A Turn-key Cryogenic Superconducting Bolometer Detector System

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***Abstract*—We describe a complete, commercially available, cryogen-free superconducting bolometer detector system. This allows detection of Terahertz radiation at frequencies from 0.1 to 20 THz, with a system optical NEP of $\sim$ 3 pW Hz^{-1}, a useful modulation frequency range from 5 Hz to $>$ 1 kHz and a linear dynamic range over 60 dB. The range of detection frequencies can be precisely defined using metal mesh filters. The system is entirely self-contained and requires only an electrical supply in order to operate. Continuous operation is possible for a period of several months or even longer.**

I. Introduction and Background

CRYOGENICALLY cooled bolometric detectors offer high sensitivity and continuous broadband frequency coverage. Traditionally, cooling is provided by liquid helium, limiting the possible applications. Handling liquid helium is potentially dangerous. Helium is also expensive and obtaining a sufficient supply is not always easy. Mechanical cryogen-free refrigerators are now available which need only an electrical supply to operate and do not demand particular skills from the operator.

Combining cryogenic detectors with such refrigerators enables "turn-key" operation for a range of applications, including locations outside research laboratories where handling liquid helium would be completely impractical.

We describe such a system which we have developed. This and similar systems are now commercially available and currently in use around the world.

II. Detector and readout

The detector is a single-pixel niobium transition edge sensor (TES), deposited on a thin silicon nitride (SiN) membrane to provide thermal isolation, and operating at a temperature of approximately 8 K. A custom readout system enables operation of the detector without the use of a SQUID and it is therefore insensitive to magnetic fields; magnetic shielding is not required. There is also no need to tune a flux-locked loop.

The detectors typically have an electrical NEP (noise equivalent power) below 1 pW Hz^{-1}. Advantages of these detectors over the more traditional semiconductor bolometers include a much greater linear dynamic range and higher speed of response. They also operate at much lower impedances, which simplifies operation in a mechanical cooler due to the reduced impact of microphonics.

Fig. 1. A detector system (the compressor is not shown; this can be located at a distance as much as 15 m from the cryostat)

III. System

The detector is cooled by a Cryomech pulse tube cooler model PT403 [1]. The cryostat containing the detector and cooler is shown in Fig. 1. The accompanying compressor is not shown - this is connected via flexible hoses and can be located as much as 15 m away from the cryostat. Operation is from a single phase electricity supply.

The cooler provides a heat sink temperature under 3.5 K. The detector is mounted on a copper platform, connected by flexible thermal links to the pulse tube cold head; this arrangement reduces the (already low) vibration and temperature fluctuations. Optical coupling to the incoming radiation is via a Winston cone (typically f/3.5 or f/4.5) which is chosen to match the incoming beam geometry. A thin (1 mm thick) HDPE window allows the detector to view the outside environment.

As with any cryogenic system with external optical access, it is necessary to prevent thermal radiation from the outside environment from warming up the cold stages. This is achieved with metal mesh filters [2] which reflect unwanted radiation while transmitting the frequencies of interest with high efficiency. They are also robust and survive frequent thermal

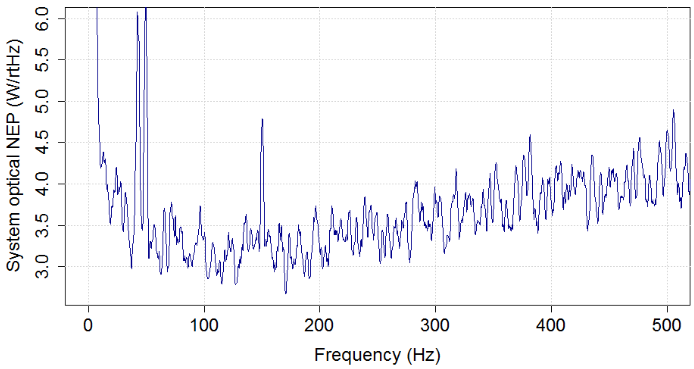

Fig. 2. System optical NEP as a function of frequency

cycling. The filters also select the range of frequencies to be detected, and can be tailored for the particular requirements of each system.

We obtain system optical NEP values of $\lesssim$ 3.5 pW Hz^{-1} between 40 and 200 Hz modulation frequency, as shown in Fig. 2. The systems operate reliably and with stable performance, and are capable of continuous operation for periods of several months or longer.

REFERENCES

[1] Cryomech, 113 Falso Drive Syracuse, NY 13211 USA
[2] P. A. R. Ade et al, "A review of metal mesh filters", Proc. SPIE 6275, 62750U (2006)