Study of a Blackbody Emissivity Measurement Method Using Quantum-Cascade Laser-Based Reflectometry

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The blackbody as a calibration source is an essential part of many thermal infrared remote sensing payloads. The requirement of high-accuracy values of the thermal infrared remote sensing, such as in climate change monitoring, has promoted the improvement of the payloads towards having high-level measurement uncertainty. It requires the development of a high-accuracy on-orbit calibration blackbody. It includes not only the pre-launch calibration, but also the validation of the blackbody temperature and emissivity values on orbit. This paper describes an emissivity measurement method that can be applied to the on-orbit blackbody emissivity validation based on a quantum cascade laser (QCL) reflectometer. The method is implemented by measuring the reflectivity of the blackbody. The QCL as a light source directly exposes the tested blackbody cavity. The reflected radiance of the laser is measured by an infrared spectrometer. The reflected power of the laser is calculated from the radiance. The reflectivity is the ratio of the reflected power to the output power of the laser. The output power of the laser is measured by a power meter. The emissivity of the blackbody can be calculated from the reflectivity of the QCL. The blackbody under test is painted with a high emissivity coating; the blackbody emissivity is 0.998 calculated by the STEEP 3 based on the Monte Carlo method. The spectrometer is a Fourier Transform Infrared Spectrometer (FTIR) from Bruker. The radiation from the tested blackbody is imaged to the object point of the FTIR input port by two off-axis parabolic mirrors in alignment. The first mirror faces the blackbody and has a 3 mm hole parallel to focused beam. The QCL is mounted behind this mirror and the laser beam is directed into the blackbody cavity through the hole. The QCL is a solid-state laser. The output power of the QCL can be set from several mW up to 40 mW depending on the temperature and the input current of the QCL. There is another blackbody applied to calibrate the FTIR. The measured emissivity of the test blackbody is in good agreement with what is simulated. The uncertainty of the measurement is 0.6 %. The QCL is suitable for integration into a remote sensing payload, provided minor changes are made to the existing layout. Together with the spectrometer in the payload, it can measure the emissivity of the blackbody without changing its position, since this is difficult in orbit. It would effectively improve the calibration accuracy of the infrared payload during the mission if this technique is applied on satellite together with blackbody temperature validation techniques.