

## Development of a laser triangulation sensor for the measurement of powder height in 3D printing

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ANSI and IEC laser classification	Class 1		Class 2		Class 3		Class 4	Notes
	Class 1	Class 1M	Class 2	Class 2M	Class 3R	Class 3B	Class 4	
	Class I	No special FDA class	Class II	No special FDA class	Class IIIa (definition is different but results are similar)	Class IIIb	Class IV	
<b>Human-accessible laser power</b> (for visible light)  <b>Label descriptive text</b>	For visible light, emits beam less than 0.39 milliwatts, or beam of any power is inside device and is not accessible during operation.	DO NOT VIEW DIRECTLY WITH OPTICAL INSTRUMENTS	Emits visible beam of less than 1 milliwatt.  DO NOT STARE INTO BEAM	No special FDA class  DO NOT STARE INTO BEAM OR EXPOSE USERS OF TELESCOPIC OPTICS	For visible light, emits beam between 1 and 4.99 milliwatts.  AVOID DIRECT EYE EXPOSURE	For visible light, emits beam between Class 3R limit (e.g. 5 milliwatts) and 499.9 milliwatts  AVOID EXPOSURE TO BEAM	For visible light, emits beam of 500 milliwatts (1/2 Watt) or more  AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION	Newer ANSI/IEC number classes are now preferred over older FDA Roman numeral classes  Non-visible lasers emitting infrared or ultraviolet are not included in this chart. Only visible lasers are discussed.  For visible-light lasers, the word "light" can be used instead of "radiation". The latter is more accurate for lasers emitting infrared and ultraviolet radiation.
<b>EYE AND SKIN HAZARDS</b>  <b>Eye hazard for intraocular exposure</b> (having a direct or reflected beam enter the eye)  <b>Maximum or typical Nominal Ocular Hazard Distance</b> (for 1 milliradian beam, exposure time less than 1/4 second)  <b>Eye hazard for diffuse reflection exposure</b> (looking at the laser "dot" scattered off a surface)  <b>Skin burn hazard</b>  <b>Materials burn hazard</b>	<b>Safe, even for long-term intentional viewing. For visible light, usually applies when the laser is enclosed inside a device (ex: CD or DVD player) with no human access to laser light.</b>  Not an eye hazard -- does not apply  <b>None</b>  <b>None</b>	<b>Safe for unaided eye exposure.</b>  Consult an LSO as described in the Technical Note below  Consult an LSO  Consult an LSO  Consult an LSO	<b>Safe for unintentional exposure less than 1/4 second. Do not stare into beam.</b>  <b>NOHD of 0.99 mW beam:</b> 23 ft (7 m)  <b>None</b>  <b>None</b>	<b>Safe for unintentional (&lt; 1/4 sec) unaided eye exposure.</b>  Consult an LSO as described in the Technical Note below  Consult an LSO  Consult an LSO  Consult an LSO	<b>Unintentional or accidental exposure to direct or reflected beam has a low risk. Avoid intentional exposure to direct or reflected beam.</b>  <b>NOHD of 4.99 mW beam:</b> 52 ft (16 m)  <b>None</b>  <b>None</b>  <b>None</b>	<b>Eye hazard; avoid exposure to direct or reflected beam.</b>  <b>NOHD of 499.9 mW beam:</b> 520 ft (160 m)  Generally safe. Avoid staring at the laser "dot" on a surface for many seconds at close range.  Can heat skin if beam is held long enough on skin at close range  Can burn materials if beam is held long enough on substance at close range	<b>Severe eye hazard; avoid exposure to direct or reflected beam.</b>  <b>NOHD of 1000 mW (1 Watt) beam:</b> 733 ft (224 m). <b>NOHD of 10 W beam:</b> 2320 ft (710 m)  To avoid injury, do not stare at laser "dot" on a surface. The light is too bright if you see a sustained afterimage, lasting more than about 10 seconds.  <b>Can instantly burn skin. Avoid direct exposure to the beam.</b>  <b>Can instantly burn materials. Avoid direct exposure to the beam, for materials susceptible to burning.</b>	Avoid eye exposure to a direct or reflected laser beam, within the NOHD. The closer you are to the laser, the greater the chance of hazard and the more serious the injury potential.  Dark materials which absorb heat, and lightweight materials such as paper and fabric, are most easily burned by visible laser light.
<b>VISUAL INTERFERENCE DISTANCES</b>  <b>Maximum or typical flashblindness distance</b> (FAA 100 μW/cm <sup>2</sup> , for 1 milliradian beam, 555 nm green light)  <b>Maximum or typical glare distance</b> (FAA 5 μW/cm <sup>2</sup> , for 1 milliradian beam, 555 nm green light)  <b>Maximum or typical distraction distance</b> (FAA 0.05 μW/cm <sup>2</sup> or 50 nanowatts/cm <sup>2</sup> , for 1 milliradian beam, 555 nm green light)	Not applicable; beam is usually contained inside a device such as a CD or DVD player  See above  See above	Consult an LSO  Consult an LSO  Consult an LSO	<b>For a 0.99 mW beam:</b> 117 ft 36 m  523 ft 159 m  5,227 ft (1 mile) 1,593 m (1.6 km)	Consult an LSO  Consult an LSO  Consult an LSO	<b>For a 4.99 mW beam:</b> 261 ft 80 m  1,169 ft 356 m  11,689 ft (2.2 miles) 3,563 m (3.5 km)	<b>For a 499 mW beam:</b> 2,614 ft (1/2 mile) 797 m (0.8 km)  11,689 ft (2.2 miles) 3,563 m (3.5 km)  116,890 ft (22 miles) 35,628 m (35.6 km)	<b>For a 1 Watt beam:</b> 3,696 ft (0.7 mile) 1,127 m (1.1 km) <b>For a 10 W beam:</b> 11,689 ft (2.2 miles) 3,563 m (3.5 km)  <b>For a 1 Watt beam:</b> 16,531 ft (3.1 miles) 5,039 m (5 km) <b>For a 10 W beam:</b> 52,275 ft (9.9 miles) 15,933 m (16 km)  <b>For a 1 Watt beam:</b> 165,307 ft (31 miles) 50,386 m (50 km) <b>For a 10 W beam:</b> 522,746 ft (99 miles) 159,333 m (160 km)	Value given is for 555 nm, the green wavelength that appears brightest to the light-adapted human eye. This gives the longest hazard distance. To approximate for red laser light, divide the distance by about 5; for blue, divide by 20.  See above  See above
<b>Technical Notes</b>	For a 1/4 second exposure to accessible visible-light beams, Class 1 limits are the same as Class 2, and such lasers are usually labeled as Class 2.  <b>Class 1</b>	We are unaware of any Class 1M laser devices intended for consumer use. If you do have such a laser, consult a qualified Laser Safety Officer for more detailed analysis.  <b>Class 1M</b>	Class 2 (and 2M) only applies to visible lasers. Infrared and ultraviolet lasers cannot be Class 2 (or 2M).  <b>Class 2</b>	We are unaware of any Class 2M laser devices intended for consumer use. If you do have such a laser, consult a qualified Laser Safety Officer for more detailed analysis.  <b>Class 2M</b>	Class 3R is either: (1) From 1 to 4.99 mW into a 7mm aperture (e.g., pupil of the eye) or (2) five times the Class 2 limit of 2.5 mW/cm <sup>2</sup> , which works out to be 12.5 mW/cm <sup>2</sup> . The second method is used by LaserSafetyFacts to determine NOHD.  <b>Class 3R</b>	<b>Class 3B</b>	<b>Class 4</b>	<b>Class 1</b>  <b>Class 2</b>  <b>Class 3</b>  <b>Class 4</b>