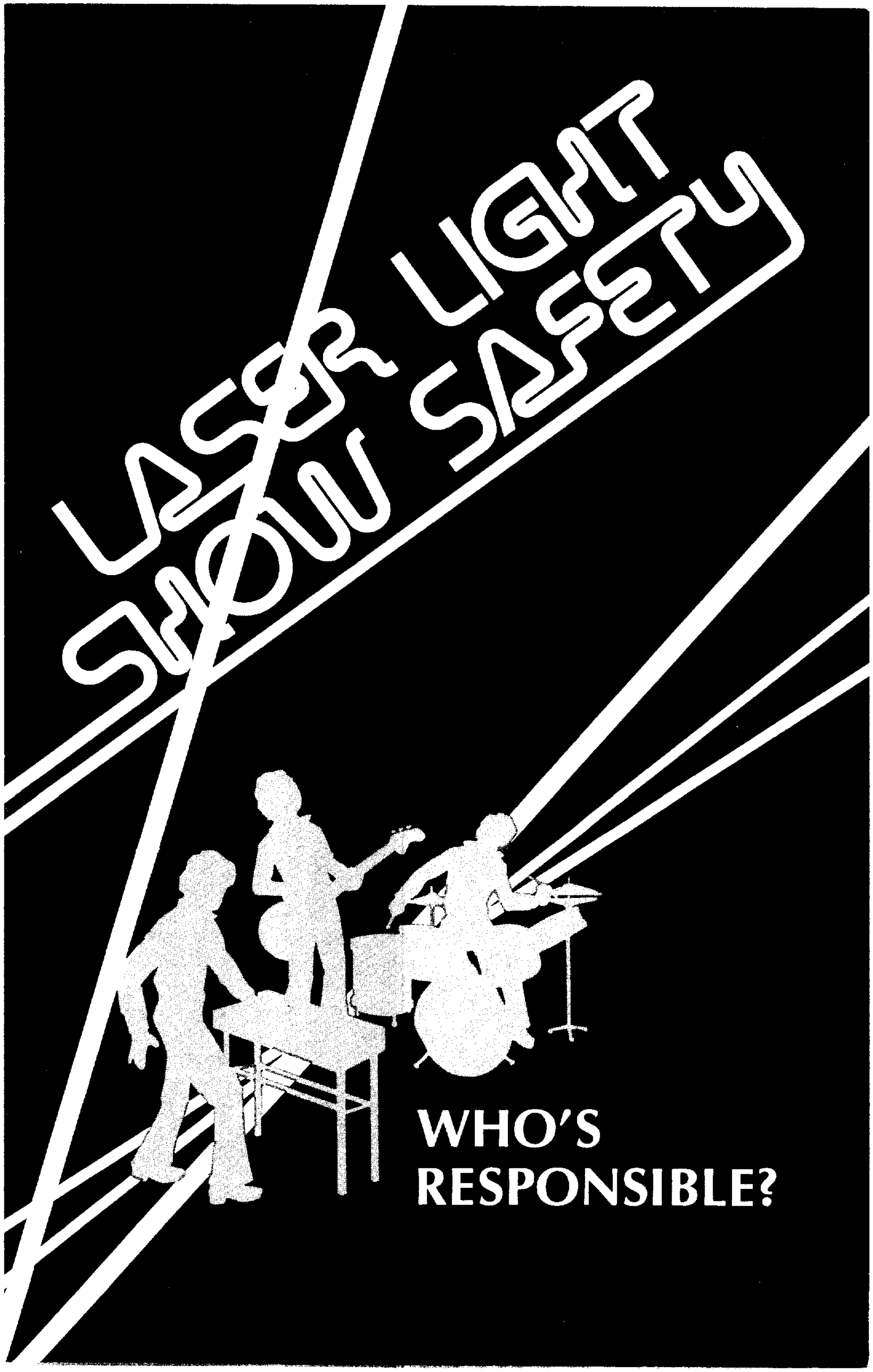
LASER LIGHT
SHOW SAFETY
WHO'S
RESPONSIBLE?

HHS Publication FDA 86-8262

LASER LIGHT SHOW SAFETY

WHO'S RESPONSIBLE?

June 1980

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U.S. Department of Health and Human Services
Public Health Service
Food and Drug Administration
Center for Devices and Radiological Health
Rockville, Maryland 20857

CONTENTS

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.

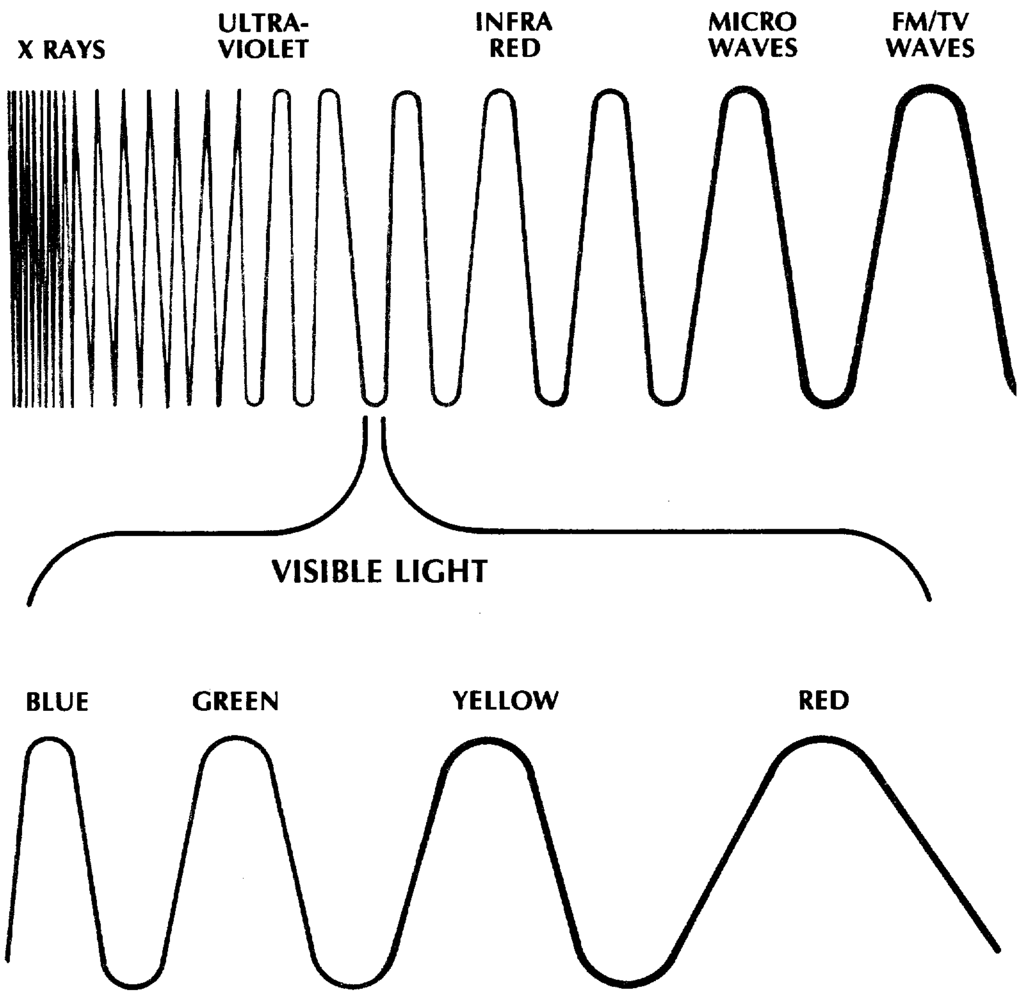
As beautiful as they can be, high power laser beams can be dangerous if they are not used with a serious concern for safety. Accidental exposure to a high power laser beam can cause permanent eye damage and severe skin burns. With laser shows that are designed and/or operated by competent and conscientious 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

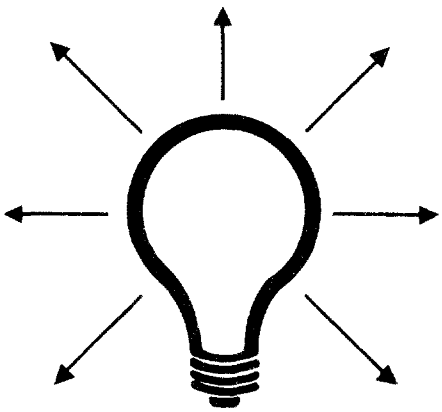
The fact that lasers give off radiation may be a surprise to some. Let's clarify this point right away.

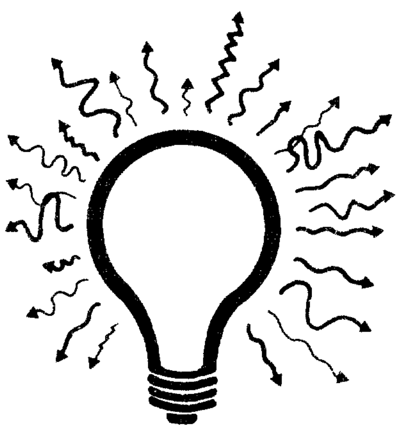
Laser light, x rays, sunlight, microwaves and broadcast radiowaves are all similar radiations that move in wave-like patterns. Each of these have different wavelengths. The radiations range from x rays, with waves less than 1 billionth of an inch long, past radiowaves with waves several miles long. Those 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

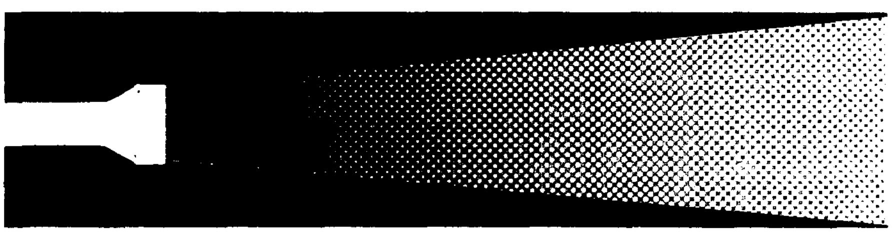




Essentially, the laser light that creates such spectacular and exotic effects, is the same radiation that comes from an ordinary light bulb... but it has some important differences. Laser light can have the purest and brightest of colors. And it can be thousands of times more intense than the light by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

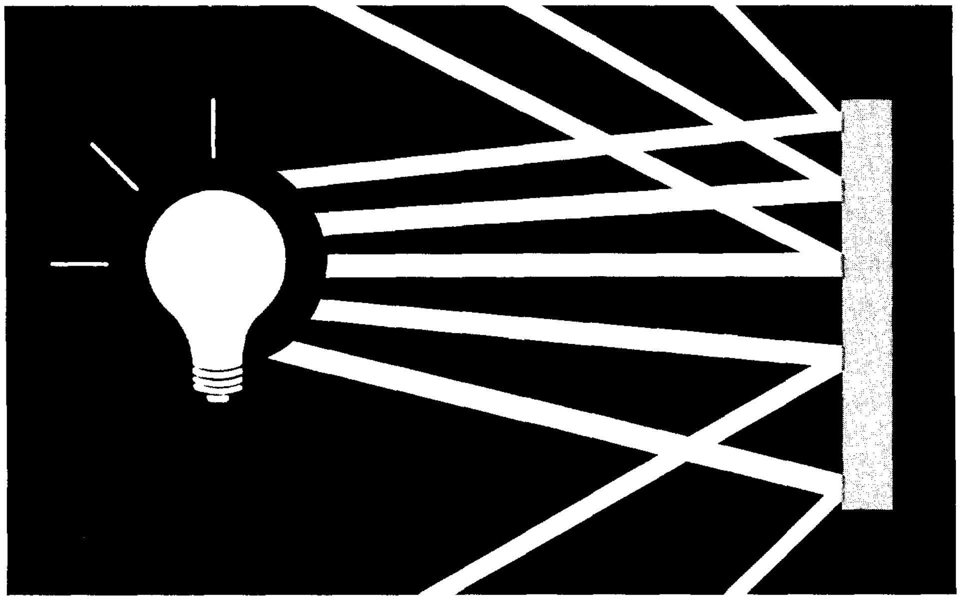


A Special Kind of Light

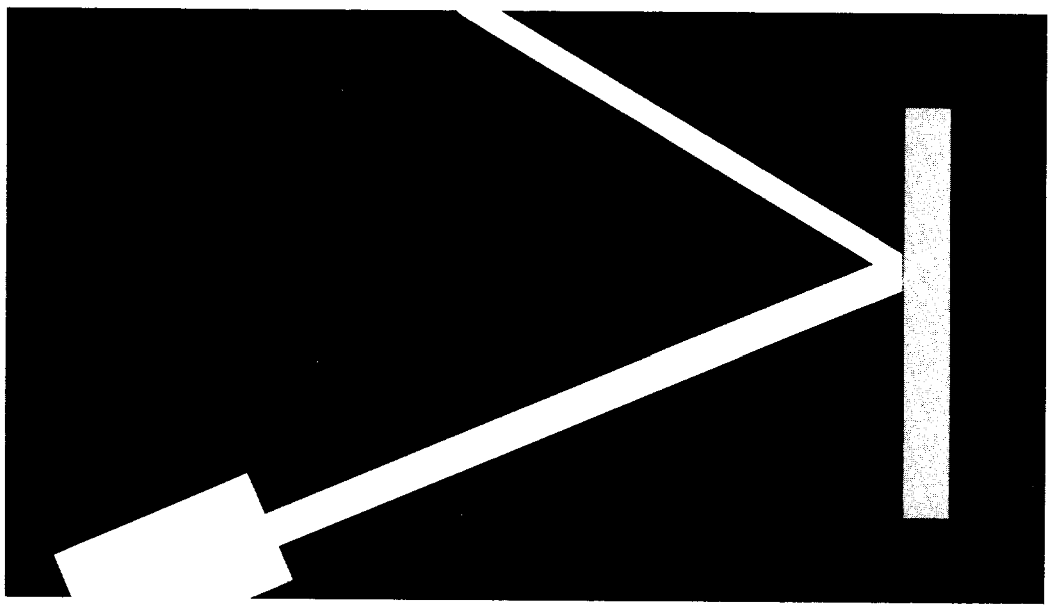
Laser light is quite different. All the light waves in a laser beam can have the same wavelength. Furthermore, they are in phase with each other. They travel in locked-step or synchronized patterns. This unique property of laser light is called "coherence." Again, color depends upon the wavelength. Since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

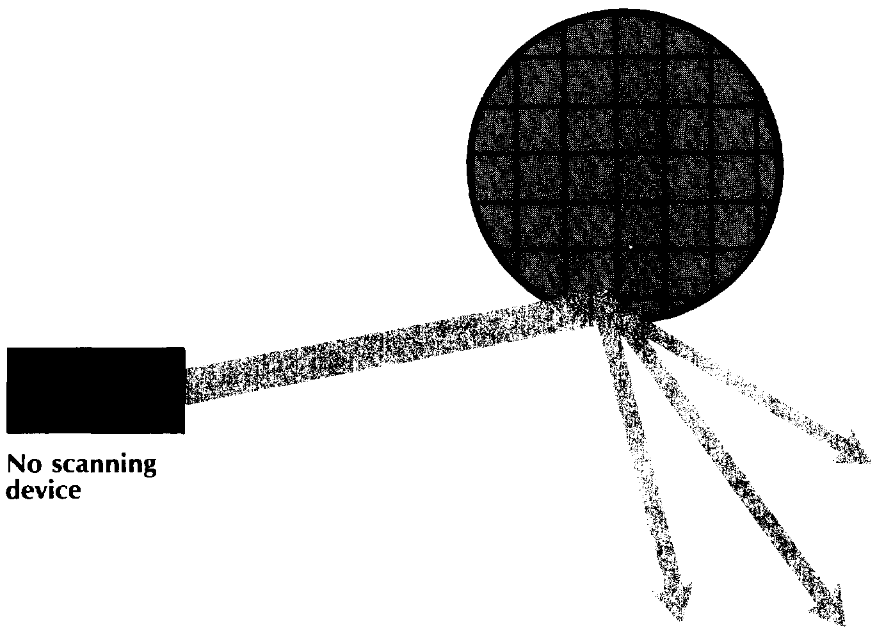


Ordinary light reflects off a mirror and its beam continues to diverge.

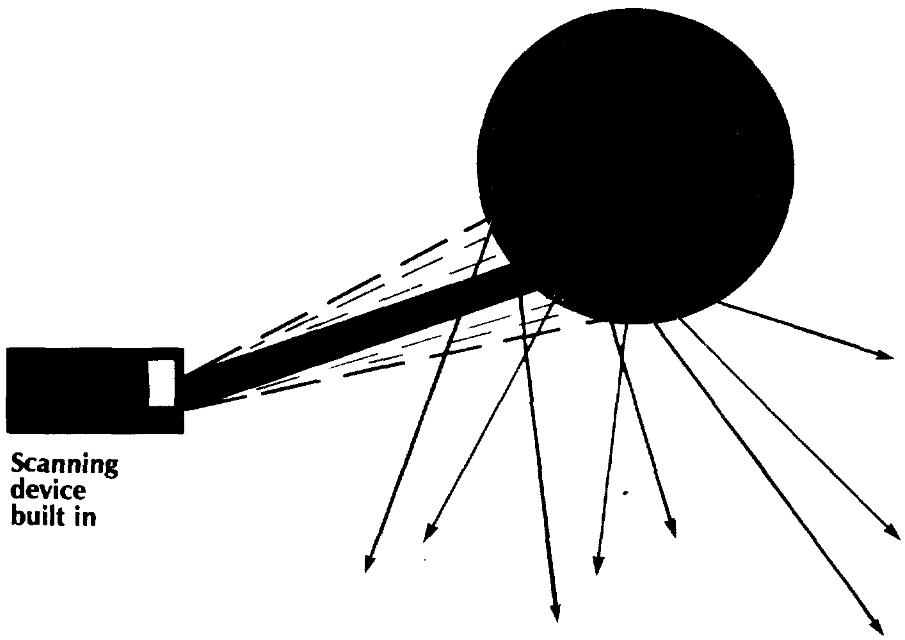


Laser light reflects off a mirror and still does not diverge very much

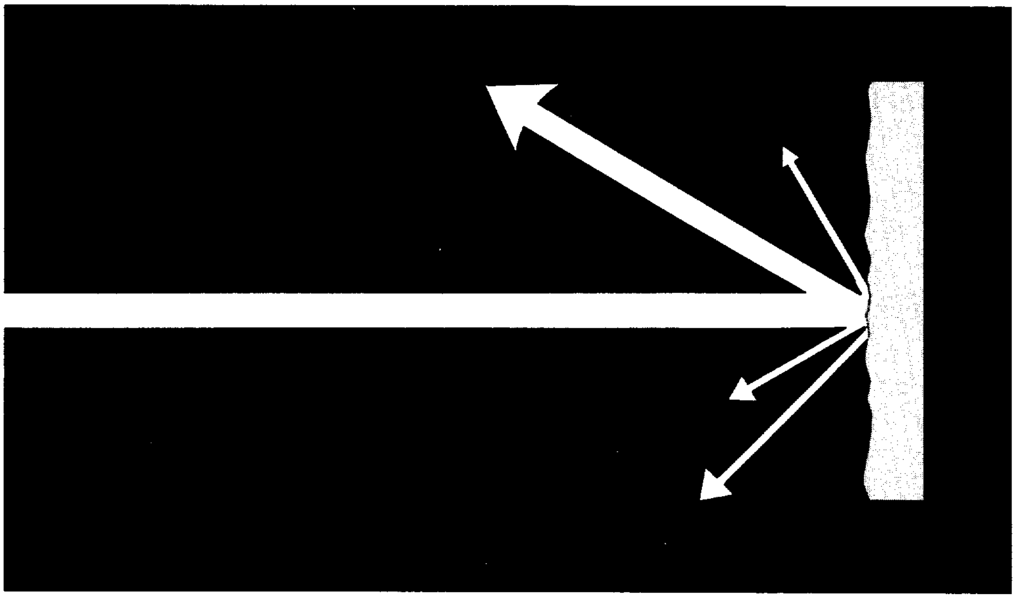
Mirror balls are frequently used in light shows to separate and reflect the laser beam into many rays of laser light. When done properly, this can significantly reduce the power and, therefore, the potential hazard of a laser beam. If the beam is reflected off enough facets on the mirror ball, the resulting 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.



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.



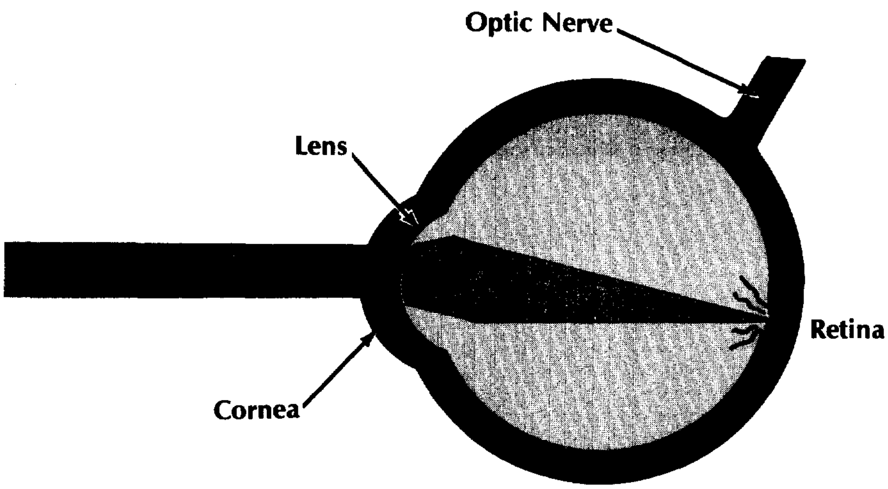
If a laser beam is reflected off a rough or irregular surface, like a concrete wall or even some "walls" of smoke, the irregularities in the surface scatter the beam in many different directions. The beam is forced to diverge and therefore lose some of its power. However, a very high powered laser beam 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:

■ **Before Class IIIb or Class IV lasers are sold, used in performances, or otherwise introduced into commerce for demonstration or entertainment purposes, manufacturers must have an approved variance from FDA.**

■ **Laser manufacturers include people who make laser products and people who receive compensation to design, assemble, or modify a laser projector and/or light show.**

This means that a musical group or others are considered manufacturers if they assemble a show. . .even if the act of manufacture is simply setting up a show in a particular location or changing a general purpose laser to light show use, without adding any new laser components. This does not mean that "all the world's a laser manufacturer." And it does not mean that a separate variance is needed for each laser show. But it does mean that first, the manufacturers of all Class IIIb or IV laser products used in shows that do 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.

FDA uses several safety criteria to determine whether a variance will be granted to a laser light show. These criteria include:

■ The laser must meet all the design and labeling requirements of its class and the following.

■ Laser radiation cannot exceed Class I limits where the audience is located. (This can be achieved by proper use of mirror balls, scanning devices, or other safeguards.)

■ If devices, like mirror balls or flat mirrors, are used to reflect the beam, scanning safeguards or other measures are required to make sure that laser radiation above Class I will not accidentally go into the audience.

■ Performers cannot be exposed to radiation above Class I limits if they must view the laser beam in the course of a performance. When they don't have to view the laser beam, performers cannot be exposed to radiation above Class II limits.

■ If the laser is not under the 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.

STATE AND LOCAL LASER LIGHT SHOW REQUIREMENTS

State and municipal governments can have their own requirements, beyond those of FDA and FAA, with which laser light shows must comply when operating in their jurisdictions. Presently, 6 State agencies have specific legislation for lasers and 25 have the authority to develop specific laser regulations. In addition, all States and many local agencies have the authority to take action if a laser show endangers the general health and safety of the public. Several States have closed down laser shows that violated the FDA safety requirements.

The State agencies with the responsibility for radiation control should be notified in advance of laser shows operating within the State boundaries. The following information should be provided in writing by the laser safety officer from either the operating group or the facility where the show is held:

- Name, address, and phone number of laser safety officer(s) or operator(s)
- Name, address, and phone number of the auditorium facility and the manager
- Type of laser show
- Date(s) and time of performance (if it is not an ongoing show)
- Length of time laser will be in operation
- Expected attendance
- Class of laser and name of manufacturer
- Sketches to describe the design or layout of the show
- If Class IIIb or IV laser product, FDA variance and accession number and date of the variance approval

Since the State requirements vary, it is important that laser show operators or facility managers contact the appropriate office directly to notify the authorities of the operation of a laser show and to ascertain what, if any, additional requirements exist. The State personnel will also be aware of any relevant municipal requirements. Managers of facilities where laser shows are held should be familiar with any local safety requirements. The addresses and phone numbers of the State radiation control offices will be found in Appendix III of this booklet.

CHAPTER 3

INDIVIDUAL RESPONSIBILITIES

RESPONSIBILITIES OF LASER MANUFACTURERS AND OPERATORS

Laser manufacturers (including operators or people who set up or assemble laser systems) should have a good understanding of the FDA laser performance standard, the requirements for the class of laser product with which they are concerned and the safety requirements for laser light show operations.

FDA and State personnel are available to help you make sure that your shows are run safely and in compliance with the law. For more information, contact the appropriate State office listed in Appendix III of this booklet, or:

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

Specifically, the following responsibilities are those of the laser manufacturer or operator of light shows:

■ You must notify FDA, in writing, at least 1 month in advance of a show. In cases of traveling shows, you may want to send to FDA the schedule for the entire tour. When this is not possible because of last minute scheduling, you should notify FDA by telephone as far in advance as possible and then confirm it in writing.

■ You must contact the State or local radiation control authorities in writing in advance of conducting a laser show in their jurisdiction. Again, when this is not possible, you should telephone the State agency as far in advance as feasible. The information you should provide to the State is listed on page 21 of this booklet. In some areas, they also have operating requirements beyond FDA's. (See Appendix III of this booklet for a list of the State authorities who must be contacted.)

■ You should also provide to the facility manager the information that is given to the State authority.

■ If you are responsible for an outdoor laser light show, you must notify the Federal Aviation Administration. (See Appendix II of this booklet for a list of which FAA office must be contacted.)

■ If there are any radiation accidents or alleged accidents, that is, if someone is hurt or an accidental exposure to a laser beam of Class III or IV occurs, you must report the incident to the local authority and FDA regardless of whether any actual injuries occurred.

■ As of September 20, 1985, if you will be using a Class IIIb or IV laser in light shows or displays, you must submit a variance aplication and receive an approved variance from FDA before a performance. You may be asked to show the documents to verify your variance to State or local authorities and facility managers. In fact, this is required in some jurisdictions. Because the public is becoming increasingly aware of potential laser hazards, you may want to include a statement in any promotional advertising of your laser show that it will be operated in conformance with FDA laser safety criteria. If you do so, however, you cannot imply that the show is "endorsed" or "approved" by FDA.

■ Before granting a variance, FDA will require that a report be filed describing your laser products and the manner by which they comply with the FDA laser safety standard and the conditions of any variances. This "initial report" must be followed up by a "model change report" should you plan to introduce a new or modified laser show or device into commerce. An annual report must also be submitted by September 1 of each year summarizing the testing and the records that must be maintained.

RESPONSIBILITIES OF THE MANAGERS OF FACILITIES WHERE LASER SHOWS ARE HELD

■ In order to safeguard your audiences,you should be aware of the safety requirements placed on the manufacturers and operators of laser shows by Federal, State and local authorities. To avoid possible liability for laser injuries, see that any shows in your facility have complied with the legal requirements.

NOTE: The laser operator should provide to you the information about the class of laser to be used and its variance status. A laser product should have a label indicating its class. If the laser is Class IIIb or IV, the company responsible for the laser should have documentation (an accession and variance number) from FDA granting a variance. You can contact the State authority (see Appendix III of this booklet) or FDA to verify the status of a company's variance.

■ One person, either the laser company's operator, or where there is no operator, an employee from the facility, should be designated as laser safety officer. A laser safety officer should be in attendance whenever a laser is in operation and should be responsible for shutting down the laser should any unsafe conditions occur.

- In order to properly set up and align a laser light system that can be operated safely, laser groups will need time in the facility before the show without members of the public present. They will need the electrical power and water supply set up early enough to test and align the equipment. Depending upon the complexity of the system, the preparation for a show may take up to several hours. Should a full inspection by FDA representatives be found necessary, it may require an additional hour or two prior to the show. This should be allowed for in the scheduling of performances.

- Should any accident occur with the laser, you should report the incident to the State authority and to FDA.

FDA and State personnel are available to help you ensure that laser shows in your facility are run safely and in compliance with the law. Contact the FDA or the appropriate State office listed in Appendix III for more information.

WHAT THE PUBLIC SHOULD KNOW ABOUT LASER SAFETY

Laser light shows can be exciting but they can also be hazardous if someone is accidentally struck (particularly in the eyes) by direct, reflected or even diffuse high power laser radiation.

You have a right to enjoy a laser show knowing that your safety is provided for by the laser manufacturer, the laser operator and the management of the facility where the show is held. Should you have reason to believe that a show is not being run safely — that is, that the precautions spelled out in this booklet are not being taken — talk with the laser operator or people in charge of the facility, or call the State authority (listed in Appendix III). If you are aware of anyone being injured at a laser show, report it to the State authority or FDA.

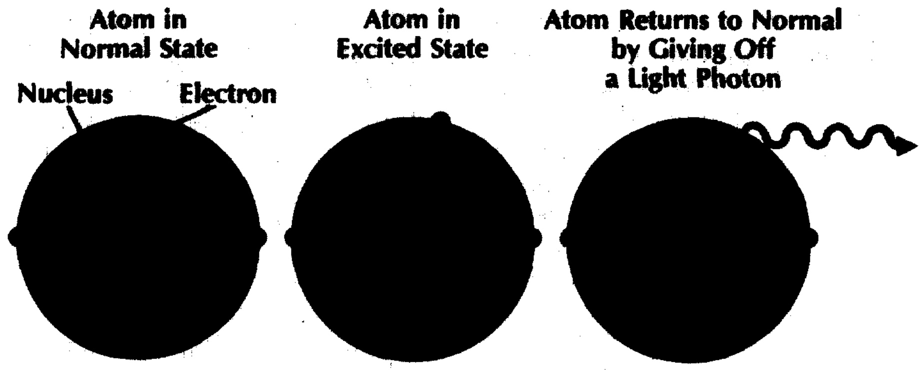
APPENDIX I

HOW LASERS WORK

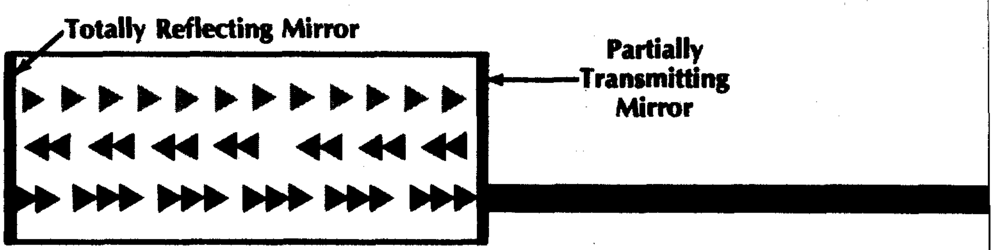
Laser is an acronym for "Light Amplification by Stimulated Emission of Radiation." The actual material that produces the laser light is called the lasing medium. It may be either a solid, liquid or a gas. Most large light shows use gas lasers with either krypton gas or a mixture of argon and krypton gases. Helium-neon gas lasers are common in smaller laser displays. The gas is usually contained in a long, thin cylindrical glass tube. The pressure and the concentration of the gas inside the tube must be just right or else the laser will not operate.

At one end of the tube is a totally reflecting mirror; at the other end is a partially transmitting mirror (that is, it allows a small portion of light to pass through). Like a fluorescent light bulb, the lasers in light shows will work only when an electric current passes through the tube containing the gases.

When the electrical energy enters the tube, it "excites" the atoms of the lasing medium. What actually happens is the electrons of an atom absorb the electrical energy by jumping to higher energy states. After a small fraction of a second, the electrons will "fall" back to their normal energy state. When they do so, the atom gives off the excess energy in the form of a "photon" or small packet of light radiation.



Depending upon the amount of energy absorbed, the atom will give off a photon with a particular wavelength. This photon of light can trigger (or "stimulate") the release (or "emission") of similar photons from the other excited atoms in the lasing medium. The photons bounce back and forth between the two mirrors at the ends of the tube. As they bounce back and forth they continue to trigger more and more photons, building up to higher and higher intensity. The stimulated photons of light radiation are of the same wavelength and move in the same direction as the original photons. Some of this light will pass out through the partially transmitting mirror at the end of the tube. This is the laser beam with the unique characteristic described before: coherence.



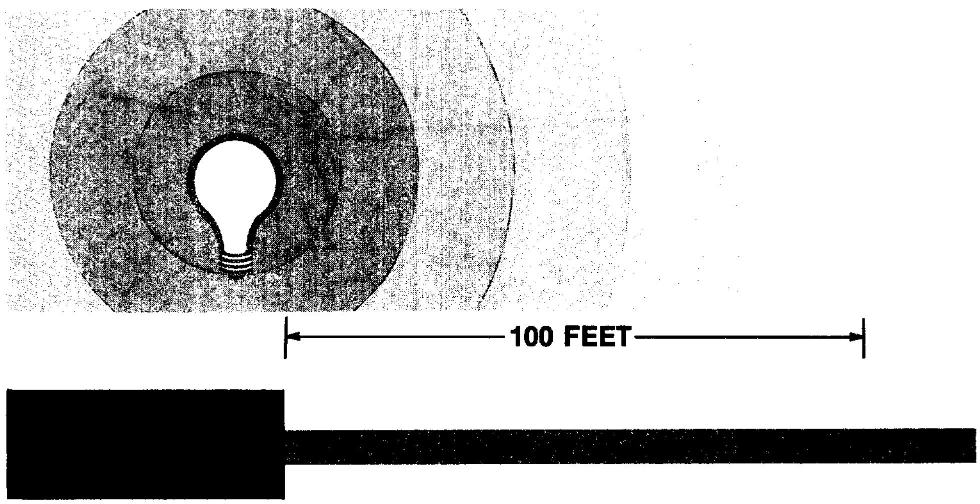
■ You may be wondering how a laser beam that is supposed to be composed of light waves with the same wavelength can result in the numerous color effects that are frequently seen in light shows. The answer lies in the atomic structure of the lasing medium and in the fact that the atom can release more than one level of energy at the same time.

Each of the electron orbits of an atom is bound to the nucleus by a specific level of energy. Those close to the nucleus are bound progressively more tightly. Those further away from the nucleus are bound progressively less tightly. In order for an electron to jump to another energy state, it must have absorbed a specific amount of additional energy to "boost" it into that higher state. And likewise, when that electron falls back to its normal state, the atom will give off the same specific amount of energy. The wavelength or color of the photon given off is determined by this specific amount of energy.

The atomic structure of krypton gas is relatively complex. It has 36 electrons. So a krypton atom has many electrons at different energy states available to absorb and then emit photons of various wavelengths and therefore various colors. By incorporating a prism at the end of the laser, the photons of the particular wavelengths (or colors) can be separated into several rays of different colors.

■ Another point that should be clarified has to do with the units by which the output of a laser is measured. Although the term "watt" is used to describe both lasers and conventional electric devices like light bulbs, the term can refer to very different things. When you have a 100 watt light bulb, the wattage refers to the power input or the electricity required to make the bulb work.

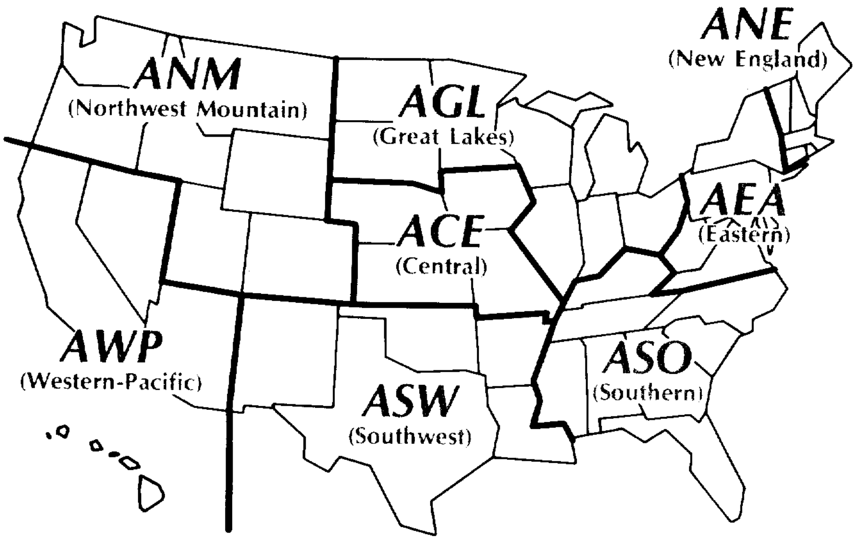
The output from a 100 watt light bulb is about 15 watts. And again, the 15 watts of energy coming out of a light bulb is spread out in all directions. When you have a 1 watt laser, the wattage refers to the optical output of the laser. This 1 watt of optical radiation is traveling in a narrow, concentrated beam in one direction. At a distance of 100 feet, the light from the 1 watt laser can be about 1 million times more concentrated than from the light bulb!



■ It should also be pointed out that the physical size of a laser has little bearing on its power output. There are many lasers that are physically small, but have more power output than some large ones. The only reliable way of telling the power output of a laser is to look at the label on the product, which should indicate its class and absolute maximum power output.

APPENDIX II

FAA REGIONAL BOUNDARIES



LOCATIONS OF REGIONAL HEADQUARTERS

Alaskan Regional Office
P.O. Box 14
Anchorage, AK 99513
(907) 271-5645

Central Regional Office
601 E. 12th St.
Kansas City, MO 64106
(816) 374-5626

Eastern Regional Office
Federal Building
JFK International Airport
Jamaica, NY 11430
(212) 917-1005

Great Lakes Regional Office
2300 E. Devon Ave.
Des Plains, IL 60018
(312) 694-7294

New England Regional Office
12 New England Executive Park
Burlington, MA 01803
(617) 273-7244

Northwest Regional Office
17900 Pacific Highway S.
Seattle, WA 98168
(206) 431-2001

Southern Regional Office
P.O. Box 20636
Atlanta, GA 30320
(404) 763-7222

Southwest Regional Office
P.O. Box 1689
Ft. Worth, TX 76101
(817) 877-2100

Western-Pacific Regional Office
P.O. Box 92007
Worldway Postal Center
Los Angeles, CA 90009
(213) 536-6427

APPENDIX III

STATE RADIATION CONTROL OFFICES

For information on State and local requirements for laser light shows, contact the appropriate office listed below.

Division of Rad. Hlth.
State Dept. of Public Hlth.
State Office Bldg.
Montgomery, AL 36130
(205) 261-5315

Radiological Hlth. Program
Dept. of Hlth. & Soc. Serv.
Pouch H-06F
Juneau, AK 99811-9976
(907) 465-3019

Arizona Rad. Reg. Agency
925 S. 52nd St., Suite 2
Tempe, AZ 85281
(602) 262-8011

Division of Rad. Control and Emergency Mgmt.
Dept. of Hlth.
4815 W. Markham St.
Little Rock, AR 72201
(501) 661-2301

Radiological Hlth. Sect.
State Dept. of Hlth. Serv.
714 P St., Ofc. Bldg. #8
Sacramento, CA 95814
(916) 322-2073

Radiation Control Div.
Dept. of Hlth.
4210 E. 11th Ave.
Denver, CO 80220
(303) 320-8333 ext. 6246

Radiation Control Unit
Dept. of Env. Protection
State Ofc. Bldg.
165 Capital Ave.
Hartford, CT 06106
(203) 566-5668

Office of Rad. Control
Dept. of Hlth. & Soc. Serv.
Robbins Bldg.
Silver Lake Plaza
P.O. Box 637
Dover, DE 19901
(302) 736-4731

Department of Consumer and Reg. Affairs
Service Fac. Reg. Admin.
614 H St., NW, Rm. 1014
Washington, DC 20001
(202) 727-7190

Office of Rad. Control
Dept. of Hlth. & Rehab. Serv.
1317 Winewood Blvd.
Tallahassee, FL 32301
(904) 487-1004

Radiological Hlth. Sect.
Dept. of Human Resources
878 Peachtree St., Rm. 600
Atlanta, GA 30309
(404) 894-5795

Bureau of Env. Hlth.
Dept. of Public Hlth. and Soc. Serv.
P.O. Box 2816
Agana, GU 96910
(671) 734-2671

Noise and Rad. Branch
Dept. of Hlth.
591 Ala Moana Blvd.
Honolulu, HI 96813
(808) 548-4383

Radiation Control Sect.
Dept. of Hlth. & Welfare
Statehouse Mail
Boise, ID 83720
(208) 334-4107

Department of Nuclear Safety
1035 Outer Park Dr.
Springfield, IL 62704
(217) 546-8100

Radiological Hlth. Sect.
State Board of Hlth.
1330 W. Michigan St.
P.O. Box 1964
Indianapolis, IN 46206
(317) 633-0152

Environmental Hlth. Sect.
Dept. of Hlth.
Lucas State Ofc. Bldg.
Des Moines, IA 50319
(515) 281-4928

Bureau of Air Quality and Rad. Control
Dept. of Hlth. & Envivon.
Forbes Field, Bldg. 321
Topeka, KS 66620
(913) 862-9360

Radiation Control Br.
275 E. Main St.
Frankfort, KY 40621
(502) 564-3700

Nuclear Energy Div.
Ofc. of Air Quality and Nuclear Energy
Div. of Env. Quality
P.O. Box 14690
Baton Rouge, LA 70898-4690
(504) 925-4518

Division of Hlth. Eng.
157 Capital St.
Augusta, ME 04333
(207) 289-3826

Division of Rad. Control
Dept. of Hlth. & Mental Hyg.
201 W. Preston St.
Baltimore, MD 21201
(301) 225-6981

Radiation Control Prog.
Dept. of Public Hlth.
150 Tremont St., 7th Fl.
Boston, MA 02111
(617) 727-6214

Division of Rad. Hlth.
3500 N. Logan St.
P.O. Box 30035
Lansing, MI 48909
(517) 373-1578

Section of Rad. Hlth.
Dept. of Hlth.
717 Delaware St., SE
P.O. Box 9441
Minneapolis, MN 55440
(612) 623-5323

Division of Rad. Hlth.
State Dept. of Hlth.
3150 Lawson St.
P.O. Box 1700
Jackson, MS 39215-1700
(601) 354-6657

Bureau of Rad. Hlth.
1730 E. Elm Plaza
P.O. Box 570
Jefferson City, MO 65102
(314) 751-8208

Occupational Hlth. Bur.
Dept. of Hlth. & Env. Sci.
Cogswell Bldg.
Helena, MT 59620
(406) 444-3671

Division of Rad. Hlth.
301 Centennial Mall, S.
P.O. Box 95007
Lincoln, NE 68509
(402) 471-2168

Radiological Hlth. Sect.
Health Div.
505 E. King St.
Carson City, NV 89710
(702) 885-5394

Radiological Hlth. Prog.
P.O. Box 148
Concord, NH 03301
(603) 271-4588

Radiation, Pesticides, and Env. Labs
Div. of Env. Quality
380 Scotch Rd.
Trenton, NJ 08628
(609) 292-8392

Radiation Protection Bur.
Dept. of Hlth. & Env.
P.O. Box 968
Santa Fe, NM 87504-0968
(505) 984-0020

Bureau of Env. Rad. Prot.
Empire State Plaza
Corning Tower
Albany, NY 12237
(518) 473-3613

Bureau for Rad. Control
NY City Dept. of Hlth.
65 Worth St.
New York, NY 10013
(212) 334-7761

Radiation Protection Sect.
Div. of Fac. Serv.
P.O. Box 12200
Raleigh, NC 27605-2200
(919) 733-4283

Division of Env. Eng.
Dept. of Hlth.
1200 Missouri Ave.
Bismarck, ND 58501
(701) 224-2348

Radiological Hlth. Prog.
Dept. of Hlth.
264 N. High St.
P.O. Box 118
Columbus, OH 43216
(614) 466-1380

Radiation and Special Hazards Service
P.O. Box 53551
Oklahoma City, OK 73152
(405) 271-5221

Radiation Control Sect.
State Hlth. Div.
P.O. Box 231
Portland, OR 97207
(503) 229-5797

Bureau of Rad. Protection
Dept. of Env. Resources
P.O. Box 2063
Harrisburg, PA 17120
(717) 787-2480

Radiological Hlth. Div.
GPO Call Box 70184
Rio Piedras, PR 00936
(809) 767-3563

Division of Occup. Hlth. and Rad. Control
Dept. of Hlth.
Cannon Bldg., Davis St.
Providence, RI 02908
(401) 277-2438

Bureau of Rad. Hlth.
Dept. of Hlth.
and Env. Control
2600 Bull St.
Columbia, SC 29201
(803) 758-5548

Licensure and Cert. Prog.
State Dept. of Hlth.
Joe Foss Ofc. Bldg.
523 E. Capital
Pierre, SD 57501
(605) 773-3364

Division of Rad. Hlth.
Dept. of Public Hlth.
Terra Bldg., 150 9th Ave. N.
Nashville, TN 37203
(615) 741-7812

Bureau of Rad. Control
Dept. of Hlth.
1100 W. 49th St.
Austin, TX 78756-3189
(512) 835-7000

Bureau of Rad. Control
State Dept. of Hlth.
Box 45500
Salt Lake City, UT 84145
(801) 533-6734

Division of Occup. and Rad. Hlth.
Dept. of Hlth.
10 Baldwin St.
Montpelier, VT 05602
(802) 828-2886

Bureau of Rad. Hlth.
Dept. of Hlth. Haz. Control
109 Governor St.
Richmond, VA 23219
(804) 786-5932

Department of Public Works
Div. of Natural Res.
P.O. Box 4340
Charlotte Amalie
St. Thomas, VI 00801
(809) 774-6420

Radiation Control Sec.
Dept. of Soc. & Hlth. Serv.
MS LF-13
Olympia, WA 98504
(206) 753-3468

Radiological Hlth. Sect.
Industrial Hyg. Div.
151 11th Ave.
S. Charleston, WV 25303
(304) 348-3526

Radiation Protect. Sect.
Div. of Hlth.
P.O. Box 309
Madison, WI 53701
(608) 273-5181

Radiological Hlth. Serv.
Div. of Hlth. & Med. Serv.
Hathaway Bldg.
Cheyenne, WY 82002-0710
(307) 777-7956