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TRANSMISSION OF INFRARED RADIATION THROUGH POLYSTYRENE AND CONSEQUENCES FOR VLPC CRYOGENICS*

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Abstract

One contribution to the heat load presented to the VLPC cryogenics system results from room-temperature infrared photons propagating through fibers into the cold volume. To investigate this effect, the transmission spectrum of polystyrene was measured in the range between 2 μm and 42 μm. The results indicate that 300°K radiation is totally absorbed in centimeter lengths of fiber, and this source of heating may be neglected.

1. Introduction

A recent note[1] estimated the heat load for the VLPC cryogenics for SSC operation both at design luminosity and at a factor of ten higher. A luminosity-independent contribution was heat from infrared photons. Basically, each section of a fiber is in thermal equilibrium with black-body radiation at the corresponding temperature, and photons may be trapped and propagate. Reference 1 presented an unrealistic worst-case result based on assuming that 3% of the

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incident room-temperature radiation was trapped and propagated through the fibers without loss. The corresponding heat load was 2.7×10^{-4} W per fiber, but the actual value was expected to be negligible.

An exact calculation is difficult but certainly requires knowledge of the infrared transmission spectrum of polystyrene which forms the fiber core. A modest library search yielded spectra for common plastics such as polyethylene and polymethylmethacrylate (Plexiglas/Lucite),[2] but no data for polystyrene was found. We thus enlisted the aid of our solid-state colleagues to make a measurement.

2. Measurements and Results

Pure polystyrene was provided by Chuck Hurlbut of Bicron Corp.[3] The sample were one-inch-diameter disks with thicknesses of 0.005 in. and 0.040 in. The measurements were made by Prof. S. Sivananthan of the UIC molecular-beam epitaxy group using a Mattson Instruments Polaris Fourier Transform Infrared Spectrometer. The resolution was 32 cm^{-1}, and no corrections were made for reflections at the disk faces. Measurements on two of the four samples of each thickness provided were found to be essentially identical.

Transmission over the range from 2 μm to 42 μm for the 5 mil and 40 mil samples is shown in Fig. 1a and 1b, respectively. Polystyrene exhibits a complicated spectrum, with many sharp peaks occurring between 2 μm and 18 μm.

The room-temperature (300°K) black-body energy density spectrum,

$$d^2U/d\lambda dV = \frac{8\pi ch}{\lambda^5} [e^{\frac{ch}{\lambda kT}} - 1]^{-1} \quad ,$$

is indicated by the dashed curve in Fig. 1a. This spectrum has its maximum at 9.7 μm. The transmission of polystyrene in the region of this maximum is shown in Fig. 2a and 2b for the 5 mil and 40 mil samples, respectively. Again, the 300°K black-body spectrum is indicated by the dashed curve in the upper figure.

The wavelength-dependent polystyrene attenuation length $X(\lambda)$ in the simple model

$$I(\lambda) = I_o \, e^{-\frac{x}{X(\lambda)}}$$

obviously exhibits a complexity corresponding to the measured transmission spectra. However, even the maximum transmission peaks that overlap the black-body spectrum correspond to maximum X values of no more than 1 mm. Hence, as expected, room-temperature infrared photons are completely absorbed in centimeter lengths of fiber and pose no heat-load problems for the VLPC cryogenics.

However, the model cryostat assumed in Ref. 1 consisted of fibers penetrating through a vacuum region to be thermally grounded at liquid nitrogen temperature (77°K). They then passed through a second vacuum region into the 7°K volume occupied by the VLPCs. With this model, infrared photons could only enter the cold volume via the fibers. The actual cryostats used in FTG tests are quite different. In these devices the fibers pass from room temperature to the 7°K region through a narrow tube where they are cooled by liquid helium boil-off gas. With this construction, room-temperature infrared photons can also radiate in directly, and careful baffling is required to avoid this source of heat and VLPC noise.

3. Acknowledgments

We wish to thank Mr. Chuck Hurlbut of Bicron Corporation for providing the polystyrene samples, and Prof. S. Sivananthan for performing the transmission measurements.

References

1. H. Goldberg, S. Margulies, and J. Solomon, "Cryogenic Issues for Solid-State Photomultiplier Operation", to be published in Proceedings of the Symposium on Detector Research and Development for the Superconducting Super Collider, Ft. Worth, TX, 15-18 Oct. 1990.

2. S. S. Ballard, K. A. McCarthy, and W. L. Wolfe, "Optical Materials for Infrared Instrumentation", Univ. of Michigan Willow Run Laboratories, Report 23389-11-S, Jan. 1959, Chap. 5.

3. Bicron Corp., 12345 Kinsman Road, Newbury, OH, 44065-9677.

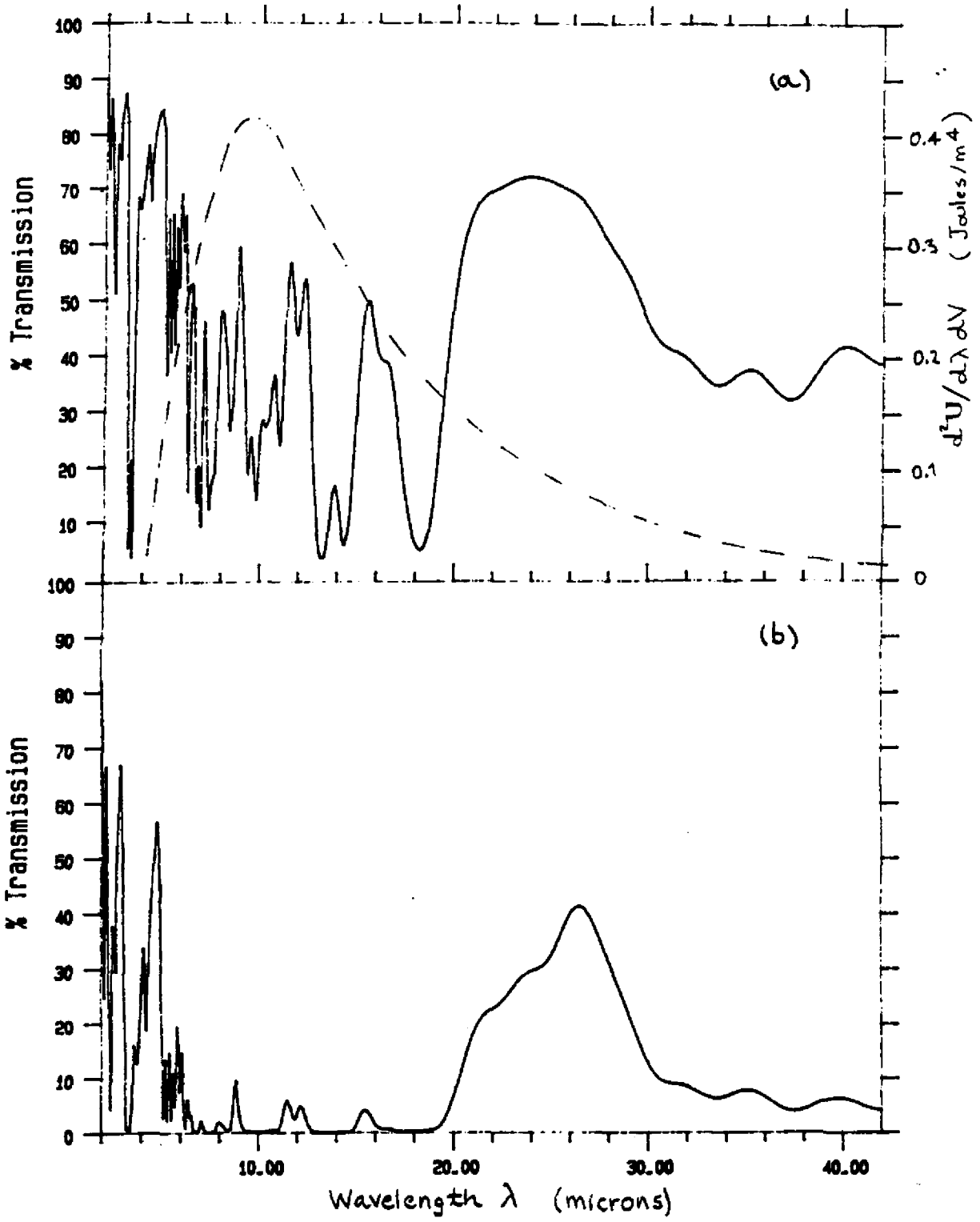

Figure 1. Transmission spectra of polystyrene in the range from 2μm to 42 μm. (a) 0.005-in.-thick sample. The dashed curve indicates the 300°K black-body energy density spectrum (right-hand scale). (b) 0.040-in.-thick sample.

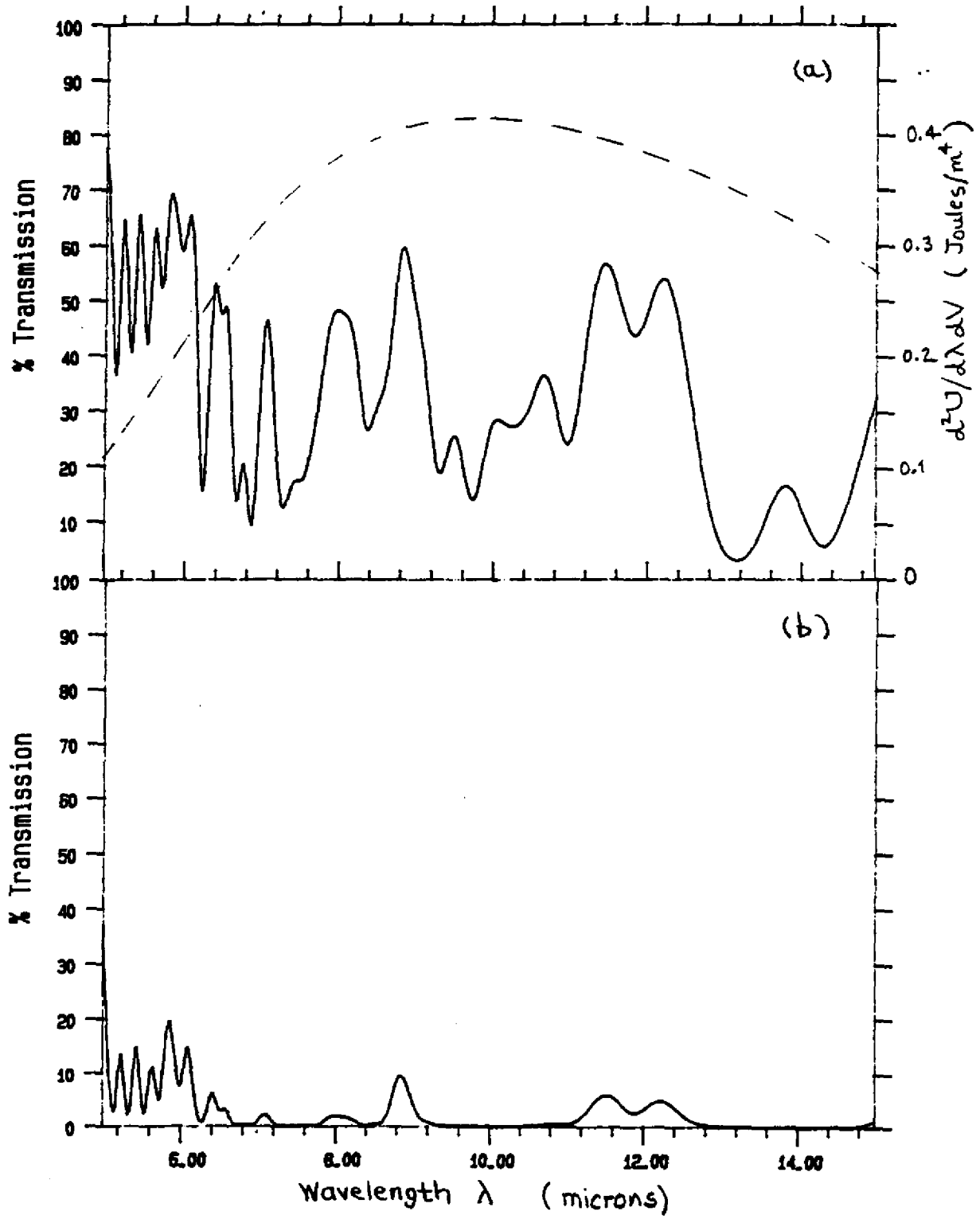

Figure 2. Transmission spectra of polystyrene in the range from 5 μm to 15 μm. (a) 0.005-in.-thick sample. The dashed curve indicates the 300°K black-body energy-density spectrum (right-hand scale). (b) 0.040-in.-thick sample.