

Laser-Driven Light Sources as Calibrated Spectral Irradiance Standard

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ABSTRACT

Laser-Driven Light Sources (LDLSTM) [1] were developed using high power diode lasers to energize high intensity Xe plasma. The LDLS sources produce 170nm to 1700nm radiation with ultrahigh brightness from the high power density plasma at the laser focal point, and exhibit long source life due to their electrodeless operation. With its high stability and much longer lamp life, an LDLS can be a better choice as a calibrated spectral irradiance standard source than a calibrated lamp or a calibrated D2 lamp.

1. INTRODUCTION

The ever-increasing development of new medical analysis instruments, optical imaging equipment and semiconductor inspection systems using UV and visible light sources increases demand for radiometry calibration. Calibrated tungsten quartz-halogen (TQH) lamps are often used as standard sources for a spectral irradiance measurement in the UV to NIR wavelengths, but they have much lower radiant powers in UV wavelengths under 350nm. To obtain a higher radiant power near 200nm in the UV range, calibrated deuterium (D2) lamps are usually used as standard sources, but their radiant powers drop more than one order of magnitude between 200nm and 400nm. In order to calibrate a source between 200nm and 800nm wavelengths, a calibrated TQH lamp and a calibrated D2 lamp have to be used. However, as shown in Figure 1 [2] and Figure 2, both TQH and D2 (calibration) lamps have lower radiant power between 300nm and 400nm. Because a tungsten filament works at high temperatures in a TQH lamp and a thermionic emission cathode is used to generate D2 plasma in a D2 lamp, these two standard sources both have about 50-hour lifetime before they require recalibration. This is inconvenient and costly.

Calibrated Xe short arc lamps are offered as spectral irradiance standard sources by one supplier, but the lamps only lasts 100 hours before recalibration and only have 500 hours of lamp service life. Due to the limitations of current density, plasma (cathode spot) temperature in a Xe short arc lamp is about 7000K. This causes a steep drop of radiant power under 250nm and raises the ratio between visible and UV radiant power.

A 20W LDLS (model EQ-99) was calibrated for spectral irradiance between 200nm and 900nm by Bentham Instruments Ltd. Spectral irradiance of the LDLS source is compared to that of one TQH standard source and one D2 standard source in Figure 2. Due to significantly higher Xe plasma temperature (10,000K – 20,000K), the LDLS source spectral irradiance is smooth and flat between 200nm and 800nm, where most UV and visible calibrations are conducted.

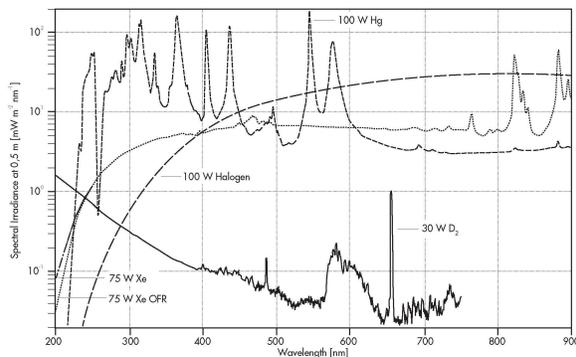


Figure 1. Spectral irradiance at 50cm for a 100W Hg lamp, a 100W TQH lamp, a 75W Xe lamp, a 75W Xe ozone-free lamp, and a 30W D2 lamp [2].

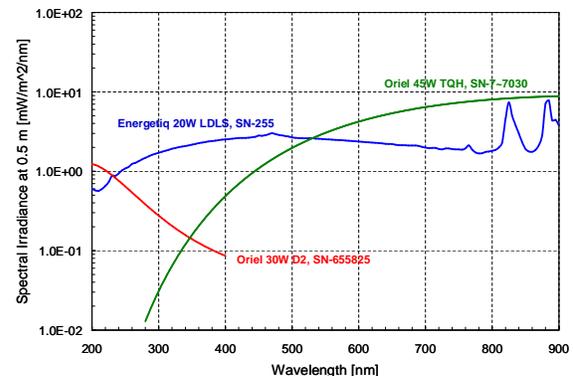


Figure 2. Spectral irradiance at 50cm for a calibrated Energetiq 20W LDLS source, a calibrated Oriel 45W TQH lamp, and a calibrated Oriel 30W D2 lamp.

2. LDLS STABILITY AND LIFETIME

During the calibration of the EQ-99 LDLS source at Bentham, the irradiance was measured over the wavelength range of 300nm to 900nm at 5nm intervals by comparison to a Quartz Halogen lamp standard calibrated by NPL (SN65786). The absolute irradiance was further verified by comparison with a Deuterium standard of irradiance from 200nm to 400nm, traceable to the NPL-2003 irradiance standard. Measurements were made using a double monochromator based spectroradiometer manufactured by Bentham.

The EQ-99 LDLS source was run in an air conditioned environment. The lamphouse of the EQ-99 was purged with nitrogen during operations and its temperature was controlled by a cold plate which was connected to a water chiller unit set at 37°C.

Evaluation of stability of the EQ-99 source was conducted by repeating the calibration procedures for several times on different dates. The results of EQ-99 irradiance at 470nm are listed in the following table:

Measurement date	03/03/12	03/13/12	03/14/12	03/15/12	03/26/12	Mean	(Max-Min)/Mean (%)
50cm Irradiance at 470nm (mW/m ² /nm)	3.0499	3.0264	3.0526	3.0922	3.0155	3.0473	2.5

Frequent lamp changes and calibrations will lower productivity by consuming valuable technical and financial resources. In electrode-driven lamps (TQH and D2 Lamps), the hot electrodes are the primary life-limiting factors, as they evaporate metal onto the quartz bulb. In an LDLS, the energy is delivered to the Xe plasma optically by a focused laser beam, so there is no high thermal, electrical, or mechanical stress on the high-pressure gas bulb. The bulb's electrodes, used for ignition only, are spaced away from the plasma and not directly heated by the plasma during operation. A comparison of life-test data highlights the differences in output drop over time between typical LDLS sources and typical Xe and D2 lamps (see table below).

Light source	Change in broadband output/1000 h (typ.)	Life-test hours to date	Notes
LDLS EQ-99	~ -1%	> 6000	Test ongoing
30W D2 lamp	-50% (depending on model)	–	Source: product data sheet
75W Xe arc lamp	-25% to -50% (depending on model)	–	Source: product data sheet

REFERENCES

- [1] US Patent #7,435,982
- [2] Lamp Spectra and Irradiance, LOT-Oriel Group Europe, www.lot-oriel.com