LASER LIGHT SHOW SAFETY

WHO'S RESPONSIBLE?

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INTRODUCTION

Laser light is one of the most exciting visual phenomena to illuminate the entertainment scene in recent years. Laser light shows have been used to complement the music of such diverse groups as the Philadelphia Orchestra and rock groups like KISS, WINGS, and the Electric Light Orchestra. Lasers are becoming routine features of planetariums, discotheques, conferences, amusement parks, state fairs, and even shopping malls.

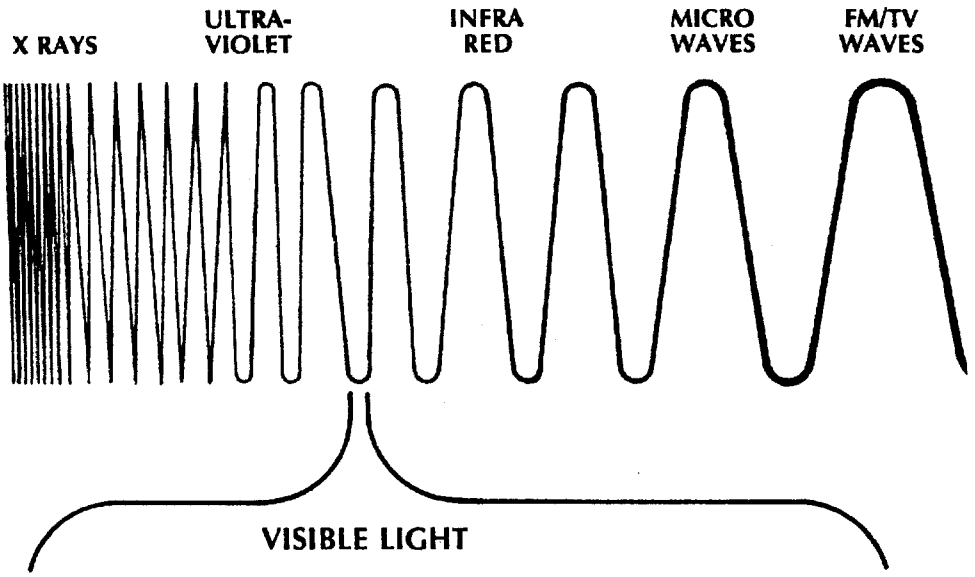
As beautiful as they can be, high power laser beams can be dangerous if they are not used with a serious concern for safety. Accidental exposure to a high power laser beam can cause permanent eye damage and severe skin burns. With laser shows that are designed and/or operated by competent and conscientious people, the chance of such accidents is negligible. Unfortunately, however, several light shows have been operated in a haphazard and hazardous manner.

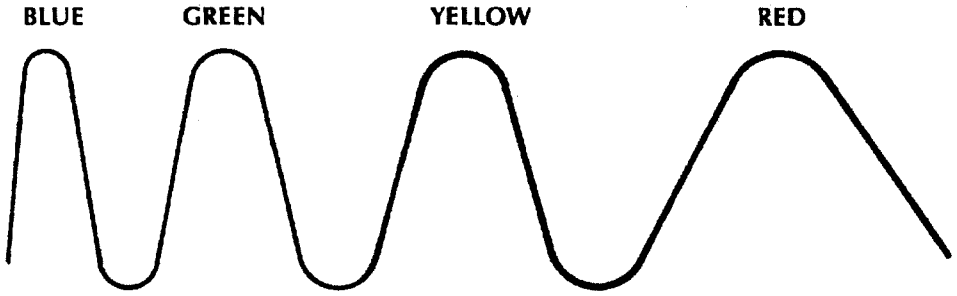
The Food and Drug Administration is the Federal agency responsible for protecting the public from radiation hazards from electronic products, including lasers. FDA's authority includes regulating the manufacture and assembly of lasers, requiring corrective action for those that do not comply with the safety regulations and educating people about laser safety. Several State radiation agencies are also active in the control of laser products and their use.

The laser products that are in compliance with the laser standard have certain safety features to reduce the chance of accidents. But such efforts cannot ensure absolute safety. It is up to the laser operator and other responsible parties to see that the laser is used in a safe manner.

We hope this booklet will help those who sponsor, arrange for, set up, insure or are otherwise involved with light shows, to carry out their part in laser safety. The booklet assumes no technical background. It describes the possible hazards, government requirements and individual responsibilities in laser light shows. The relevant government offices are included so people can get more information on their responsibilities and other aspects of laser light show safety.

SPECTRUM OF RADIATIONS





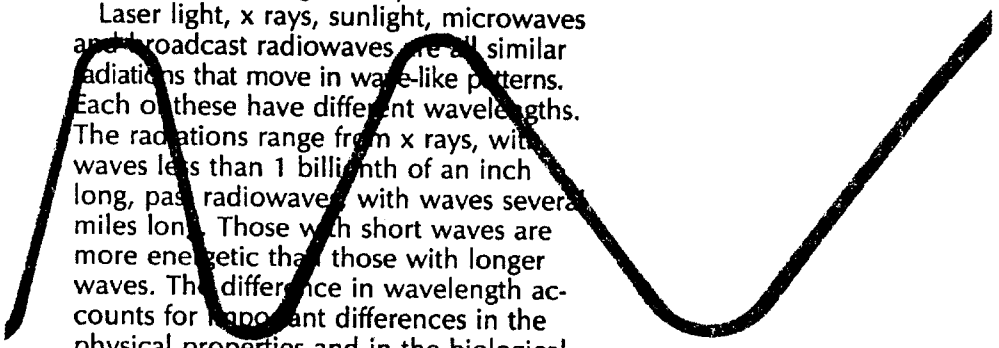
Chapter I

BACKGROUND

A WORD ABOUT RADIATION AND LASER LIGHT

The fact that lasers give off radiation may be a surprise to some. Let's clarify this point right away.

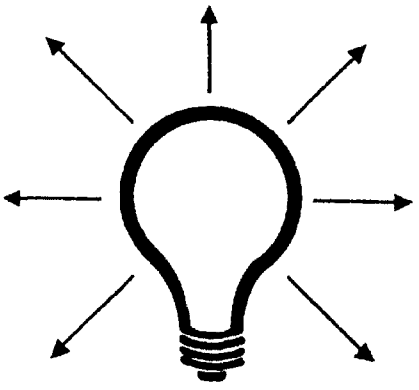
Laser light, x rays, sunlight, microwaves and broadcast radiowaves are all similar radiations that move in wave-like patterns. Each of these have different wavelengths. The radiations range from x rays, with waves less than 1 billionth of an inch long, past radiowaves with waves several miles long. Those with short waves are more energetic than those with longer waves. The difference in wavelength accounts for important differences in the physical properties and in the biological effects of the various types of radiations.

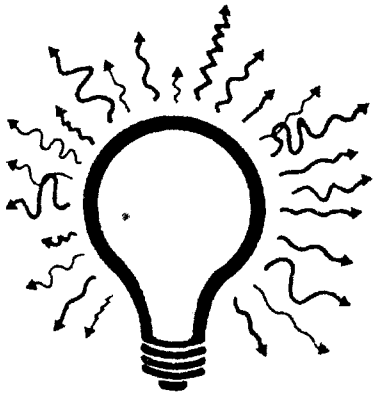


So, although laser light is part of this family of radiations, it should not be confused with the others. For example, unlike x rays or radioactivity, visible light radiation has not been associated with causing cancer or genetic damage.

Light radiation falls on the spectrum of radiations ranging from ultraviolet through infrared (or heat). Within this range, only a small band of wavelengths is visible to the human eye. Each color that we see is actually light radiation of a particular wavelength. Visible light spans from violet, with short waves, to red, with longer waves. Lasers generally give off visible or optical radiation; some lasers can also give off radiation in the ultraviolet or infrared ranges that we can't see. Of course, lasers used in light shows give off visible radiation.

LASERS

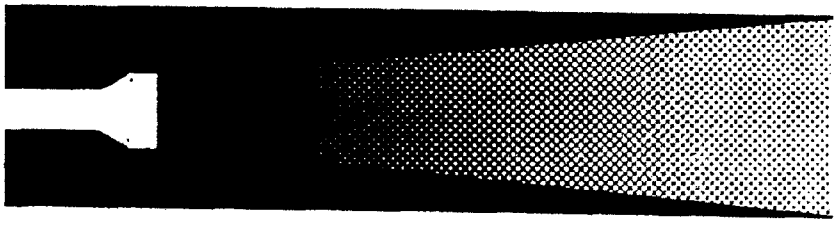




Essentially, the laser light that creates such spectacular and exotic effects, is the same radiation that comes from an ordinary light bulb... but it has some important differences. Laser light can have the purest and brightest of colors. And it can be thousands of times more intense than the light by which we read.

The light from a light bulb radiates in all directions. If you were able to separate and trace the waves of light, you'd see a jumble of different wavelengths, and directions. In the light from a light bulb all the colors of the spectrum (i.e., the various wavelengths) are present and add to each other so that the light appears white.

Because the light from a light bulb spreads out, its power falls off or decreases as you move farther away. This is because of a property called "divergence." Think of a flashlight, whose light beam spreads out as you move farther away from it. This divergence or spreading out of the beam means that the power of the light is spread over an increasingly larger area as you move farther away.

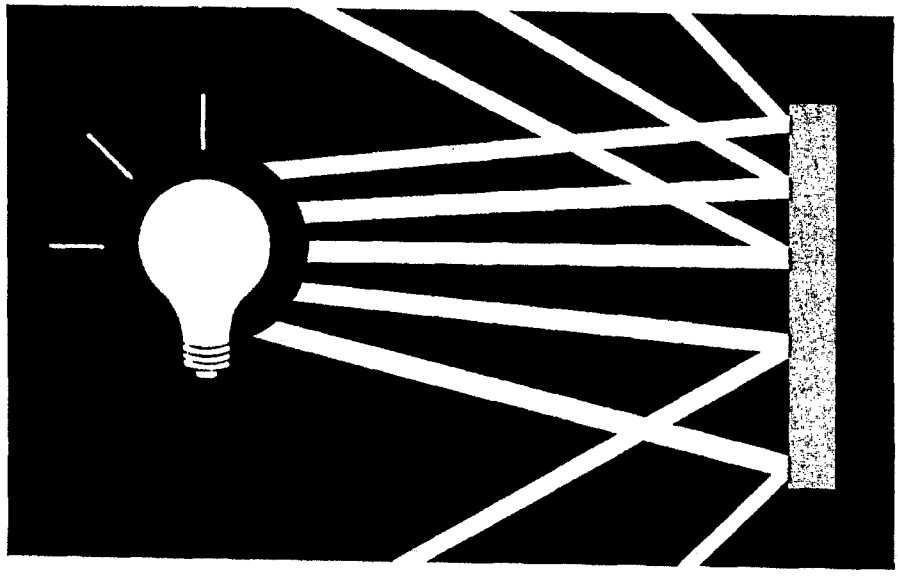


A Special Kind of Light

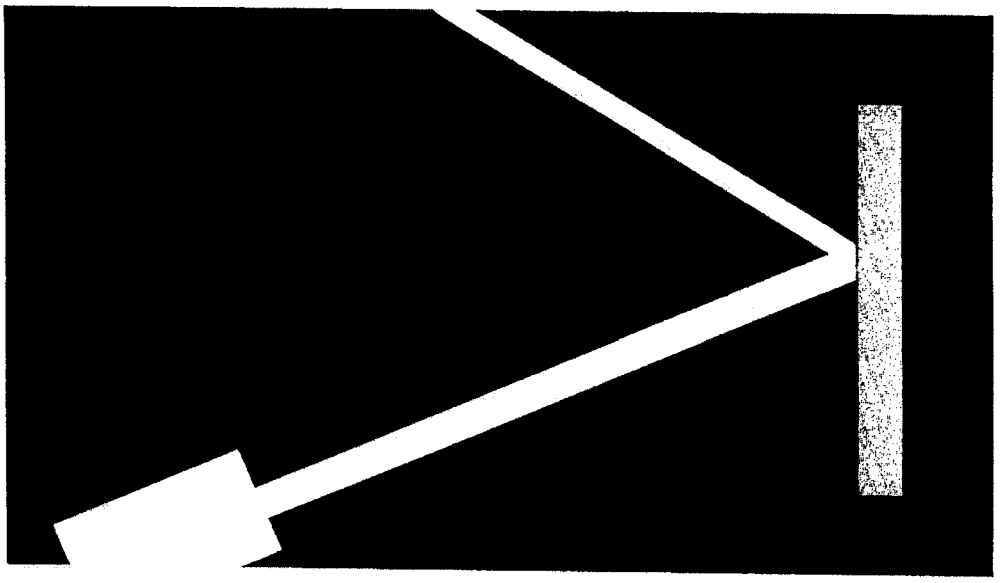
Laser light is quite different. All the light waves in a laser beam can have the same wavelength. Furthermore, they are in phase with each other. They travel in locked-step or synchronized patterns. This unique property of laser light is called "coherence." Again, color depends upon the wavelength. Since a laser beam is composed of light of the same wavelength, it has an extraordinarily pure color.

And, most important, unlike the flashlight, a laser beam does not diverge or spread out very much. The laser light can travel in a very narrow beam even over long distances. Because of this, its power can be extremely concentrated. In fact, some lasers can produce a beam of light that, even miles away, can be thousands of times brighter than the sun's surface appears from earth. The fact that a laser beam can retain such high power, even over long distances, partly accounts for its use in light shows and many other applications. But this same fact also accounts for its potential hazard.

A laser beam loses very little power when it is reflected off a smooth, shiny surface. When the light from a light bulb is reflected off a mirror, it continues to diverge and spread its energy over even larger areas. When a laser beam is reflected off a mirror or other smooth, shiny surfaces, such as water, glass, metal beams or a glossy floor, it still does not diverge very much. So a reflected laser beam can have almost the same power and potentially the same hazard as a direct laser beam.

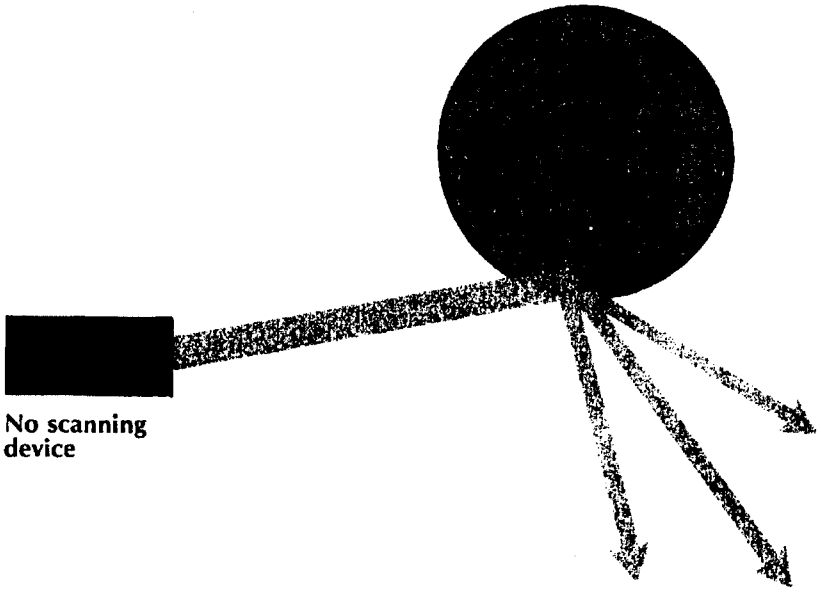


Ordinary light reflects off a mirror and its beam continues to diverge.



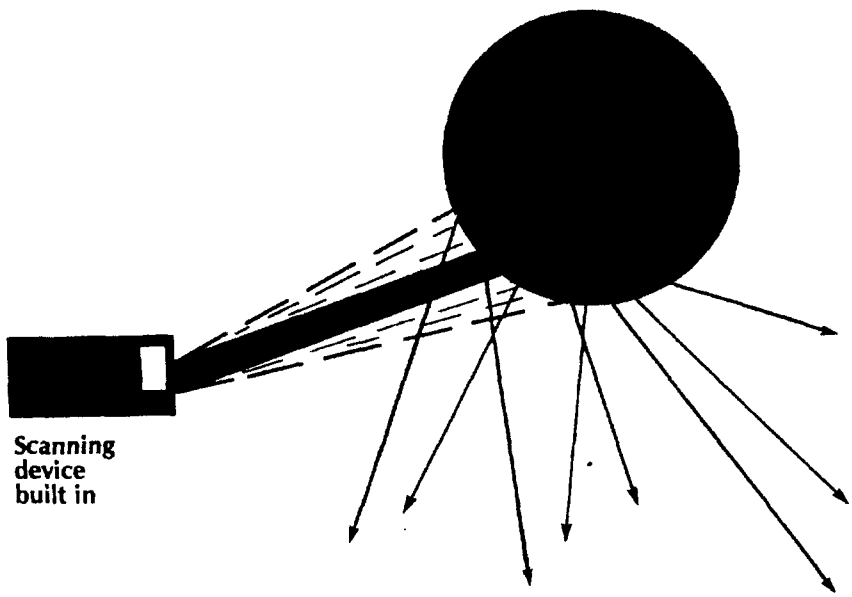
Laser light reflects
off a mirror and still
does not diverge very much

Mirror balls are frequently used in light shows to separate and reflect the laser beam into many rays of laser light. When done properly, this can significantly reduce the power and, therefore, the potential hazard of a laser beam. If the beam is reflected off enough facets on the mirror ball, the resulting rays will go off in many directions. Although the individual rays still do not diverge very much, each has only a fraction of the power in the direct beam. Obviously, the degree of safety that this can produce depends upon the power of the direct laser beam, and the number of rays and directions into which the beam is split.



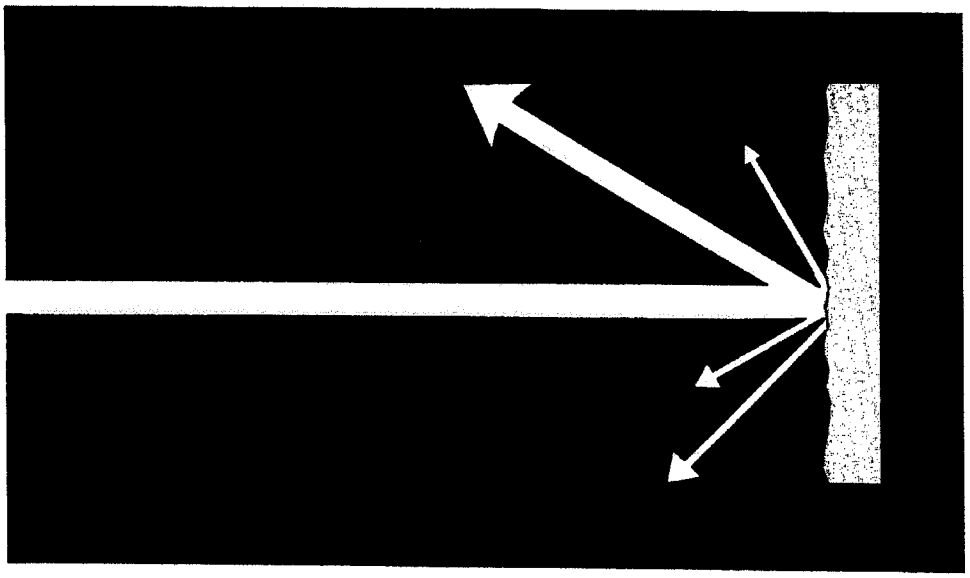
No scanning device

The more rays into which the beam is split, the smaller the fraction of power each reflected ray will have. A scanning device is usually used to sweep the beam back and forth across a broad section of the mirror ball so that the beam is broken up by several facets on the ball. Rotating the mirror ball can provide even more safety because the movement of the reflected rays reduces any exposure time. Without a scanning device, or without a properly designed scanning system, the beam is broken by the mirror ball into fewer rays, each having a larger fraction of the power in the direct beam. This means that even with a mirror ball there could still be a potential for harm.



Scanning device built in

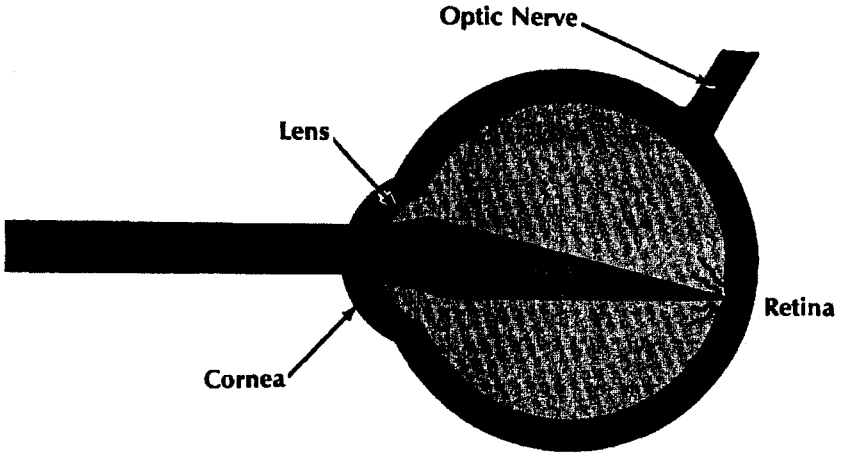
If a laser beam is reflected off a rough or irregular surface, like a concrete wall or even some "walls" of smoke, the irregularities in the surface scatter the beam in many different directions. The beam is forced to diverge and therefore lose some of its power. However, a very high powered laser beam can still retain enough of its intensity after reflecting off a rough or irregular surface to cause injury. In addition, some rough surfaces may have shiny spots that allow for a mirror-like reflection of part of the beam.



LASER HAZARDS

The high powered lasers that are increasingly used in laser shows can produce enough light radiation to cause permanent eye damage as well as severe skin burns. Should any accidental direct exposure occur, there is a high chance of injury to the individual.

The lens and cornea of the eye concentrate light and focus it on the retina. In a sense, the eye acts like a magnifying lens to concentrate the light. The retina translates the light into nerve impulses that travel through the optic nerve to the brain, where an image is



EYE

perceived. If a laser beam enters the pupil of the eye, its power is concentrated by the lens into a smaller area, resulting in more light and heat per unit area. The intensity of the laser beam can actually be increased by 10,000 times or more by the time it reaches the retina! If the laser beam strikes the eye from the side (hitting the area of the eye used for peripheral vision), damage can occur but may not be noticed right away, although a number of burns in this part of the retina might impair vision. If the beam comes directly head on at the eye (striking the eye's area for sharp vision) the burn could result in a very noticeable blind spot or other serious impairments to vision. It may only take a fraction of a second for the damage to occur.

Because the eye focuses light, it is the most sensitive part of the body to laser radiation. But severe skin burns can also be caused by laser light. With some lasers, you can light a cigarette merely by putting the end of it in the laser beam. If the beam has enough power to light a cigarette, you can imagine the kind of skin burns it could cause.

The question of safety or hazard with laser light shows is "To what levels of power might people be exposed?" The mere presence of a high powered laser does not necessarily pose a hazard. Scanning safeguards and other means can be taken to protect people from laser hazards. But:

■ **There is a hazard whenever a high power laser beam could possibly strike someone, particularly in the eyes.**

■ **The beam could be dangerous even if it is reflected off a smooth or shiny surface. If the laser is high enough in power, it could be dangerous even when the beam is reflected off a rough surface or scattered by fog or smoke.**

■ **It only takes a fraction of a second to cause serious injury!**

These are the reasons for the government's safety requirements for laser light shows. But such efforts cannot ensure absolute safety. So it is important that you, as a person involved with producing a laser show, carry out your part in laser safety.

CHAPTER 2

GOVERNMENT REQUIREMENTS

FDA'S REGULATORY STANDARD FOR ALL LASERS

All laser products made since August 1976 must meet the FDA laser performance standard. Each manufacturer of laser products must report to FDA about the types of laser products produced.

The standard divides laser products into four classes, based on the potential for injuring people and the intensity of the radiation in the laser beam (the power of the laser beam is measured in watts*).

■ Class I products produce levels of radiation that have not been found to cause biological damage. Class I visible radiation lasers emit less than 0.39 microwatts (or 0.39 millionths of a watt) continuous output.

*The term "watts," when used to describe laser output, is NOT equivalent to wattage, when used to describe an electric light. Refer to page 28 of Appendix I for an explanation of the distinction.

■ Class II lasers produce radiation that could cause eye damage after direct, long-term exposure. Class II lasers emit less than 1 milliwatt (or 1 thousandth of a watt) continuous output.

■ Class III laser products produce radiation powerful enough to injure human tissue with one short exposure to the direct beam or its direct reflections off a shiny surface. Class III visible radiation lasers emit less than 500 milliwatts (or one-half watt) continuous output.

Class III is subdivided into Classes IIIa and IIIb. Class IIIa is limited to five milliwatts in the visible spectrum. More stringent requirements apply to Class IIIb lasers.

■ Class IV lasers produce radiation so powerful that it can cause injury with a direct or reflected exposure, even when the beam is scattered or diffused by a rough surface or even by some smoke screens. Class IV visible radiation lasers emit more than one-half watt continuous output.

All laser products above Class I, made after August 1976, must have labels that indicate the class to which they belong. Additional safety design and labeling features are required according to the class of the product.

WHAT THE FDA STANDARD MEANS FOR LASER LIGHT SHOWS

FDA's standard was developed when the use of lasers in the entertainment world was in its infancy. Lasers for demonstration purposes fell primarily into Class I or II and the standard reflected this. But because of the low visibility of their beams, Class I and II lasers are not effective with very large crowds. The light shows at concerts and discotheques nowadays often use Class IIIb and even Class IV lasers. FDA recognizes that it is possible to use these high powered lasers in such a way that they will be as safe as Class I and II demonstration lasers as long as the manufacturers can assure safety. FDA does this by means of a "variance." A variance is permission from FDA to deviate from one or more of the requirements of a standard when alternate steps are taken to assure safety. Before May 1980, all of the safety requirements described below were imposed for laser shows except the requirement of an approved variance prior to performance. As of September 20, 1985, the following policy is legally binding:

not already have a variance, must obtain one for each **type** of show performed. Second, all "manufacturers" must submit to FDA a report on all the types of laser products manufactured. A variance must be obtained **before** a laser can be used in a performance or display.

continuous control of an operator, laser radiation above Class II limits must be restricted so that it comes no closer than 6 meters (about 20 feet) above, or 2.5 meters (about 8 feet) on the sides or below the floor where the audience would be.

■ If the laser is under the continuous control of an operator, laser radiation above Class II limits can come no closer than 3 meters (about 10 feet) above or 2.5 meters (about 8 feet) on the sides or below the floor where the audience would be.

■ Appropriate controls must be taken to make sure that unauthorized persons cannot interfere with the safe operation of the laser. A person must be designated as the laser safety officer who will be responsible for shutting down the laser should any unsafe conditions occur (e.g., should individuals in the audience try to get within the direct laser beam by climbing on a chair or someone's shoulders, or should reflective articles be thrown in the beam). In some situations, as when the audience becomes unruly, strict security measures should be taken to keep the laser operating area free and under the full control of the authorized personnel.

■ Other criteria may be included depending upon the particular show. They may include such requirements as compliance with State and local requirements, contacting the Federal Aviation Administration for outdoor shows, certification of operators, use of laser cut-off devices or safety shields, time limitations for particular effects and restrictions on the location of the operator or performers.

■ Once a variance is granted, representatives of FDA must be allowed to inspect the laser equipment and the safety procedures to assure that the conditions of the variance are met.

■ FDA should be notified in writing of all shows at least 1 month in advance. When this is not possible bcause of last minute scheduling, FDA should be notified by telephone as soon as possible and then a written confirmation should be sent to FDA.

Anyone who operates laser light shows without an approved FDA variance or who otherwise violates the FDA laser safety standard may be subject to a court injunction and/or civil penalties (fines up to $300,000) as provided for in Section 360C of the Radiation Control for Health and Safety Act. When FDA becomes aware of a particular laser show that is operated in violation of the law or otherwise in an irresponsible fashion, FDA will notify the manufacturer or operator and require corrective action. If the problem is serious, FDA will also notify the State and local authorities and facility managers who can take additional, immediate legal steps to halt a hazardous show.

To apply for a variance or for more information about the variance status of a particular laser show manufacturer, reporting requirements, variance applications and safe operation of laser light shows, contact:

Office of Compliance HFZ-312
Center for Devices and Radiological Health
8757 Georgia Avenue
Silver Spring, MD 20910
(301) 427-8228

OPEN AIR LASER LIGHT SHOWS AND FAA REQUIREMENTS

Even though the chances are small that an aircraft passenger or pilot would be injured by a laser beam from an outdoors light show, the possibility of harm does exist. Therefore, the Federal Aviation Administration must be notified before any open air laser light shows operate.

- FAA will not object if the output power of the laser beam is less than or equal to one half watt (that is, the laser is Class I, II, or III). As long as aircraft fly no closer than the required 1,000 feet over congested areas or over an outdoor assembly of people, there should be little risk from a laser beam of this power. If the show is adjacent to an airport, however, the FAA may object because of the possible risk to aircraft landing and taking off.

- FAA will not object to open air shows with Class IV laser beam powers between one-half and 12 watts if the laser manufacturer/operator informs FAA of the location, time and laser output sufficiently in advance of the show and if FAA can restrict the air traffic in the area.

- In most cases, FAA will object if the laser beam power is greater than 12 watts. A laser of this power is rarely needed for an effective light show and could require extensive restrictions on air traffic.

Notification to the FAA of a proposed open air laser light show should be made in writing at least 2 weeks and preferably 4 weeks in advance of the performance. FAA can usually respond with a determination within 7 days. The notification should be directed to the Chief of the Airspace and Procedures Branch at the regional office having jurisdiction over the area where the laser show will take place. The addresses and phone numbers of the appropriate office for each area will be found in Appendix II.