CORRECTION TO THE PAPER "PRECISION IN A SCANNING INTERFEROMETER"*

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It has been brought to the authors' attention (Hanes, personal communication) that the results obtained for the limiting precision in a scanning optical interferometer (Hill and Bruce 1962) are invalid for the particular conditions examined. Although there does exist a photon noise distinct from the shot noise in the photodetector its effect is very small. The transmittance of the Fabry-Perot interferometer was incorrectly evaluated and when allowance is made for this the limiting precisions of the Michelson and Fabry-Perot interferometers are about equal.

Photon Noise and Shot Noise

When the photon noise was calculated previously (Hill and Bruce 1962, hereafter referred to as paper I) it was assumed that the light source showed coherency over the area viewed by the photodetector. For normal sources this does not apply and the noise signal arising from each elemental area which does show coherency will be randomly phased to the rest of the noise signal (Forrester, Gudmundsen, and Johnson 1955). If the elemental area is A it is given by λ^2/Ω, where λ is the wavelength of the radiation and Ω the solid angle spread of energy. In the practical case considered in paper I the magnification of the optical system was approximately unity and $A = \lambda^2.4f^2/\pi D^2$, when f was the focal length of the projection lens and D the diameter of the interferometer plates. For the same reason the area of the light source being viewed is given by πb^2 where $2b$ is the diameter of the photodetector aperture.

Then N, the number of elemental areas, is given by $\pi b^2.\pi D^2/(\lambda^2.4f^2)$. If the mean square photon noise for unit area of coherency is $\overline{p^2}$, the total noise, assuming complete coherence as in paper I, is $\overline{p^2}.N^2$; and for an incoherent source it is $\overline{p^2}.N$. The ratio of the r.m.s. noise assuming incoherence to that assuming coherence is thus given by $N^{-\frac{1}{2}}$ and for the instrument described in paper I this is approximately $0 \cdot 014$.

It can thus be seen that, although the photon noise from a coherent source is comparable to the shot noise in the photodetector, the photon noise from an incoherent source is negligible.

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Interferometer Transmittance T

The interferometer intensity distribution for the Fabry-Perot in paper I should have been written as

$$\frac{I_{(t)}}{I_{(i)}} = \frac{T^2}{(1-R)^2} \cdot \frac{1}{1+F\sin^2 2\pi n}$$
$$= F_{(n)},$$

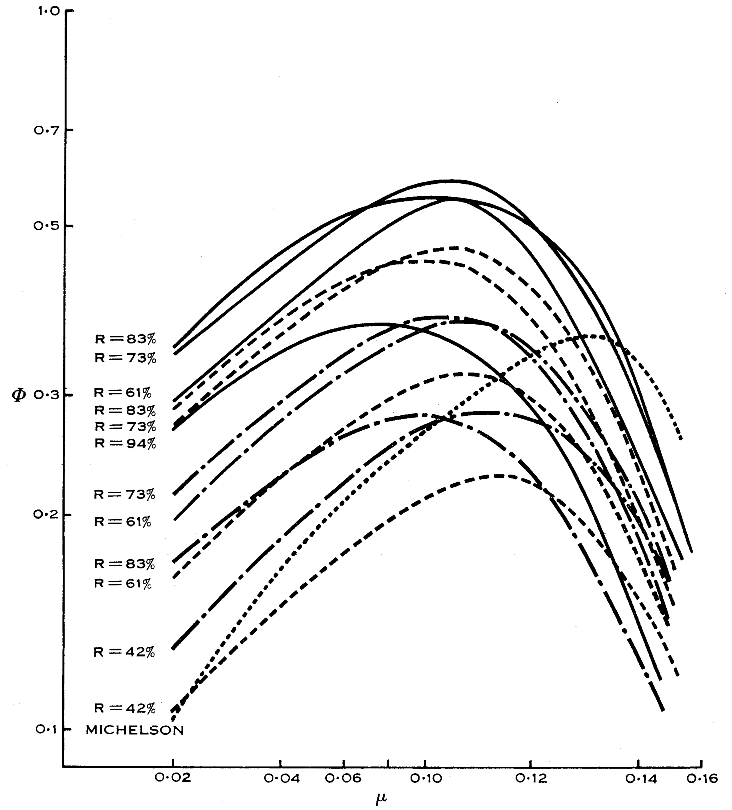

Fig. 1.—Total noise function Φ as a function of μ. $a = 0 \cdot 125$, b = optimum value.

Fabry-Perot	dielectric films	————
	silver films	— — — —
	aluminium films	— - — - —
Michelson		....

where F is the finesse of the interferometer and is given by $4R/(1-R)^2$. The Fourier expansion form of this can be shown to be

$$F_{(n)} = \frac{T^2}{(1-R)^2} \cdot \frac{(1-R)}{(1+R)} \cdot \left\{1+2\sum_{k=1}^{\infty} G_k \, . \cos 2\pi kn\right\},$$

where $(1-R)/(1+R)$ is a constant of the expansion and forms an additional transmittance factor.

TABLE 1

MAXIMUM PRECISION OF SETTING

Interferometer	Spectral Line (Å)	Coating	Reflectance R (%)	Total Noise Function Φ	Precision $(n/\delta n)_0$
Fabry-Perot	Kr 86 6056	Dielectric	73	0·59	$3 \cdot 14 \times 10^9$
	Hg 198 5461	Dielectric	73	0·59	$5 \cdot 52 \times 10^9$
	Cd 114 6438	Dielectric	73	0·59	$2 \cdot 64 \times 10^9$
	Kr 86 6056	Silver	73	0·49	$2 \cdot 62 \times 10^9$
	Hg 198 5461	Silver	73	0·49	$4 \cdot 58 \times 10^9$
	Cd 114 6438	Silver	73	0·49	$2 \cdot 20 \times 10^9$
	Kr 86 6056	Aluminium	73	0·39	$2 \cdot 08 \times 10^9$
	Hg 198 5461	Aluminium	73	0·39	$3 \cdot 65 \times 10^9$
	Cd 114 6438	Aluminium	73	0·39	$1 \cdot 75 \times 10^9$
Michelson	Kr 86 6056			0·36	$1 \cdot 94 \times 10^9$
	Hg 198 5461			0·36	$3 \cdot 37 \times 10^9$
	Cd 114 6438			0·36	$1 \cdot 61 \times 10^9$

TABLE 2

MAXIMUM PRECISION OF WAVELENGTH COMPARISON

Inter-ferometer	Spectral Lines A	Spectral Lines B	Coating	Reflectance R (%)	Total Noise Function Φ_A	Total Noise Function Φ_B	Precision $R/\delta R$
Fabry-Perot	Kr 86 6056	Hg 198 5461	Dielectric	73	0·53	0·53	$1 \cdot 10 \times 10^9$
			Silver	73	0·46	0·46	$0 \cdot 96 \times 10^9$
			Aluminium	73	0·35	0·35	$0 \cdot 73 \times 10^9$
	Kr 86 6056	Cd 114 6438	Dielectric	73	0·50	0·50	$0 \cdot 84 \times 10^9$
			Silver	73	0·44	0·44	$0 \cdot 74 \times 10^9$
			Aluminium	73	0·34	0·34	$0 \cdot 57 \times 10^9$
Michelson	Kr 86 6056	Hg 198 5461				0·34	$0 \cdot 71 \times 10^9$
	Kr 86 6056	Cd 114 6438				0·32	$0 \cdot 54 \times 10^9$

The transmittance used throughout paper I for the Fabry-Perot interferometer should be multiplied by this extra transmittance factor. This affects the evaluation of the photon noise, the shot noise, and the total noise function Φ.

Comparison of Interferometers

As the photon noise is negligible we need only consider the corrected Figure 2 of paper I for a comparison of precisions. The new total noise function as a function of the fraction of an order of interference taken up by the line width is shown in Figure 1, and the corrected limiting precisions of setting and maximum precision of wavelength comparison tables are given in Tables 1 and 2 (cf. Tables 4 and 5 of paper I).

The conclusions given earlier for the optimum aperture size and amplitude of oscillation are still valid.

Optimum Reflectance

The optimum reflectance for the three interferometer coatings is now 73% for silver films, aluminium films, and dielectric films.

Comparison of Experimental and Theoretical Precisions

The correction to the transmittance factor of the Fabry-Perot interferometer reduces the theoretical precisions calculated in paper I for comparison with the experimental precisions obtained at that time. The neglect of the photon noise term increases the precision slightly so that the agreement between the experimental curves and the theoretical values is better than shown in paper I.

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References

Forrester, A. T., Gudmunsen, R. A., and Johnson, P. O. (1955).—*Phys. Rev.* **99**: 1691.
Hill, R. M. and Bruce, C. F. (1962).—*Aust. J. Phys.* **15**: 194.