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Are laser pointers a danger to the eye?

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In investigating this question we worked together with the "Monitor" television programme of the West German Broadcasting Company (WDR) in Cologne. We measured 10 laser pointers (purchased at the end of January) and then 23 laser pointers (purchased in early March) from various manufacturers or distributors. The lasers used in the pointers are semiconductor lasers with focusing optics to produce a narrow beam which does not widen out very much even after several metres.

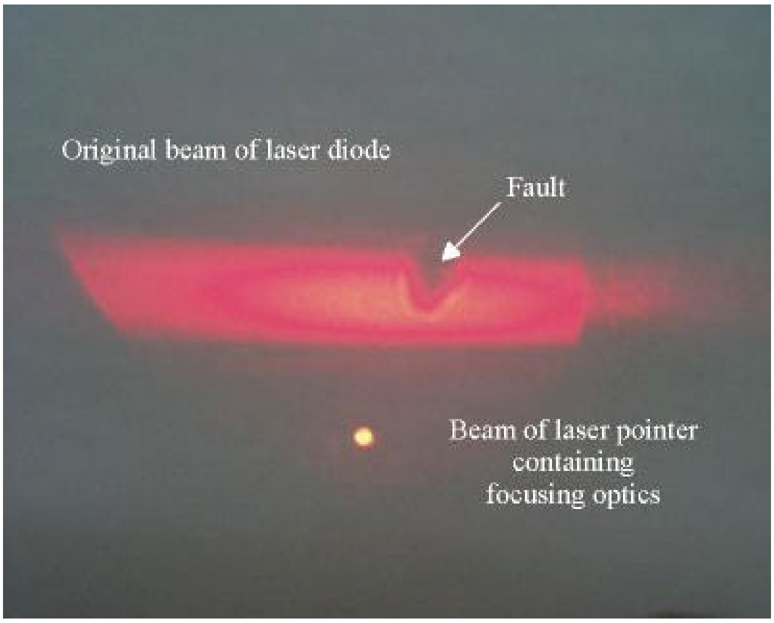

Fig. 1: original beam of laser diode compared to the post-focused beam leaving the laser pointer.
In most cases - as can be seen here - faulty laser diodes are used in laser pointers on grounds of cost.

One typical use of such laser pointers is as an optical “pointing stick” when slides or transparencies are projected onto a wall several metres away during a talk or presentation. The irradiance of such pointers must be intensive enough to render the point of the laser clearly visible on the illuminated wall.

At the same time the irradiance must be kept down to a level at which people’s eyes are not injured if they accidentally look directly into the laser beam.

On the basis of DIN EN 60825-1:1997 this is the case for lasers in the 400 to 700 nm spectrum with a power of no more than 1 mW (laser class 2), and also for lasers whose beam is widened so much that a power no greater than 1 mW (laser class 3a) can enter the pupil of the eye (diameter 7 mm). The dangerous nature of lasers is classified in line with this international standard. In order to check the classification we measured the power of the laser behind a 7 mm aperture situated 10 cm from the laser (Fig. 1). The irradiance according to DIN EN was obtained by taking the power measured and dividing it by the aperture area.

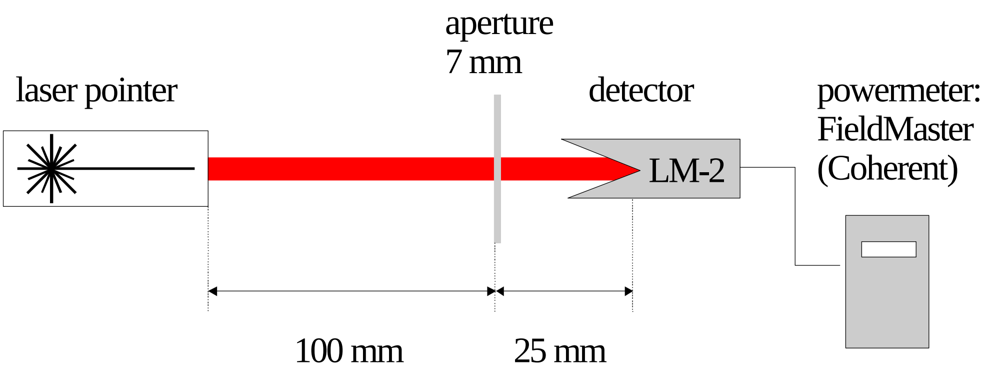

Fig. 1 : Set-up for determining irradiance in acc. with DIN EN 60825-1 (1997).

If the irradiance calculated for lasers in the visible wavelength range is above 25 W/m^2, then damage to the eyes (the retina to be more precise) is to be expected, despite the blink reflex of the eyelid. Such lasers are classified as belonging to laser class 3B. Lasers which in line with the American standard FDA (Code of Federal Register 21 CFR 1040.10 & 1040.22) correspond to laser class IIIA, come within laser class 3B under the DIN standard, since the FDA does not stipulate the irradiance limit of 25 W/m^2 as a classification criterion.
Class 3B lasers used in commerce and industry must be notified to the relevant Employer's Liability Insurance Association and the Labour Protection Authorities. Strict protective measures such as wearing laser safety goggles and being given instruction by a laser safety officer must be strictly adhered to.

We conducted another study to determine actual irradiance on the retina. We started by determining the laser pointer’s real irradiance. Using a CCD camera we mapped the actual spot size of the laser beam at a given distance from the laser. From this image we can determine the area over which the total power is spread. Taking the power measured and dividing it by this area gives the actual irradiance.

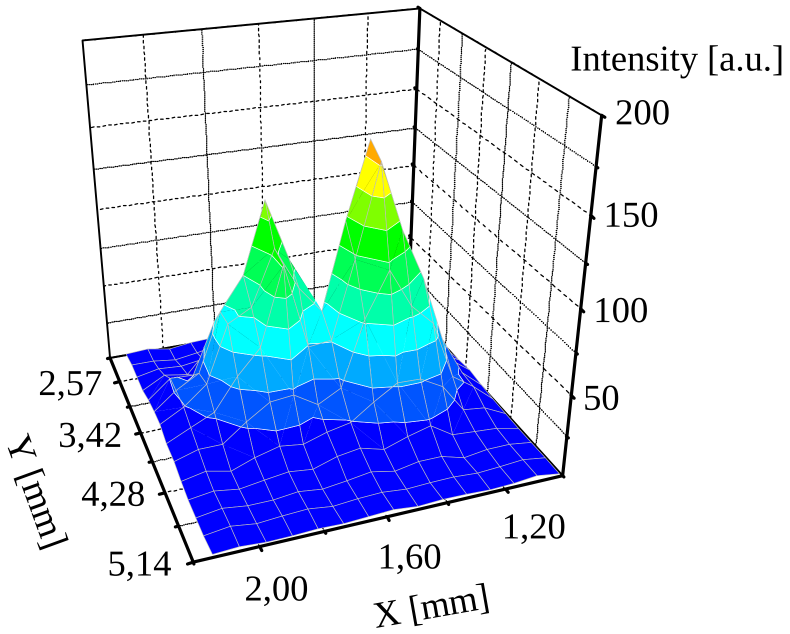

Fig. 3: Spatial irradiance of laser pointer No 9, mapped 1.5 m from laser.

To help made things clearer, Fig. 3 gives the image of the intensity of laser pointer No 9 as mapped with the CCD camera. As we can see from the spatial distribution of the irradiance, it is not evenly spread over the area irradiated; on the contrary, it is very inhomogeneous.

In order to be able to assess the affect of the irradiance falling on the retina the laser beam was scanned using a model eye (Fig. 4).

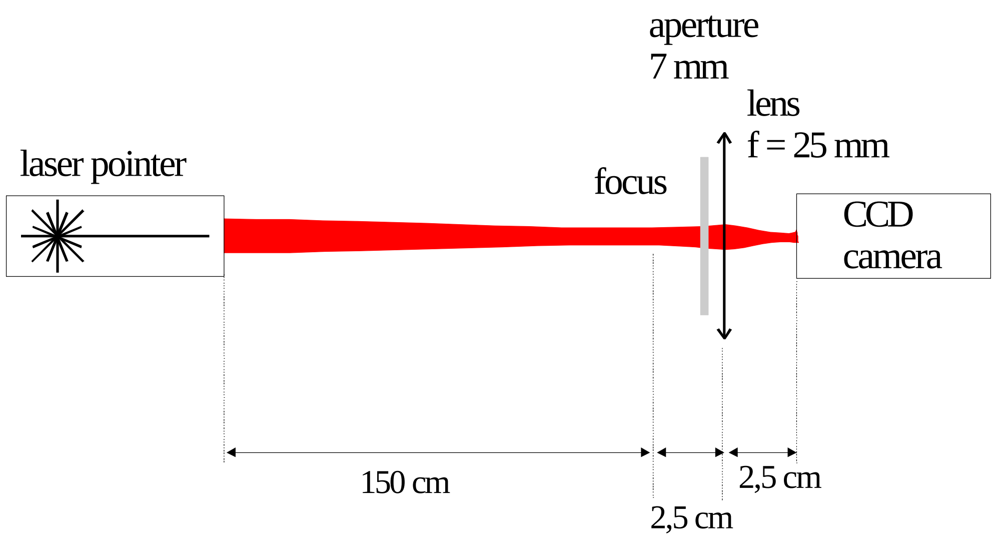

Fig. 4: model for determining irradiance on retina.

This model eye consists of a 7 mm aperture (pupil) behind which there is a lens with a focal length of 25 mm (corresponding to the total refractive power of the eye). The CCD camera, located 25 mm (eye length) behind the lens, represents the retina. Thus the beam spot size, mapped by the CCD camera, corresponds to the actual beam spot size on the retina using this model. Dividing the power by the spot size gives the irradiance. The figure below shows the spatial distribution of the irradiance after the beam has passed through the model eye. The image shows clearly that the beam spot size is smaller as compared to Fig. 3 (the absolute scale in mm is the same for both images).

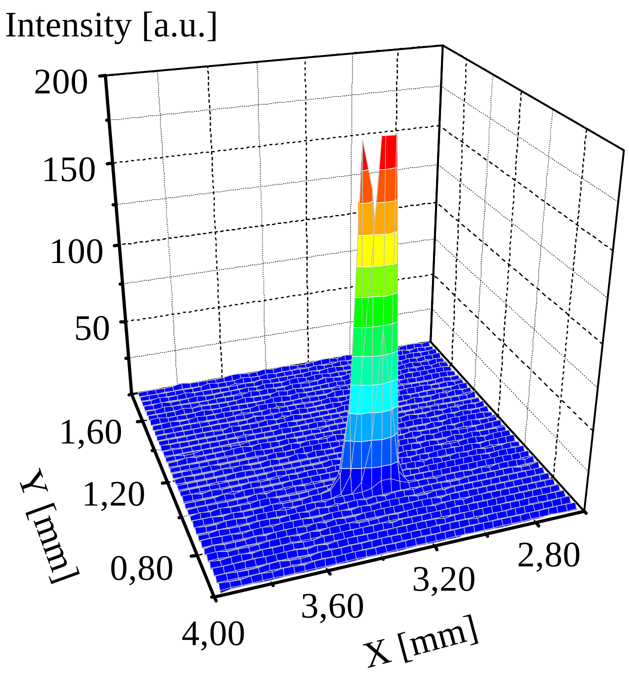

Fig. 4: spatial irradiance of laser pointer No 9 after focusing by model eye

Indicating the actual irradiance striking the retina is of particular interest for ophthalmologists because it allows comparison with medical studies of the retina irreparably.

	manufacturer's data			measurements						
laser pointer number.	power [mW]	wavelength [nm]	laser class	wavelength [nm]	power [mW]	irradiance according to DIN EN60825-1 [W/m^2] limit value 25 W/m^2	laser class as determined according to DIN EN60825-1	actual irradiance 1.5 m away [kW/m^2]	spot size on the retina (model) [mm^2]	irradiance on the retina (model) [kW/m^2]
1	<1	670	2	677	1.5	39	3B	4.3	0.0036	417
2	not given	not given	not given	654	3.4	88.4	3B	26.2	0.0025	1380
3	<5	635-680	IA	666	1.3	33.7	3B	4.6	0.0032	405
4	<5	650 630-680	IIIA	655	3.8	98.8	3B	15.8	0.0021	1843
5	<5	650 630-680	IIIA	651	2.5	65	3B	31.3	0.0022	1163
6	<5	660-680	IIIA	674	1.3	33.8	3B	4.2	0.0018	732
7	<1 <5	660 639 660-680	2	654	1.1	28.6	3B	6.1	0.0017	635
8	<5	630-680	IIIA	649	2.5	65	3B	6.6	0.0037	681
9	<1	630-650	2	671	1.8	46.8	3B	3.5	0.0035	511
10	<5	630-680	IIIA	672	3.6	93.6	3B	5.4	0.327	11

Table 1: laser pointer data given by manufacturers and the corresponding measurement results (measurements taken end January 1998)

		manufacturer’s data			measurements			
laser pointer number	place of purchase	power [mW]	wavelength [nm]	laser class	wavelength [nm]	power [mW]	irradiance according to DIN EN60825-1 [W/m^2] limit value 25 W/m^2	laser class as determined according to DIN EN60825-1
1	Munich	<1	660-680	2	664	0.6	15.6	2
2	Munich	<1	630-680	2	672	0.7	18.2	2
3	Berlin	<5	630-680	IIIA	681	4.9	127.4	3B
4	Berlin	<5 <3	630-680	IIIA 2	648	3.7	96.2	3B
5	Berlin	<1	630-680	2	647	0.93	24.2	2
6	Mainz	<5	640-680	IIIA	676	3.3	85.8	3B
7	Mainz	<5	635-680	IIIA	676	1.4 with 3.0V 3.1 with 4.5V	36.4 80,6	3B
8	Mainz	<5 / <3	630-680	IIIA / 2	648	3.7	96.2	3B
9	Frankfurt	<5	630-680	IIIA	678	3.1	80.6	3B
10	Frankfurt	<5	630-680	IIIA	650	4.9	127.4	3B
11	Hamburg	<5	635-670	IIIA	650	4.7	122.2	3B
12	Hamburg	<1	660	2	660	0.82	21.3	2
13	Cologne	<1	630-680	2	673	1.3	33.8	3B
14	Cologne	<1	630-680	2	674	0.81	21.1	2
15	Cologne	<1	630-680	2	650	0.71	18.5	2
16	Cologne	<1	660-680	2	675	2.3	59.8	3B
17	Cologne	<1	630-680	2	658	0.84	21.8	2
18	Cologne	<5	640-680	IIIA	676	6.5	148.2	3B
19	Stuttgart	<0,95	630-660	2	660	1.2	31.2	3B
20	Dresden	<1	660-680	2A	675	1.1	28.6	3B
21	Dresden	<1	630-680	2	652	0.76	19.8	2
22	Halle	<1	660-680	2A	broadband around 670 nm	1.19	30.9	3B
23	Halle	<5	635-680	IIIA	broadband around 670 nm	1.5	39.0	3B

Table 2: laser pointer data given by manufacturers and the corresponding measurement results (measurements taken early March 1998.

<u>Results:</u>

The above table gives both the manufacturer's data and the measurements done by us. It was necessary to measure the wavelength so as to tune in the power meter (FieldMaster with an LM-2 detector head, from Coherent, Santa Clara, California).

Table 1:

The irradiance measurement conducted according to DIN EN 60825-1 clearly shows that all 10 laser pointers fall under laser class 3B. It should also be noted that not a single device was correctly classified by the manufacturer or distributor in accordance with DIN EN 60825-1.

<u>All these lasers are dangerous because the eye is no longer protected by the blink reflex.</u>

Furthermore, a comparison between irradiance in front of the eyes and the resultant irradiance on the retina shows that it is not possible to state in general terms to what extent the laser beam is made narrower by the optical properties of the eye. The narrowing factor lies - one particular case excepted - between 40 and approximately 180.

We also investigated the beam quality of such laser pointers to answer the question, which reduction of the spot size on the retina can be reached with the eye lens. The beam quality of a laser pointer is similar to that of a HeNe laser with the minimal reachable spot size on the retina of 10 µm (worst-case).

The potential hazard of laser pointers must be analysed under two aspects. In our view dazzling people in a situation where they have to be concentrated (e.g. drivers) is by far the highest danger increased due to the small and unrecognisable size of the laser pointer in someone's hand. Thus an irradiation is always a very unexpected event with predictable reaction of the victim. The second hazard is the reversible or irreversible damage of the retina by direct irradiation. So far no visible irreversible damage is reported to our knowledge after inspection of the retina. However also invisible irreversible damage is reported with laser power less than half of the visible damage threshold. [8] Thus no reported irreversible damage does not mean that there is non.

An ophthalmoscopically visible damage threshold was detected with 9 - 15 mW (worst-case) for 150 - 270 ms exposure in the visible range [8]. Other much more sensitive methods for damage detection, such as fluorescence angiography, microscopy and electron microscopy, lead to a maximum permissible exposure (MPE) value to be defined as 1/10 of the determined visible threshold. The safety factor of 10 is therefore absolutely necessary.

The correct units for measuring the damage threshold of the retina is rather W/m than W/cm^2 [9], because the damage with cw laser pointers is thermal and so heat-conduction has to be consider. With a theoretical model [10] the temperature increase produced in the retina after exposure can be calculated. The thermal response is dependent upon the wavelength of the incident light. A laser pointer with an output energy of 5 mW can produce an temperature increase of 15 to 20 °C (wavelength: 700 nm - 500 nm) after 0.1 s exposure (provided a fixed irradiation area). Because of such a temperature increase a thermal microbiological damage is getting probable and serious for longer exposure time. In an opthalmological report [11] the photocoagulation on a primate retina with an argon laser (514.5 nm, spot size 200 µm, exposure 0.2 s, power 100 mW) was investigated. In this case the calculated temperature increase on the retina is 24 °C. This example shows that with temperatures of round about 20 °C a thermal injury can be produced.

Given the current situation, where lasers have become small and easy to use and are being sold at favourable prices to private individuals, it is probably high time that the regulations governing such lasers were revised. One thing is certain - there should be a ban on selling such lasers to children and youngsters, because they are the very ones who have no idea at all of how dangerous such devices are.

Table 2:

The laser pointers listed in Table 2 were purchased in various cities in Germany some five weeks after the WDR's "Monitor" tv programme on laser pointers was shown at the end of January. As you can see, even now people can still purchase laser pointers with an output power of over 1 mW (which therefore puts them in class 3B).

The Institute for Laser Medicine is currently conducting further studies on this matter. Check out our WWW pages from time to time. They are constantly updated.

If you have any questions or comments please do not hesitate to contact us:

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