Development of Simple Band-Spectral Pyranometer and Quantum Meter Using Photovoltaic Cells and Bandpass Filters

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Abstract. In recent years, greenhouse automatic-control, based on the measurement of solar irradiance, has been attracting attention. This control is an effective method for improving crop production. In the agricultural field, it is necessary to measure Photon Flux Density (PFD), which is an important parameter in the promotion of plant growth. In particular, the PFD of Photosynthetically Active Radiation (PAR, 400-700 nm) and Plant Biologically Active Radiation (PBAR, 300-800 nm) have been discussed in agricultural plant science. The commercial quantum meter (QM, PAR meter) can only measure Photosynthetically Photon Flux Density (PPFD) which is the integrated PFD quantity on the PAR wavelength.

In this research, a band-spectral pyranometer or quantum meter using PVs with optical bandpass filters for dividing the PBAR wavelength into 100 nm bands (five independent channels) was developed. Before field testing, calibration of the instruments was carried out using a solar simulator. Next, a field test was conducted in three differing weather conditions such as clear, partly cloudy and cloudy skies. As a result, it was found that the response rate of the developed pyranometer was faster by four seconds compared with the response rate of the commercial pyranometer. Moreover, the outputs of each channel in the developed pyranometer were very similar to the integrated outputs of the commercial spectroradiometer. It was confirmed that the solar irradiance could be measured in each band separately using the developed band-spectral pyranometer. It was indicated that the developed band-spectral pyranometer could also be used as a PV band-spectral quantum meter which is obtained by converting the band irradiance into band PFD.

INTRODUCTION

Solar irradiance is important for a variety of fields[1] such as meteorology[2], solar energy[3], agriculture[4], and healthcare[5]. Generally, a thermopile pyranometer (TP pyranometer) is used to measure solar irradiance because it has an advantage in responding to a wide wavelength range of 300-2,800 nm[3, 6, 7, 8]. On the other hand, silicon (Si) photodiode (PD) pyranometer (PD pyranometer) is frequently used to measure solar irradiance[9, 10] because the Si sensor type is less expensive than the TP type[11]. Moreover, photovoltaic (PV) Si solar cell pyranometers (PV pyranometer) are also developed[12]. The performance and output signal of a PV pyranometer are high enough to use as an irradiance measurement, and the cost is also reasonable. The PV pyranometer is used for many applications such as in the environmental energy fields and meteorology science studies[13, 14, 15].

The greenhouse environmental control system has been developed to increase the production of plants[21, 22] by using such features as temperature and ventilation control systems[23]. In recent years, more complicated control systems have been used to diagnose and control plant growth based on measurements of CO_2 concentration and solar irradiance[24, 25]. We have reported the development of a simple PV array pyranometer for greenhouse applications[16, 17] where it could avoid the effects of the artificial shadow created by the greenhouse structural frames. In our previous study, the

The Irago Conference 2015
AIP Conf. Proc. 1709, 020025-1–020025-11; doi: 10.1063/1.4941224