Systematic errors are examined for a differential laser-power measurement method.

Wire grid bolometers are widely used [1] for measuring high-level continuous-wave laser power. The sensor temperature rises, and the basic physical parameters do not remain constant (temperature coefficient of resistance $\alpha$, absorption factor $q$, heat-transfer coefficient $\gamma$, and specific heat $c$), and this combines with unevenness in the incident power distribution to produce nonlinear conversion and a systematic error, which in stationary and integral power measurement methods [2] is only slightly dependent on the design, in contrast to the systematic errors in differential methods. In [3] there is a discussion of a differential power measurement method, in which the negative systematic error due to the time factor is partially balanced by the positive systematic error due to increase in the recorded power and the uneven power distribution.

It is of interest to examine the systematic error in differential laser power measurement. We consider the conversion factor for the case where the basic parameters are linearly dependent on temperature:

$$
\alpha(T) = \alpha_0 + \alpha_1 T; 
q(T) = q_0 + q_1 T; 
\gamma(T) = \gamma_0 + \gamma_1 T 
$$

in which $\alpha_0$, $q_0$, $\gamma_0$, and $c_0$ are the values of those parameters at the environmental temperature, while $\alpha_1$, $q_1$, $\gamma_1$, and $c_1$ are the temperature-dependence coefficients.

The total length of the bolometer grid is larger than the beam diameter by at least an order of magnitude, so one can assume that the incident power and the temperature distribution along the bolometer are ergodic stationary random functions.

The time derivative of the relative resistance increment averaged over the length is

$$
\frac{d\Delta R(t)}{dt} = \left[\frac{\alpha_0 + 2\alpha_1 \delta T(t)}{R_0}\right] \frac{d\bar{T}(t)}{dt}.
$$

in which $R_0$ is the resistance of the bolometer at environmental temperature; $\Delta R(t)$ is the increment in resistance at time $t$; $\bar{T}(t)$ is the temperature averaged along the bolometer; $\delta = 1 + \sigma_{T_0}^2$ is the integral parameter for the nonuniformity of the temperature distribution along the bolometer; and $\sigma_{T_0}^2$ is the relative variance in bolometer temperature.

The derivative $d\bar{T}(t)/dt$ is derived from the homogeneous nonstationary heat-balance equation averaged along the bolometer after the input power is switched off, $\bar{P}(0) = 0$:

$$
\sigma_0 + c_1 \delta T \frac{d\bar{T}}{dt} + (q_0 + q_1 \delta T) \bar{T} = (q_0 + q_1 \delta T) \bar{P}.
$$

in which $m$ is the mass of the bolometer per unit length and $\bar{P}$ is the mean incident power per unit length.

The relation between this derivative and the input power is obtained by using (1). In a grid bolometer, the sensor’s dimensions are inhomogeneities in the beam intensity should be larger than the grid period, and the heat loss by convective heat transfer with the environment from a length in the bolometer close to the grid will be much larger than the heat leak along the bolometer on account of the thermal conductivity. Then the correlation coefficient in (1) between the incident power and
the temperature along the entire bolometer will be one, and the temperature along the entire bolometer will be one, and the nonuniformity in the incident power distribution coincides with that in the temperature distribution.

We use the homogeneous equation (1) and the initial condition $\delta T(0) = \delta T_1$, in which

$$\delta T_1 = \frac{T_0 - q_1 \delta P}{2 \gamma_1} \left[ 1 + \frac{\frac{4 \gamma_1 q_0 \delta P}{(T_0 - q_1 \delta P)^2} - 1}{1} \right]$$

is the positive root for the stationary equation (1), to get the value for the derivative of the increment in the relative resistance with respect to normalized time at the instant when the input power is switched off:

$$\frac{d \Delta R(0) / R_0}{d(t_1)} = -\eta_0 F(\delta \overline{P}) \overline{P}.$$ 

in which $\eta_0 = \alpha_0 q_0 / \gamma_0$ is a conversion factor in the linear stationary state for small optical power levels and $\tau = m c_0 / \gamma_0$ is the thermal time-constant in the linear state, while

$$F(\delta \overline{P}) = \frac{1 + \frac{q_1 \delta \overline{P}}{q_0} \left( 1 + \frac{q_1 \delta \overline{P}}{q_0} \right)}{1 + \frac{\gamma_1}{\gamma_2} \delta \overline{P}}$$

is the normalized conversion factor, which is dependent on the effective power $\delta \overline{P}$ and which is related to the effective temperature $\delta \overline{T}_1$ by (2).

The normalized conversion factor $F(\delta \overline{P})$ determines the nonlinearity in the conversion characteristics and is dependent on the product of the incident power and the nonuniformity in the distribution $\delta \overline{P}$. The quantity $F(\delta \overline{P}) - 1$ is the systematic error in measuring the incident power $\overline{P}$.

Calculations have been performed for a single-grid bolometer and a laser beam at wavelength 10.6 $\mu$m having linear polarization parallel to the axes of the bolometric elements, whose basic physical parameters have the following temperature