Field Guide to

Optomechanical Design and Analysis

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Introduction to the Series

Welcome to the *SPIE Field Guides*—a series of publications written directly for the practicing engineer or scientist. Many textbooks and professional reference books cover optical principles and techniques in depth. The aim of the *SPIE Field Guides* is to distill this information, providing readers with a handy desk or briefcase reference that provides basic, essential information about optical principles, techniques, or phenomena, including definitions and descriptions, key equations, illustrations, application examples, design considerations, and additional resources. A significant effort will be made to provide a consistent notation and style between volumes in the series.

Each *SPIE Field Guide* addresses a major field of optical science and technology. The concept of these Field Guides is a format-intensive presentation based on figures and equations supplemented by concise explanations. In most cases, this modular approach places a single topic on a page, and provides full coverage of that topic on that page. Highlights, insights, and rules of thumb are displayed in sidebars to the main text. The appendices at the end of each Field Guide provide additional information such as related material outside the main scope of the volume, key mathematical relationships, and alternative methods. While complete in their coverage, the concise presentation may not be appropriate for those new to the field.

The *SPIE Field Guides* are intended to be living documents. The modular page-based presentation format allows them to be easily updated and expanded. We are interested in your suggestions for new Field Guide topics as well as what material should be added to an individual volume to make these Field Guides more useful to you. Please contact us at **fieldguides@SPIE.org**.

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Field Guide to Optomechanical Design and Analysis

Optomechanics is a field of mechanics that addresses the specific design challenges associated with optical systems. This *Field Guide* describes how to mount optical components, as well as how to analyze a given design. It is intended for practicing optical and mechanical engineers whose work requires knowledge in both optics and mechanics.

Throughout the text, we describe typical mounting approaches for lenses, mirrors, prisms, and windows; standard hardware and the types of adjustments and stages available to the practicing engineer are also included. Common issues involved with mounting optical components are discussed, including stress, glass strength, thermal effects, vibration, and errors due to motion. A useful collection of material properties for glasses, metals, and adhesives, as well as guidelines for tolerancing optics and machined parts can be found throughout the book.

The structure of the book follows Jim Burge's optomechanics course curriculum at the University of Arizona. We offer our thanks to all those who helped with the book's development and who provided content and input. Much of the subject matter and many of the designs are derived from the work of Paul Yoder and Dan Vukobratovich; their feedback is greatly appreciated.

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List of Symbols and Acronyms

%TMC	Percent total mass lost
%CVCM	Percent collected volatile condensable material
a	Acceleration
A	Area
CAD	Computer-aided design
COTS	Commercial off-the-shelf
C_p	Specific heat capacity
CTE	Coefficient of thermal expansion
CVD	Chemical vapor deposition
d	Displacement
d	Distance
D	Diameter
D	Thermal diffusivity
D	flexural rigidity
E	Young's modulus
f	Focal length
F	Force, load
f_0	Natural frequency (Hz)
FEA	Finite element analysis
FEM	Finite element method
g	Gravity (9.8 m/s^2)
G	Shear modulus
GD&T	Geometric dimensioning and tolerancing
h	Height, thickness
IR	Infrared
k	Stiffness
K	Bulk modulus
K_c	Fracture toughness
K_s	Stress optic coefficient
l	Length
L	Length
LMC	Least material condition
LOS	Line of sight
m	Magnification
m	Mass
MMC	Maximum material condition
MoS	Margin of safety
n	Index of refraction
NA	Numerical aperture
NIST	National Institute of Standards and Technology

List of Symbols and Acronyms

OPD	Optical path difference
P	Preload
p	Pressure
PEL	Precision elastic limit
ppm	Parts per million (1×10^{-6})
PSD	Power spectral density
psi	Pounds per square inch
P–V	Peak to valley
Q	Heat flux
r	Radius (distance, i.e., $0.5D$)
R	Radius (of curvature)
RSS	Root sum square
RTV	Room-temperature vulcanization
t	Thickness
T	Temperature
UTS	Unified thread standard
UV	Ultraviolet
x, y, z	Distances in the x, y, or z axis
α	Coefficient of thermal expansion
β	Therm-optic coefficient (coefficient of thermal defocus)
γ	Shear strain
δ	Deflection
ΔT	Change in temperature
Δx	Change in lateral distance (x axis)
Δy	Change in lateral distance (y axis)
Δz	Change in axial distance
ϵ	Emissivity
ε	Strain
ζ	Damping factor
θ	Angle
λ	Thermal conductivity
ν	Poisson ratio
ρ	Density
σ	Stress
σ_{ys}	Yield strength
τ	Shear stress
ω	Frequency
ω_0	Natural frequency (rad/s)