Improvements to the Ultraviolet Measurement Capabilities of RTS

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We report on recent improvements to performance of NIST's Reference Transmittance Spectrophotometer (RTS) in the ultraviolet (UV) and visible spectral range. The improvements include the installation of a new UV source for increased spectral radiance and a monitor line for reduced signal-to-noise ratio.

INTRODUCTION

The National Institute of Standards and Technology maintains the national scale for regular spectral transmittance through the operation of the Reference Transmittance Spectrophotometer (RTS). The instrument provides the transmittance scale realization and validation for NIST's calibration service for regular spectral transmittance [1] and Standard Reference Materials (SRMs) for spectrophotometry [2,3], respectively, from the ultraviolet to the short-wave infrared (250 nm to 2500 nm).

There has been growing interest in UV measurements, due in part to the wider availability of UV radiation sources, including UV light emitting diodes. RTS originally used a deuterium lamp to provide UV radiation for wavelengths below 350 nm. The deuterium lamp is significantly less stable than the quartz-tungsten-halogen (QTH) incandescent lamp used for longer wavelengths, resulting in UV uncertainties that are an order of magnitude larger in comparison to those in the visible and near-infrared.

LASER-DRIVEN LIGHT SOURCE

To improve performance of RTS in the UV and reduce uncertainties, we procured a high-intensity, laser-driven light source (LDLS) to use in place of the deuterium lamp. The LDLS is a compact, broadband source that uses a continuous wave laser to produce a discharge from a xenon plasma. This discharge provides significantly improved spectral radiance compared to traditional UV lamp sources. Early measurements of the LDLS indicated that signal noise was significant. Consequently, we installed a monitor line.

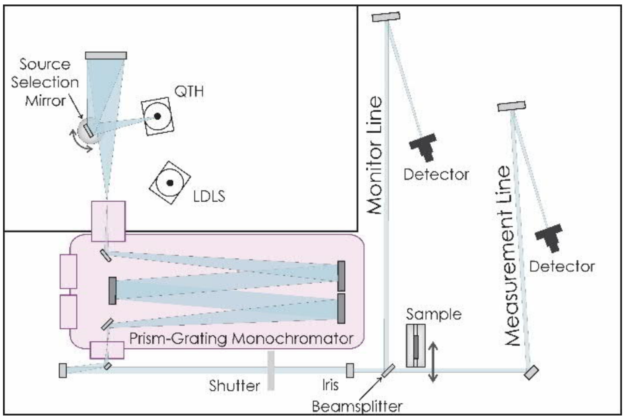

Figure 1. RTS layout, which includes two possible sources, a measurement line, and a monitor line.

SYSTEM LAYOUT

RTS is a custom-built instrument consisting of an illuminator, sample translator, and receiver (Fig. 1). The illuminator generates a nearly monochromatic (3 nm spectral bandwidth), collimated beam. There are two possible radiation sources, a laser-drive light source (LDLS) and a quartz-tungsten-halogen (QTH) incandescent lamp. A rotating mirror selects the appropriate source to be focused onto the entrance slit of a prism-grating monochromator. Upon exiting the monochromator, the beam is collimated by a parabolic mirror.

The sample translator consists of a sample holder mounted on translation stages that have both horizontal and vertical motion. The horizontal motion enables the sample to be moved out of and into the beam path so that both the incident and transmitted flux can be measured. The sample is centered in the beam using both horizontal and vertical motion.

The receiver measures both the incident and transmitted flux. It consists of a shutter, beam splitter, focusing mirrors, and detectors. The shutter is used to collect the dark current. The beam splitter, which is placed ahead of the sample translator, diverts a portion of the beam (30%) to the monitor line where it is focused onto the monitor detector. The remaining portion of the beam is directed through the sample translator to the measurement line where it is focused onto the measurement detector. Both detectors are silicon photodiodes.

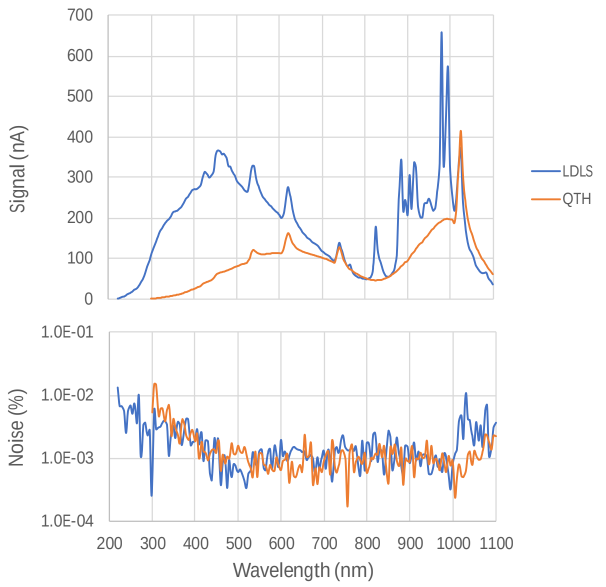

Figure 2. (Top) Signals of the LDLS and QTH sources as measured by the measurement line detector. (Bottom) Noise as a percentage of the signal.

Care was taken to ensure that the conditions for the measurement and monitor lines were nearly equivalent in terms of components and optical dimensions.

INITIAL RESULTS

Fig. 2 shows the signal and noise for the LDLS and QTH sources as measured by the measurement line detector over the spectral of 220 nm to 1100 nm. The LDLS source has 10^2 more signal than the QTH in the UV and most of the visible.

The signal noise is improved by ratioing the signals from the measurement and monitor lines. For both sources, the signal noise (%) is on the order of 10^{-2} for the UV and 10^{-3} for the visible. This represents a significant drop in noise of 2 and 1 orders of magnitude for the LDLS and QTH sources, respectively, for the case with no monitor line (data not shown).

An initial uncertainty budget, which considers contributions from the signals and electronics, was developed for the transmittance measurements. The results for a filter of 0.5 nominal transmittance are provided in Table 1.

The contributions considered in this budget include linearity of the silicon photodiode, accuracy of the digital multimeter, random fluctuations in the voltage measurements, accuracy of the voltage measurements, accuracy of the amplifier gain, and accuracy of the offset voltage for the amplifier.

Table 1. Initial uncertainty budget, which considers contributions from the signals and electronics, for a filter with nominal transmittance of 0.5.

Source	Wavelength (nm)	Rel. Unc. (%) ($k = 1$)
LDLS	300	0.14
	500	0.31
	900	0.17
	1000	0.33
QTH	500	0.013
	900	0.014
	1000	0.059

In general, the largest contributor to the relative uncertainties listed in Table 1 is the random fluctuations in the voltage measurements for the LDLS source; whereas, the largest contributor for the QTH source is the accuracy of the digital multimeter.

FUTURE WORK

Characterization of additional uncertainty components is underway. These components include wavelength accuracy, stability of the signal-to-monitor ratio, out-of-band stray light, and inter-reflections. Also, in progress is validation of transmittance measurements in terms of the measured values.

It is noted that the recent improvements described here do not include any changes to the method for transmittance measurements in the near-infrared and short-wave infrared. These will be implemented in the near future.

REFERENCES

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