Laser Institute of America
Laser Applications and Safety

ANSI Z136.7 Standard for Testing and Labeling of Laser Protective Equipment and ISO Eye Protection Standards

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ANSI Z136.7—newly published!

- *American National Standard for Testing and Labeling of Laser Protective Equipment,* ANSI Z136.7-2008, was published by LIA in early 2008.
- A decade of effort under the chairmanship of Dr. James Sheehy, US Navy Space & Naval Warfare System Command

ANSI Z136-SSC-7, Testing and Labeling of Laser Protective Equipment

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Testing procedures are provided

- Aim: To ensure that eyewear, windows, and barriers maintain their specified level of protection throughout the life of the products.
- Protective equipment (devices) include:
  - laser eye protective devices
  - instrument filters
  - laser window filters
  - laser area protective barriers or screens
  - beam blocking curtains.
- Depending on the protective device, laser type, pulsed or CW operation and wavelength(s), different test methods may be required. Methods in Appendices

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Stepwise procedure to use standard

- Determine the type of protective equipment (device); eyewear, barrier, or window.
- Determine the filter technology used; absorptive, reflective, or hybrid.
- Determine the material type of eyewear/windows under study; material, metal, plastic, glass, hybrid, etc.
- Determine the appropriate laser or laser system; continuous wave, Q-switched, or sub-nanosecond, or some combination of pulse durations.
- Determine the wavelength or wavelength band of the laser protection.
- Determine the specified optical density or barrier threshold level as identified by the manufacturer at the wavelength in question.

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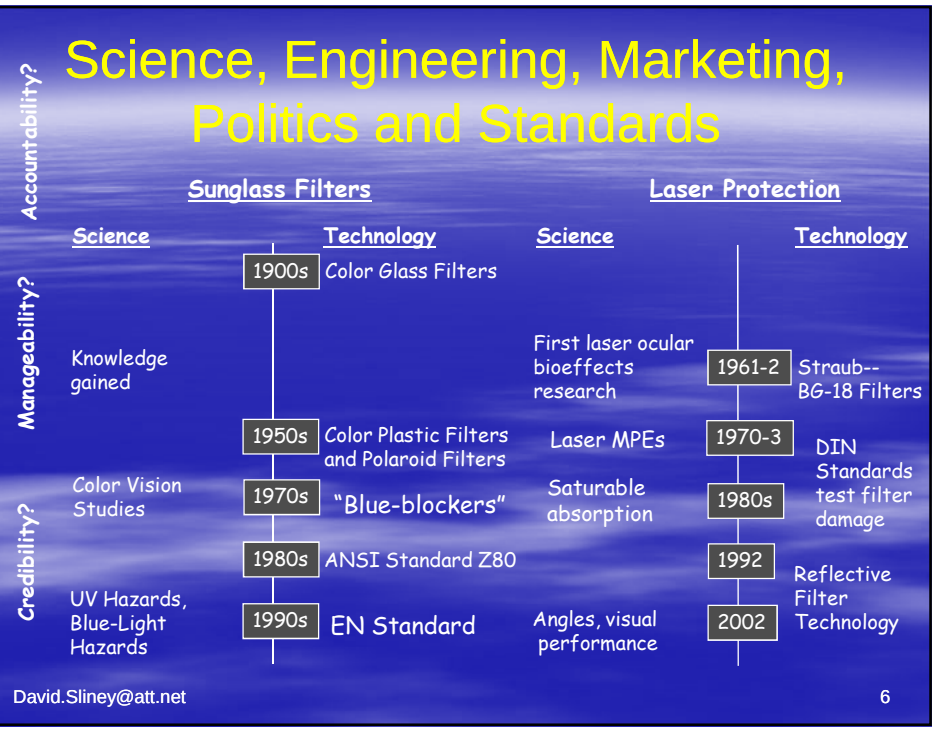
Science, Engineering, Marketing, Politics and Standards



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ISO TC94 Eye Protection

- ISO TC94 - Reactivated in 2002, because Australia, Japan, US frozen out of EN activities in sunglasses, eye protectors
- Meetings: New York, Jun 2003, Berlin, June 2004,,.Winterthur, 2007
- WG3 Sunglasses - Convener: Graziano (I)
- WG4 Laser Protection – Henderson (UK)

- Issue: Do ISO standards impact eye protection for US manufacturers (and military visors)?
- Testing, Specifications: YES!

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Laser Eye Protection

- Initially developed for laboratory use—Straub, Army HDL—1962; Swope, AO—1966
- Plastic filter materials developed under Army Contract by American Cyanimide, 1970-1972
- Reflective technology for military—1990s to …

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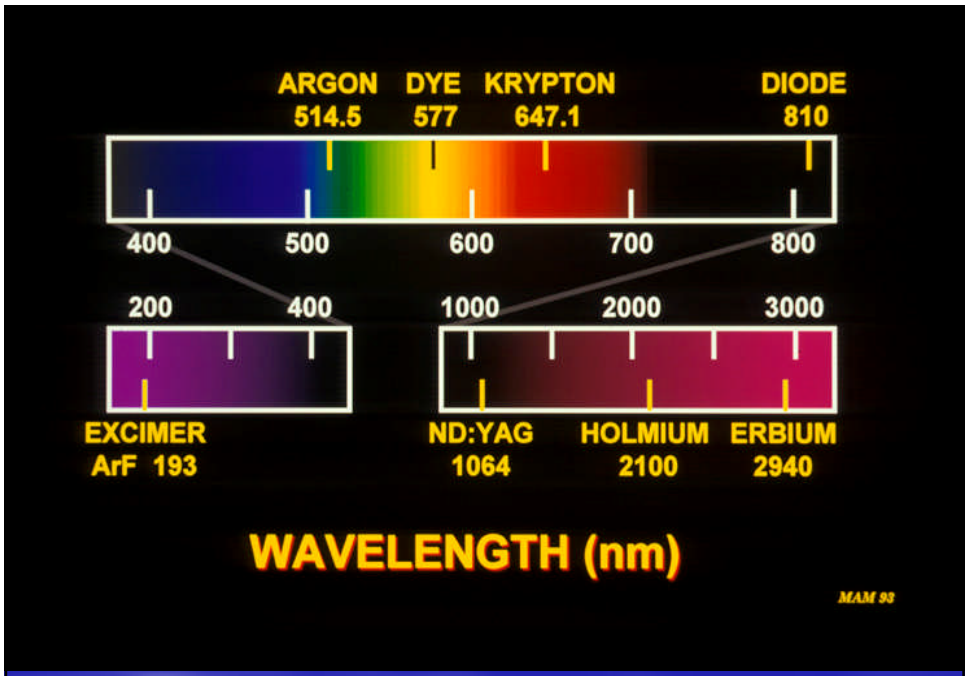
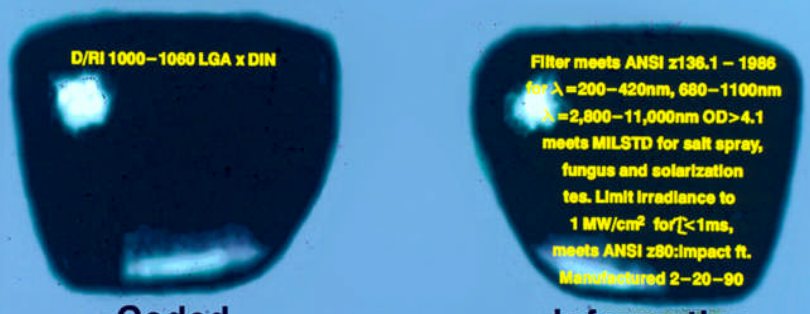

ARGON
514.5
DYE
577
KRYPTON
647.1
DIODE
810
400
500
600
700
800
200
400
1000
2000
3000
EXCIMER
ArF 193
ND:YAG
1064
HOLMIUM
2100
ERBIUM
2940
WAVELENGTH (nm)
MAM 93

Labeling:

Laser Eye Protection



Coded Informative

Labeling lenses: The problem

History of Laser Eye Protection Standards

- US ANSI and BSI 1973-era standards emphasized OD, saturable absorption visibility and compatibility for the user
- DIN Standard developed by Dr. Ernst Sutter and manufacturers and focused on filter damage, *but why?*
  - US Glendale had the corner on light-weight plastic filter market and German manufacturers developed resistant glass filter materials (R+H)
  - DIN TC had safety/welding filter background

Saturable Absorption of Filter

- Saturable absorption, or reversible bleaching, occurs when the energy of excitation produced by photon absorption to an excited singlet state is transferred by non-radiative transition to a metastable triplet state leading to transient bleaching
- Normally the lowest singlet state is excited when a non-radiative transition takes place, therefore if saturable absorption does not occur in the visible, it would not occur in the near-infrared

US Position on filter testing has been….

- Burn-through testing is not needed
- Any safety officer who thinks workers will be exposed to kW/cm^2 CW lasers should worry about face and skin protection too! *Enclose the beam!*
- EN 207, 208, based upon earlier DIN standards adds a needless cost for testing with high-power lasers. A 10-s static test is rather unrealistic.
- Saturable absorption testing and angular testing are truly relevant to the user
- Deal with filter damage by default values that can be provided to the concerned user, test only if the manufacturer wishes to claim higher thresholds

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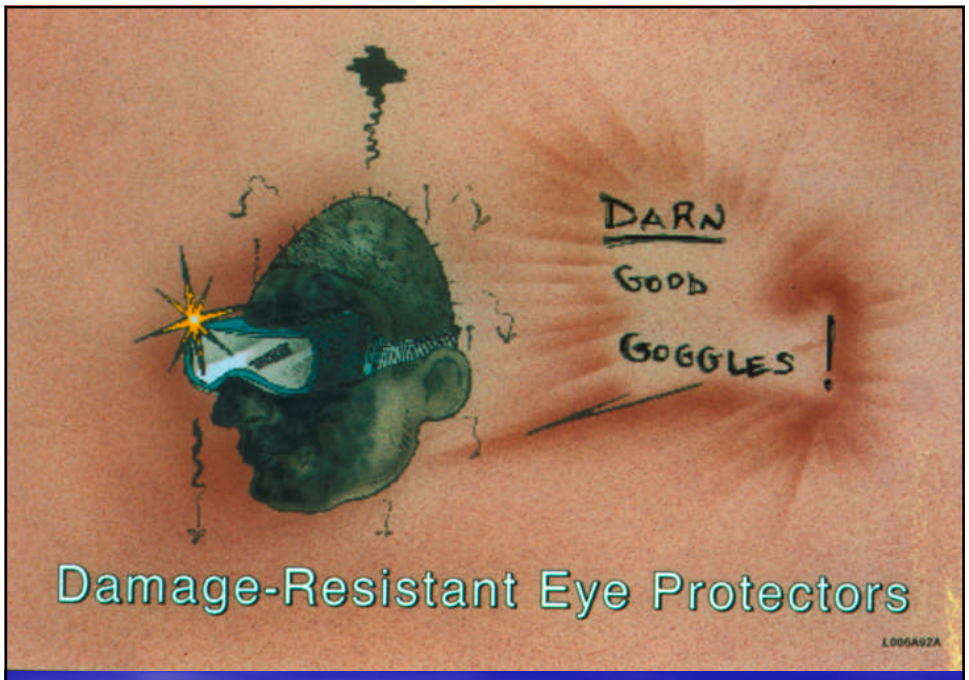

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Our US Responsibilities

- To assure that ISO standards do not adversely affect ANSI eye protection requirements, standardization and testing protocols
- Prepared ANSI-Z136.7-compatible draft materials for ISO standard and aid Roy Henderson (Cambridge) in drafting the requirements that do not emphasize filter resistance to damage—and costly testing

ANSI Z-136.7 Laser Protective Eyewear and Laser Barriers

- Committee Introduced
  - reflective filter tests
  - default levels to avoid costly testing
  - both eyewear and barriers included

Different Approaches Between ANSI Z136.7 and EN 207:1998

- EN 207:1998 combines user requirements with manufacturer performance and testing requirements as in Table 1
  - Takes decision making on OD determination away from the user and adds additional safety factor. The intent was to simplify the determination, but it restricts local decisions.
  - Test Condition D for failure is for 10 s.
- ANSI provides requirements only for the laser eye protector itself.

Advantages of Separating Manufacturer and User Requirements

- Avoids maintenance issues of updating the standard each time the MPEs are modified.
- Separates manufacturer requirements from user requirements—two separate communities with different regulations
- Allows the user greater flexibility to deal with different environments and use conditions

Angular Dependence of Protection

- EN 207-1998
  - Para 3.10 refers to frame
  - (Amendment 2; 2002) Annex A (informative) specifies angles of 0-30º for assessment
  - This approach ignores peripheral vulnerability
- ANSI Z136.7 introduces a complex, but more advanced procedure for testing the OD of reflective filters (Appendix C)

Different approaches to filter-damage ("stability") testing

- EN 207 and 208 requires a 10-s CW beam test (Condition D) or use a repetitively-pulsed laser exposure
  - Minimum PRF of 5 Hz or CW laser to be used
  - Restricts beam to > 2 mm for CW or long pulse, but smaller for shorter pulses
  - Requires simultaneous OD measurement during exposure. Can this not burn up a detector?
- ANSI gives default failure threshold values
  - Testing only for claims of greater thresholds

ANSI Z136.7 Testing of OD

- **Optical Density Test Parameters.** Optical transmittance [$\tau(\lambda)$] is measured by placing the sample in the beam and irradiating it at the required level while recording the incident and transmitted energy or power. Optical density is calculated as:
- $D(\lambda) = \log_{10} (\Phi/\Phi_0) = - \log_{10}[\tau(\lambda)]$

OD Tests Shall Specify

- Wavelength to be determined within ± 1 nm.
- Resolution of the system (incident radiation, etc.) shall be specified (nm).
- Beam diameter on the sample specified within ± 10% at the 1/e intensity point.
  - Absorptive: minimum diameter typically 1 mm
  - Reflective: variable diameter based on desired scan pattern
- Spatial profile of beam (e.g., TEM_{00} or flat-top).
- Temporal profile consistent with intended time regime.
- Polarization of the incident beam (reflective-technology filter).
- Incidence angle of beam on the protective substrate (reflective-technology filter).

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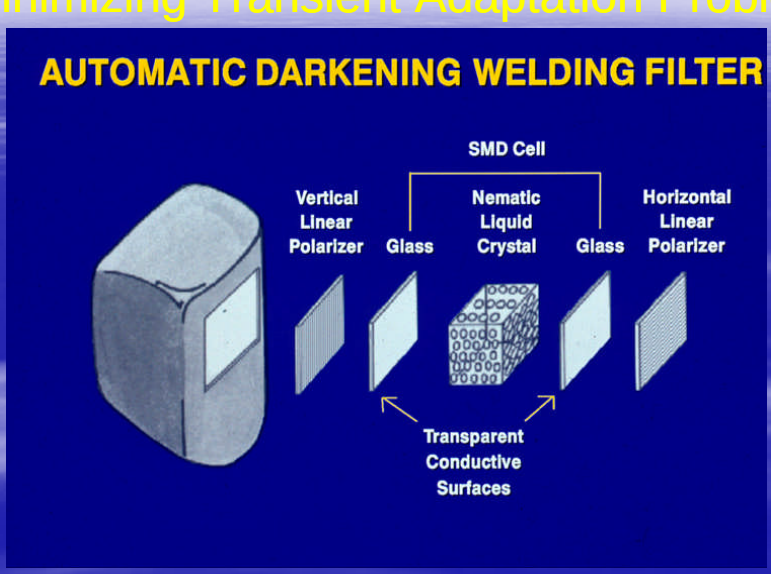
Dealing with Intense Pulse Light (IPL)— Minimizing Transient Adaptation Problem



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Filters in Viewing Optics

Laser Barriers and Curtains

- Applications
  - enclose laser controlled area
  - used at entryway
  - temporary laser controlled area

- Should not be flammable or emit toxic by-products

Laser Barriers and Curtains

- Must know damage threshold for a given time (traditionally 60 or 100 seconds)
- Barrier threshold limit (T_L) = damage threshold
  - Fabric curtain range of T_L's: 5 to 350 W/cm^2
  - Metal barrier T_L = 1200 W/cm^2 for 3 min
  - Active barriers of value with very high irradiances
- Calculate separation distance (D_s)

ANSI Z136.7 Definitions

- **barrier (laser safety).** Moveable or fixed equipment (devices) used to block or attenuate laser energy. Typically placed on or around where a laser is in use. See also *laser protective windows, view ports, and barriers*.
- **barrier threshold level (TL).** The highest irradiance incident on a laser barrier for which no penetration occurs for an exposure of 100 sec at a specified exposure diameter.
- **laser protective windows, view ports and barriers.** Absorbing/reflecting devices (e.g., curtains, screens) used to limit the transmission of the laser energy at or below the MPE.

§4.4.5 Laser Barrier Materials

- **4.4.5 Laser Barrier Materials.** Laser area controls frequently include an opaque non-transmissive beam block, area protective barriers, screen or beam blocking curtains as a means of either temporary or permanent protection.
- The laser protective barrier testing protocol described is based on the ability of the barrier to withstand beam penetration when exposed for a finite (pre-selected) time period at a maximum incident irradiance level. The exposure time shall be 100 seconds.
- The beam irradiance for which protection is afforded defines the Barrier Threshold Level (TL) for a given barrier design.
- Studies have shown that laser exposures of some barrier designs often display a spot-size dependence in the TL. Since this is an important factor, the barrier shall be tested over a range of beam diameters. The testing should be done over a range of 3 mm to 10 mm.

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Effects to Look For

- Effects noted would be:
- First Visible Damage (FVD): Any visually observable change or structural alteration in the protective barriers surface (melting, pitting, cracking, discoloration, etc.) that occurs during or following the exposure.
- Flame, smoke and sign of thermal distortion or fumes shall be captured and analyzed for toxic content. Where appropriate a MSDS (material safety data sheet) shall be prepared.
- Penetration Threshold Level (PTL). The initial power level at which beam breakthrough of the material occurs.
- Caution: Note that multi-layered laser-resistant barriers will not be penetrated up to a specified irradiance for very long times; however, once a critical irradiance level is reached, burn through will occur almost immediately.

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§ 5.2 Laser Barrier Information

- **5.2.1 Intended Use and Limitations.** It shall be indicated that the protective device is intended to provide protection against accidental exposures to laser radiation and the conditions for which protection is specified. A description of the filter optical density, the angular protection afforded by the reflective filter, or barrier exposure limitation for the device shall be provided (see Section 4.6.2.4 of ANSI Z136.1-2007 or current version).
- **5.2.2 Labeling Information.** An explanation of the markings used in the label shall be provided.
- **5.2.3 Cleaning and Storage Instructions.** The manufacturer shall provide directions for storage. The manufacturer shall provide appropriate instructions including care and cleaning instructions and/or chemical exposure warnings.
- **5.2.4 Inspection Instructions.** Manufacturer's recommended guidelines for periodic inspection shall be provided to the extent known. The protective devices/filters shall be examined and retested if it appears they have been damaged (scratched, delamination) or undergone a color change per ANSI Z136.1-2000 or current version.

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§ 6.3 Barrier Labeling.

- All laser protective barriers shall be labeled with the minimal information identified below. Complete barriers shall be permanently labeled by the final manufacturer. Barrier materials intended to be cut, modified or applied after purchase shall be provided with this information for labeling by the user. The minimal information that must be provided in the barrier labeling includes threshold limit (TL) and exposure time for which the limit applies and the exposure conditions under which protection is afforded. The manufacturer and model of the barrier or barrier material shall be clearly identified on the product. A manufacturer's registered trademark fulfills the requirement for marking the name of the manufacturer.

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Limits for Barriers, Curtains, and Windows

- Reflective technologies in general are not found in large area protection such as curtains, blocks and windows: the cost of fabrication precludes such application. Protective windows, barriers or similar applications are the most likely to be subjected to potentially damaging radiant exposures. The useful damage variable for protective materials is the burn-through time, which is a function of incident power, material thickness and material type.

Barrier Testing Parameters and Protocol (Test Procedure) - part 1

- The required laser wavelength will be selected at the beginning of each series of protective barrier tests
- The required temporal mode of operation (CW, pulsed, etc.) will be selected at the beginning of the series of tests.
- The prepared samples of the protective barrier shall be:
- a. Select sample at least 250mm x 250 mm in size
- b. Of representative thickness and of dimensions not less than 3 times the maximum beam dimension (1/e) encountered at the exposure location.
- c. Supported such that overlap of the sample edge and the mount shall not exceed 3 mm from the edge of the sample.
- d. Placed in a stable mount that holds the sample at $\pm$3 degrees of normal relative to the incident laser beam at the position at which the incident beam irradiance was determined.
- e. Placed no further than 3 times the focal length of the lens.

Barrier Testing Parameters and Protocol (Test Procedure) - part 2

- If deemed necessary, a band bass filter will be inserted in the beam path to assure that only radiation at the laser wavelength will be measured.
- Determine TEM mode.
- Laser incident beam diameter will be established at this laser power setting by the aperture transmission method or other established method. The beam diameter and area will be determined at the position at which the protective barrier is to be placed, assuring that the measured diameter is the incident diameter at the protective barrier's surface.
- It is recommended that beam diameters between 3 – 10 mm be included in the test data. For certain applications beam diameters outside these dimensions could also be used, but shall be supported by technical data.
- The beam irradiance shall be calculated and confirmed by a calibrated power meter for each condition of beam power and diameter size.
- Care will be taken to maintain a constant incident beam diameter of the protective barriers surface.
- The incident laser power will then be decreased to reduce irradiance in appropriate increments until beam penetration through the barrier does not occur within 100 seconds or less.

User Questions: Installation? Is this a Class 1 Condition?

Track Barriers

Frame Barriers