ICNIRP STATEMENT ON LASER POINTERS

International Commission on Non-Ionizing Radiation Protection*†

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INTRODUCTION

Laser pointers are as ubiquitous as they are useful. The common laser pointers, which emit up to 5 mW, are dazzling even if the eye is exposed only momentarily. Among the public there is a concern about their safety as a result of many well publicized incidents of ocular exposure. Individuals have even been prosecuted for assault after deliberately shining a laser pointer into a police officer's eyes since diode lasers have also been mistaken for lasers used as rifle or pistol aiming devices.

A decade ago, laser pointers were used almost exclusively by academics and professional lecturers, who were cautious not to point the laser beam into the audience. However, in recent years—largely because of the entrance into the market of very inexpensive pointers, the general public has purchased pointers sold as key-chain holders and novelties. Many children have obtained them as toys and used them with little understanding of the effects upon the eye if the laser pointer is directed at an onlooker's face. Indeed, some manufacturers have adapted laser pointers into novelty items incorporating holographic lenses to project various images. These lenses increase the likelihood of intentional exposure and off-axis visual distraction.

All visible laser pointers are capable of producing a dazzle and after-image if the beam enters a person's eye. When the involuntary viewer is startled by such a temporary visual disturbance, the reaction can range from surprise to anger and concern about delayed effects. When exposed subjects consult an ophthalmologist, the patients may be concerned about long-term consequences of accidental laser pointer exposures, occasionally consulting attorneys about perceived injuries. Some persons may allege visual problems long after a laser pointer exposure, a problem that has been encountered with high school students in the U.S. Most persons who have been exposed to a dazzling laser pointer beam are comfortable with an ophthalmologist's reassurance that a momentary laser pointer exposure is safe. Other patients want more information, so it is helpful to clarify some details about laser pointers and their potential hazards and current regulation. Current ICNIRP guidelines for laser exposure provide exposure limits and guidance for safe exposure but do not address specific products such as diode pointers (ICNIRP 1996).

LASER POINTER CHARACTERISTICS

Currently, most laser pointers produce red light, ranging from 632.8 nm for helium-neon to 670 nm for a GaAlAs diode with output powers ranging from about 0.5 to 5 mW. The least expensive, and therefore the most numerous, types of pointers emit at 670 nm, but some of the newer diodes emit at shorter wavelengths (e.g., 635 or 650 nm). Since the visibility of monochromatic radiation varies strongly with wavelength—as quantified by the CIE photopic luminous efficiency function $V(\lambda)$ which peaks at 555 nm (Fig. 1)—the degree of visual disturbance depends not only on the radiant power entering the eye's pupil, but very much upon wavelength. For the same radiant power, the visual response of a 670-nm diode laser beam is only 3% of the 555-nm green laser beam and 13% of the brightness of a 632.8-nm He-Ne laser beam. Therefore, merely limiting radiant power to 1 mW will not eliminate the complaints of severe visual disturbances from direct ocular exposure. A 0.5 mW 555-nm laser pointer would be three times brighter than a 5-mW diode laser pointer emitting at 670 nm. See Fig. 1.

PRODUCT SAFETY STANDARDS AND REGULATIONS

Lasers are strongly regulated in some countries by standards governing both manufacturers and users. In most countries, laser standards are harmonized with the

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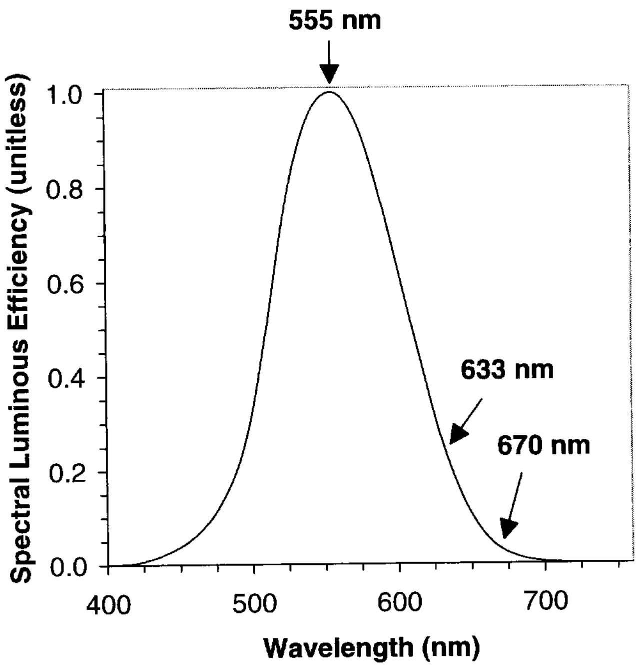

Fig. 1. CIE photopic (daylight color vision) relative sensitivity function V(λ). Note the significant difference in visual stimulus between the He-Ne 633-nm red laser line vs. that of the 670-nm diode laser.

International Electrotechnical Commission (IEC) standard (IEC 1998). Laser products are covered under IEC Standard 60825-1.1:1998 (and in Europe by the companion CENELEC Standard EN 60825-1 with Amendment 11) (IEC 1998; CENELEC 1997). These standards obligate manufacturers to label each laser device with a warning appropriate to its potential degree of hazard. Class 1 lasers are considered incapable of causing ocular damage and do not require control measures. The maximum power output for a visible laser to be classified as a Class 1 device varies with wavelength, ranging from about 0.04 mW for blue or green light to about 0.22 mW for red light (IEC 1998). Class 2 lasers produce laser power that is less than 1 mW. Class 3A lasers have an output power between 1 and 5 mW with a 0.25-s maximum permissible exposure (MPE) irradiance limitation (although this irradiance limitation does not exist in the USA Federal regulation for Class IIIA). Class 3B laser products have an output power up to 500 mW. Class 4 devices are dangerous industrial, military, or surgical lasers that generate more than 500 mW of laser power. The fact that the U.S. Federal standard considers all visible lasers with an output power between 1 and 5 mW as Class IIIA rather than IEC Class 3B has led to further confusion and to misclassification of laser pointers sold outside the U.S. (CDRH 1989). In either case, the manufacturer and warning requirements are the same. More disturbing have been a few reports of misclassification where some lasers with Class 2 or IIIA labels have been sold which actually had an output power of 5–10 mW.

Ophthalmologists routinely use power settings between 100 and 500 mW for retinal photocoagulation (Mainster 1986), so Class 3B devices certainly pose a serious ocular risk. By regulation, laser pointers are either Class 2 (1 mW or less) or Class 3B devices limited to an output power of less than 5 mW (Class IIIA in the U.S.).

POTENTIAL RETINAL HAZARDS

Based upon current medical knowledge, a 5-mW laser is incapable of producing a permanent retinal thermal injury (*photocoagulation*) for a momentary (0.25-s) exposure under ideal optical conditions of exposure. This can be stated even though the ICNIRP exposure limit is 1 mW (25 W m^{-2} in a 7-mm aperture); the difference existing because of a safety factor (ICNIRP 1996). Red light has negligible potential for producing a photochemical retinal injury (*photic retinopathy*) but certainly can cause retinal photocoagulation at high retinal irradiances (Mainster 1986; Ham et al. 1970). As diode lasers emitting shorter wavelengths become available, the risk of laser pointer phototoxicity will increase but remain negligible. Although an unintentional momentary intrabeam viewing will not produce a permanent retinal injury, it is theoretically possible to produce retinal photocoagulation in an eye with perfectly clear ocular media by staring at a collimated 5-mW laser beam for more than 10 s (Ham et al. 1970). Since deliberate staring into a 5-mW beam is hazardous, it is particularly important to keep laser pointers away from infants and children who may not understand the risk. In adults, the pupillary, blink, and aversion responses terminate accidental laser pointer exposures in less than 0.25 s, so there is no realistic risk of immediate or delayed retinal damage from momentarily viewing of a 3–5-mW laser pointer (Ham et al. 1970; Sliney and Dennis 1994; Mansah et al. 1998). Nonetheless, the label of a 1 to 5 mW red laser pointer cautions users to avoid shining a laser pointer beam into anyone's eye. It makes good sense to follow this advice, just as it is good common sense not to stare into the beam of a 35-mm slide projector or the headlight of an approaching locomotive.

To reduce the risk from laser pointer exposures, the authorities in some countries have restricted the sale or use of laser pointers above Class 2. While this will increase the safety factor against any permanent retinal injury, it will not eliminate complaints of dazzle and visual disturbances unless laser users exercise caution to never shine the beam into anyone's eyes.

CONCLUSION AND RECOMMENDATIONS

The power of laser pointers could be decreased significantly by using wavelengths more sensitive to the human eye. For example, a Class-2, 0.12-mW green pointer operating at 555 nm has the same apparent photopic brightness as today's typical 4-mW, 670-nm red diode laser pointer. While this effort should further reduce the risk of retinal injury, the adverse effects of visual disturbances will not decrease and health and safety authorities should recognize that the need for public education on the safe use of laser pointers will still be required. Pointing a visible-wavelength laser directly at the human eye must be discouraged and deliberate intrabeam staring into a laser beam must be avoided. The degree of visual disturbance depends upon the ambient lighting conditions, with the most severe effects under night conditions. The safety implications of direct exposure must be recognized. Ocular exposure below the exposure limit can still produce adverse temporary visual disturbances such as dazzle and after-images, with concomitant potential for catastrophic side effects from operators of vehicles and dangerous machinery. It is recommended that Class 2 laser pointers should be used rather than those with a power exceeding 1 mW wherever feasible, and that even Class 2 laser pointers not be given to children for play. More information can be obtained from the WHO (Fact Sheet No. 202, 1998) and from many national radiation protection boards.

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