

American National Standard

*American National Standard
Recommended Practice for
Laser Safety Measurements
for Hazard Evaluation*



ANSI®
Z136.4-2005
First Printing

**American National Standard
Recommended Practice for
Laser Safety Measurements
for Hazard Evaluation**

Secretariat
The Laser Institute of America

Approved January 26, 2005
American National Standards Institute, Inc.

**American
National
Standard**

An American National Standard implies a consensus of those substantially concerned with its scope and provisions. An American National Standard is intended as a guide to aid the manufacturer, the consumer and the general public. The existence of an American National Standard does not in any respect preclude anyone, whether he has approved the standard or not, from manufacturing, marketing, purchasing, or using products, processes or procedures not conforming to the standard. American National Standards are subject to periodic review and users are cautioned to obtain the latest editions.

CAUTION NOTICE: This American National Standard Recommended Practice may be revised or withdrawn at any time. The procedures of the American National Standards Institute require action be taken periodically to reaffirm, revise, or withdraw this standard. Purchasers of American National Standards may receive current information on all standards by calling or writing the American National Standards Institute.

Published by

**Laser Institute of America
13501 Ingenuity Drive, Suite 128
Orlando, FL 32826**

ISBN: 0-912035-78-1

Copyright© 2005 by Laser Institute of America
All rights reserved.

No part of this publication may be reproduced in any form,
in an electronic retrieval system or otherwise, without the
prior written permission of the publisher.

Printed in the United States of America

Foreword

(This introduction is not a normative part of ANSI Z136.4-2005, American National Standard Recommended Practice for Laser Safety Measurements for Hazard Evaluation.)

In 1968, the American National Standards Institute (ANSI) approved the initiation of the Safe Use of Lasers Standards Project under the sponsorship of the Telephone Group.

Prior to 1985, Z136 standards were developed by ANSI Committee Z136 and submitted for approval and issuance as ANSI Z136 standards. Since 1985, Z136 standards are developed by the ANSI Accredited Standards Committee (ASC) Z136. A copy of the procedures for development of these standards can be obtained from the secretariat, the Laser Institute of America, 13501 Ingenuity Drive, Suite 128, Orlando, FL 32826 or viewed at www.z136.org.

The present scope of ASC Z136 covers protection against hazards associated with the use of lasers and optically radiating diodes.

ASC Z136 is responsible for the development and maintenance of this standard. In addition to the consensus body, ASC Z136 is composed of standards subcommittees (SSC) and technical subcommittees (TSC) involved in Z136 standards development and an editorial working group. At the time of this printing, the following standards and technical subcommittees were active:

SSC-1	Safe Use of Lasers (parent document)
SSC-2	Safe Use of Lasers and LEDs in Telecommunications Applications
SSC-3	Safe Use of Lasers in Health Care Facilities
SSC-4	Measurements and Instrumentation
SSC-5	Safe Use of Lasers in Educational Institutions
SSC-6	Safe Use of Lasers Outdoors
SSC-7	Eyewear and Protective Barriers
TSC-1	Biological Effects and Medical Surveillance
TSC-2	Hazard Evaluation and Classification
TSC-4	Control Measures and Training
TSC-5	Non-Beam Hazards
TSC-7	Analysis and Applications
EWG	Editorial Working Group

The five standards currently issued are:

ANSI Z136.1-2000, American National Standard for Safe Use of Lasers (replaces ANSI Z136.1-1993)

ANSI Z136.2-1997, American National Standard for Safe Use of Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources (replaces ANSI Z136.2-1989)

ANSI Z136.3-2005, American National Standard for Safe Use of Lasers in Health Care Facilities (replaces ANSI Z136.3-1996)

ANSI Z136.5-2000, American National Standard for Safe Use of Lasers in Educational Institutions

ANSI Z136.6-2000, American National Standard for Safe Use of Lasers Outdoors

This American National Standard Recommended Practice provides guidance for optical measurements associated with laser safety requirements. The information provided in this recommended practice is intended to assist users who are entrusted with the responsibility of conducting laser hazard evaluations to ensure that appropriate control measures are implemented. Laser safety requirements and the rationale for them are specified in ANSI Z136.1 American National Standard for Safe Use of Lasers. The procedures and methodologies described in this recommended practice are based on requirements previously established in ANSI Z136.1. As the name implies, this recommended practice contains recommendations that will lead to the desired end result. On many occasions, there is more than one measurement approach to achieve the end result, and the recommended measurement techniques in this recommended practice should be viewed as plausible practical options, and not necessarily as the exclusive techniques to perform a given task.

This recommended practice has been published as part of the American National Standard Z136 series. The basic document is American National Standard for Safe Use of Lasers, Z136.1. In general, this recommended practice may be used as a supplement to ANSI Z136.1 when additional details on laser safety measurements are desired.

It is expected that this recommended practice will be periodically revised as new information and experience in the use of lasers are gained. Future revisions may have modified methodology, and use of the most current document is highly recommended.

While there is considerable compatibility among existing laser safety standards, some requirements differ among state, federal, and international standards. These differences may have an effect on the particulars of the applicable safety measurements.

Suggestions for improvements of the standard are welcome. They should be sent to ASC Z136 Secretariat, Laser Institute of America, 13501 Ingenuity Drive, Suite 128, Orlando, FL 32826.

This standard was processed and approved for submittal to ANSI by Accredited Standards Committee Z136 on the Safe Use of Lasers. Committee approval of the standard does not necessarily imply that all members voted for its approval.

- Ron Petersen, Committee Chair
- Jerry Dennis, Committee Vice-Chair
- Sheldon Zimmerman, Committee Secretary

Notice

(This Notice is not a normative part of ANSI Z136.4-2005, American National Standard Recommended Practice for Laser Safety Measurements for Hazard Evaluation.)

Z136 standards and recommended practices are developed through a consensus standards development process approved by the American National Standards Institute. The process brings together volunteers representing varied viewpoints and interests to achieve consensus on laser safety related issues. As secretariat to ASC Z136, the Laser Institute of America (LIA) administers the process and provides financial and clerical support to the committee.

The LIA and its directors, officers, employees, members, affiliates and sponsors, expressly disclaim liability for any personal injury, property or other damages of any nature whatsoever, whether special, indirect, consequential or compensatory, directly or indirectly resulting from the publication, use of, or reliance on this document or these standards. The LIA's service as secretariat does not constitute, and LIA does not make, any endorsement, warranty or referral of any particular standards, practices, goods, or services that may be referenced in this document. The LIA also makes no guaranty or warranty as to the accuracy or completeness of any information published herein. The LIA has no power, nor does it undertake to police or enforce compliance with the contents of this document.

In issuing and making this document available, the LIA is not undertaking to render professional or other services for or on behalf of any person or entity. Nor is the LIA undertaking to perform any duty owed by any person or entity to someone else. Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances.

Participants

At the time it approved this standard, ASC Z136 had the following members:

<i>Organization Represented</i>	<i>Name of Representative</i>
Academy of Laser Dentistry	Joel White
American College of Obstetricians & Gynecologists	Ira Horowitz
American Dental Association	Douglas Dederich
American Glaucoma Society	Michael Berlin
American Industrial Hygiene Association	R. Timothy Hitchcock
American Society for Laser Medicine & Surgery	Jerome Garden
	James S. McCaughan (Alt)
American Society of Safety Engineers	Thomas V. Fleming
	Walter Nickens (Alt)
American Veterinary Medical Association	Kenneth Bartels
American Welding Society	Mark McLear
	William Arthur (Alt)
Association of periOperative Registered Nurses	Penny J. Smalley
Camden County College	Fred Seeber
Cincinnati State Technical & Community College	Prem Batra
Corning, Inc.	C. Eugene Moss
Delphi Corporation	Paul Daniel Jr.
Health Physics Society	Thomas Johnson
	David Sliney (Alt)
	Richard Hughes
High-Rez Diagnostics, Inc.	
Institute of Electrical and Electronics Engineers, Inc. (SCC-28)	Ron Petersen
International Imaging Industry Association (I3A)	Joseph Greco
Laser and Electro-Optic Manufacturers Association	Breck Hitz
Laser Institute of America	Richard Greene
LFI International	Roberta McHatton
Laser Safety Consulting, LLC.	Darrell Seeley
Lawrence Berkeley National Laboratory	Ted deCastro
	Gary Zeman (Alt)
Lawrence Livermore National Laboratory	Ken Barat
Los Alamos National Laboratory	Connon Odom
National Aeronautics and Space Administration	Guy Camomilli
	Randall Scott (Alt)
National Institute of Standards & Technology (NIST)	John Lehman
Optical Society of America	James Zavislan
Rockwell Laser Industries	William Ertle
	Jay Parkinson (Alt)
Terabeam	John Bell
Underwriters Laboratories, Inc.	Peter Boden
	David Dubiel (Alt)
University of Texas, Southwestern Medical Center	John Hoopman
US Department of Health and Human Services, Center for Devices and Radiological Health	Jerome Dennis
US Department of Labor, Occupational Safety & Health Administration	Robert Curtis
US Department of the Air Force, Air Force Research Laboratory	Benjamin Rockwell
	Robert Thomas (Alt)
US Department of the Air Force, Office of the Air Force Surgeon	William P. Roach
US Department of the Army, Medical Research & Materiel Command	Bruce Stuck

US Department of the Army,
US Army CHPPM

James Franks
Jeffrey Pfoutz (Alt)

US Department of the Navy,
Naval Sea Systems Command

Sheldon Zimmerman
Mary Gorschboth (Alt)

US Department of the Navy,
Space & Naval Warfare System Command

James Sheehy

Individual Members

Robert Aldrich
Richard Crowson
Robert Handren, Jr.
Ami Kestenbaum
David J. Lund
Wesley Marshall
Frank Rainer
David Sliney
James Smith
Nikolay Stoev
Stephen Trokel
Robert Weiner
Myron Wolbarsht
Anthony Zmoreski

The various subcommittees that participated in developing this standard had the following members:

Measurements and Instrumentation SSC-4

Sheldon Zimmerman, Chairman
Robert Thomas, Vice-Chair

Robert Aldrich
Howard Carter
Jerome Dennis
Robert Faaland
James Franks
Jose Gonzalez
Mary Gorschboth
Ken Keppler
Ami Kestenbaum
John Lehman
David J. Lund
Terry Lyon
Wesley Marshall

Wallace Mitchell
Noel Montgomery
John O'Hagan
Jay Parkinson, Secretary
Ron Petersen
Benjamin Rockwell
Thomas R. Scott
David Sliney
Shawn Sparks
Venkat Venkataramanan
Robert Weiner
Bruce Wolfe

Biological Effects and Medical Surveillance, TSC-1

Bruce Stuck, Chairman
Myron Wolbarsht, Vice-Chair

Robert Aldrich
Kenneth Bartels
Alan Blatterman
Jeremiah Brown, Jr.
Clarence Cain
Francois Delori
Jerome Dennis
William Ertle
Donald Farrer
Mary Gorschboth
Thomas Johnson
Maurice Landers
Charles Lin
David J. Lund
Martin Mainster
Wesley Marshall

Russell McCally, Secretary
Don McDuffie
Leon McLin
C. Eugene Moss
John O'Hagan
Ron Petersen
William P. Roach
Benjamin Rockwell
James Sheehy
David Sliney
Robert Thomas
Stephen Trokel
James Zavislan
Sheldon Zimmerman
Joseph Zuclich
Harry Zwick

Hazard Evaluation & Classification, TSC-2

David Sliney, Chairman
James Franks, Vice-Chair

Robert Aldrich
Jerome Dennis
Howard Donovan
Robert Faaland
Jerome Garden
R. Timothy Hitchcock
Kimberly Kantner
Martin Langlois
David J. Lund
Wesley Marshall
Leon McLin
John O'Donnell
Connon Odom
Jay Parkinson

Mary G. Payton
Ron Petersen
William P. Roach
Benjamin Rockwell
Dale Smith
Gregory Smith
Nikolay Stoev
Bruce Stuck
Robert Thomas, Secretary
Bill Triplett
Stephen Trokel
Robert Weiner
James Zavislan
Sheldon Zimmerman

Control Measures & Training, TSC-4

William J. Ertle, Chairman
R. Timothy Hitchcock, Vice-Chair

Robert Aldrich
William Arthur
Ken Barat
Judy Chamberlain
Paul Daniel, Jr.
Jerome Dennis
Marc Gleichert
Richard Greene
Robert Handren
Tom Johnson
Johnny Jones
Kimberly Kantner
Susan Lohr
Wesley Marshall
Mark McLear
C. Eugene Moss
William Murray
John O'Donnell
John O'Hagan
Jay Parkinson

Ron Petersen
Frank Rainer
William P. Roach
Benjamin Rockwell
James Sheehy
David Sliney
Penny J. Smalley
James Smith
Dale Smith
Casey Stack
David Stefanovsky
Bruce Stuck
Robert Thomas
Stephen Trokel
R. J. Tucker
Robert Tucker
Robert Weiner
Myron Wolbarsht
Sheldon Zimmerman
Tony Zmorenski, Secretary

Analysis & Applications, TSC-7

Wesley Marshall, Chairman
Robert Thomas, Vice-Chair

Robert Aldrich
James Franks
Mary Gorschboth
R. Timothy Hitchcock
Jay Parkinson
Ron Petersen
Benjamin Rockwell

Dale Smith
Nikolay Stoev
Dan Thomas
Mark Webb, Secretary
Robert Weiner
Sheldon Zimmerman
Tony Zmorenski

Editorial Working Group, EWG

Ami Kestenbaum, Chairman

Mary Gorschboth
Richard Hughes
Barbara Sams

Nikolay Stoev
Sheldon Zimmerman

Contents

1. General.....	1
1.1 Scope.....	1
1.2 Application.....	1
2. Definitions.....	1
3. Detector Properties.....	6
3.1 Responsivity.....	6
3.2 Spatial Uniformity.....	6
3.3 Response Linearity.....	7
3.4 Damage Threshold.....	7
3.5 Active Area.....	8
3.6 Power/Energy Range.....	8
3.7 Environmental Sensitivity.....	8
3.8 Background or Stray Radiation.....	8
3.9 Detector Speed.....	8
3.10 Spectral Responsivity.....	8
3.11 Pulse Repetition Effects.....	9
3.12 Field of View and Alignment.....	9
3.13 Calibration and Measurement Uncertainty.....	9
3.14 Noise Equivalent Power.....	9
3.15 Normalized Detectivity.....	10
3.16 Radiometric Instrument Detector Systems.....	10
4. Laser Classification and Hazard Evaluation.....	10
4.1 Background.....	10
4.2 Laser Classification Schemes.....	16
4.3 Laser Hazard Evaluation and Hazard Class Determination.....	18
5. Laser Measurements.....	18
5.1 Wavelength (spectral content).....	18
5.2 Limiting and Measurement Apertures.....	18
5.3 Power or Energy.....	18
5.4 Irradiance and Radiant Exposure.....	18
5.5 Apparent Visual Angle (Angular Subtense α).....	19
5.6 Beam Shape, Profile, and Size.....	21
5.7 Beam Waist.....	23
5.8 Beam Divergence.....	23
5.9 Pulse Duration (Δt).....	24
5.10 Measuring the Number of Pulses in an Exposure.....	24
5.11 Polarization.....	24
6. Optical Density Measurements.....	25
6.1 Optical Density (D_λ).....	25
6.2 Automated Systems.....	25
6.3 Laser Measurement.....	25
6.4 Sample Test Methods.....	25
6.5 High Optical Density Goggles.....	25
6.6 Instrument Linearity.....	26
6.7 Interference Filters.....	26
6.8 Saturable Absorbers.....	26
Appendix A.....	27
Acronyms, Abbreviations, and Variable Symbols.....	27
Appendix B.....	30
Detectors.....	30
B.1 Thermal Detectors.....	30
B.2 Quantum Detectors.....	30

SECTION	PAGE
Appendix C	33
Detector Specifications.....	33
Appendix D.....	35
Laser Hazard Evaluation and Classification.....	35
D.1 Determine Wavelength or Wavelengths	35
D.2 Determine Pulse Properties.....	35
D.3 Determine Exposure Duration (T_{max}).....	35
D.4 Determine Beam Diameter (D_L) and Divergence (ϕ).....	35
D.5 Determine Angular Subtense	35
D.6 Determine Total Power or Energy	35
D.7 Determine Laser Class	35
D.8 Determine Evaluation Distance	37
D.9 Determine Diffuse Reflection Hazards	37
D.10 Determine Specular Reflection Hazards	37
D.11 Determine MPE and Limiting Apertures for Skin	37
D.12 Calculate Irradiance and/or Radiant Exposure.....	38
D.13 Select Protective Eyewear.....	38
Appendix E	39
Examples	39
E.1 Detector Selection Example 1	39
E.2 Detector Selection Example 2	42
E.3 Selecting Measurement Apertures.....	44
E.4 Energy Measurement.....	45
E.5 Classification.....	46
E.6 Beam Diameter, Beam Profile, Irradiance Distribution	49
E.7 Diode Laser Illuminator	51
E.8 Q-Switched Nd:YAG Laser	53
E.9 Beam Divergence	55
E.10 Extended Sources	56
E.11 Uncertainty Analysis	61
E.12 Beam Splitters	64
Appendix F	67
Measurement and Analysis of Laser Radiation for Regulatory Purposes	67
Appendix G.....	80
References	80
Appendix H.....	81
Measurement Pitfalls.....	81

Appendix F, *Measurement and Analysis of Laser Radiation for Regulatory Purposes* reproduced with permission from the Proceedings of the International Laser Safety Conference, November 1990. Copyright© 1991, Laser Institute of America, Orlando, Florida.