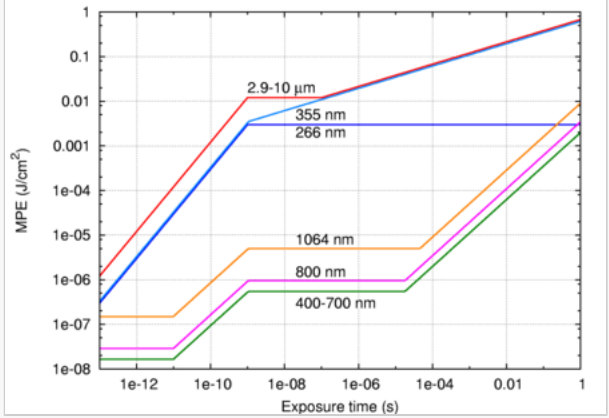
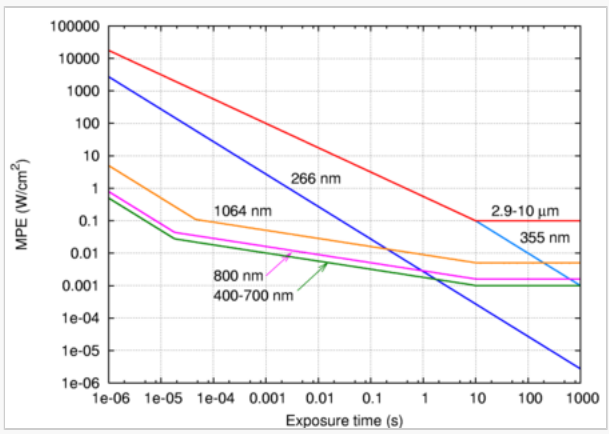
Maximum permissible exposure

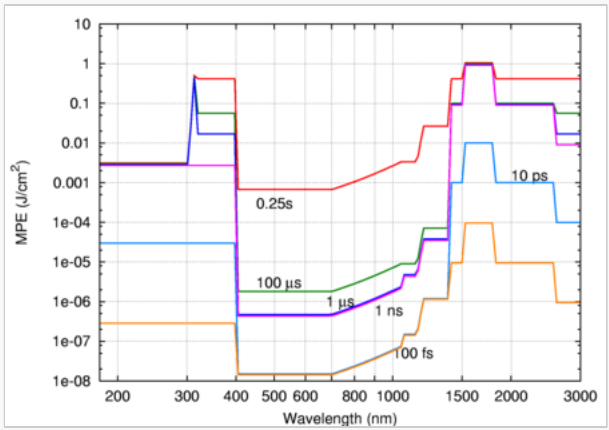
The *maximum permissible exposure* (MPE) is the highest power or energy density (in W/cm^2 or J/cm^2) of a light source that is considered safe, i.e. that has a negligible probability for creating damage. It is usually about 10% of the dose that has a 50% chance of creating damage[7] under worst-case conditions. The MPE is measured at the cornea of the human eye or at the skin, for a given wavelength and exposure time.



Maximum permissible exposure (MPE) at the cornea for a collimated laser beam according to IEC 60825, as energy density versus exposure time for various wavelengths.



MPE as power density versus exposure time for various wavelengths.



MPE as energy density versus wavelength for various exposure times (pulse durations).

A calculation of the MPE for ocular exposure takes into account the various ways light can act upon the eye. For example, deep-ultraviolet light causes accumulating damage, even at very low powers. Infrared light with a wavelength longer than about 1400 nm is absorbed by the transparent parts of the eye before it reaches the retina, which means that the MPE for these wavelengths is higher than for visible light. In addition to the wavelength and exposure time, the MPE takes into account the spatial distribution of the light (from a laser or otherwise). Collimated laser beams of visible and near-infrared light are especially dangerous at relatively low powers because the lens focuses the light onto a tiny spot on the retina. Light sources with a smaller degree of spatial coherence than a well-collimated laser beam, such as high-power LEDs, lead to a distribution of the light over a larger area on the retina. For such sources, the MPE is higher than for collimated laser beams. In the MPE calculation, the worst-case scenario is assumed, in which the eye lens focuses the light into the smallest possible spot size on the retina for the particular wavelength and the pupil is fully open. Although the MPE is specified as power or energy per unit surface, it is based on the power or energy that can pass through a fully open pupil (0.39 cm^2) for visible and near-infrared wavelengths. This is relevant for laser beams that have a cross-section smaller than 0.39 cm^2. The IEC-60825-1 and ANSI Z136.1 standards include methods of calculating MPEs.[3]

Regulations

In various jurisdictions, standards bodies, legislation, and government regulations define classes of laser according to the risks associated with them, and define required safety measures for people who may be exposed to those lasers.

In the European Community, eye protection requirements are specified in European standard EN 207. In addition to EN 207, European standard EN 208 specifies requirements for goggles for use during beam alignment. These transmit a portion of the laser light, permitting the operator to see where the beam is, and do not provide complete protection against a direct laser beam hit. Finally, European standard EN 60825 specifies optical densities in extreme situations.

In the U.S., guidance for the use of protective eyewear, and other elements of safe laser use, is given in the ANSI Z136 series of standards. A full copy of these standards can be obtained via ANSI or the secretariat and publisher of these standards, the Laser Institute of America.[8] The standards are as follows:

- ANSI **Z136.1** - *Safe Use of Lasers*

  As the parent document of the Z136 series of laser safety standards, the Z136.1 is the foundation of laser safety programs for industry, military, research and development (labs), and higher education (universities).[9]

- **ANSI Z136.3** – *Safe Use of Lasers in Health Care*

  Provides guidance for individuals who work with high power Class 3B and Class 4 lasers and laser systems in health care (including, but not limited to: Operating room personnel designated as Laser Safety Officer (LSO)[10]

- **ANSI Z136.4** – *Recommended Practice for Laser Safety Measurements for Hazard Evaluation*

  Provides guidance for measurement procedures necessary for the classification and evaluation of optical radiation hazards.[11]

- **ANSI Z136.5** – *Safe Use of Lasers in Educational Institutions*

  This standard addresses laser safety concerns in educational settings.[12]

- **ANSI Z136.6** – *Safe Use of Lasers Outdoors*

  This standard provides guidance for the safe use of lasers in an outdoor environment, e.g., construction, displays/laser lightshows, scientific/astronomical research, and military (DoE/DoD).[13]

- **ANSI Z136.7** – *Testing and Labeling of Laser Protective Equipment*

  The objective of this standard is to provide reasonable and adequate guidance on the test methods and protocols used to provide eye protection from lasers and laser systems.[14]

The U.S. Food and Drug Administration (FDA) requires all class IIIb and class IV lasers offered in commerce in the US to have five standard safety features: a key switch, a safety interlock dongle, a power indicator, an aperture shutter, and an emission delay (normally two to three seconds). OEM lasers, designed to be parts of other components (such as DVD burners) are exempt from this requirement. Some non-portable lasers may not have a safety dongle or an emission delay, but have an emergency stop button and/or a remote switch