

# Large Solar-Rejection Filter

This lightweight filter comprises a multilayer spectral coating on a flexible membrane.

NASA's Jet Propulsion Laboratory, Pasadena, California

An optical filter consisting of a multilayer spectral coating on a flexible membrane has been designed to be placed in front of the 200-in. (5.08-m) Hale telescope on Mt. Palomar. The filter is intended to protect the telescope against solar radiant flux and limit solar heating of the interior of the telescope dome while transmitting light at the 1,064-nm wavelength of the Mars Laser Communication Demonstration.

For supporting a multilayer spectral coating in this application, the flexible membrane was chosen as a lightweight, less-expensive alternative to a conventional thick optical-glass substrate. Multilayer spectral coatings have been used for decades, and membranes have more recently come into use as substrates for mirrors. However, until now, there have been few (if any) published instances of

multilayer coating of membranes to form lightweight solar-rejection/narrow-band-pass filters.

The main problem to be solved in designing the present filter was to satisfy both (1) the need for a large number (hundreds in a typical first approximation) of coating layers needed to obtain the desired broad-band-solar-rejection/narrow-band-pass spectral characteristic and (2) the need to limit the number of layers to no more than the maximum ( $\approx 60$ ) that the membrane could support. The solution is a design of fewer than 50 layers having the following features:

- The front surface of the membrane is coated with 25 dielectric layers alternating between higher and lower indices of refraction. These layers are designed to efficiently reflect the visible and near-infrared (wavelengths up to

1.0  $\mu\text{m}$ ) light in which the Sun predominantly radiates.

- The back surface of the membrane is coated with very thin layers of copper and silicon chosen to reject the remainder of the spectrum.
- Multiple dielectric layers stacks are deposited on what would otherwise be the exposed opposite outer surfaces of the aforementioned layers. The materials and thicknesses of these layers are chosen to induce the desired narrow passband, centered at 1,064 nm, in the broad-band-reject spectrum of the silicon and copper layers.

This work was done by William Roberts of Caltech, David Sheikh of Surface Optics Corporation, and Brian Patrick of SRS Corporation for NASA's Jet Propulsion Laboratory. For more information, contact [taoffice@jpl.nasa.gov](mailto:taoffice@jpl.nasa.gov) NPO-41942

# Improved Readout Scheme for SQUID-Based Thermometry

Flux-unit-counting ambiguities would be eliminated.

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An improved readout scheme has been proposed for high-resolution thermometers, (HRTs) based on the use of superconducting quantum interference devices (SQUIDs) to measure temperature-dependent magnetic susceptibilities. The proposed scheme would eliminate counting ambiguities that arise in the conventional scheme, while maintaining the superior magnetic-flux sensitivity of the conventional scheme. The proposed scheme is expected to be especially beneficial for HRT-based temperature control of multiplexed SQUID-based bolometer sensor arrays.

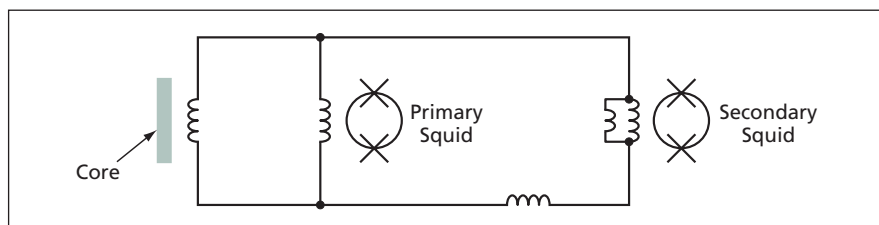
SQUID-based HRTs have become standard for measuring and controlling

temperatures in the sub-nano-Kelvin temperature range in a broad range of low-temperature scientific and engineering applications. A typical SQUID-based HRT that utilizes the conventional scheme includes a coil wound on a core made of a material that has temperature-dependent magnetic susceptibility in the temperature range of interest. The core and the coil are placed in a DC magnetic field provided either by a permanent magnet or as magnetic flux inside a superconducting outer wall. The aforementioned coil is connected to an input coil of a SQUID. Changes in temperature lead to changes in the susceptibility of the core

and to changes in the magnetic flux detected by the SQUID.

The SQUID readout instrumentation is capable of measuring magnetic-flux changes that correspond to temperature changes down to a noise limit  $\approx 0.1$  nK/Hz<sup>1/2</sup>. When the flux exceeds a few fundamental flux units, which typically corresponds to a temperature of  $\approx 100$  nK, the SQUID is reset. The temperature range can be greatly expanded if the reset events are carefully tracked and counted, either by a computer running appropriate software or by a dedicated piece of hardware.

While adequate for many applications, the conventional scheme has drawbacks: If the temperature is changed rapidly or the temperature noise is high, the counting hardware and/or software loses flux count. In the case of a software counter, the temperature reading is lost entirely if the software is reset or restarted. In the case of a multiplexed SQUID controller, these drawbacks become more severe because flux readings are taken less frequently.



A Branch Containing a Secondary SQUID would be added to a single-SQUID HRT circuit. The secondary SQUID would register a small fraction of the flux passing through the primary SQUID.

The proposed scheme is intended to eliminate these drawbacks. The scheme calls for including a secondary SQUID and its readout instrumentation that would register a small fraction of the magnetic flux passing through a primary SQUID. The scheme includes the following elements:

- Winding a secondary coil of fewer turns around the core to a second readout; or
- Forming a circuit branch parallel to the main coil with the secondary SQUID input coil in series with a large (compared to the SQUID input coil inductance) inductor; or

- Forming a circuit branch parallel to the main coil with a large inductor in series with a SQUID input coil shunted by a small inductor (see figure).

The goal is to avoid having to reset the secondary SQUID in the temperature range of interest, while maintaining the capability of determining the flux state of the primary SQUID unambiguously. If the secondary SQUID readout were monitored by a 16-bit data-acquisition board and the digitization effected by the board determined the readout accuracy, then the dynamic range afforded by this scheme could be optimized by designing the secondary

SQUID readout to be about 1/32,000 as sensitive as is the primary SQUID readout. In a typical application, this level of secondary-SQUID sensitivity would correspond to a temperature range  $\approx 3$  mK. In this temperature range, there would be no need to actively track the flux state to maintain fidelity of the readout. To avoid the need for counting hardware altogether, a tertiary readout could be added.

*This work was done by Konstantin Penanen of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-41757*