DOT/FAA/AM-01/7

Office of Aviation Medicine
Washington, D.C. 20591

Laser Pointers: Their Potential Affects on Vision and Aviation Safety

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April 2001

Final Report

U.S. Department of Transportation
Federal Aviation Administration

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalcog No.
DOT/FAA/AM-01/7		

4. Title and Subtitle	5. Report Date
Laser Pointers: Their Potential Affects on Vision and Aviation Safety	April 2001
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Nakagawara, V.B., Montgomery, R.W.	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
FAA Civil Aeromedical Institute P.O. Box 25082 Oklahoma City, OK 73125	11. Contract or Grant No.
12. Sponsoring Agency name and Address	13. Type of Report and Period Covered
Office of Aviation Medicine Federal Aviation Administration 800 Independence Ave., S.W. Washington, DC 20591	14. Sponsoring Agency Code

15. Supplemental Notes

This work was performed under task AM-B-00-TOX-203

16. Abstract

INTRODUCTION. Laser pointers have been used for years to highlight key areas on charts and screens during visual presentations. When used in a responsible manner, laser pointers are not considered hazardous. While momentary ocular exposure to the light emitted by these devices can be startling to the observer and may result in temporary visual impairment, such exposures are too brief to cause any permanent ocular injury. However, as the availability of laser pointers has increased, so have reports of their misuse by some children and adults. In recent years, both the Food and Drug Administration and the American Academy of Ophthalmology have issued warnings concerning the possibility of eye injury from handheld laser pointers and recommended keeping these devices away from children. The purpose of this report was to investigate the illumination of aircraft by laser pointers in the National Airspace System. CASE REPORTS. From January 1996 to July 1999, the FAA's Western-Pacific Region identified more than 150 incidents in which low-flying aircraft were illuminated by lasers. Laser pointers were used in the majority of these incidents, and there were several occurrences of visual impairment to the pilot. Representative examples of documented reports are presented that involved the illumination of civilian flight crewmembers by these hand-held devices. CONCLUSIONS. Laser pointers have caused ocular injury and may compromise aviation safety when used to illuminate aircraft in critical phases of flight. The physiological effects of exposure to laser light and the regulation and classification of commercial laser products are discussed. The proper selection and use of these devices can minimize the threat of temporary incapacitation and eye injury.

17. Key Words	18. Distribution Statement
Aviation, Vision, Laser, Aircraft Incident, Aircraft	Document is available to the public through the National Technical Information Service Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	10	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Laser Pointers: Their Potential Affects on Vision and Aviation Safety

INTRODUCTION

Teachers and lecturers have used laser pointers for years to highlight key areas on charts and screens during visual presentations. When used in a responsible manner, laser pointers are not considered to be hazardous (see Figure 1). However, as the availability of such devices has increased so have reports of their misuse. As a result, the Food and Drug Administration (FDA) issued a warning in December 1997 on the possibility of eye injury to children from handheld laser pointers (1). Of particular concern was the promotion of laser products as children's toys, such as those that can project cartoon figures and other images. In the wake of two reports of eye injuries involving young children caused by laser pointers, the American Academy of Ophthalmology (October 1998) upgraded an earlier caution to a warning, stating that laser pointers can be hazardous and should be kept away from children (2).

There have been other disturbing reports involving the misuse of laser pointers (3,4). Some of these include: arrests made by police after a red beam was interpreted to be that of a laser-sighted weapon, spectators aiming laser pointers at athletes during sporting events, the illumination of drivers on highways, and numerous incidents involving the illumination of fixed-wing aircraft, and law enforcement and medical evacuation helicopters. The visible range of a laser pointer can vary considerably depending on its wavelength, output power, and environmental factors such as background illumination and air quality. The misuse of laser pointers involving exposure distances greater than 10 feet is not likely to cause permanent eye injury. However, at very close range, the light energy that laser pointers can deliver into the eye may be more damaging than staring directly into the sun. This is due to the refractive properties of the cornea and crystalline lens, which increases irradiance (W/cm^2) to the retina by 10^5. An irradiance of 1 W/cm^2 at the cornea would have an irradiance of 10 kW/cm^2 at the retina (5).

Figure 1: Commercially available laser pointers come in different styles.

A classmate exposed an 11-year-old girl to a laser pointer to determine whether the light beam would cause her pupil to constrict. After staring into the beam for several seconds and more than once, the girl immediately noticed her vision was impaired in her right eye. An initial medical examination found her best-corrected visual acuity to be 20/60-2 OD, and an Amsler Grid test revealed a 2° central scotoma. After 11 months, the girl's best-corrected visual acuity gradually improved to 20/25+1 OD, the central scotoma resolved, and only mild irregular pigmentation was evident at the site of the injury (6).

Momentary exposure from a laser pointer can cause discomfort and temporary visual impairment (glare, flashblindness, and afterimages), without causing permanent physical damage. Glare is the dazzling sensation induced by a relatively bright light, which produces unpleasantness, discomfort, or interferes with optimal vision (7). A typical example of a glare-producing stimulus would be an oncoming automobile's headlights at night. The visual effects of glare usually cease once the stimulus is removed. However, residual effects, such as spatial disorientation or loss of situation awareness, can persist. Flashblindness is defined as visual loss during and following exposure to a light flash of extremely high intensity (7). An example is the temporary loss or severe reduction of vision experienced after exposure to a camera flashbulb. This type of visual impairment may last for several seconds to a few minutes. Afterimage is a persisting sensation or image perceived after the correlated physical stimulus has been removed. Visually, an afterimage may be the continued perception of the essential form, motion, brilliance, or color qualities of the removed stimulus (7). Although temporary, visual impairment and its associated residual effects can be hazardous if the exposed person is engaged in a vision-critical activity, such as driving a car or flying an aircraft.

As a result of a growing number of ground-based laser illumination of aircraft, several of which resulted in vision impairment to flight crewmembers, the Federal Aviation Administration (FAA) revised FAA Order 7400.2D (Procedures for Handling Airspace Matters; Part 8, Miscellaneous Procedures; Chapter 34, Outdoor Laser Demonstrations), which regulates outdoor laser operations in the National Airspace System (NAS). This guidance protects the critical airspace around airports and other sensitive air traffic corridors. In addition, guidance material is currently being developed to protect international airspace against the adverse effects of laser activity on flight operations through a collborative effort with the International Civil Aviation Organization (ICAO) Laser Emitters and Flight Safety Study Group. This report reviews the incidents of laser pointer illumination of aircraft in the NAS.

CASE REPORTS

A survey of the FAA's Western-Pacific Region found 150-plus laser illumination incidents of low-flying aircraft for the period, January 1996 to July 1999. Many of the reported incidents involved laser pointer illuminations of civilian transport, medical evacuation, law-enforcement, military, and private aircraft (8). Several incidents resulted in visual impairment (glare, flashblindness) of illuminated crewmembers. The survey suggests that helicopters are the most vulnerable to threat of laser pointer illumination, due to their relatively slow movement and low-altitude flight.

The following are documented reports that describe typical examples of the rapidly growing list of aviation incidents involving laser pointers.

- In August 1996, a police helicopter in Seminole County, FL, was illuminated by a red spot of light the size of a basketball, leading the pilot to believe a laser-sighted weapon was aimed at the aircraft. It was determined that the perpetrators were two local individuals shining a laser pointer into the trees, not realizing the light beam could reach the helicopter (9).
- In June 1998, in San Panqual Canyon, CA, an individual leaving a party used a red laser pointer to illuminate a San Diego police helicopter while it was flying at 600 feet above ground level (AGL). The pilot's temporary loss of visual reference was made even more dangerous due to the canyon setting. The suspect was arrested after the incident (10).
- In June 2000, a 15-year-old boy was booked into the Youth Service Center, Seattle, WA, for first-degree unlawful discharge of a laser, a felony, after reportedly flashing a laser beam at the King County Sheriff's helicopter, Guardian One. Shortly after 11 p.m., Guardian One was about 1,200 feet AGL just east of Renton when the laser illuminated the helicopter. The crew was able to direct ground units to the home where the beam originated. The teenager was arrested and two laser pointers were confiscated. This episode was the third in two weeks in which a laser disrupted the helicopter crew in flight (11).

DISCUSSION

While there is little or no risk of biological damage resulting from momentary exposure to laser pointers, misuse of these devices can and has resulted in ocular injury (12). Such injuries from laser pointers are usually the result of prolonged self-exposure or malicious illumination by another individual. Visible and near-infrared wavelengths (400-1400 nm) are focused by the cornea and lens and absorbed by the retina (see Figure 2). Injury occurs when the energy level and duration of a laser exposure are sufficient to damage the eye's retina. Since the power output of laser pointers is relatively low (< 5 milliwatts), an exposure that could cause injury must be from close range (10 feet or less) and be several seconds to a few minutes in duration. Retinal injury can result from a delayed photochemical reaction or acute thermal damage caused by the absorption of laser energy in the retinal tissue. While these injuries can sometimes result in permanent visual impairment, exposure from a laser pointer is not likely to cause biological damage to aircraft pilots due to atmospheric attenuation, extended distance, and low power output.

When selecting a laser pointer, the consumer should be familiar with the different product labels. The FDA's Center for Devices and Radiological Health (CDRH) regulates the manufacture of commercial laser products. Manufacturers are required to classify laser products as Class I, II, IIIA, IIIB, or IV; certify by means of product labels; and submit a report demonstrating that requirements of compliance standards are met (13). Laser classification is based upon the potential of a beam to cause biological damage from unintentional viewing. The maximum permissible exposure (MPE) for visible, continuous-wave lasers is 2.5 milliwatts per centimeter squared (mW/cm^2) for a 0.25 sec. exposure (13). Table 1 provides a summary of the different classes of visible lasers, including their maximum output power (expressed in mW) and the FDA-required information that can be found on the product label.

Class I lasers are not considered hazardous and require no special labeling. Eye injury from unintentional exposure to Class II and Class IIIA lasers would be prevented by the natural blink response (i.e., $\leq$ 0.25 seconds). However, Class IIIA laser pointers can cause permanent injury from prolonged viewing (12) or when viewed through optical instruments, such as binoculars or telescopes. A DANGER logo is required on all Class IIIA lasers manufactured as pointers if the MPE is exceeded during brief exposures of less than 0.25 seconds (13). (Note: The American National Standards for Safe Use of Lasers [ANSI Z136.1] recommends laser safety training and area warning signs for all Class IIIA lasers that carry the DANGER logo.) Although not manufactured for use as "legal" laser pointers, some Class IIIB devices can cause eye injury if the beam is momentarily viewed, either

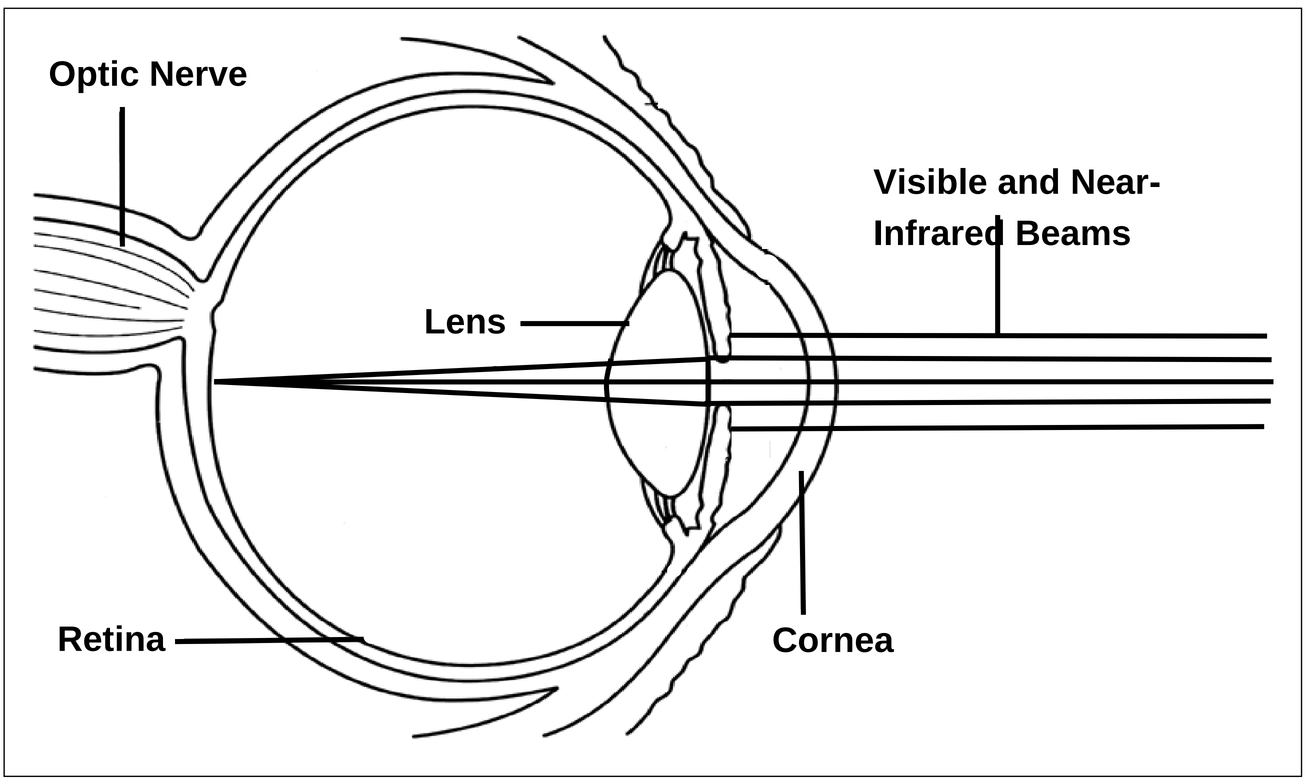

Figure 2: Visible and near infrared beams are focused by the cornea and lens onto the retina.

Class	Max Power MW	Logotype	Warning Labeling
I	0.0004	None Required	None Required
II	1	CAUTION	Laser Radiation – Do Not Stare into Beam
IIIA	5	CAUTION (Irradiance < 2.5 mW/cm^2)	Laser Radiation – Do Not Stare into Beam or View Directly with Optical Instruments
		DANGER (Irradiance ≥ 2.5 mW/cm^2)	Laser Radiation – Avoid Direct Eye Exposure
IIIB	500	DANGER	Laser Radiation – Avoid Direct Exposure to Beam

Table 1: Laser pointer FDA classification and labeling requirements.

directly or off a reflective surface. (Note: There have been reports of Class IIIB laser pointers imported for sale via the Internet (14).)

The color of a laser beam is directly related to its wavelength. If two laser pointers are of equal power but different wavelengths, one may appear brighter than the other. This is due to the human eye's inherent sensitivity to some wavelengths (see Figure 3). Most laser pointers are red or red-orange in color, with wavelengths ranging from 630 to 680 nanometers (nm). The 650-nm wavelength pointer is often selected because of its relatively low cost and increased brightness, about 2 times that of the 670-nm laser pointer. The 635-nm pointer is generally more expensive, but is very bright (approximately 10 times the brightness of the 670-nm pointer) and is useful for outdoors or in environments where there is excessive ambient light (15).

Green laser pointers are relatively new devices that emit a 532-nm beam of light. This wavelength is near the eye's peak sensitivity, resulting in exceptional visibility and brilliance. The human eye perceives a 532-nm beam to be about 35 times brighter than an equivalent powered 670-nm laser beam (15). A green laser pointer is considerably more expensive than a red laser pointer, since the green laser diode costs much more than standard red laser diodes. In addition, the high electrical current required by the green diodes rapidly depletes battery power making them more costly to operate. It is important to note that individuals with color deficiency may not see red or green laser light very well, depending on their particular impairment (16), and could be at increased risk of overexposure and injury from unknowingly staring into the laser beam.

Laser pointers can pose a threat to commercial aviation safety. The most serious recorded aviation incident occurred on October 29, 1997, when an Airworld Airbus carrying passengers enroute from Crete, was illuminated by laser light about two miles from Manchester Airport (England) at an altitude of 600 feet AGL. While the plane was on approach, the captain was forced to look away as a laser pointer illuminated the cockpit (14). The Civil Aviation Authority warned the public that endangering an airline pilot in-flight is a criminal offense carrying a maximum two-year jail sentence. As a result of this and other incidents, the British government subsequently banned the sale of more powerful laser pointers (i.e., those with a maximum power output > 1 mW) (see Figure 4).

In the United States, there have been numerous reports of laser pointers illuminating aircraft in-flight. The City of Los Angeles Department of Airports has reported several laser illuminations around their airports and is currently documenting such incidents to quantify the extent of the problem. Reports of laser incidents from the Sacramento, CA, and Tucson, AZ, areas have also been documented. Authorities have confiscated laser pointers from perpetrators, counseling some and arresting others. The danger from laser pointer illumination is the visible beam hitting an aircraft's

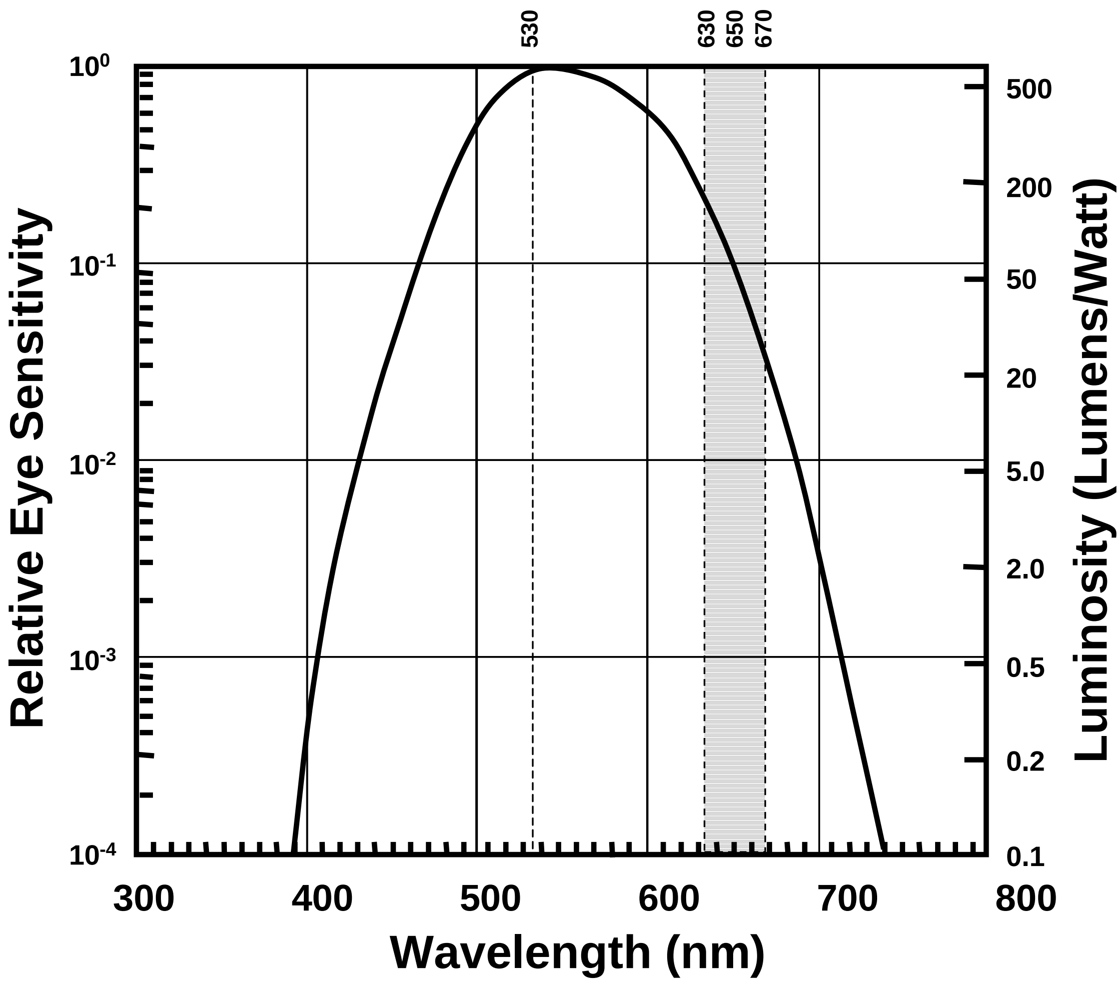

Figure 3: The eye's relative sensitivity as a function of the wavelength of visible light.

windshield, which can scatter light and completely obliterate a pilot's forward vision. In low-level flight, such as that of emergency medical or police helicopters, this type of exposure can substantially increase the risk of accidents due to temporary visual incapacitation, startle effects, spatial disorientation, or the loss of situational awareness. In response to such incidents, recommendations to modify the Code of Federal Regulations have been initiated. This action will help provide a method to effectively prosecute individuals who use lasers to illuminate aircraft.

In summary, when used properly, the risk of eye injury from a laser pointer is extremely low. An individual who receives a transient exposure may experience a dazzling effect, resulting in distraction or temporary visual impairment. The duration and severity of these effects varies between individuals and with their state of dark adaptation at the time of exposure. An eye examination to rule out permanent eye injury from a laser illumination should be performed if afterimages persist for several hours or if a loss of clarity is apparent. To reduce the risk of eye injury, should they fall into the hands of

Figure 4: Low-level laser illumination viewed through an aircraft windscreen.

children or irresponsible individuals, Class II laser pointers (rather than Class IIIA) are recommended for use by the general public. An increase in the perceived brightness of red laser pointers can be achieved without the need for additional power by selecting those that emit light of wavelengths shorter than 670 nm. While Class IIIA laser pointers can continue to be used by responsible adults, they should be replaced by lower powered pointers whenever possible. Finally, to minimize the threat to aviation safety, pilots should be educated on the dangers of in-flight laser illumination and how to best compensate for its debilitating effects. Although the FAA has established guidelines to protect flight crewmembers from laser illumination during terminal operations, additional regulations may be necessary to defend against the careless or malicious misuse of these devices.

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