# Absolute intensity calibration of LII detectors

K. A. Thomson, D. R. Snelling, G. J. Smallwood
Institute for Chemical Process and Environmental Technology
National Research Council, Canada

Absolute intensity calibration is an integral component of auto-compensating laser induced incandescence (AC-LII) and other two-colour LII methods. Three sources: a tungsten strip filament, an irradiance standard with a calibrated reflector, and a lamp coupled with an integrating sphere, are compared. Differences between sphere and filament are below 10%. The irradiance standard differs by 30%. The integrating sphere is the preferred standard for excellent output uniformity (< 1 % deviation) across a large field-of-view, high intensity, good intensity control, and minimum indirect radiation bias.

**Introduction**

AC-LII is a valuable tool for the determination of soot concentration and effective particle diameter for soot aerosols in a variety of settings [1]. The method does not require calibration of the LII signal using a soot aerosol of known concentration; however, an absolute light intensity calibration of the LII apparatus is required. Several intensity calibration standards are commercially available. A comparison of three standards is presented.

**Apparatus**

The centre portion of the filament (i.e. 1 mm diameter) of a tungsten strip filament lamp is approximately invariant (< 10% variation) and can be used to calibrate LII systems which sample a small field-of-view. The lamp is small and fits various experimental setups (e.g. pressure vessels). The lamp used here was calibrated at NRC for brightness temperature ($T_b$) as a function of lamp current. Spectral radiance can be calculated from $T_b$ using Planck function and the emissivity of tungsten. Commercial lamps are available.

Irradiance standards are lamps for which the spectral irradiance at a set distance from the bulb is uniform and known. The spectral radiance off a highly reflective (>98%) diffuse reflector located at this distance can be calculated. The reflector can be various sizes (e.g. 25 mm dia.); however, must face normal to the irradiance source. Therefore it cannot be normal to the detector. This does not impact the radiance observed by the detector provided the collection optic has a good depth-of-field. The radiance from the reflector is of fixed intensity and is weak against the background of stray emission from the intense irradiance standard (200 W bulb). Indirect radiation bias can be a problem.

The lamp and integrating sphere uses a bulb coupled to a highly reflective sphere. The spectral radiance of light emitted from a port on the side of the sphere (35 mm diameter here) is spatially uniform (< 1 % variation) and can be varied in intensity using a shutter. The spectral output is monitored by a spectrometer coupled to a second port on the sphere. Thus variation in intensity due to the shutter position or lamp aging is accounted for.

The experiment layout is shown in Fig. 1. The radiant emission from the measurement field-of-view (1 $mm^2$) was imaged onto a fiber optic (1:1) coupled to a de-multiplexer and two PMTs (Hamamatsu H5783-03 bialkali photosensor and H5783-20 photosensor) filtered for 445 and 783 nm. A light chopper modulated the light.

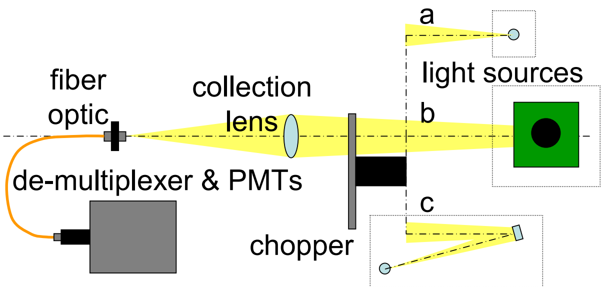


*Figure 1: Calibration setup a.) strip filament lamp, b.) integrating sphere, and c.) irradiance standard*

Table 1 includes the measured calibration factors. The filament and sphere standards agree to within 10%. The irradiance standard differs more significantly. It is postulated that the lamp has aged since purchase and a new lamp is on order.

*Table 1: Calibration Factors [$W/m^3$ ster V]*

| λ | Filament | Irradiance | Sphere |
|---|---|---|---|
| 445 nm | 7.52e9 | 1.05e10 | 8.21e9 |
| 783 nm | 1.67e12 | 2.00e10 | 1.52e12 |

The filament and sphere sources are easier to implement since the source sits in the location of LII measurement. The strength of the radiant emission is much stronger than that from an irradiated reflector and they face the detector normally. The sphere provides a large uniform source and lamp aging is internally account for; however, this assumes no drift of the lamp spectrometer. It is our opinion that the lamp coupled to an integrating sphere is the optimal light source for detector absolute intensity calibration. Future work will involve testing the source calibrations with help from the National Institute for Measurement Standards.

[1] D. R. Snelling et al., Appl. Opt. v44, p6773-6785, (2005).