Cryogenic radiometer developments at NPL

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Abstract Cryogenic radiometers are widely used as the primary standard of choice for optical radiometric measurements. This has led to increased demand for designs optimised for specific applications. NPL has pioneered the field of cryogenic radiometry, both in terms of design and application, from its first successful implementation in the 1970's through to the wide range of instruments and applications available today.

This paper will review some of these developments and how they have progressed into the designs of today. Particular emphasis will be given to a new instrument optimised for the low powers ~ 1 μW which typify the output of monochromators whilst maintaining the flexibility of mechanical cooling i.e. no liquid cryogens.

Introduction

Since the first cryogenic radiometer of Quinn and Martin, designed to measure total radiation from a black body for determining the Stefan-Boltzmann constant (1), there have been numerous designs and applications (2). NPL has been at the forefront of the technology and has been the source of many designs over the years, originally exploited by Oxford Instruments Ltd and more recently by NPL directly.

One of the trends in recent years has been the drive towards the lower cost more flexible operation of mechanical cooling engines, coupled with the desire for greater operational flexibility. This has been achieved through the use of lower power monochromator based radiation sources, eliminating the use of more expensive laser sources in wavelength regions outside of the visible spectrum.

NPL has been engaged in the parallel development and operation of a number of cryogenic radiometers;-

1/ The Absolute Radiation Detector, ARD for a new radiometric determination of the Stefan Boltzmann constant (and consequently Boltzmann constant for a potential future redefinition of the Kelvin). (3)

2/ The mechanical cooled (~15 K) cryogenic radiometer for laser based radiometry. (4)

3/ A space based cryogenic radiometer for measurements of Total Solar Irradiance and Earth reflected spectral radiance. (5)

4/ A mechanically cooled (4 K) cryogenic radiometer for lower power, monochromator based applications.

This paper will concentrate on this latter development.

Summary

The new radiometer uses a 4 K mechanical cooling engine to directly cool a "helium pot" mounted on the second stage of the cold head. This helium pot is connected to an external helium gas reservoir and the gas is cooled to the liquid phase and collected in the pot, providing a thermal buffer to which the reference block is mounted via a heat link. By pumping on the helium pot we can achieve a base temperature of around 2 K and an operating temperature of around 3.7 K.

Custom built ac resistance bridge electronics are being developed to optimise the control of temperature stability of the reference block. The three reference resistors in the bridge are mounted directly on the reference block alongside the temperature sensor, to minimise noise. The radiation cavity, also of novel design, will be operated in active mode (with a constant power). The radiometer is designed so that the cavity and heat link are modular, and can easily be changed, so that the sensitivity can be optimised for specific applications. The cavity temperature will also be monitored using an ac resistance bridge.

The cryostat is mounted on a rotating arm so that either the cavity or the detectors to be calibrated can be moved into the path of the beam. The detectors are mounted modularly to the vacuum chamber, allowing interchange of detectors when cold.

The design objectives are for a measurement of optical radiant power at the 1 μW level with uncertainties of <0.01 %.

References

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