100GBASE-SR4 Laser Safety Assessment

Richard Johnson, Finisar Corporation
August 2014

100GBASE-SR4 requirements on maximum average power per lane

IEEE Spec for average power per lane (into fiber), max = 2.4 dBm

Applicable Standards

- IEC 60825-1, Edition 3.0 (May 2014)
  - Relaxed Class 1 requirements: 100 mm test distance
  - No Class 1M option for diverging sources
  - New Class 1 is equivalent to old Class 1M from previous editions
- IEC 60825-2, Edition 3.0 (September 2010)
  - Class 1 test at 70 mm
  - Class 1M test at 100 mm
- IEC 60825-13, Edition 2.0 (October 2011)

IEC documents are available from http://www.iec.ch and from other sources.

- United States government 21CFR1040.10, available from http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm?FR=1040.10.
- Food and Drug Administration Laser Notice 50 (June 24, 2007), available from http://www.fda.gov/downloads/MedicalDevices/.../ucm094366.pdf.

The IEC just published Edition 3.0 of 60825-1 three months ago. There has not been time for the various agencies (e.g., FDA Laser Notice 50 or Europe EN 60825-1) to align to this latest standard. Therefore I include discussions about both Edition 2.0 and Edition 3.0 requirements.

I must confess that I am struggling to understand IEC 60825-2 guidance. I am consulting a couple of experts in the field of laser safety. So take my comments below on IEC 60825-2 requirements with caution.

Basic Laser Hazard Test

The test involves a 7 millimeter diameter aperture in front of a broad area detector. (I use an integrating sphere.) The light emerging from the transceiver or from an optical cable is measured at the following distances:

Standard	Hazard level	Test distance
IEC 60825-1 Edition 3.0	Class 1	100 millimeters
	Class 1M	Not available for diverging sources
IEC 60825-2	Class 1	70 millimeters
	Class 1M	100 millimeters

A word of explanation about the test configuration: the 7 millimeter aperture is intended to correspond to the pupil of the eye, through which the laser light must pass to reach the retina. 7 millimeters corresponds to a young person with dark-adapted eyes. Most of us would have pupil diameters much less than 7 millimeters.

100 millimeters corresponds to the "working distance" for a near-sighted person, meaning how far from the eyes that person would hold a book or newspaper. The FDA in 21CFR1040.10 uses 200 millimeters, which is the working distance for most people. The IEC uses 100 millimeters because it is more restrictive. This test assumes that no optics are used (meaning microscope or eye loupe).

The 70 millimeters assumes that an eye loupe of 7X or 8X is used to view the laser or end of the fiber.

An earlier edition of IEC 60825-1 (no longer in effect) had 14 millimeters as a test distance, assuming the use of much higher power magnifying optics while the laser is ON.

The predictions listed in this document evolve from a test I just ran in my laser safety test lab using a Finisar QSFP10 with MPO cable attached. I measured the light emerging from this cable when the end was placed right next to a 7 mm aperture in an integrating sphere, and again with the fiber end placed 70 mm from the aperture, and yet again with the fiber placed 100 mm from the aperture. At 70 mm, approximately four fifths of the light expanded out such that it missed the 7 mm aperture, and only one fifth was captured. The ratio of light power in the fiber to light captured is 6.6 dB. At 100 mm, almost nine tenths of the light missed the aperture. The ratio of light in the fiber to light captured by the aperture is 9 dB.

Class 1 Limits

The Class 1 limits for VCSEL light depend upon the precise wavelength, being most restrictive at the shortest wavelength. For the following analysis, I assume 840 nanometer laser light. There are also different limits depending upon how many of the 4 lasers are turned ON at any given time. The details of this calculation are given in IEC 60825-13 in clause 7.5.4.3.

Number of Lasers ON	Class 1 limit (840 nm)
1	0.75 milliwatt
2	1.00 milliwatt
3	1.61 milliwatt
4	2.21 milliwatt

Laser safety is assessed for various combinations of lasers turned ON or OFF. We look for that condition closest to the Class 1 limit. Most typically this occurs for two lasers adjacent to each other turned ON, with remaining lasers turned OFF.

100GBASE-SR4 Laser Safety Analysis

Consider a 70 millimeter distance requirement. Assume that the laser power in each lane is set for the maximum average power allowed by the 100GBASE-SR4 specifications, which is +2.4 dBm. At 70 millimeter the power captured by the 7 millimeter entrance pupil is some 6.6 dB lower, for a predicted power per laser of 2.4 – 6.6 = -4.2 dBm = 0.38 milliwatts. With two lasers turned ON, power captured would be double this, or 0.76 milliwatts. Etc.

For a 100 millimeter distance requirement the power captured by the 7 millimeter entrance pupil is some 9 dB lower, for a predicted power per laser of 2.4 – 9 = -6.6 dBm = 0.22 milliwatts. With two lasers turned ON, the captured power would be double this, or 0.44 milliwatts. Etc.

So let us apply these predictions to the various laser safety standards:

IEC 60825-1 Edition 3.0				
Number of lasers ON	Test Distance	Estimated Power Captured	Class 1 Power Limit	Ratio to Limit
1	100 mm	0.22 mW	0.75 mW	29%
2	100 mm	0.44 mW	1.00 mW	44%
3	100 mm	0.66 mW	1.61 mW	41%
4	100 mm	0.88 mW	2.21 mW	40%

IEC 60825-2 Edition 3.0				
Number of lasers ON	Test Distance	Estimated Power Captured	Class 1 Power Limit	Ratio to Limit
1	70 mm	0.38 mW	0.75 mW	51%
2	70 mm	0.76 mW	1.00 mW	76%
3	70 mm	1.14 mW	1.61 mW	71%
4	70 mm	1.52 mW	2.21 mW	69%

Conclusions

If we only care about IEC 60825-1, we have comfortable margin. However, the IEEE has also stated that this product needs to comply with IEC 60825-2. For Class 1 the worst case margin is getting uncomfortably close to the limit. However, please keep in mind my disclaimer that my interpretation of IEC 60825-2 requirements may be in error.