Title of innovation

UV array spectroradiometer with innovative scattered light correction

Image of the innovation

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Brief description of the innovation

Many applications in the UV range could until now only be realised with slow, complex, expensive, and above all large double monochromators. The systems required complex installation and logistics. Much more compact and stable structures can be realised with array spectroradiometers. Until now, the limiting factor has always been inadequate scattered light suppression in the UV range.

The limiting factor for the use of array-based spectroradiometers in the UV spectral region has been their inadequate stray light suppression. Therefore, many UV applications could previously only be implemented with double monochromators. Such systems are inconveniently large and slow due to their mechanical scanning. Typically, they require complex installation and operation as well as being expensive. With the innovative BTS2048-UV-S device series from Gigahertz-Optik GmbH, a production-ready technology has been developed to overcome this limitation. In an international measurement comparison on Mount Teide, Tenerife, the irradiance of the sun was measured. Thanks to its innovative filter-based scattered light suppression and its DAkkS-traceable calibration, the BTS2048-UV-S showed very good absolute conformity over several orders of magnitude compared with an internationally accepted reference instrument (double monochromator). This was an impressive demonstration of the quality of the technology. The considerably shorter measurement time (a few seconds compared to many minutes) and the small size (reduction in volume by 98 %) open up new areas of application and investigation. In addition, the new technology can be used anywhere, operating in a compact, weatherproof box with low energy consumption, meaning that the system allows for much easier solar UV and ozone measurement without major infrastructure and logistical requirements, even in exposed locations such as the Zugspitze. Other applications include radiation risk assessment in occupational safety and the measurement of UV LEDs, to name but a few.

Detailed description

State of the art and its limits

Common array spectroradiometers have no special technical adaptations for reducing the scattered light within the UV region. Best performing devices are usually only distinguished by an optimised optical beam path and high-quality optical components. These reduce the scattered light, but not to the extent of double monochromators that achieve high scattered light suppression by coupling two monochromators in series. However, their disadvantage is that only one wavelength can be measured at any one time as double monochromators employ a mechanical scanning technique. This results in long measurement times of typically 15 minutes if high resolution in the UV range is required. A mathematical method for scattered light reduction of array spectroradiometers was developed some years ago. This uses a characterisation of the spectroradiometer by means of a tuneable laser and a mathematical scattered light correction based on it. This method is used successfully in the visible to near-UV range, but reaches its limits in the deeper UV range, where the quality of the scattered light correction is not sufficient for many applications. Usually, only a correction of one order of magnitude can be achieved. Furthermore, this method is not suitable for fully optimised UV spectroradiometers, since the entire sensitivity range of the detector chip must be characterised for efficient correction. The most frequently used Si detectors have a sensitivity ranging from 200 nm to 1,100 nm, while pure UV spectroradiometers only measure from 200 nm to 400 nm, i.e. a large part of the spectral range (400 nm to 1100 nm) cannot be corrected. In addition, the signal levels in the visible spectral range are usually considerably higher than those in the UV range, i.e. the remaining scattered light from the visible spectral range dominates the signal to be measured in the UV range. Therefore, many applications in the UV range cannot yet be realised with array spectroradiometers.

Description of the core of the innovation (e.g. functional principle / structure) and its advantages

The innovative power lies in the fact that various optical filters, including bandpass, interference, and edge filters are dynamically introduced into the beam path of the array spectral radiometer behind the input optics. This drastically reduces scattered light and therefore makes it suitable for a wide range of demanding UV applications offering the advantages of array spectroradiometers such as robust compact systems with short measurement times. This technology enables smart and automated measuring routines based on individual measurements. The measurements are corrected for scattered light, as only a small amount of radiation can penetrate the spectrometer unit through the optical filters. The results are then intelligently combined to form an overall measurement. Which filters are used depends on the light source to be measured. Thus, logical measurement sequences can be optimised for different light sources. It is the combination of these measurement sequences and the robust software implementation of the mathematical correction as well as the opto-mechanical design that make this technology powerful. Background on scattered light formation: Scattered light is produced in the spectrometer unit, e.g. by diffuse scattering from optical components and the housing wall, multiple reflections on the mirrors, grating, and detector array, higher diffraction orders of the grating, grating ghosts, etc. Therefore, it is advantageous if only that part of the spectral distribution that should be measured finds its way into the spectrometer, because any further radiation generates additional scattered light.

The basic principle of the double monochromator is based on only selecting the radiation wavelength that is to be detected. In array spectroradiometers, all radiation wavelengths are detected simultaneously. We solve this problem by dividing the entire spectrum over several measurements. The optical filters fulfil the function of the first monochromator by spectrally preselecting the input radiation. This significantly reduces scattered light. Consequently, the quality of the overall optical measurement is comparable to that of a double monochromator, but the measurement time is still considerably shorter. A measurement time of 8 seconds was achieved when measuring the global irradiance of the sun with the BTS2048-UV-S. The reference device, a double monochromator, took 15 minutes. With this technology, measurement data of comparable quality can be achieved while offering all the benefits of array spectroradiometers (compact, attractively priced, fast, versatile, robust, etc.).