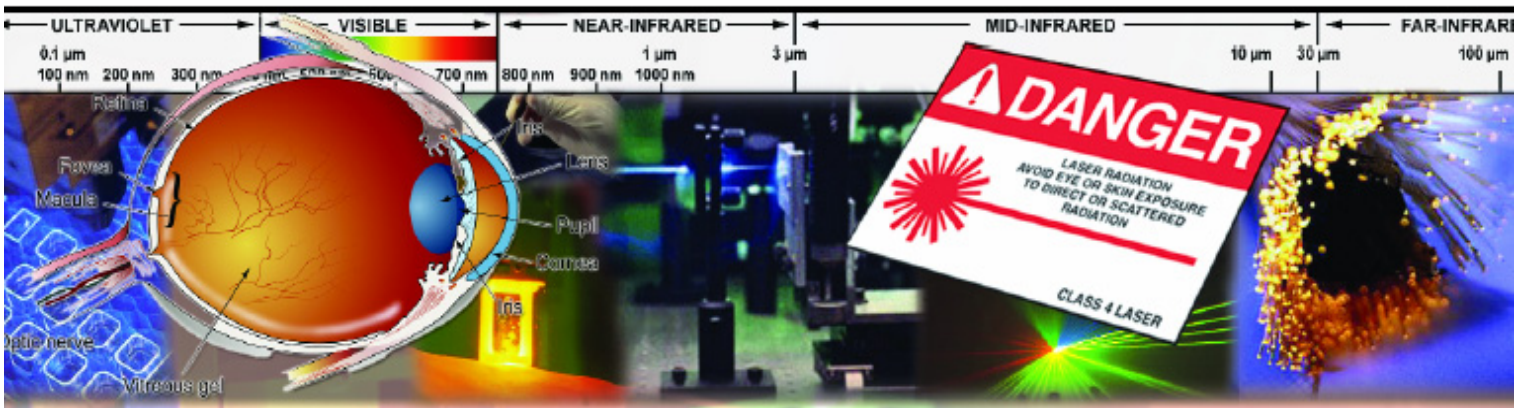
Laser Institute of America
Laser Applications and Safety

alliance
An OSHA Cooperative Program

laser safety
Information Bulletin
激光安全
信息手册



本简明手册是由美国激光学会（LIA）和职业安全与健康管理联盟（OSHA）编写的。OSHA 和 LIA 认识到为了培养更为安全和健康的工作场所而建立一种合作关系的价值。本简明手册宗旨是针对激光新用户所关心的与激光安全有关的问题给予培训。

This brief bulletin has been prepared as a product of the Laser Institute of America (LIA) and the Occupational Safety and Health Administration (OSHA) Alliance. OSHA and LIA recognize the value of establishing a collaborative relationship to foster safer and healthier American workplaces. This brief bulletin is intended to educate new laser users on the concerns and issues related to laser safety.

What is a Laser?

LASER is an acronym which stands for Light Amplification by Stimulated Emission of Radiation. The energy generated by the laser is in or near the optical portion of the electromagnetic spectrum (see Figure 1). Energy is amplified to extremely high intensity by an atomic process called stimulated emission. The term "radiation" is often misinterpreted because the term is also used to describe radioactive materials or ionizing radiation. The use of the word in this context, however, refers to an energy transfer. Energy moves from one location to another by conduction, convection, and radiation. The color of laser light is normally expressed in terms of the laser's wavelength. The most common unit used in expressing a laser's wavelength is a nanometer (nm). There are one billion nanometers in one meter.

什么是激光？

LASER 是 Light Amplification by Stimulated Emission of Radiation 的缩写。激光产生的能量在电磁光谱（图 1）中的光部分内或附近。能量由一个叫做受激辐射的原子过程放大到极高的程度。这里的术语“辐射”经常被误解，因为该术语也用来描述放射性材料和电离辐射。然而，本书中辐射一词是指能量转换。能量通过传导、对流和辐射从一个位置移动到另一个位置。激光的颜色一般用激光的波长来表述。最常用的激光波长单位是纳米（nm）。一米等于 10 亿纳米。

Laser Hazards

Laser Beam Hazards

The laser produces an intense, highly directional beam of light. If directed, reflected, or focused upon an object, laser light will be partially absorbed, raising the temperature of the surface and/or the interior of the object, potentially causing an alteration or deformation of the material.

激光危害

激光束危害

激光产生高强度和高方向性的光束。如果对准、反射或聚焦到一个物体上，激光将部分被吸收，会使物体表面或内部温度升高，引起材料的局部变化或变形。

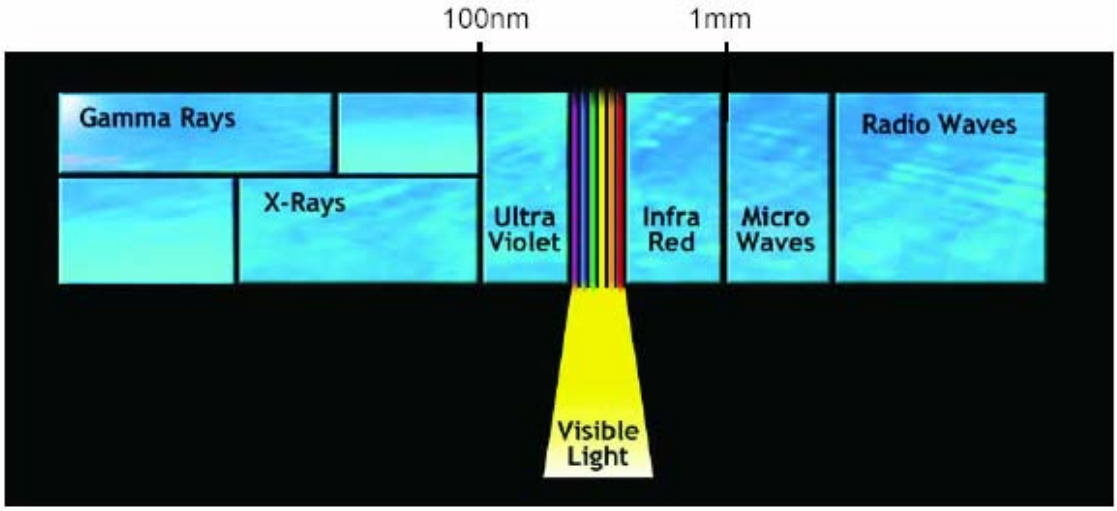


Figure 1. The optical spectrum. Laser light is non-ionizing and ranges from the ultraviolet (100-400 nm), visible (400-700 nm), and infrared (700 nm-1 mm).

Lasers have the potential to damage both the eye and the skin

These properties which have been applied to laser surgery and materials processing can also cause tissue damage. In addition to these obvious thermal effects upon tissue, there can also be photochemical effects when the wavelength of the laser radiation is sufficiently short, i.e., in the ultraviolet or blue region of the spectrum. Today, most high-power lasers are designed to minimize access to laser radiation during normal operation. Lower-power lasers may emit levels of laser light that are not a hazard.

The human body is vulnerable to the output of certain lasers, and under certain circumstances, exposure can result in damage to the eye and skin. Research relating to injury thresholds of the eye and skin has been carried out in order to understand the biological hazards of laser radiation. It is now widely accepted that the human eye is almost always more vulnerable to injury than human skin. The cornea (the clear, outer front surface of the eye's optics), unlike the skin, does not have an external layer of dead cells to protect it from the environment. In the far-ultraviolet and far-infrared regions of the optical spectrum, the cornea absorbs the laser energy and may be damaged. Figure 2 illustrates the absorption characteristics of the eye for different laser wavelength regions. At certain wavelengths in the near-ultraviolet region and in the near-infrared region, the lens of the eye may be vulnerable to injury. Of greatest concern, however, is laser exposure in the retinal hazard region of the optical spectrum, approximately 400 nm (violet light) to 1400 nm (near-infrared) and including the entire visible portion of the optical spectrum.

激光对眼睛和皮肤有潜在的损害

这些性质应用到激光手术和材料加工也会引起组织破坏。此外对这些受明显热影响的组织，当激光波长足够短的时候，即在光谱的紫外或蓝色区域，也会有电化学效应。今天，最高功率的激光器设计要使在正常操作时的激光辐射降到最小。较低功率的激光器可发出无害的激光水平。

人体对特定的激光输出是脆弱的，在特定的环境里，暴露在激光面前会导致眼睛和皮肤的损伤。为了了解激光辐射的生物危害，针对眼睛和皮肤伤害阈值的研究已经在进行。一般来讲，人的眼睛比人的皮肤更脆弱。不像皮肤，角膜（眼球透明的外前表面）没有死细胞的外表层保护。在光谱的远紫外或远红外区域，眼睛的透镜体容易受到损伤。然而，最关注的是在视网膜光谱损害区域，大约 400nm（紫光）到 1400nm（近红外），并包括了光谱的整个可见光部分。

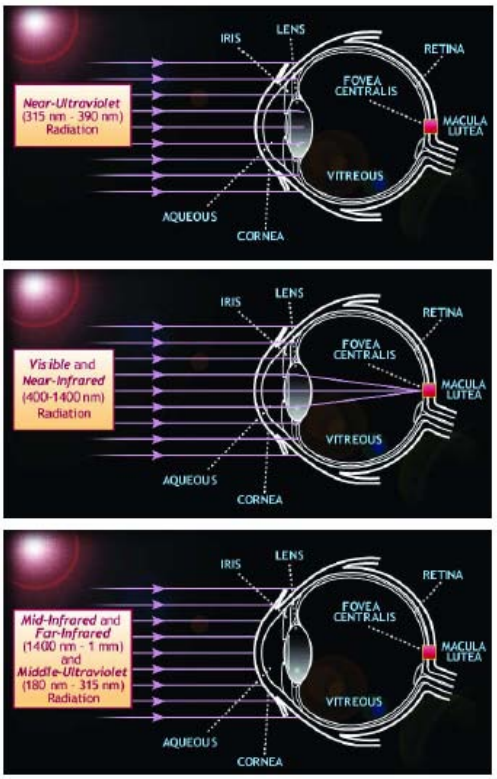


Figure 2. Absorption characteristics of the human eye.

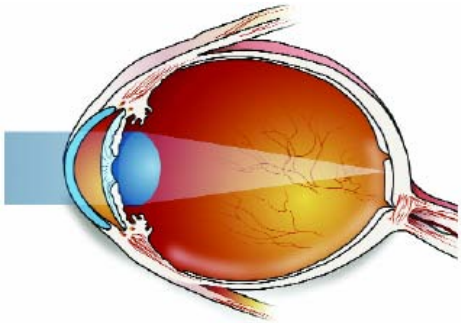


Figure 3. Focussing effects of the human eye.

Within this spectral region collmated laser rays are brought to focus on a very tiny spot on the retina. This is illustrated in Figure 3.

在这个光谱区内，直射的激光可在视网膜上聚焦为一个很细小的斑点。如图 3 所示。

In order for the worst case exposure to occur, an individual's eye must be focussed at a distance and a direct beam or specular (mirror-like) reflection must enter the eye. The light entering the eye from a collimated beam in the retinal hazard region is concentrated by a factor of 100,000 times when it strikes the retina. Therefore, a visible, 1 milliwatt/cm^2 laser beam would result in a 100 watt/cm^2 exposure to the retina, which is more than enough power density (irradiance) to cause damage.

要发生最糟糕的暴露事件，一个人的眼睛肯定是一定距离被聚焦并且直射光束或镜面反射肯定进入眼睛。视网膜危害区的准直光束进入眼睛照射在视网膜后会以 100,000 倍聚集。因此，一束可见的 1 毫瓦/平方厘米的激光将造成 100 瓦/平方厘米照射到视网膜，这是足以引起损伤的功率密度（照度）。

If the eye is not focussed at a distance or if the beam is reflected from a diffuse surface (not mirror-like), much higher levels of laser radiation would be necessary to cause injury. Likewise, since this ocular focussing effect does not apply to the skin, the skin is far less vulnerable to injury from these wavelengths.

如果眼睛不是在一定距离被聚焦，或光束是由漫散的表面（非镜面）反射，引起损伤需要更高水平的激光辐射。同样，由于这种眼部聚焦效果不适用于皮肤，皮肤受到此类波长的损害很小。

Non-Beam Hazards

In addition to the direct hazards to the eye and skin from the laser beam itself, it is also important to address other hazards associated with the use of lasers.

These non-beam hazards, in some cases, can be life threatening, e.g., electrocution, fire, and asphyxiation. Table 1 indicates some of the potential non-beam hazards associated with laser usage. Because of the diversity of these hazards, the employment of safety and/or industrial hygiene personnel to effect the hazard evaluations may be necessary.

Table 1 - Non-Beam Hazards Associated with Laser Use

Noise
X-Radiation
Fire
Explosion
Electrical
Plasma Radiation
Compressed Gas
Laser Generated Airborne Contaminants (LGAC)

非光束危害

除了激光束本身对眼睛和皮肤的直接危害，列出激光应用有关的其它危害也很重要。

在某些情况下，这些非光束危害可能造成生命威胁，例如，触电、火灾和窒息。表 1 列出了与激光应用有关的潜在非光束危害。由于这些危害的多样性，雇用安全或工业卫生专业人员进行有效危害评估是必要的。

表 1 与激光应用有关的非光束危害

噪音
X 线辐射
火灾
爆炸
触电
等离子辐射
压缩气体
激光产生的悬浮物污染物（LGAC）

Safety Standards

There are a variety of laser safety standards including Federal and state regulations, and non-regulatory standards.

OSHA Standards

The regulatory administration of the U.S. Department of Labor with the responsibility of assuring a safe work place is vested in the Occupational Safety and Health Administration (OSHA). At this time, OSHA does not have an all encompassing and comprehensive laser standard. There is an OSHA standard which covers the use of lasers in the construction field only (29 CFR 1926).

However, there have been OSHA citations issued relative to lasers using the authority vested under the "general duty clause" of Public Law 91-596; the Occupational Safety and Health Act of 1970. In these cases, the OSHA inspectors have asked the employers to revise their reportedly unsafe work-place using the recommendations and requirements of such industry consensus standards as the ANSI Z 136.1 Standard. For more information, see the Laser Safety and Health Topics Page at www.osha.gov.

ANSI Z136 Laser Safety Standards

The most important and most often quoted laser safety standard is the American National Standards Institute's Z136 series of laser safety standards. These are consensus standards that represent the standard of safety and are the foundation of laser safety programs in industry, medicine, research, and government. The ANSI Z136 series of laser safety standards are referenced by OSHA and many U.S. states as the basis of evaluating laser-related occupational safety issues. For example, OSHA may refer to ANSI Z136 standard when applying the "General Duty Clause."

ANSI Z136.1 *Safe Use of Lasers*, the parent document in the Z136 series, provides information on how to classify lasers for safety, laser safety calculations and measurements, laser hazard control measures, and recommendations for Laser Safety Officers and Laser Safety Committees in all types of laser facilities.

It is designed to provide the laser user with the information needed to properly develop a comprehensive laser safety program.

安全标准

有很多激光安全标准，包括联邦和州立的规章和非规章标准等。

OSHA 标准

有确保安全工作场所责任的美国劳动部的规章管理在职业安全与健康管理（OSHA）中实施。此时，OSHA 还没有一个全面的和综合性的激光标准。仅有一个在建筑领域覆盖激光用户的 OSHA 标准（29CFR1926）。

然而，现在已经有了在公共法 91－596 的“通则条款”下权威实施的与激光有关的 OSHA 引文；1970 年的职业安全与健康条例。在这些情况下，OSHA 监督员要求雇主采用工业协商标准如 ANSI Z136.1 标准给出的建议和要求改进报告的不安全工作场所。更多信息，见激光安全和健康主题网页 www.osha.gov.

ANSI Z136 激光安全标准

最重要和最常引用的激光标准是美国国家标准研究院的 Z136 系列激光标准。这些协商标准代表了激光安全标准，是激光安全计划在工业、医疗、研究和政府的基础。ANSI Z136 系列激光安全标准被 OSHA 和许多美国州作为评估激光有关的职业安全事件的基础。例如，OSHA 在实施“通则条款”时可参考 ANSI Z136 标准。

ANSI Z136.1 激光的安全使用，Z136 系列中的母版文件，提供了关于如何针对安全、激光安全计算和测量，给所有类型激光设施的**激光安全官员**和**激光安全委员会的建议**，对激光分类的信息。

按设计提供激光用户以适当发展综合激光安全计划所需的信息。

FDA Standards

For manufacturers of laser products, the standard of principal importance is the regulation of the Center for Devices and Radiological Health (CDRH), Food and Drug Administration (FDA), which regulates product performance. All laser products sold in the USA since August 1976 must be certified by the manufacturer as meeting certain product performance (safety) standards, and each laser must bear a label indicating compliance with the standard and denoting the laser hazard classification.

FDA 标准

对激光产品制造厂来讲，最重要的标准是**仪器和射线健康中心（CDRH）**，规范产品特性的**食品和药品管理中心（FDA）**的规章。1976 年 8 月以来在美国销售的所有激光产品必须由制造商证明满足特定的产品性能（安全）标准，每种激光必须佩带符合标准的标签并指明激光的危害等级。

Laser Hazard Classification

Research studies, along with an understanding of the hazards of sunlight and conventional, man-made light sources have permitted scientists to establish safe exposure limits for nearly all types of laser radiation. These limits are generally referred to as Maximum Permissible Exposures (MPE's) by laser safety professionals. In many cases it is unnecessary to make use of MPE's directly. The experience gained in millions of hours of laser use in the laboratory and industry has permitted the development of a system of laser hazard categories or classifications. The manufacturer of lasers and laser products is required to certify that the laser is designated as one of four general classes, or risk categories, and label it accordingly. This allows the use of standardized safety measures to reduce or eliminate accidents depending on the class of the laser or laser system being used. The following is a brief description of the four primary categories of lasers:

激光危害分类

随着人们对阳光和常规人造光源危害的理解加深，研究成果允许科研人员可以对几乎所有激光辐射设立安全暴露极限。这些极限通常被激光安全专业人员看做**最大允许暴露（MPE’s）**值。一般情况下不需要直接利用 MPE’s 值。在实验室和工业上百万小时的激光应用经验已经允许发展激光危害分类或等级的体系。激光器和激光产品制造商需要证明其激光是四类或危害分类中的一种，并标识出来。这就允许使用标准的安全测量方法根据激光或激光系统的种类来减少或消除意外发生。以下是四种主要的激光分类的简要描述；

Class 1

A Class 1 laser system is considered to be incapable of producing damaging radiation levels during operation, and exempt from any control measures or other forms of surveillance. Although some Class 1 lasers emit very weak, non-hazardous beams, most Class 1 laser systems incorporate "embedded" higher-power lasers, which can be accessed only if important safety features such as interlocks are defeated or deliberately bypassed as sometimes done during servicing. In this case, the system temporarily reverts back to the original laser classification (requiring special safety procedures).

NOTE: Products which have been previously classified as Class 2a should be treated the same as Class 1.

1 类

1 类激光系统被认为在操作过程中不能产生可造成损伤水平的辐射，不用采取任何控制措施或其它形式的监管。尽管某些一类激光发出很微弱的无害光束，多数一类激光系统混和“嵌入”的高功率激光，而高功率激光只有在重要的安全特点比如联锁被打破或像在服务期有时做的那样精心绕过的时候才能允许。这种情况下，系统暂时回复到原始激光分类（需要特殊的安全程序）。

注：以前分类为 2a 类的产品应按一类处理。

Class 1M
A Class 1M laser system is considered to be incapable of producing hazardous exposure conditions during normal operation unless the beam is viewed with an optical instrument such as an eye-loupe (diverging beam) or a telescope (collimated beam), and is exempt from any control measures other than to prevent potentially hazardous optically aided viewing; and is exempt from other forms of surveillance.

1M 类
1M 类激光系统被认为在正常操作条件下不能产生有害的暴露，除非用光学仪器观察，比如眼罩（eye-loupe）（发散光束）或放大镜（准直光束）；除了要避免光学辅助观察的潜在危害不用采取任何控制措施；不需要进行其它形式的监管。

Class 2
A Class 2 laser system emits in the visible portion of the spectrum (400-700 nm), and eye protection is normally afforded by the human aversion response, which is .25 second.

2 类
2 类激光系统发出可见光谱（400－700nm），一般人的 0.25 秒反感反应可使眼睛得到保护。

Class 2M
A Class 2M laser system emits in the visible portion of the spectrum (400-700 nm), and eye protection is normally afforded by the human aversion response for unaided viewing. However, Class 2M is potentially hazardous if viewed with certain optical aids.

2M 类
2M 类激光系统发出可见光谱（400－700nm），对无助观察来说一般人的反感反应可使眼睛得到保护。然而，如果用特定的光学辅助观察可有潜在的危害。

Class 3 (medium-power)
Class 3 laser systems may be hazardous under direct and specular reflection viewing conditions, but is normally not a diffuse reflection hazard or fire hazard. There are two subclasses, Class 3R and Class 3B. A Class 3R laser system is potentially hazardous under some direct and specular reflection viewing conditions if the eye is appropriately focused and stable, but the probability of an actual injury is small. This laser will not pose either a fire hazard or diffuse reflection hazard. A Class 3B laser system may be hazardous under direct and specular viewing conditions, but is normally not a diffuse reflection or fire hazard.

NOTE: Products which have been previously classified as Class 3a should be treated the same as Class 3R.

3 类（中等功率）
3 类激光系统在直接和镜面反射条件下观察可能有害。但一般不是散射危害或燃烧危害。有 2 个亚类，3R 类和 3B 类，如果眼睛被适当聚焦并稳定，一个 3R 类激光系统在直射和镜面反射观察条件下有潜在危害，但实际损伤可能性很小。这种激光既不会造成燃烧危害也不会造成散射危害。一个 3B 激光系统在直接和镜面反射观察条件下可能是危险的，但一般不会是散射或燃烧危害。

注：以前分类为 3a 类的产品应按等同 3R 类处理。

Class 4 (high-power)
A Class 4 laser system is a hazard to the eye and skin from the direct beam, and may pose a diffuse reflection or fire hazard, and may also produce laser generated airbourne contaminants and hazardous plasma radiation.

4 类（高功率）
直对 4 类激光光束对眼睛和皮肤是有危害的，并可造成散射或燃烧危害，也可以产生悬浮污染物和有害的等离子体辐射。

The Laser Safety Officer (LSO)

ANSI Z136.1 specifies there shall be a designated LSO for all circumstances of operation, maintenance, and service for a Class 3B or Class 4 laser or laser system.

This person should have the authority and responsibility to monitor and enforce the control of laser hazards. This person is also responsible for the evaluation of laser hazards and the establishment of appropriate control measures.

激光安全员（LSO）

ANSI Z136.1 指出，对 3B 类或 4 类激光或激光系统，在所有操作、维护和服务环境下，应指定激光安全员。

这个人应有权威和责任监督和加强激光危害的控制。这个人也有责任评估激光危害并采取适当的控制措施。

For Class 3B and 4 lasers, a Laser Safety Officer shall be designated to oversee safety

对 3B 类和 4 类激光，应任命一个激光安全员来监督安全

The Laser Safety Officer (LSO) may be a full or part-time position depending on the demands of the laser environment. This person may be someone from occupational health and safety, industrial hygiene, or similar safety related departments. The LSO may also be part of the engineering or production department. In any case, the LSO must be provided the appropriate training to properly establish and administer a laser safety program.

激光安全员（LSO）根据激光环境要求可以是全职的或兼职的岗位。此人可来自职业健康和安全、工业卫生，或类似的安全有关的部门。LSO 也可以是工程或产品部门的一员。任何情况下，LSO 必须有适当的培训以便建立和管理一个激光安全程序。

Some of the duties the LSO may perform include hazard evaluation and establishment of hazard zones, control measures and compliance issues, approval of Standard Operating Procedures (SOP's) and maintenance/service procedures, approval of equipment and installations, safety training for laser personnel, recommendation and approval of personal protective equipment, and other administrative responsibilities.

LSO 可以履行的责任包括危险评估和规划危险区域，控制措施和守则发布，批准标准操作程序（SOP's）和维护/服务程序，批准设备安装，激光从业人员安全培训，推荐和批准个人防护设施，以及肩负其它管理责任。

Z136 Recommendations for Controlling Laser Hazards

Like any other potentially hazardous operation, lasers can be used safely through the use of suitable facilities, equipment, and well trained personnel. The ANSI Z136.1 *Safe Use of Lasers* standard provides a detailed description of control measures which can be put into place to protect against potential accidents.

These control measures are divided into two distinctive categories, Engineering Controls and Administrative/Procedural Controls. Examples of Engineering Controls include protective housings and interlocks, protective filter installations, key-controls, and system interlocks. Administrative/Procedural Controls include standard operating procedures and personal protective equipment including laser eyewear. Engineering Controls are generally more costly to develop but are considered far more reliable by removing the dependence on humans to follow rigorous procedures and the possibility of personal protective equipment failure or misuse.

Administrative/Procedural Controls are designed to supplement Engineering Controls to assure that laser personnel are fully protected from potential laser hazards. The focus of these controls are to provide adequate education and training, provisions for protective equipment, and procedures related to the operation, maintenance and servicing of the laser.

Safety training is required for those working with Class 3 or Class 4 lasers and systems. Operation within a marked, controlled area is also recommended. For Class 4 lasers or systems, eye protectors are almost always required and facility interlocks and further safeguards are used. Control measures for each laser classification are defined fully in the ANSI Z136.1 *Safe Use of Lasers* standard. **This document is the single most important piece of information regarding the safe use of lasers and should be part of every laser safety program.** Other standards in the ANSI Z136 series include:

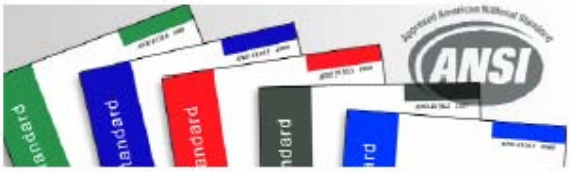
Z136 控制激光危害建议

像其它任何潜在危险操作一样，通过使用适当的设施和训练有素的人员，激光可被安全使用。ANSI Z136.1 **激光安全使用**标准详细描述了避免潜在意外发生的控制措施。

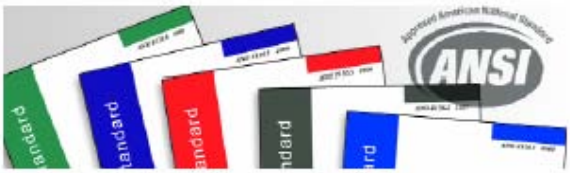
这些控制措施被分为两个不同类别，工程控制和管理/程序控制。工程控制的实例包括保护房屋和联锁装置，保护过滤安装，键盘控制，和系统联锁。管理/程序控制包括标准操作规程和人员保护设施如激光眼罩。总的来讲，工程控制的发展比较昂贵，但通过除去依赖于人，遵守严格的程序，在人员保护设备失效或误用的可能性，被认为更为可靠。

管理/程序控制被设计用于补充工程控制措施以确保激光从业人员得到完全的保护。这些控制的焦点是提供足够的教育和培训，提供保护设施，以及与激光操作、维护和服务相关的程序。

工作在 3 类或 4 类激光和系统时需要进行安全培训。也推荐在一个标刻的、受控制的范围内操作。对 4 类激光或系统而言，眼睛保护总是需要的，设备联锁和进一步的安全警报也要采用。对每一种激光分类的控制措施在 ANSI Z136.1 激光安全使用标准中被完全定义。**本文件为单一最重要的一条关于激光安全使用的信息，应该是每种激光安全计划的一部分**。ANSI Z136 中其它标准包括：



- ANSI Z136.2 - *Safe Use of Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources*
- ANSI Z136.3 - *Safe Use of Lasers in Health Care Facilities*
- ANSI Z136.4 - *Recommended Practice for Laser Safety Measurements for Hazard Evaluation*
- ANSI Z136.5 - *Safe Use of Lasers in Educational Institutions*
- ANSI Z136.6 - *Safe Use of Lasers Outdoors*



- ANSI Z136.2 – 使用激光二极管和 LED 光源光纤通讯系统安全使用
- ANSI Z136.3— 健康护理设施中激光安全使用
- ANSI Z136.4- 有害评估激光安全测量建议方法
- ANSI Z136.5—教育机构激光安全使用
- ANSI Z136.6- 户外激光安全使用

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