XX IMEKO World Congress
Metrology for Green Growth
September 9−14, 2012, Busan, Republic of Korea

THE KRISS PLUS (PULSED LASER-BASED UNIFORM SOURCE) FACILITY FOR MEASUREMENT OF SPECTRAL RADIANCE RESPONSIVITY

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Abstract: We are developing a pulsed laser-based uniform source facility for measurement of spectral radiance responsivity. By using an optical parametric oscillator, a wide wavelength range from 210 nm to 2500 nm can be covered by a single device. Realization of the two basic concepts based on the pulse-to-pulse data acquisition are presented and discussed.

Keywords: spectral radiance, uniform source, tunable laser, pulsed OPO

INTRODUCTION

Radiance is a quantity measured by most of cameras and radiometers with an imaging optics. The human eye is a good example of such a radiance meter sensitive in the visible range, where a special quantity of luminance is defined to consider its wavelength dependence. Measurement of spectral dependence of responsivity is an essential step to test and calibrate a radiance meter. High-accuracy measurement of radiance responsivitiy is of particular interest in the field of radiometry and radiation thermometry, where a wavelength-filtered radiance meter is used as a transfer standard linking between the temperature scale and the radiometry scale [1].

Spectrally-integrated radiance responsivity is calibrated against a blackbody with a known temperature. In order to measure the spectrally-resolved responsivity, however, one needs a more sophisticated calibration source that should be monochromatic and wavelength-tunable. Moreover, a high level of spectral radiance is required because most of radiance meters are optimized for an integrated quantity. A tunable laser-based integrating sphere source is known as the most effective method to measure the spectral radiance responsivity. Successful realizations and applications based on multiple continuous-wave (cw) laser systems are reported, for instance, from the SIRCUS facility at NIST, USA [2].

We propose an alternative approach to realize a facility for measurement of spectral radiance responsivity. Instead of a cw tunable laser, we use a pulsed tunable laser to illuminate an integrating sphere. The main advantage of this pulsed laser-based concept is that a large wavelength range can be covered by only a single laser, which saves a lot of space and budget. The main challenge, on the other hand, is to overcome the pulse-to-pulse fluctuation and to consider the nonlinearity of the pulse responsivity of the device under test (DUT).

In this report, we present the concept and progress of the pulsed laser-based uniform source facility at KRISS, Korea, which we designate as the KRISS PLUS facility.

THE PULSED LASER SOURCE

As the wavelength-tunable pulsed laser for the KRISS PLUS facility, we use a Q-switched optical parametric oscillator (OPO) pumped at a wavelength of 355 nm [3]. With the built-in second-harmonic generation and sum-frequency generation, the tuning range of the OPO covers from 210 nm to 2500 nm. The pulse width is smaller than 5 ns, and the repetition rate is fixed at 1 kHz. The spectral linewidth is specified to be less than 2 cm^{-1} (60 GHz) in the visible range.

Figure 1 shows the measured pulse energy averaged over 1 s as a function of wavelength (symbols) together with the manufacturers test data (line), which confirms the wide wavelength coverage. The pulse energy in the UV and in the mid-IR is in the level of 10 μJ, which corresponds to the average power of 10 mW at a repetition rate of 1 kHz. The pulse shape and width is measured by using fast Si and InGaAs photodiodes at several wavelengths from UV to IR, which confirmed the pulse width of less than 5 ns.

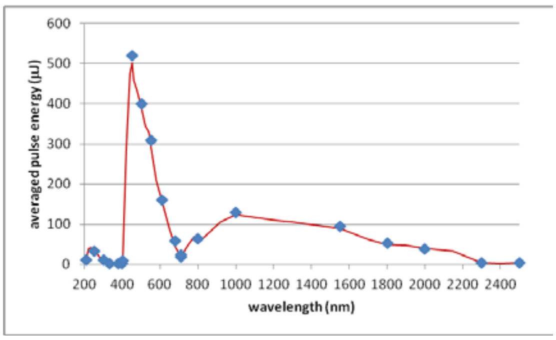

Fig. 1. Output pulse energy of the OPO used for the KRISS PLUS facility as a function of wavelength. The measured results (symbols) are compared with the manufacturer’s test data (line).

The shortcoming of the OPO is, however, the large pulse-to-pulse fluctuation of the pulse energy, which is an intrinsic property of a Q-switched ns laser system. At several wavelengths, the relative standard deviation of the pulse energy is measured to be larger than 20 %. This means that we cannot expect a stable radiance output of the KRISS PLUS facility by monitoring the average power of the OPO source. Two solution concepts are currently traced to overcome this problem. The first is to monitor the energy of each pulse by using a beam splitter and a pulse-to-pulse data acquisition scheme. The second is to actively stabilize the energy of each pulse by using a pulse-to-pulse feedback control scheme.

PULSE MONITORING CONCEPT

The main idea of the pulse monitoring concept is to measure the energy of each pulse by using a data acquisition (DAQ) scheme which is fast enough to follow the repetition rate of 1 kHz. In this concept, the KRISS PLUS is applied as a pulsed source with a known value of spectral radiance for each pulse. If the response of a DUT is slower than 1 kHz, the average radiance within a specified exposure time should be determined. However, as the pulse energy of each pulse is monitored and recorded, the accuracy of the spectral radiance exposure can be high.

Figure 2 schematically shows the proposed setup of the KRISS PLUS based on the pulse monitoring concept. The output beam of the pulsed OPO is delivered to an integrating sphere (IS) with a diameter of 305 mm via a multi-mode optical fiber (MMF). Before the input of the fiber, a beam splitter (BS) is used to sample a portion of the pulse energy from the OPO to a monitoring detector (A). On the IS, another monitoring detector (B) is attached, which delivers a signal proportional to the spectral radiance at the output port with a diameter of 70 mm. Note that the ratio of the signals of both monitoring detectors can be differ as the wavelength changes due to spectral dependence of transmittance through the MMF. A test and a reference radiometer is placed at a specific distance from the output port of the IS for a substitution measurement. A small fraction of back-reflection from the MMF is directed to a wavelength meter for real-time monitoring of the output wavelength. A computer-controlled shutter is used at the input port of the IS to control the exposure time of spectral radiance.

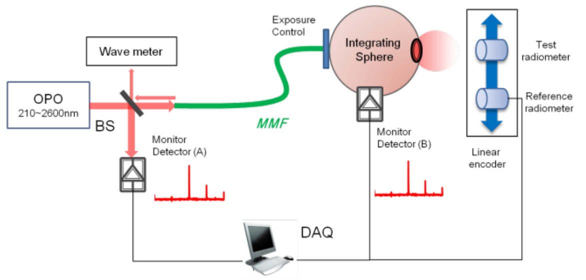

Fig. 2. Schematic setup of the KRISS PLUS based on the pulse monitoring concept.

The key technique of the pulse monitoring concept is a pulse-to-pulse DAQ scheme, which we realized based on a fast digital oscilloscope. The temporal shape of each pulse is recorded and analyzed by computer software to get a value that is proportional to the pulse energy of each pulse. The large fluctuation of pulse energy requires a good linearity of the pulse energy monitoring and DAQ. Currently, we realized a pulse-to-pulse energy monitoring with an uncertainty of less than 0.5 % [4].

PULSE STABILIZATION CONCEPT

In the pulse stabilization concept, the pulse energy of each pulse is not only monitored, but also actively controlled to a pre-defined value via a modulator. The proposed setup is shown in Fig. 3. As soon as the output pulse energy is measured via the monitor detector (A) and the pulse-to-pulse DAQ scheme as shown in Fig. 2, its value is converted to an error signal by comparing with a pre-set value. The error signal is then applied to a modulator after a proper gain control through an amplifier, which controls the energy of the same pulse delayed within a fiber delay line for the DAQ process time of several hundreds of ns. The advantage of the stabilization concept of Fig. 3 against the monitoring concept of Fig. 2 is that the output from the IS can be regarded as a stable quasi-cw radiation for the most of DUTs with a slow response. However, the main challenge of this concept is the development of the high-bandwidth high-dynamic range modulator. We are developing a novel modulator based on a fiber-based acousto-optic tunable filter [5].

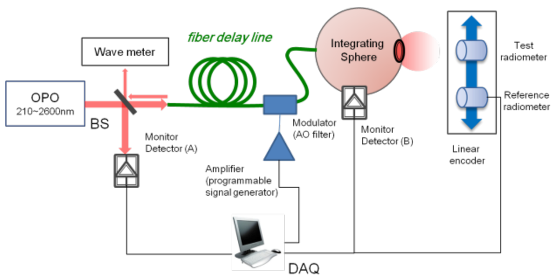

Fig. 3. Schematic setup of the KRISS PLUS based on the pulse stabilization concept.

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