field vector is H.

Using the field and aperture vectors we can define fans of rays in a meridional plane by setting the field vector $\vec{H}$ and the aperture vector $\vec{\rho}$ parallel to each other ($\phi = 0$). We can define sagittal rays by setting the vectors perpendicularly to each other ($\phi = 90°$).

2.7 Real, first-order, and paraxial rays

Rays of light are traced through an optical system in an iterative manner. The initial data are the spatial coordinates of a point and the direction of the ray. The ray is traced by finding its intersection coordinates with the next surface. Then

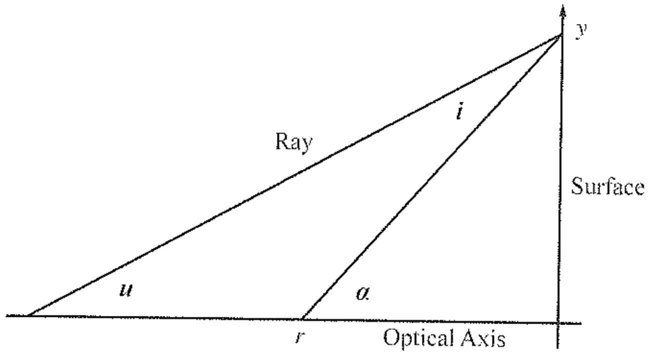

Figure 2.9 In object space there are three first-order slopes, the incident ray slope u, the normal line slope α, and the slope of incidence i (not an angle). The segment $\overline{ry}$ represents the normal line to the surface of radius r and curvature $c = 1/r$.

the direction of the ray after refraction is determined by applying Snell's law. For spherical surfaces or conic surfaces the ray intersection is determined using closed-form equations. For other surfaces an iterative algorithm is used until the intersection point is found to a high degree of accuracy. This ray-tracing process is repeated until the image plane is reached.

By real rays we mean rays of light that are traced accurately using Snell's law of refraction and that may not be close to the optical axis. Snell's law is

$$n' \sin(I') = n \sin(I), \tag{2.3}$$

where I and I' are the angles of ray incidence and refraction, and n and n' are the indices of refraction of the media surrounding the refracting surface. The normal line to the surface, the incident ray, and the refracted ray are coplanar. In accurate, real ray tracing the actual shape of the refracting surface is used.

By first-order rays we mean rays of light that are a first approximation to the path of a real ray. First-order rays are traced using a linear approximation to Snell's law,

$$n'i' = ni. \tag{2.4}$$

The optical surfaces are considered planar as shown in Figure 2.9, but with optical power properties. The first-order ray-tracing equations, for refraction and transfer respectively, are[2]

$$n'u' = nu - \frac{n' - n}{r} y, \tag{2.5}$$

$$y' = y + u't, \tag{2.6}$$

[2] See, for example, J. Greivenkamp, *Field Guide to Geometrical Optics*, SPIE Press, 2004.

DOCKET ALARM

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.

WHAT WILL YOU BUILD? | **sales@docketalarm.com** | **1-866-77-FASTCASE**

fastcase® Smarter legal research.