

SACCADOMETER

Infrared (IR) photoemission analysis under IEC62471

Saccadometer eye movement measuring technology, uses the method of eye socket illumination with near infrared radiation. For this reason we evaluate the effects of the used radiation (940 nm) on the safety of the person whose eye movement is measured. Our calculations and measurements are based on IEC 62471 standard: "Photobiological safety of lamps and lamp systems". **Both corneal and retinal exposure are at safe level.**

1. Calculation of Corneal Exposure limit (long exposure time >1000s was assumed):

$$E_e = \sum_{\lambda=780}^{\lambda=3000} (E_\lambda \cdot \Delta\lambda) \leq 10 \frac{\text{mW}}{\text{cm}^2}$$

Saccadometer uses 940 nm SFH4441 IR light diodes with regulated current 0-7.5mA and 50% signal duty cycle. Standard distance from light source to eye cornea in Saccadometer system is 10mm.

Corneal exposure in this case can be calculated from the diode radiant intensity I_e and the distance between LED and cornea d .

$$E_e \cong \frac{I_e}{d^2} \cdot 50\%$$

At maximum current (7.5mA) SFH4441 diode radiant intensity is between $I_e=2.6 \text{ mW/sr}$ (min) to 5.2 mW/sr (max). Assuming maximum radiant intensity value, irradiance at 10 mm distance from light source is $E_{e(\text{max})} \approx 5.8 \cdot 50\% \text{ mW/cm}^2$, which is safely below the long time IR exposure limit (10 mW/cm^2).

$$E_{e(\text{max})} = 2.9 \text{ mW/cm}^2 \leq 10 \text{ mW/cm}^2$$

2. Measurement of Corneal Exposure

Table below contains measured values of the surface irradiance, at distance of 4 to 10 mm from Saccadometer sensor. The measurement were made using TEMD7100x1 photodiode, with OPA365 amplifier. The measurement circuit was calibrated against Advantest ADCE8230E optical power meter. In intended use conditions, Saccadometer sensor uses adaptation procedure to limit the IR illumination to a value optimal for eye movement measurement. The table contains measured surface irradiance value for maximum sensor's

IR illumination, which can be considered as worst case, being the unintended use or single-fault device malfunction value, as well as surface illumination in IR illumination adaptation mode, which is Saccadometer's normal operation condition. For both cases, the measurement represents average irradiation at maximal irradiance point on the illuminated surface.

Measured surface IR irradiance, as a function of distance to Saccadometer sensor.

Distance between surface and Saccadometer sensor	Surface irradiance [mW/cm ²] <i>Sensor's IR illumination at maximum radiant intensity</i>	Surface irradiance [mW/cm ²] <i>Sensor's IR illumination in adaptive mode. (normal operating conditions)</i>
10 mm	1,73 mW/cm ²	0,19 mW/cm ²
8 mm	2,46 mW/cm ²	0,18 mW/cm ²
6 mm	5,40 mW/cm ²	0,19 mW/cm ²
4 mm	6,85 mW/cm ²	0,22 mW/cm ²

3. Calculation of IR Retinal exposure limit according (IEC 62471).

Weak visual stimulus (no retinal nor eyelid reflex), and long time exposure was assumed:

$$L \cong \frac{I_e \cdot R(\lambda)}{\left(\frac{L+W}{2}\right)^2} \leq \frac{6000}{\alpha} = 545.5 \frac{mW}{sr \cdot mm^2}$$

$$L = \frac{5.2 \cdot 0.33}{0.3^2} = 19.1 \frac{mW}{sr \cdot mm^2}$$

Retinal exposure L=19.1 mW/(sr*mm²) is far below limit of 545.5 mW/(sr*mm²) for 940 nm range.

Bibliography:

- IEC-62471 Photo biological safety of lamps and lamp systems, 2006
- Eye Safety of IREDs used in Lamp Applications, 2010 OSRAM Opto Semiconductors
- Eye Safety for Proximity Sensing Using Infrared Light-emitting Diodes, 2015 Intersil Corp.