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# Application Note AN-20240603v1
Ophthalmic Instrument Safety

**Abstract** This documents describes a standards-compliant method with which the safety of light shone into the eye by an opthalmic instrument may be assessed, and how this measurement may be performed using Bentham equipment.

## Introduction

Ophthalmic instruments that shine light into the eye, such as the slit lamps used by opticians and optometrists, are subject to standardised safety assessments to prevent damage to the eye from excess irradiance. Two similar standards that prescribe methods and requirements are ANSI Z80.36 and ISO 15004-2. This documents outlines a method of assessing the safety of some of these devices in a manner compatible with these standards.

This brief document cannot act as a substitute for the actual standards documents which cover a far greater range of scenarios. We make no guarantees or assurances regarding the accuracy of the information presented in this application note.

### Standard Revisions

The values and limits in this document are based on the values and limits in ANSI Z80.36-2016 and ISO 15004-2:2007. More up-to-date standards are available.

## Application

The devices considered in this note are lamps that are intended to illuminate the retina with a Maxwellian view, a converging beam focused on the pupil projecting a homogeneous image onto the retina regardless of the optical power of the eye's lens. This scenario is one of the simplest to assess, the well-defined homogeneus beam side-stepping the requirement to assess retinal irradiance with microscopic apertures or limited fields of view.

### Other Geometries

This application note describes a method for assessing instruments that project a homogeneous beam onto the retina. For other geometries, additional field-of-view limiting apertures must be placed in the beam path so that the peak irradiances in small areas can be measured.

## ANSI Z80.36 and ISO 15004-2 Methodology

ANSI Z80.36 and ISO 15004-2 prescribe a measurement setup that reproduces how the instrument will be used, with a spectral photodetector with various apertures taking the place of the eye.

In addition to the limits for each of a number of hazard values, these standards describe:

- how to calculate various hazard values from spectral irradiances
- how to measure or calculate spectral irradiance on the cornea or retina
- averaging apertures to use for each hazard (5 in total satisfy both standards).
- specific considerations for pulsed and time-limited instruments

The standards are aligned in approach but vary on specifics, for example to evaluate $E_{\text{IR-CL}}$, the "Unweighted corneal and lenticular infrared radiation irradiance", Z80.36 calls for a simple spectral integral of the spectral irradiance measured in the corneal plane with a 3.5mm diameter aperture between 915nm and 2500nm, whereas ISO 15004-2 evaluates the same integral from 770nm and for data measured with a 1mm aperture. Compliance with one standard does not assure compliance with the other, and often measurements done for one standard are insufficient to calculate the hazards for the other.

### Calculating hazard values

Hazard values are calculated as spectral sums, "integrals" of discrete data. For example, from ISO 15004-2,

$$E_{\text{IR-CL}} = \sum_{\lambda=915\text{nm}}^{2500\text{nm}} E_{\lambda C,1\text{mm}} \Delta\lambda$$

where $E_{\lambda C,1\text{mm}}$ is the spectral irradiance measured in the corneal plane using a circular aperture of 1mm and a measurement bandwidth of $\Delta\lambda = 5\text{nm}$. $E_{\text{IR-CL}}$ does not use a weighting factor, but for some of the hazard the spectral irradiance is multiplied by a spectral weighting factor prior to integrating. The integral yields an irradiance, in units of power per area.

Some limits are given as radiant exposure instead, where typically $H_{IR\text{-}CL} = t \cdot E_{IR\text{-}CL}$, which introduces limits on exposure time or pulse count.

### Calculating retinal irradiance from corneal irradiance

In our application the retinal irradiance can be calculated by dividing the total spectral power that enters the eye (passing through a 7mm aperture in the corneal plane) by the illuminated retinal area:

$$E_{\lambda R} = \frac{E_{\lambda C,7mm} a_p}{a_r}$$

where $E_{\lambda C,7mm}$ is the spectral irradiance measured in the corneal plane using a 7mm pupil aperture, $a_p = \pi\left(\frac{7mm}{2}\right)^2$ is the area of this pupil, and from geometrical considerations the exposed retinal area $a_r = \pi(17mm\tan(\theta))^2$, where θ is the half angle of the beam and 17mm is the diameter of the eye.

### Measuring corneal irradiance

Measuring the corneal irradiance in a single measurement can be fundamentally difficult due the requirement of measuring a very broad spectral range (250nm to 2500nm) absolutely and with a very large dynamic range, with the standards prescribing limits of as high as 20 $\frac{W}{cm^2}$ and as low as $400\frac{nW}{cm^2}$ for different spectral hazards. However, the standards explicitly permits combining multiple measurements (such as integrated absolute and relative spectral), so this is the approach taken here. Under the assumption that our instrument is dominated by the visible region, we will measure the visible region absolutely, and the ultraviolet and infrared regions using a relative but more sensitive method, finally combining all measurements into a single measurement with a dynamic range of more than 6 orders of magnitude.

### Stray Light

Even if the system is fundamentally capable of measuring very bright and very dim sources of light, it is still possible that stray light from intense light in one spectral band can overwhelm sensitive measurements in another.

Due to the high dynamic range, the stray light rejection characteristics of a double monochromator is required for this measurement. The sensitive UV region can further be isolated from intense visible light by the inclusion of a UV short- or bandpass filter, such as a UG5 filter, used only when measuring this spectral range. The less-sensitive IR region is typically well-enough protected by the double grating and order-sorting filters of the monochromator.

### Spectral ranges

The ultraviolet spectral range is best measured using a high density grating such as 2400 lines/mm blazed in the UV, using a photomultiplier sensor. This allows measurement between 250nm and approximately 800nm. Beyond this, a silicon sensor and lower density grating are required to enable measurements to 1100nm. For LED based devices, the spectral range between 1100nm and 2500nm is not normally expected to yield hazard-relevant quantities of light as the emission should be well into the exponential tail of the phosphor. Spectral measurements in this region are possible when required but typically require optically chopped measurements.

#### 1100nm - 2500nm

If the spectral region beyond 1100nm is required, a lead-sulphide detector may be used. This additionally requires measurements to be optically chopped and performed in AC mode

## Using Bentham Equipment

A Bentham double monochromator is configured with a Bentham DH_3 Multi-Alkali Photomultiplier detector on its first exit and a Bentham DH-Si Silicon detector on its second exit. One of the positions of its filter wheel is populated with a UG5 filter. The monochromator's motorised slits are configured for a bandwidth of 5nm. A Bentham DIFF_D6 diffuser is connected to its entrance. A laser-cut measurement aperture is mounted onto the diffuser. This system is intensity-calibrated by measuring a Bentham CL2 irradiance calibration standard. The diffuser/aperture is then positioned in front of the device under test, where the eye would normally be located, and the spectral irradiance is measured from 250 to 1100nm using its three diffraction gratings, automatically changing from one to the next where required, and varying the slit width to maintain a constant measurement bandwidth, and selecting the detector most suitable for each wavelength. Measurements are performed with a 487 picoammeter.

The measurement is repeated for each measurement aperture.

#### Bentham AC Mode

For deeper IR measurements, Bentham's DH_PBS_TE thermoelectrically-cooled Lead-Sulphide detector may be added to a third exit of the monochromator, with an optical chopper mounted on a relay optic on the entrance. Data aquisition for this AC mode measurement is performed via 477 preamplifier and 496 lock-in amplifier. The data can be stitched to the absolute measurement as before.

### Refinement in UV and IR

Depending on the intensity of the lamp the above measurement may be sufficient. However, due to the high dynamic range the standard allows for, it may be the case that the IR or UV regions require refinement either due to measurement noise or stray light. In this case the above measurement is repeated once more without the DIFF_D6 diffuser. The relative data in the UV and IR may be scaled to match the absolute data, and a final dataset can be assembled out of the absolute and scaled relative data.