ture. One obtains

$$Q_0 = Q_{00} \cdot \frac{p}{p_0} \cdot \tag{3}$$

The magnetic quality factor Q_m is independent of p for constant relative cross-sectional dimensions. Since the isolator Q-factor Q_i depends on the fields in the slow wave structure in the same way as Q_m [4], we can write

$$\frac{1}{Q_i} = r \cdot \left| \frac{1}{Q_m} \right| \tag{4}$$

where $r<1$ and typically $r<0.2$. Using (1) through (4), we now obtain the net gain

$$G(p) = G(p_0) \frac{\frac{p_0}{p} - \frac{|Q_m|}{(1-r)Q_{00}} \left(\frac{p_0}{p}\right)^2}{1 - \frac{|Q_m|}{(1-r)Q_{00}}} \cdot \tag{5}$$

The net gain $G(p)$ has a maximum for

$$p = p_{\mathrm{opt}} = p_0 \frac{2|Q_m|}{(1-r)Q_{00}} \tag{6}$$

i.e.,

$$Q_{0,\mathrm{opt}} = \frac{1-r}{2|Q_m|} \cdot \tag{7}$$

The optimum net gain becomes

$$G(p_{\mathrm{opt}}) = G(p_0) \frac{p_0/p_{\mathrm{opt}}}{2 - p_{\mathrm{opt}}/p_0} = 27 \frac{L \cdot s}{\lambda_0} \frac{1-r}{2|Q_m|} \cdot \tag{8}$$

In Fig. 2 $G(p_{\mathrm{opt}})/G(p_0)$ is plotted for different values of p_0/p_{opt}. The optimum pitch represents a compromise between the ohmic losses and the slowing factor, and the optimum gain is obtained when the electronic gain (the gain obtained for $Q_i = Q_0 = \infty$) is approximately twice the ohmic losses (7).

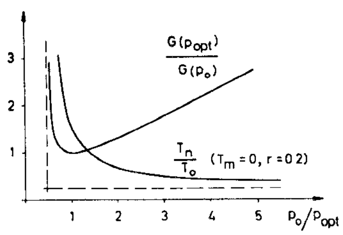

Fig. 2. $G(p_{\mathrm{opt}})/G(p_0)$ with G in dB and T_n/T_0 with $T_m = 0$ and $r = 0.2$ as a function of p_0/p_{opt}.

For $p_0 \leq \frac{1}{2} p_{\mathrm{opt}}$ the ohmic losses becomes so high that no net gain is obtainable. It may be advisable to choose $1 \leq p_0/p_{\mathrm{opt}} \leq 1.5$.

The noise temperature for the pitch p_0 of the TWM [1] becomes, using (3) and (7):

$$\begin{aligned} T_n &= \frac{G-1}{G} \frac{1/|Q_m|}{1/|Q_m| - 1/Q_i - 1/Q_{00}} T_m + \frac{1/Q_i + 1/Q_{00}}{1/|Q_m| - 1/Q_i - 1/Q_{00}} T_0 \\ &= \frac{G-1}{G} \left[\frac{p_0/p_{\mathrm{opt}}}{2p_0/p_{\mathrm{opt}} - 1} \cdot \frac{2T_m}{1-r} + \frac{r + 1/(2p_0/p_{\mathrm{opt}} - 1)}{1-r} T_0 \right]. \end{aligned} \tag{9}$$

For $p_0 = p_{\mathrm{opt}}$, $r = 0.2$, $T_m \ll T_0$ one obtains $T_n = 1.5 \cdot T_0$, a reasonable noise temperature for liquid helium cooled masers. For high temperature masers it may be wiser to choose a pitch larger than the optimum pitch in order to obtain a lower noise temperature (see Fig. 2).

It may be emphasized that the scaling procedure proposed here does not change the frequency characteristic of the pass band, i.e., the tunable bandwidth of the maser remains constant. Further, the coupling to the structure is also unchanged since the impedance levels are constant. The saturation power at the signal frequency of the maser is changed with a factor of p/p_0.

Investigations of published data of several traveling-wave masers reveal that the net gain could have been considerably increased by optimizing the pitch. Very often the optimum pitch is shorter than the design pitch by a factor of 2 to 3, leading to a loss in net gain (L unchanged) by a factor of 1.33 to 1.80. A substantial decrease of the pitch and a scaling down of the cross-sectional dimensions correspondingly may, of course, in some cases lead to fabrication difficulties.

Care has to be taken in applying the foregoing results to longitudinally stagger-tuned masers, since $|Q_m|$ in that case becomes different in different sections of the TWM. If the stagger-tuning is performed transversely, i.e., the paramagnetic line is broadened identically for each period, the results are very well applicable

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Measurement of Microwave Power in WR137 Waveguide (5.85–8.20 GHz)

The Radio Standards Laboratory of the NBS Institute for Basic Standards (U. S. Department of Commerce), Boulder, Colo., announces a calibration service in WR137 waveguide for the measurement of effective efficiency, efficiency, and calibration factor of bolometer units, and of calibration factor of bolometer-coupler units. The measurement of efficiency of a bolometer unit is made available for the first time by the Radio Standards Laboratory, but for the present is limited to WR137 waveguide. Although calibrations can be performed within the useful range of the waveguide, some degree of economy to the customer results if calibrations are performed at the selected[1] frequencies of 6.45, 7.00, and 7.40 GHz.

The four quantities measured are defined as follows:

Effective Efficiency for Bolometer Units: The ratio of the substituted dc power in the bolometer unit to the microwave power dissipated within the bolometer unit.

Calibration Factor for Bolometer Units: The ratio of the substituted dc power in the bolometer unit to the microwave power incident upon the bolometer unit.

Efficiency for Bolometer Units: The ratio of the microwave power absorbed by the barretter element to the microwave power dissipated within the bolometer unit.

Calibration Factor for Bolometer-Coupler Units: The ratio of the substituted dc power in the bolometer unit on the side arm of the directional coupler to the microwave power incident upon a nonreflecting load attached to the output port of the main arm.

Because of certain limitations in adapting the microwave microcalorimeter measurement technique to the larger waveguide sizes, the effective efficiency and calibration factor of bolometer units in WR137 waveguide are measured somewhat indirectly by using a working standard that has been calibrated by the impedance method.[2–4] The impedance technique yields a direct measurement of the efficiency of a bolometer unit. This efficiency measurement, usually of special interest only, is available for the first time at the Radio Standards Laboratory as a calibration service. The bolometer units must be fitted with a barretter element of a purely resistive type (thermistor-type element cannot be used) with a nominal resistance of 200 ohms. The efficiency measurements are performed with an uncertainty no greater than ±1 percent.

The effective efficiency and calibration factor of a bolometer unit, as well as the calibration factor of a bolometer-coupler unit, are measured with an uncertainty no greater than 2 percent in WR137 waveguide. For these measurements the element can be of the barretter or thermistor type, and of either 100- or 200-ohm resistance, operating at a bias current between 3.5 and 15 mA. The bolometer unit can be of either the fixed-tuned or untuned broadband type. Power measurements can be made on bolometer units over a range of 0.1 to 10 mW.

Power measurements can be made on bolometer-coupler units in WR137 waveguide with coupling ratios from 3 to 20 dB. A bolometer unit of either the fixed-tuned or untuned broadband type must be permanently attached to the side arm of the coupler. The coupler should have a directivity of no less than 40 dB, and a VSWR no greater than 1.05 for the input and output ports of the main arm of the coupler.

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[1] Performing microwave calibrations, a considerable amount of time is usually needed to prepare the system for a measurement operation. Much of this preparation is related to adjustment of the system to the frequency of operation selected for the calibration. Time and cost often can be reduced by minimizing the number of times the operating frequency of the calibration system must be readjusted.

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