From R002, it is required that the design limits the current supplied to the laser diode in use, to adhere to the standard set by AS/NZS IEC 60825.1:2014 [30]for what is referred to as a Class 1M Laser. This standard covers the hazard posed by lasers to eyes and skin by lasers within the range of 180nm-1mm wavelengths, thus capturing the OPV300 850nm laser within its range. The OPV300 is marketed as Class 1M as per IEC/EN 60825-1/A:2:2001 [31], an earlier version of the standards. Regardless, it is a requirement of this report to verify the adherence to Class 1M, as suitable optical power meters are not available, the verification will be performed analytically.

To appropriately assess the lasers compliance with Class 1M, a host of assumptions must be made. These assumptions are listed below:

1. The laser aperture size (d_{src}) is 0.5mm
2. The laser will be treated as a continuous wave (CW) laser
3. The maximum exposure time to eyes will be 0.25s aligning with an accidental glance
4. The laser will be operated at 12mA thus producing 2.85mW output power [5]
5. Increase in temperature and thus effects on laser power output are negligible
6. The full beam divergence of the laser is 24° [5]

Whilst the laser will not be operating continuously, this assumption is made to provide an overestimate of the expected power and thus take a conservative approach to the safety of our design. A flowchart of the Class 1M verification process is produced below in **Figure** 1:

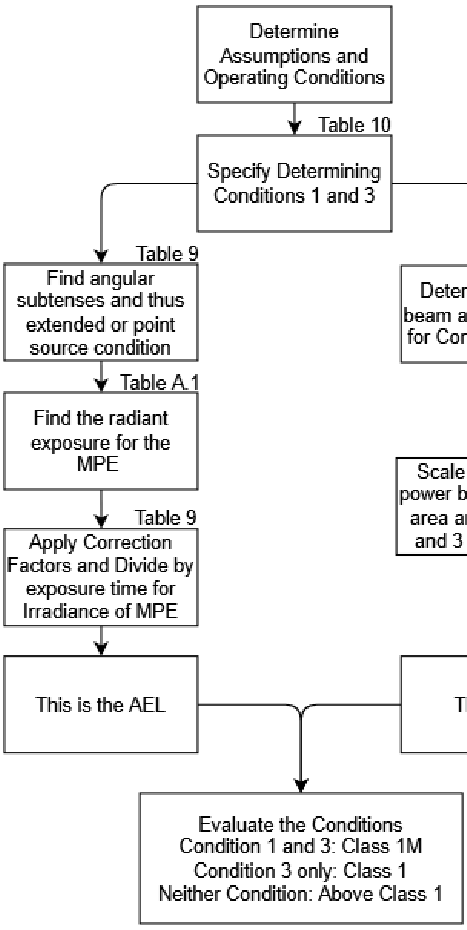

Figure *1*: General Flowchart of Laser Class Verification

To be classified as a Class 1M, the laser is judged against two conditions, where condition 3 determines the adherence to the class, and condition 1 determines the hazard associated with telescopic optics (as provided in Table 10 [30] for 400-1400nm wavelength lasers):

Condition 1: $AE_1 > AEL_1$ for an aperture stop of 50mm, 2000mm away (z = 2m)

Condition 3: $AE_3 < AEL_3$ for an aperture stop of 7mm, 100mm away (z = 0.1m)

To confirm these conditions, the AEL for each scenario is calculated below. The first step is to determine the angular subtense (α) and thus the related extended source correction factor (C_6). The angular subtense is calculated below:

$$\alpha_1 = \frac{d_{src}}{z} = \frac{0.0005}{2} = 0.00025\, radians = 0.25\, mrad$$

$$\alpha_3 = \frac{d_{src}}{z} = \frac{0.0005}{0.1} = 0.005\, radians = 5\, mrad$$

The angular subtense is then compared in the range from α_{min} to α_{max} (1.5mrad and 100mrad respectively) to determine the appropriate extended source correction factor ($\boldsymbol{C_6}$), as shown in **Table *1*** below.

Table 1: C_6 Value from Angular Subtense for 400-1400nm Wavelength Lasers

Angular Subtense Range	$\boldsymbol{C_6}$
$\alpha \leq \alpha_{min}$	1
$\alpha_{min} < \alpha \leq \alpha_{max}$	$\frac{\alpha}{\alpha_{min}} = \frac{\alpha}{1.5}$
$\alpha > \alpha_{max}$	$\frac{\alpha_{max}}{\alpha_{min}} = \frac{100}{1.5} = 66.7$

Given the calculated angular subtense, for the classification of the laser in this report, the following correction factors are used.

$$C_{6_1} = 1$$

$$C_{6_3} = \frac{\alpha_3}{1.5} = \frac{5}{1.5} = 3.\dot{3}$$

Next, it is required to determine the MPE for maximum exposure time of 0.25s to an 850nm laser. From the standard, for a 700-1050nm wavelength laser, the radiant exposure of the MPE can be found via the following equation (as per Table A.1 [30]):

$$H_{MPE} = 18t^{0.75}C_4\, J/m^2$$

Where t is the exposure time (0.25s) and C_4 is another correction factor which may be determined simply for lasers of wavelength between 700 and 1050nm (as per Table 9 [30]), as shown below:

$$C_4 = 10^{0.002(\lambda-700)} = 1.995$$

Thus, producing a radiant exposure of $H_{MPE} = 12.7\, J/m^2$ which aligns with an irradiance of:

$$E_{MPE} = \frac{H_{MPE}}{t} = \frac{12.7}{0.25} = 50.8\, W/m^2$$

Now, this irradiance will be applied to the area associated with the aperture stops of each condition to determine the accessible emission limit (AEL):

$$A_1 = \pi {r_1}^2 = \pi \times \left(\frac{0.05}{2}\right)^2 = 0.002m^2$$

$$A_3 = \pi r_3{}^2 = \pi \times \left(\frac{0.007}{2}\right)^2 = 0.000038m^2$$

$$AEL_{1,point} = E_{MPE} \times A_1 = 50.8 \times 0.002 = 0.09975\ W = 99.75\ mW$$

$$AEL_{3,point} = E_{MPE} \times A_3 = 50.8 \times 0.000038 = 0.001955\ W = 1.955\ mW$$

This AEL is assuming a point source, where given the large angular subtense earlier determined for Condition 3, the specified setup is extended source, and thus the extended source correction factor C_6 is applied:

$$AEL_{3,extended} = AEL_{3,point} \times C_{6_3} = 1.955\ mW \times 3.\dot{3} = 6.52\ mW$$

Now that the AEL for each condition has been determined, it is necessary to calculate their associated accessible emissions for the laser under test. For a conservative approach for the sake of safety, the beam will be assumed initially infinitesimally small. Given the full beam divergence of 24° of the OPV300 laser diode, the beam area at the distances specified by each of the conditions is calculated below:

$$A_{beam_1} = \pi r(z_1)^2 = \pi \times \left(z_1 tan(12°)\right)^2 = 0.56m^2$$

$$A_{beam_3} = \pi r(z_3)^2 = \pi \times \left(z_3 tan(12°)\right)^2 = 0.0014m^2$$

As both beam areas are larger than the aperture area associated with their conditions, the power must be scaled to the ratio of beam incident upon the aperture, thus given the 2.85mW optical power produced by the OPV300, the following accessible emissions are produced:

$$AE_1 = P_{Opt} \times \frac{A_1}{A_{beam_1}} = 2.85 \times \frac{0.002}{0.56} = 0.01\ mW$$

$$AE_3 = P_{Opt} \times A_3 A_{beam_3} = 2.85 \times \frac{0.000038}{0.0014} = 0.077\ mW$$

Assessing these accessible emissions and AELs with regards to the two conditions for a Class 1M laser yield:

$$\text{Condition 1: } AE_1 = 0.01\ mW > AEL_{1,point} = 99.75\ mW$$

$$\text{Condition 3: } AE_3 = 0.077\ mW < AEL_{3,extended} = 6.52\ mW$$

Evidently, condition 3 is achieved, verifying that the laser is classified as Class 1 for unaided viewers, however condition 1 is not achieved, thus the laser is not considered potentially hazardous with the use telescopic optics. This result places the OPV300, under the specified operating conditions, as a Class 1 laser, which, as a classification which is less powerful than

Class 1M, fulfils the requirement for this design of only producing lasers that fall within the limits of a Class 1M laser.

Additionally, the AE for the laser upon an assumed eye aperture of 7mm diameter and AEL for Class 1 compliance were compared for the entire range of distances of which the device is intended to operate between, for which it was found that at all distances, at the specified operating conditions, the laser will be compliant with Class 1 requirements.

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To appropriately assess the lasers compliance with Class 1M, a host of assumptions must be made. These assumptions are listed below:

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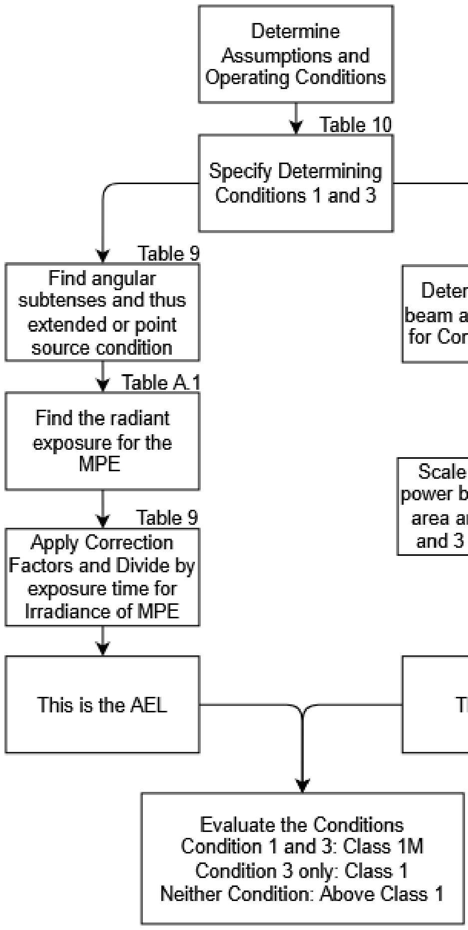

Figure *2*: General Flowchart of Laser Class Verification

To be classified as a Class 1M, the laser is judged against two conditions, where condition 3 determines the adherence to the class, and condition 1 determines the hazard associated with telescopic optics (as provided in Table 10 [30] for 400-1400nm wavelength lasers):

Condition 1: $AE_1 > AEL_1$ for an aperture stop of 50mm, 2000mm away (z = 2m)

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The angular subtense is then compared in the range from α_{min} to α_{max} (1.5mrad and 100mrad respectively) to determine the appropriate extended source correction factor ($\boldsymbol{C_6}$), as shown in **Table *1*** below.

Table 2: C_6 Value from Angular Subtense for 400-1400nm Wavelength Lasers

Angular Subtense Range	$\boldsymbol{C_6}$
$\alpha \leq \alpha_{min}$	1
$\alpha_{min} < \alpha \leq \alpha_{max}$	$\frac{\alpha}{\alpha_{min}} = \frac{\alpha}{1.5}$
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Given the calculated angular subtense, for the classification of the laser in this report, the following correction factors are used.

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