

Traceable Ultraviolet Measurements in New Zealand

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Abstract . This paper outlines the work of the national metrology institute of New Zealand (MSL) and its role in ensuring that traceable measurements and calibrations are available for all users of ultraviolet radiation measurements in New Zealand.

Introduction

Light pervades our everyday life. Its reflection off surfaces is the primary way in which we interact with the physical world. Even in wavelength regions that we cannot visually perceive it has its effects, from the heat of the infrared to the responses of objects to ultraviolet radiation. However, despite its ubiquitous nature, it is one of the more difficult physical quantities to measure.

Globally there is interest in ultraviolet (UV) radiation, both its uses and influences, from the semiconductor industry through to researchers interested in interactions between solar UV at the Earth's surface and its impact on the atmosphere, plants, animals and materials. UV radiation is measured in order to quantify its influence in these areas. In some cases these measurements may extend over long time sequences and in other cases the measurement will be spatially distributed and involve more than one device in the measurement process. To ensure confidence in the measured UV requires that the sensing equipment is well characterised, including a traceable calibration and an assurance that if the calibration is transferred to other devices the traceability is maintained.

Measurement Traceability

Traceability is a method of demonstrating that a measurement is an accurate representation of the measurand in terms of relevant national or international standards traceable to SI (International System of Units). Traceability not only requires calibration against a known scale or reference standard but that the technical procedure used for the calibration and the personnel carrying out the procedure are competent for the task.

Turnkey solutions purchased by users often claim some form of traceability to a national measurement institute (NMI). For such claims to be valid the manufacturer of the equipment should be able to guarantee an unbroken chain of calibration and comparison back to the SI. One form of guarantee is that the provider of the calibrated artefact has been independently assessed to provide the calibration service. This usually requires accreditation to ISO 17025; in New Zealand the accreditation body is IANZ (International Accreditation New Zealand) and in Australia NATA (National Association of Testing Authorities).

With traceability the measurements made are more likely to be reliable and accurate. The impact of traceable measurements is recognised both internationally and nationally in, for example, the move toward traceability for all climate data (Fox, 2005). The underlying need in this

case is for reliable data both spatially and temporally when making decisions around climate change. On a more local note, a manufacturer of UV water disinfection systems required accurate measurements of the irradiance of medium pressure mercury lamps. The UV radiometer used to measure the lamps indicated the output for the lamps was lower than required for the application. Fortunately, the manufacturer decided to have the radiometer recalibrated in spite of its having a current "traceable" calibration from its supplier. The meter was not only found to be measuring 30 % low in terms of irradiance but also had cosine response to $\pm 5^\circ$ not the $\pm 60^\circ$ required.

New Zealand's Radiometric Measurement Scales

The Measurement Standards Laboratory of New Zealand is entrusted by an Act of Parliament to realise and maintain scales of physical measurement for New Zealand users. These scales encompass the six base SI units, including the unit of light, the Candela. The Candela is defined radiometrically as the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} Hz and has a radiant intensity in that direction of $1/683$ of a watt per steradian. This unit is in turn determined from the scales of detector spectral responsivity and spectral irradiance at MSL. These scales cover both detectors and sources of light and are realised and maintained not only through the visible but also in the near infrared (NIR) and UV spectral regions.

The scale of detector spectral responsivity realised in New Zealand starts with measurements of laser power, made using our cryogenic radiometer (Nield *et al.*, 1998); these measurements are accurate to parts in 10^5 . Using these measurements and the response of detectors to the laser power, a scale of detector spectral responsivity in A W^{-1} is realised. In the visible this scale is accurate to within ± 0.03 %. In the UV where measurement is more difficult the scale is accurate to ± 0.5 % at 240 nm improving to ± 0.3 % above 260 nm.

So this covers spectral responsivity, but what about sources and spectral irradiance ($\text{W m}^{-2} \text{nm}^{-1}$), a measurand commonly used when observing the influence of ultraviolet light? Spectral irradiance standards are commonly used to calibrate spectroradiometers such as those used for solar UV measurements, these standards themselves have occasionally been found to be unstable, especially in the UV (Harrison *et al.*, 2000). In New Zealand we maintain a scale of spectral irradiance on a set of 1 kW tungsten halogen lamps traceable to NIST (Yoon *et al.*, 2002) in the USA. The scale transferred from MSL is accurate to ± 2.3 % at 250 nm improving to ± 1.3 % by 400 nm.

As we can see the uncertainty (a measure of accuracy) of these scales in the UV is somewhat larger than in the visible or NIR. This can lead to challenges for experiments that measure small effects of or changes in,

for example, ultraviolet radiation.

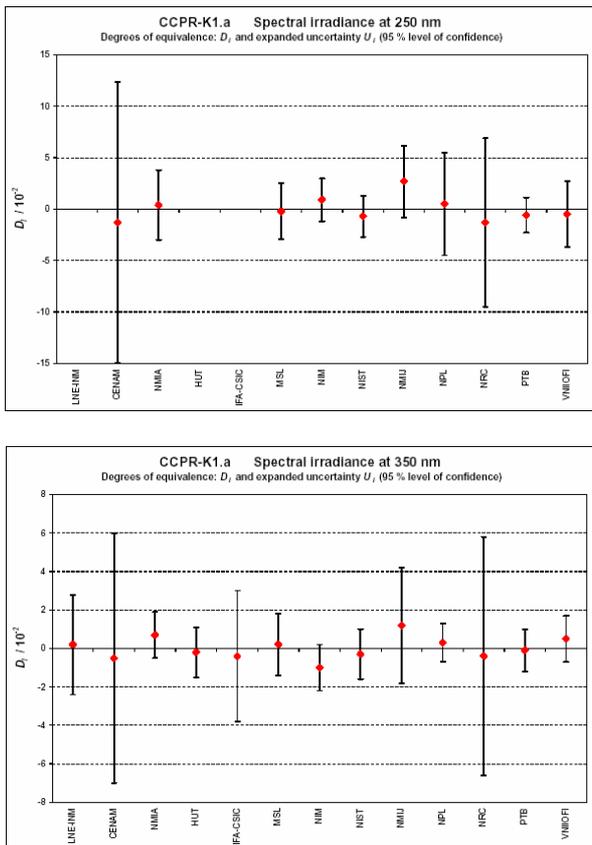


Figure 1. International Comparison results at 250 nm and 300 nm for CCPR-K1a, spectral irradiance (Woolliams *et al.*, 2006).

Over the past thirteen years MSL has taken part in international comparisons of all the aforementioned radiometric scales, including a comparison of detector spectral responsivity (Kohler *et al.*, 1996), spectral irradiance (Woolliams *et al.*, 2006), Figure 1, and cryogenic radiometers (Goebel *et al.*, 1999), Figure 2. These comparisons are organised by the Consultative Committee on Photometry and Radiometry (CCPR) of which MSL is a member in recognition of past and current work in radiometry including the realisation of UV detector spectral response scales (Bittar, 1996, Nield *et al.*, 1997 and Nield *et al.*, 2005). Results of these comparisons have demonstrated MSL's ability to realise scales traceable to the SI.

As the NMI for New Zealand, MSL ensures that the traceability of our scales is maintained when disseminated from our laboratory by accreditation to ISO 17025. As part of the process overseas experts have assessed all the facilities and staff of the laboratory. This is also supported by participation in the aforementioned international comparisons.

Conclusion

Traceability enables users to make meaningful and reliable measurements. This is particularly important to support conclusions and decisions made on the basis of the

measurements made. To support traceability in New Zealand MSL maintains and realises radiometric scales that are available to all users of UV measurement. Over and above the calibration of equipment accreditation systems ensure that the traceability chain remains intact from the SI to users through NMIs, secondary calibration laboratories, and equipment suppliers.

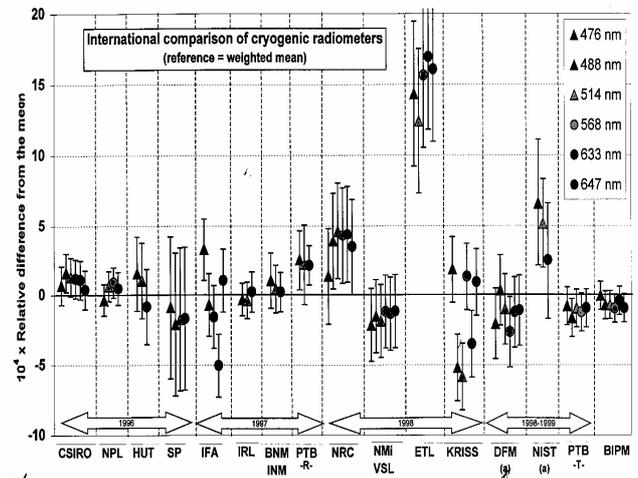


Figure 2. Results of the CCPR comparison of cryogenic radiometers.

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Note: all measurements uncertainties stated in this paper refer to an expanded uncertainty at the 95 % confidence level.