

Modern Optics Drawings

The ISO 10110 Companion

Modern Optics Drawings

The ISO 10110 Companion

Eric Herman

David M. Aikens

Richard N. Youngworth

SPIE PRESS

Bellingham, Washington USA

Library of Congress Control Number: 2021949589

Published by
SPIE
P.O. Box 10
Bellingham, Washington 98227-0010 USA
Phone: +1 360.676.3290
Fax: +1 360.647.1445
Email: books@spie.org
Web: www.spie.org

Copyright © 2021 Society of Photo-Optical Instrumentation Engineers (SPIE)

All rights reserved. No part of this publication may be reproduced or distributed in any form or by any means without written permission of the publisher.

The content of this book reflects the work and thought of the author. Every effort has been made to publish reliable and accurate information herein, but the publisher is not responsible for the validity of the information or for any outcomes resulting from reliance thereon.

Printed in the United States of America.
First Printing.

For updates to this book, visit <http://spie.org> and type “PM346” in the search field.

SPIE.

Table of Contents

<i>Preface</i>	<i>xi</i>
<i>Acknowledgments</i>	<i>xii</i>
Chapter 1 Drawing Notation and Default Tolerances	1
1.1 Background	1
1.2 Differences between ISO and US Standards	2
1.3 Overview of Coded Notation	2
1.4 Fundamental Information	2
1.5 Table and Drawing Field	4
1.6 Indications on Drawings	6
1.7 Subassemblies	10
1.8 Non-Toleranced Data (Default Tolerances)	12
1.9 Discussion of Other Standards in Use	12
1.9.1 MIL-STD-34	12
1.9.2 ASME/ANSI Y14.18M	13
1.10 Drawing Example	14
References	16
Chapter 2 Optical Materials	19
2.1 Background	19
2.2 Finished Part versus Raw Material	20
2.3 Overview of Material Properties	21
2.3.1 Refractive index	21
2.3.2 Stress birefringence	22
2.3.3 Bubbles and inclusions	22
2.3.4 Homogeneity	22
2.3.5 Striae	23
2.4 Indications on Drawings	23
2.4.1 Material property notation	23
2.4.2 Stress birefringence	23
2.4.3 Bubbles and inclusions	24
2.4.4 Homogeneity and striae	25
2.4.5 Material tolerance notation on ISO 10110 drawings	26
2.5 Infrared versus Visible Materials	28

2.6	Drawing Example	28
2.6.1	Material property notation	28
2.6.2	Stress birefringence	29
2.6.3	Bubbles and inclusions	29
2.6.4	Homogeneity and striae	30
	References	31
Chapter 3	Surface Figure and Form	33
3.1	Background	33
3.2	Units	34
3.3	Indications on Drawings	34
3.3.1	General quantifiers	34
3.3.2	RMS quantifiers	35
3.3.3	Peak-to-valley quantifiers	36
3.3.4	Slope quantifiers	37
3.3.5	Zernike coefficient quantifiers	38
3.3.6	Table notation	40
3.4	Surface Figure	40
3.5	Zernike	43
3.6	Component or System Wavefront	44
3.7	Drawing Example	46
	References	47
Chapter 4	Surface Texture: Roughness and Waviness	49
4.1	Background	49
4.1.1	The language of roughness	50
4.1.2	Form, waviness, and roughness	50
4.1.3	Origin of roughness symbols in ISO 10110	51
4.2	Indications on Drawings	52
4.2.1	Polish grades	53
4.2.2	Band-limited RMS roughness and waviness notations	54
4.2.3	Slope tolerance notations	55
4.2.4	Power spectral density notations	56
4.2.5	Areal versions of roughness and waviness specifications	58
4.2.6	Table notation	59
4.2.7	Differences in slope using Part 5 and Part 8	59
4.3	Meaningful Surface Texture Specifications	59
4.3.1	Spatial bands and RMS calculations	60
4.3.2	Meaningful roughness and waviness specifications	61
4.3.3	Considerations when choosing a spatial band	61
4.4	Drawing Example	64
	References	65

Chapter 5 Surface Imperfection Tolerances	67
5.1 Background	67
5.2 Indications on Drawings	69
5.2.1 Dimensional method drawing notation and interpretation	69
5.2.2 Visibility method drawing notation and interpretation	72
5.3 Meaningful Surface Imperfection Specifications	76
5.3.1 Cosmetic blemishes	76
5.3.2 Scatter and diffraction effects	77
5.4 Inspection for Surface Imperfections	78
5.4.1 Test method	78
5.4.2 Inspecting to the dimensional method	78
5.4.3 Inspecting to the visibility method	79
5.5 Drawing Example	79
References	81
Chapter 6 Laser Damage	83
6.1 Background	83
6.1.1 A word of caution	84
6.2 Units	85
6.3 Indications on Drawings	85
6.4 Test Methods	86
6.5 Drawing Example	88
References	90
Chapter 7 Surface Treatment and Coating	91
7.1 Background	91
7.2 Types of Optical Coatings	93
7.2.1 Reflective	93
7.2.2 Antireflective	94
7.2.3 Absorbing filters	96
7.2.4 Attenuator	97
7.2.5 Beamsplitter	97
7.2.6 Bandpass and band rejection filters	99
7.2.7 Long and short pass filters	99
7.2.8 Polarizer	100
7.2.9 Phase changing	100
7.2.10 Laser optic	101
7.3 Indications on Drawings	101
7.4 Standard Coatings	105
7.5 Surface Treatments	106
7.6 Testing and Durability	107
7.6.1 Durability testing indications on drawings	108
7.6.2 Environmental changes	109
7.6.3 Adhesion and abrasion test methods	110

7.7 Drawing Example	111
References	112
Chapter 8 Centering and Tilt Tolerances	115
8.1 Background	115
8.2 Datum Definitions	116
8.2.1 Datum notation	117
8.2.2 Datum construction	117
8.3 Coordinate Systems	119
8.4 Aspheric and Freeform Element Centration Factors	120
8.5 Indications on Drawings	121
8.5.1 Datum axis	122
8.5.2 Datum point	124
8.5.3 Optical centering tolerance	124
8.5.4 Nonoptical centering tolerance	126
8.6 Explicit versus Implicit Indication Examples	126
8.7 Fabrication Explanation	132
8.8 Drawing Example	138
References	139
Chapter 9 Nonspherical Surfaces	141
9.1 Background	141
9.2 Using ISO Standards for Nonspherical Profile Surfaces	142
9.3 Defining Nominal Surfaces with ISO 10110	144
9.3.1 Equations for rotationally invariant aspheric surfaces in ISO 10110-12	145
9.3.2 Formulas for rotationally variant aspheric surfaces in ISO 10110-12	146
9.3.3 General surfaces in ISO 10110-19	147
9.4 Indications on Drawings	148
9.4.1 Per ISO 10110-12	148
9.4.2 Per ISO 10110-19	148
9.5 Drawing Examples	149
References	151
Chapter 10 System Evaluation	153
10.1 Background	153
10.2 Table of Generally Useful System Performance Standards	154
10.3 Selection of Specific System-Performance Metrics	156
10.3.1 Finding an appropriate standard	157
10.3.2 Wavefront error	158
10.3.3 Resolution	158
10.3.4 Distortion	162
10.3.5 Transmittance	166

10.3.6 Stray light	168
10.3.7 Relative illumination	170
10.4 Indications	172
References	172
Chapter 11 Environmental Testing	175
11.1 Background	176
11.2 Testing Sequence and Evaluation	176
11.3 Indications	178
11.4 Overview of Environments	180
11.5 Test Methods	181
11.5.1 Temperature and humidity	182
11.5.2 Mechanical stress	183
11.5.3 Atmospheric pressure and immersion	184
11.5.4 Rain	185
11.5.5 Dew, hoarfrost, and ice	186
11.5.6 Salt mist	187
11.5.7 Dust	187
11.5.8 Acid atmosphere	187
11.5.9 Solar weathering	188
11.5.10 Mold	189
11.5.11 Contamination	189
11.5.12 Combined environments	190
11.6 Testing Equipment	193
11.7 Notation of Environmental Test Parameters	195
References	195
Chapter 12 Standards in Practice	197
12.1 System Parameters	197
12.2 Optical Design and Tolerance Analysis	198
12.2.1 Optical design	198
12.2.2 Optical tolerances	199
12.3 Optical Element Drawings	200
12.3.1 Doublet optical element	201
12.3.2 Aspheric optical element	203
12.3.3 Spherical optical element	204
12.4 Optical Assembly Drawing	206
12.5 Expected Deliverable	207
12.5.1 Transmitted wavefront test report	208
12.5.2 Optical system transmittance test report	208
12.5.3 Environmental test report	209
References	210
Epilogue: The Path Forward	213
<i>Index</i>	215

Preface

The purpose of this book is to provide optical engineers, fabricators, and all parties in between a better understanding of the ISO 10110 drawing standard, and how to use the standard to create modern optical drawings. The authors presume that the reader has access to all parts of ISO 10110 and associated standards, and at least a basic familiarity with optics component technical drawings.

The world of standards is very small, and volunteer-based. Those who work on these committees are trying to do the right thing for our industry. Those few people are willing to take the time to draft, edit, and review these standards. Most of the time the result of their efforts is the result of compromise, and often it is far from perfect. Pursuit of an international standard that reflects the diversity of opinions, applications, and needs of the community comes at a price.

The first version of ISO 10110 was published in 1995 and has been the subject of multiple revisions, additions, and subtractions over the past 25 years. Today, there are twelve parts; 1, 5, 6, 7, 8, 9, 11, 12, 14, 17, 18, and 19. Because of this international effort over the past fifteen years, the ISO 10110 drawing standards have become a truly international standard reflecting the needs of the global optics community. It is vastly better today than in 1995 or 2005, and much more in harmony with US industry.

Even so, the standards can be difficult to read, more complex than we would like, and sometimes seem unfamiliar and unfriendly. We have written this book as a friendly guide to unfamiliar language, symbols, and a way of thinking about optics tolerances and specifications. However, the book is meant as a guide—not a replacement—for reading the standards themselves.

Additionally, there are a half-dozen other standards that are essential to using ISO 10110, and even more that can be used to make ISO 10110 more effective. As a result, this book is structured in chapters by subject, rather than by part of 10110, with related standards grouped within a chapter. Many practical examples are provided with a view toward a complete adoption of the methodology of standardized optics drawings including the drawing notation standards; and the metrology, environmental, and system performance test standards. It is the authors' hope that the book is readable enough to be read and understood by the uninitiated, and that the book serves as a useful reference or guide to users of the standard as they navigate the details of full implementation.

Acknowledgments

This book has been needed in the community for some time. It's incredibly important in the implementation of standards that people know how to use them. We'd first like to thank Bob Parks and Ron Kimmel for writing the previous iteration of this type of guide. Over the years, their book has been a great resource in learning the standards.

We want to thank the standards community, which has taken on the (often) thankless task of developing these standards and keeping them updated. The time and energy that has been put into these documents by a few hearty volunteers is a tribute to our community.

We want to thank the good people at ANSI, ISO, and DIN; without whom there would be no standards at all.

Throughout the development of this book, there were many people who assisted in discussions. We would like to thank Ray Williamson, Stan Schwartz, Michael Thomas, Dennis Leiner, and Daniel Gray; and the others we may have forgotten to mention.

We are grateful to Jeremy Govier, Cory Boone, Paul Smith, Mark Malburg, Eddie LaVilla, and Jim Wyant for assistance in providing necessary resources for us to create some of the figures in the book.

Mostly, we'd like to thank our partners for their patience and encouragement throughout the writing of this book. We wouldn't have been able to finish without their continuous encouragement.

Eric Herman
Dave Aikens
Richie Youngworth
September 2021