Safety Calculations for the Optitron Flash Lamp
to be used in the
G^0 Gain Monitoring System

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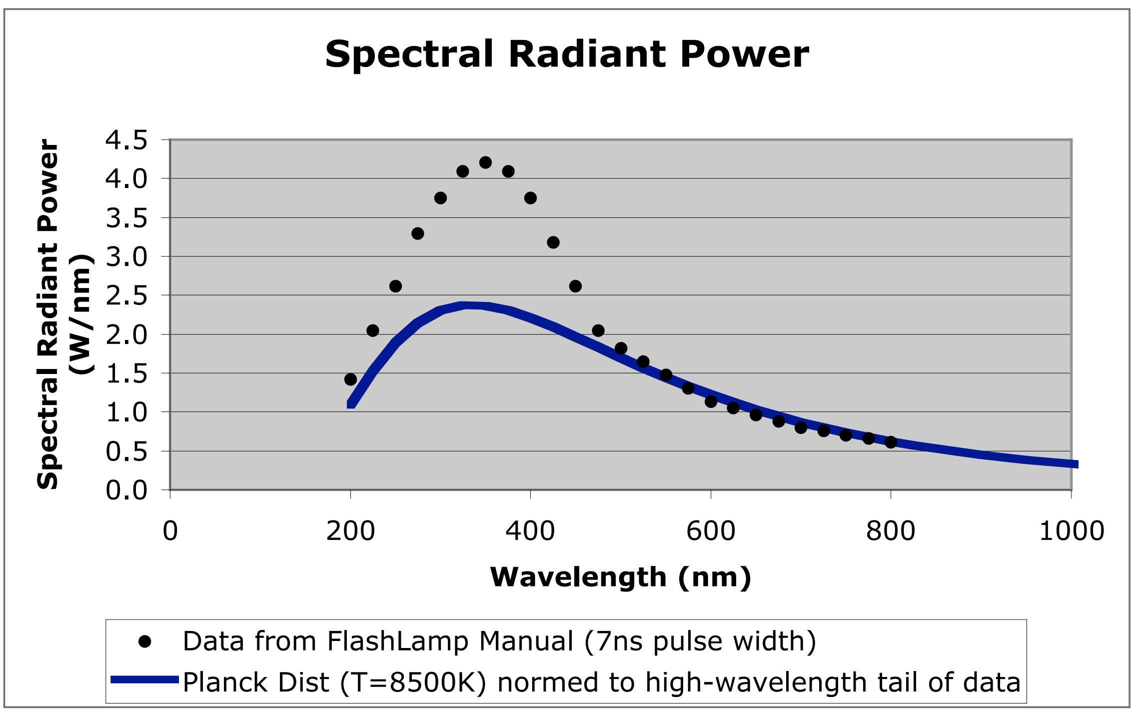
A Model NR-1A Optical Pulse Radiator, made by the Optitron Co., will be used as an optical source for a gain monitoring system in the G^0 Experiment in Hall C. This lamp produces a brief flash of photons (about 6 ns in duration) via an electrical discharge in a chamber of nitrogen gas. This document describes the optical hazard calculations performed in association with this device.

Spectrum of Light Produced: The manual provided with the lamp provides several important pieces of information for understanding the amount of light the lamp can produce.

(1) Peak Radiant Power in the beam (summed over all wavelengths) = 1.5 kW
(2) Range of Wavelengths in the beam: 200-3500 nm
(3) An unnormalized plot of the power spectrum, for wavelengths 200-800 nm

The power spectrum plot is shown below. The data in the manual (black dots) do not cover the majority of the infrared (IR) region of the light output (700-3500 nm), so in order to provide an estimate of the amount of IR radiation we have fitted a Planck distribution (blue line) to the high-wavelength tail of the data from the manual. The data have been renormalized so that the integral of the data (over 200-700 nm) and the Planck distribution (over 700-3500 nm) gives the correct peak radiant power, 1.5 kW.



Safety Considerations: Using the Threshold Limit Values (TLV) and data tables published in the American Conference of Governmental Industrial Hygienists Guide (2001), we calculate the number of pulses needed to exceed the TLV for three different hazards. In these calculations, we have used a pulse length of 6 ns, a beam diameter of 5 cm, and a viewing distance of 20 cm.

> **UV Hazard:** The table of "Relative Spectral Effectiveness" is used to compute a weighted sum of the spectral radiant power over the range 200-400 nm. For a single pulse, the result is 4.4×10^{-8} J/cm^2. The TLV is 0.003 J/cm^2. Therefore, the number of pulses required to reach the TLV is 68,000. [A UV light meter was borrowed from the JLab Safety Group. It was set to "integration" and the lamp was run at 200 Hz with 150 PSI of nitrogen and 20 kV voltage. After 10 seconds of integration the sensor reported 7.8 μJ/cm^2. Therefore each pulse produces only (7.8 μJ/cm^2)/(10*200)= 0.39×10^{-8} J/cm^2. This value is about 10 times less than the optimal performance described by the manual and computed above. At any rate, the device does not produce more light than the manual suggests.]
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> **Blue Light Hazard:** The "Blue Light Hazard Function" is used to compute a weighted radiance, which must not exceed 100 J/(cm^2 sr). The result of the computation is 1.3×10^{-11} J/(cm^2 sr), so a total of 7.36 trillion pulses would be needed to exceed the TLV.
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> **Retinal Thermal Hazard:** The "Retinal Thermal Hazard Function" is used to compute a weighted radiance, which must not exceed $(5/\alpha t^{1/4})t$, where t is the length of the pulse and α is the viewing angle [in our case, α = (5 cm)/(20 cm)]. The TLV is then 2.1×10^{-6} J/(cm^2 sr). The weighted radiance computed is 1.35×10^{-10} J/(cm^2 sr), and so the number of pulses required to exceed the TLV is 16,000.

For perspective, the highest firing rate of the lamp is 200 Hz, which in one 8-hour day would amount to 5.8 million pulses. However, except for short tests, we do not plan to run the lamp at 200 Hz. In addition, since the lamp emits plenty of light in the visible regime, a user is unlikely to stare at it for more than a few seconds before looking away.

Normal Use of the Lamp in the Gain Monitoring System: The lamp will normally be positioned very close to a filter mount and to the masking system in our light distribution box. In this position, intrabeam viewing is not possible. So, for normal operations, we need only consider the hazard presented by reflected light. All of the illuminated surfaces involved are either blackened (so they absorb visible light) or are complex in shape (so they do not produce a specular reflection). Therefore, we can consider diffuse reflection as an approximation. Also, the normal operating mode for the lamp will be at a pulse rate of about 1-2 Hz.

Conclusion: This lamp does not constitute a severe optical hazard to personnel. No special safety procedures are required. Signs will be posted warning personnel not to stare into the lamp.