Upgrade of cryogenic radiometer control electronics and software

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The successful upgrade of control electronics and software for a cryogenic radiometer is described. A commercially available temperature controller using ac resistance thermometry was used with an existing radiometer. The upgrade did not involve any change to the radiometer hardware except the controller electronics. The upgrade was therefore relatively easy to implement. New software in LabView was also developed. Initial results show an improvement in performance and calibration results in line with expectations.

INTRODUCTION

Absolute Cryogenic Radiometers (ACRs) are commonly used at National Metrology Institutes (NMIs) for the realization of absolute radiant flux. These devices, based on electrical-substitution radiometry carried out at cryogenic temperatures in vacuum, provide the lowest achievable uncertainties for a wide range of power levels and wavelengths [1]. However, given their operating principles, there are generally large costs associated with building or purchasing such systems. Hence, it is worthwhile to prolong the lifetime of already existing older systems. Many NMIs are still using ACR systems that were manufactured in the 1990s, although the electronics and software may not be compatible with modern technology.

The photometry and radiometry group at RISE Research Institutes of Sweden has since 1995 been using the commercial LaseRad ACR from Cambridge Research & Instrumentation Inc. (CRi). It is used for realization of absolute radiant flux in the visible and NIR wavelength range. Due to increasing communication problems and excess noise in the electronics, in 2016 a decision was made to rebuild the LaseRad ACR using a commercially available cryogenic temperature controller. This paper describes the steps taken for this upgrade to be successful, including initial performance evaluation of the upgraded system.

METHOD

The cryogenic radiometer operates by absorbing radiation in a Receiver, see Figure 1. The Receiver has blackened surfaces which act to absorb incident radiation, thereby leading to a certain Receiver temperature. Typical sensitivity is 0.6 K/mW. The Receiver temperature is accurately monitored by the use of a carbon film resistor thermometer.

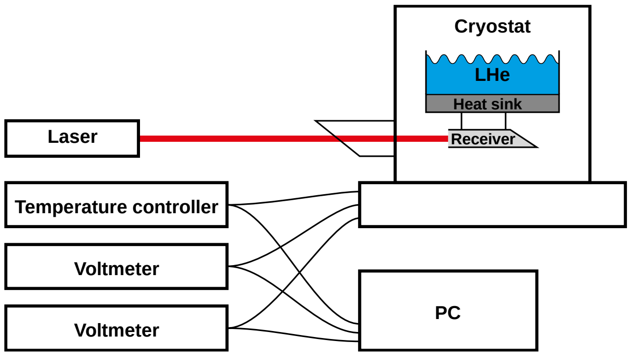

Figure 1. Schematic setup of the ACR with new control electronics.

The Receiver is thermally connected to a Heat sink which is used to provide a long-term stable temperature. The Heat sink temperature is monitored by a Germanium thermistor and can be controlled by means of a heater.

In operation, the radiation is blocked, and electrical power is fed to the Receiver via a small resistive heater, placed near the location where the radiation is absorbed. By measuring this electrical power by external means, a measure for the radiation power is obtained.

The basis for the operation is that two control loops are used to stabilize the temperatures of both the Receiver and Heat sink. The control loops were realized in the supplied Control electronics, together with AC bridge measurement of the two thermometer resistances.

RISE ACR experienced difficulties in obtaining a stable control of the two temperatures. The reason was attributed to self-oscillation in the control electronics and could not easily be remedied. For this reason, a new temperature controller (TC) was acquired from Lakeshore Cryotronics [2] and interfaced to the existing ACR. A similar controller has been used in another ACR and proved suitable [3]. The internal hardware (thermometers and heaters) of the ACR was left unchanged, but some electronic PCBs which were originally placed in the base of the cryostat were removed.

The TC is a Model 372 AC Resistance Bridge and Temperature Controller. It has provisions for two independent closed-loop PID controls, each using a range of thermistor resistances. The measuring principle is *ac* measurement of resistance in tandem with an internal lock-in amplifier in order to extract small measurement signals. This enables very low excitation currents to be used and excellent rejection of noise.

The TC is directly connected to the internal hardware of the ACR, by the use of standard shielded twisted-pair wires. The only component placed thermally isolated in the cryostat housing was a 1000-Ω precision resistor, used for measuring the Receiver heater current. The voltages across the resistor and across the heater are each measured with an 8 ½-digit voltmeter and the product constitutes the measurand (electrical power = optical power).

The software originally provided with the ACR ran in a DOS-like environment and was directly interfaced to the original electronics. Consequently, it was most desirable to also exchange it when the new TC was implemented. New software for control was developed in LabView and subsequently used for evaluation of system performance and performing calibrations.

RESULTS

In addition to the up-to-date software and communications of the upgraded ACR, enabling easy and stable operations, the electrical performance of the ACR was improved compared to before the upgrade. Even though the system has not yet been fully optimized regarding shielding of cables and TC settings, the RMS noise of the Receiver heater power at 400 µW is around 0.01 %, see Figure 2.

In May 2019, the first calibration of silicon trap detectors was done using the upgraded ACR. When comparing the obtained detector responsivities to historical data, see Figure 3, the results are in line with what was expected, clearly indicating that the ACR is functioning properly.

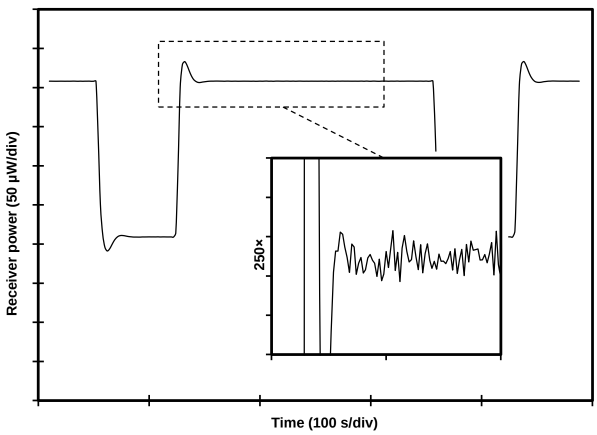

Figure 2. Results from system performance study with incident radiation of 200 µW being switched on and off, resulting in a rapid change in the measured temperature of the Receiver.

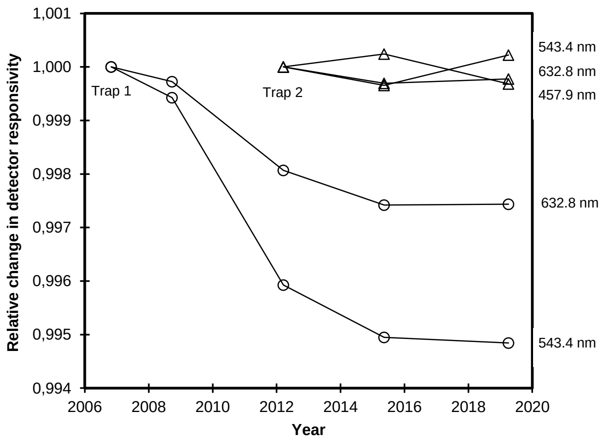

Figure 3. Results from trap calibration. The results from 2019 are using the upgraded control electronics. Measurement uncertainties (*k*=2) are typically 0.05–0.06 %.

REFERENCES

1. A. Parr *et al.*, Optical Radiometry Vol. 41, Academic Press, 2005.
2. Lake Shore Cryotronics, Inc. www.lakeshore.com
3. S. M. Carr *et al.*, Experimental measurements and noise analysis of a cryogenic radiometer, Rev. Sci. Instr 85, 075105, 2014.