

NIST BXR II Infrared Transfer Radiometer

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Introduction

The Low-Background Infrared calibration facility (LBIR) at NIST is developing a transfer radiometer offering a variety of infrared source evaluation modes. The instrument is capable of measuring the absolute radiance of Lambertian sources, the absolute irradiance of collimated sources, the spectral distribution of those sources, and their polarization. The design and operation of this radiometer, named the BXR II, will be presented.

The primary mission of the LBIR facility at NIST is to maintain the infrared power measurement standard. To this end the facility operates absolute cryogenic radiometers (ACRs) which are electrical-substitution radiometers whose response is directly tied to the national standard High Accuracy Cryogenic Radiometer (HACR). The LBIR ACRs are designed to measure low optical power levels typically at the 10 nW level within a 1% standard uncertainty. Most of the effort of the LBIR facility is directed towards providing calibration support of infrared source chambers which are in turn used to calibrate space-based sensors. Whereas the LBIR facility has typically used the ACR to calibrate the blackbody sources used in the source chambers, advantages can also be realized using the ACR to calibrate portable transfer radiometers. Calibrated portable radiometers can be shipped directly to facilities maintaining source chambers to provide calibrations under conditions similar to those used to calibrate the space-based sensors. Any intervening optics between the calibrated blackbody source and the sensor can then be included in the calibration. The calibrations are based on the comparison of the measured signals from the portable radiometer and the expected signal from a source chamber model, which includes the calibrated blackbody source, the throughput of the optical components, and a correction for diffraction effects. Source calibrations using a filter-based transfer radiometer, the BXR I, have already been conducted. These calibrations have been used to compare irradiances from chambers at different facilities and different chambers within a facility. However, a growing need for greater spectral resolution and absolute power measurements has led to the development of the next generation transfer radiometer, the BXR II.

The BXR II is a liquid-helium cooled radiometer that includes a collimated blackbody source and two types of detectors, an electrical substitution radiometer and As-doped Si Blocked Impurity Band (BIB) detectors. Its collection optics include a 7 cm defining input aperture and an off-axis primary parabolic mirror with an eight-position spatial filter wheel at its focus. Apertures placed in the spatial filter wheel reduce background radiation and define the angular acceptance of the radiometer. A

confocal, off-axis, secondary parabolic mirror recollimates the input beam into a smaller diameter beam into which a rotating polarizer, filters and a cryogenic Fourier transform spectrometer (FTS) can be positioned. Finally, a tertiary off-axis mirror focuses light onto any one of seven different BIB detectors mounted on a three-axis translation stage. All the radiometer optical elements are mounted on a two-axis tilt stage allowing alignment with the optical axis of a source chamber.

Although the critical components of the transfer radiometer are designed to operate at temperatures below 15 K, the BXR II is capable of providing calibrations for both ambient and low-temperature source chambers. An integral, liquid-helium cooled sliding baffle tube can be used to mate the shrouds of the radiometer with those of low-temperature source chambers. Three primary source evaluation modes are available with the instrument.

Electrical-Substitution Radiometer Mode

Absolute power measurements of both collimated and uncollimated sources can be made using the liquid-helium cooled electrical substitution radiometer, the ACR III. The ACR III is placed near the focus of the primary parabolic mirror, which along with a cold ZnSe window and the 7 cm defining aperture is the only optical element between the source being calibrated and the radiometer. The ACR III has a noise floor below 50 pW yielding an effective noise floor of 1 pW/cm² for BXR II irradiance measurements. This mode is particularly useful for making absolute radiance measurements of both broadband and narrow band sources using a well-defined aperture placed at the focus of the primary mirror.

Filter-Based Radiometer Mode

Four filter wheels placed in the radiometer allow source measurements over more than ten narrow bands between 4 μm and 20 μm using the BIB detectors which are operated at 11 K. This mode is capable of measuring in-band irradiances as low as 1 fW/cm² as well as uncollimated power. Unlike the electrical-substitution radiometer, which is absolute to better than 0.1%, the BIB detectors and all collection optics within the BXR II must be calibrated. Irradiance calibrations of the BXR II in this mode will be accomplished with an external calibrated collimated source, the LBIR 10 cm Collimator (10CC). Calibration stability in this mode will be confirmed, both after shipping the radiometer and during chamber evaluations, with the internal collimated blackbody source. A large aperture external blackbody source at the LBIR facility will be used for total radiance BXR II calibrations.

FTIR Mode

Further spectral capability of the BXR II is available by directing the beam recollimated by the secondary mirror into the cryogenic FTS. This operation is accomplished while the radiometer is cold using a translating periscope. This mode provides relative spectral measurements with 1 wavenumber resolution over the wavelength range from 2 μm to 20 μm . These relative spectra can then be fixed at the several wavelength bands in the filter-based radiometer mode. The stability of the cryogenic FTS will also be monitored using the internal collimated blackbody source. Finally, in-situ measurements of the BXR II filter transmission spectra can be collected with the FTS. A comparison of these measurements to independent absolute transmission spectra collected at NIST can be used to eliminate systematic errors due to the filters.

Conclusion

The design phase of the BXR II has been completed and many of its components have been procured. Performance testing of the ACR III has also been completed and the electrical-substitution radiometer mode of the BXR II will be fully capable by the end of 2005.

References

Jung, T. M., Carter, A. C., Lorentz, S. R., Datla, R. U., NIST-BMDO Transfer Radiometer (BXR), *Infrared Detectors and Focal Plane Arrays VI, Proceedings of SPIE Vol. 4028 99*, 2000.