LETTERS TO THE EDITORS

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Production of a High Resolving Power by means of Multilayer Coatings

MANY astrophysical problems, for example, Zeeman-effect studies of the solar disk and the structure of some of the Fraunhofer lines, necessitate a very high resolving power, of the order of 10^5, for the spectrographic equipment.

For several instruments, in particular the Fabry–Perot interferometer, the resolving power increases rapidly with increasing reflectivity of the surfaces. However, in the case of silver films, which have hitherto been used for the reflecting surfaces, the useful upper limit for the reflexion coefficient is reached at $R = 0{\cdot}90$, because the transmission coefficient[1] is then small, about 0·045. Hence, 5·5 per cent of the incident light is absorbed by the metal film. The resolving power for such a coating, using a 0·75-cm. étalon, is theoretically 672,000 at $\lambda = 5500$ A.; but this value is not attained in practice owing to imperfections of the optical surfaces.

Since the reflectivity at the interface between two transparent media is proportional to the square of the difference of their refractive indices, it is possible to achieve very high reflectivities with successive alternate layers of high and low refractive index dielectrics of a suitable thickness. For maximum reflectivity the requisite optical thickness is $\lambda/4$.

Quarter-wave coatings of cryolite (index of refraction 1·36) and zinc sulphide (index of refraction 2·37) as deposited by evaporation *in vacuo* are eminently suitable for this purpose. Banning[2], in 1942, using a visual method of thickness control, successfully produced a multilayer coating possessing the anticipated high reflexion coefficient, the absorption being reported as negligible. However, the change of the interference colours of thin films of high index with thickness is not very pronounced for thicknesses less than approximately $\lambda/4$. Dufour[3] overcame this lack of precision by recording the variation in reflectivity of the thin film during its deposition, the reflected intensity being a minimum in the case of a quarter-wave coating of transparent dielectric of lower index than its glass supporting base. For the zinc sulphide the amount of reflected light is a maximum when the optical thickness is $\lambda/4$.

At the St. Andrews University Observatory an evaporation plant has been installed and suitably modified to produce dielectric coatings of controlled thickness, the arrangement being similar to that of Dufour. The accuracy has been investigated by measuring independently the thickness of the deposit by an interference method, the deviation from the desired thickness of $\lambda/4$ being not more than 4 per cent.

We owe to Dr. W. L. Wilcock, of the Physical Laboratories, University of Manchester, the suggestion that since the coatings were to be used in a Fabry–Perot interferometer, the determinations of the reflexion, transmission and absorption coefficients should be performed under similar conditions.

Composition of coating	Reflexion (per cent)	Absorption (per cent)	Transmission (per cent)
5 quarter-wave layers of zinc sulphide; 4 quarter-wave layers of cryolite	97	2	1
4 quarter-wave layers of zinc sulphide; 3 quarter-wave layers of cryolite	94	1	5

Photometric measurements have confirmed the superiority of the new multilayer coatings over silver films, typical values for the mercury 5461 line being as shown in the table.

The keeping properties of the new coatings is excellent, no deterioration occurring over several months.

Further experiments, with enhanced metal films, that is, silver plus layers of dielectric films, have indicated that owing to the very small absorption of the dielectrics it is possible to increase the overall reflectivity of the coating without adding to the absorption.

A pair of high-quality ($\lambda/40$) crystalline quartz optical flats, coated with four zinc sulphide and three cryolite quarter-wave layers, arranged in a Fabry–Perot étalon (fused silica spacer, 0·75 cm. thick) for examination of the 5461 mercury line, was found to give a resolving power of at least $1{\cdot}0 \times 10^5$. These flats have been incorporated into the solar spectrograph at the Cambridge University Observatory.

Experiments for the application of such plates in the focal plane of telescopes are proceeding.

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[1] Tolansky, S., *Physica*, 12, 650 (1946)
[2] Banning, M., *J. Opt. Soc. Amer.*, 792 (1947).
[3] Dufour Ch., *Le Vide*, Nos. 16–17, 480 (1948).

WHEN one applies the Fabry–Perot interferometer to absorption spectra, as has been done with some success in solar physics[1], high reflectivity and small absorption are essential if high resolving power is required. This is partly because one is compelled, in nearly all such cases, to use in combination with the interferometer a rather powerful auxiliary spectrograph, which in itself causes a considerable loss of light. Also, one can attain greater resolution only to a very limited degree by increasing the separation of the Fabry–Perot plates, because the greater separation reduces the range of the interferometer. It is well known that this range should be in a certain useful ratio to the intensity (or width) of the absorption line under investigation[1]. There is, in addition, an important connexion between the maximum plate separation (which determines the range) and the instrumental line-width of the auxiliary spectrograph[2]. The result is that in the visible spectrum the separation should not exceed about 10 mm. in air.

A. H. Jarrett's multi-coated interferometer, which has been described above, has a considerable superiority over the usual silver-coated interferometer in the desired direction, that is, it is of high reflectivity