in statistics. Therefore, only the principal properties can be given in Table 2. The energy of 642 keV of the most intense γ-ray, measured as mentioned in the preceding section, agrees with that of a transition occurring in the α-decay of ^{240}Pu and assigned to a K, $I^{\pi} = 2, 2^-$ level in ^{236}U [6].

Previously, a half-life value of 12.5 ± 1.0 min and β-rays of 3.35 ± 0.10 MeV maximum energy have been attributed to ^{236}Pa produced by bombardment of ^{238}U with 26-MeV deuterons [7]. Since no γ-rays have been reported, it remains open whether this activity and the one found in our work are identical.

Protactinium-235. The 24-min ^{235}Pa, identified in the $^{234}Th(n,\gamma)^{235}Th \xrightarrow{\beta^-} {}^{235}Pa$, $^{238}U(d,\alpha n)^{235}Pa$ and $^{238}U(p,\alpha)^{235}Pa$ reactions [8, 9], is confirmed. Half-life and β-ray energy (Table 2) agree with earlier measurements [9] which gave 23.7 ± 0.5 min and, by absorption techniques, 1.4 MeV. In addition, ^{235}Pa is found to emit a complex γ-ray spectrum of about 3% abundance.

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The Immersion Grating: Spectroscopic Advantages and Resemblance to the Echelon Grating

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The function of the immersion grating is explained and special attention is given to the role of the prism, which has been subject to misunderstandings. The analogy between the immersion grating and the echelon grating, used in reflection through the glass, is demonstrated.

The immersion grating consists of two solid components, a reflection grating and a prism. These are held in optical contact by means of the third component, a film of immersion oil, such as monobromnaphthalene. The contribution of each component, as well as the dispersion and resolving power of the system as a whole, have been considered by Hulthén and Neuhaus [1]. The use in spectroscopy of immersion gratings was first suggested by Hulthén [2] and the results of a number of experiments have been reported [1, 3–5].

Recently, this instrument has been described by Stroke [6], in his chapter on Diffraction Gratings in Flügge's Handbuch der Physik. The present note offers some comments, as we consider Stroke's treatment rather misleading. At the same time we draw attention to the close theoretical analogy between the immersion grating and the echelon grating when used as a reflection grating illuminated through the glass. A theoretical explanation of the latter arrangement was given by Mitra [7], who did not, however, point out the above analogy.

Let us first consider a diffraction grating covered with a plane parallel film of a dielectric medium with a high refractive index. It is easily shown [1, 6] that the grating equation is not altered by the presence of the medium. From this it may be concluded: The spectra from a free and an immersed grating, as observed in air, coincide in all orders. Thus the medium *per se* does not contribute to the dispersion or resolving power of the grating. But this does not mean that no spectroscopic advantages are to be won by the immersion arrangement.

However, a better performance from the grating can only be attained by the immersion technique if the grating is blazed. This is the crucial point of the argument, and one that is overlooked by Stroke.

We shall denote the blaze angle of the grating by ε, and throughout the discussion we presume that the grating works in autocollimation, so that the angle of diffraction is approximately equal to the angle of incidence α on the grating. Thus we have for a free grating in air the equation

$$m \lambda = 2 d \sin \alpha \tag{1}$$

and for an immersed grating we may write

$$m_i \lambda_i = 2 d \sin \alpha_i . \tag{2}$$

If, in both cases, we work close to the blaze in order to ensure maximum intensity, we have the additional condition

$$\alpha \approx \varepsilon \approx \alpha_i \tag{3}$$

and noting that $\lambda_i = \lambda / n_i$, where n_i is the refractive index of the dielectric medium, it will be seen immediately that

$$m_i \approx m \cdot n_i . \tag{4}$$

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The $\approx$ sign is called for by the fact that both m_i and m must be integers; this will be better fulfilled the larger the value of m. (In practice it is quite well fulfilled for high order gratings when $m \geqq 10$. Even for low order gratings, though, there is a marked redistribution of intensity among orders, as has been shown experimentally [1].) This result may be expressed: The effect of the medium is to shift the blaze into an order of spectrum that is higher by a factor $\sim n_i$, for the same wavelength in air. The resolving power of the immersed grating in the direction of the blaze will be

$$R = \frac{2\,W \sin \varepsilon}{\lambda}\, n_i\,. \tag{5}$$

Now of course the angle of incidence upon the surface of the medium is not α_i but γ, given by

$$n_{\text{air}} \sin \gamma = n_i \sin \alpha_i\,.$$

This angle γ will be fairly large, especially for a grating with a large blaze angle. Because of reflection losses it is thus suitable or even necessary to let the rays enter the medium through a face that is as nearly as possible perpendicular to the rays, i. e. to give the dielectric medium the shape of a prism, like the prism on the Lummer-Gehrcke plate. Obviously this does not affect the validity of Eq. (2) above; it is still true that the blaze is shifted into a higher order. On the other hand, if the surface of the medium is perpendicular to the rays, these will not change their direction on entering or leaving the medium. Consequently, with the prism arrangement, the diffracted rays constituting the spectrum of order $m_i \approx m \cdot n_i$ will have approximately the same direction in air as those of the m-th order spectrum produced by a free grating.

Stroke finishes his treatment of the subject by saying that the increase in dispersion is due to the *prism* and not to any new property of the grating or the grating equation. While we do not dispute the general validity of the grating equation, it should be clear from the above discussion that the presence of the medium effects a redistribution of intensity among the different spectral orders, thus making available higher orders than otherwise and thereby in practice increasing the dispersion and resolving power of the apparatus.

The resolving power at blaze angle of the immersion grating with prism arrangement (when the rays are perpendicular to the prism face) has been given by Hulthén and Neuhaus [1]

$$R = \frac{2\,W \sin \varepsilon}{\lambda}\, n_i - 2\,W \sin \beta \left(\frac{\partial n_g}{\partial \lambda}\right). \tag{6}$$

Here the first term is the resolving power of the immersion grating proper as by Eq. (5), while the second term is recognized as the resolving power of a prism with base $W \sin \beta$, twice traversed, if the refractive angle of the prism is β. Note that

$$n_g \sin \beta = n_i \sin \alpha_i \approx n_i \sin \varepsilon\,.$$

The normal dispersion of the glass $\partial n_g / \partial \lambda$ being negative, it is true that the two terms add up to give a larger resolving power than that of the immersion grating proper. It must be noted, though, that the second term contributes much less than that the factor n_i, which represents the increase of resolving power over that of the same grating without immersion, other circumstances being equal. We might say that the contribution of the prism is a fringe benefit that is gratefully acknowledged but not essential to the function of the system.

The arrangement described by Mitra [7] is in fact an immersion grating with the glass of the echelon plates acting as the immersion oil and prism. (For clarity, the prismatic part ABC of the echelon is shown by dashed lines in Fig. 1.) When Mitra calculated the theoretical resolving power of the reflection echelon, he arrived at the result

$$R = \frac{2\,N\,t}{\lambda}\left(\mu - \lambda\,\frac{\partial \mu}{\partial \lambda}\right). \tag{7}$$

Mitra's notation is explained in Fig. 1. The same figure also shows that our notation transforms into that of Mitra through the substitutions

$$n_g \equiv n_i \equiv \mu\,,$$
$$\beta \equiv \alpha_i \approx \varepsilon\,,$$
$$W \sin \beta \approx W \sin \varepsilon = N\,t$$

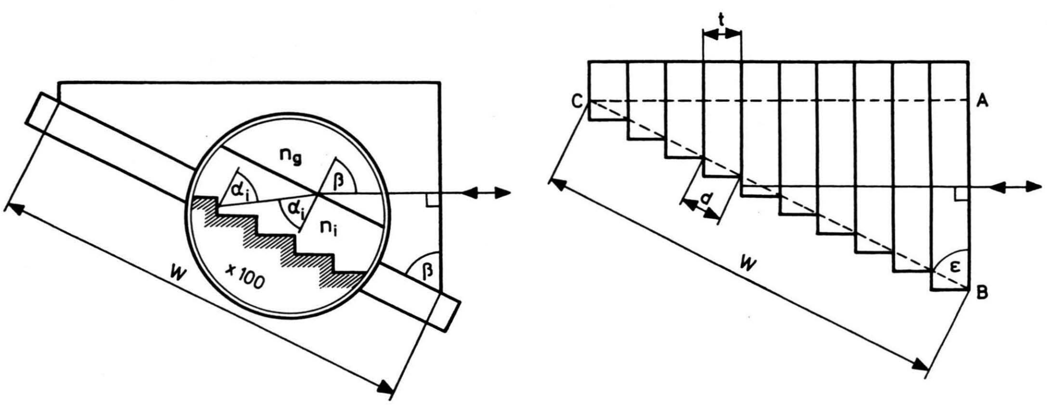

Fig. 1. Comparison between immersion grating and echelon grating in reflection.

which also, obviously, transform Eq. (6) into Eq. (7). In Fig. 1 the refracting angle of the echelon is denoted by ε, which symbol also means the blaze angle of the immersion grating. This is justified by the assumption that we work close to the blaze. $n_g \equiv n_i$ implies $\beta \equiv \alpha_i$, of course.

It is very interesting to note that the second term of Eq. (7), as before, represents the resolving power of the prism. Mitra neglects this term in comparison with the "immersion" part μ. The same term also appears when the echelon is used in transmission. To our knowledge, though, no author has found it worthwhile to discuss the contribution of the prism, with the possible exception of VON LAUE [8], wo did not, however, consider the dispersion nor the resolution.

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Nichtgleichgewichtsrechnungen zu einem mittels einer Laval-Düse erzeugten Plasma-Parallelstrahl

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In der folgenden Arbeit sollen an Hand möglichst einfacher Modellvorstellungen einige theoretische Untersuchungen über strömende Plasmen durchgeführt und mit experimentellen Ergebnissen verglichen werden. Der allgemeinen Betrachtung liegt ein kräftefreier Plasma-Parallelstrahl zugrunde, der mittels eines sogenannten Plasmabrenners durch Entspannung eines lichtbogengeheizten Argonplasmas in einer Laval-Düse erzeugt wurde. Allein dieser Erzeugungsmechanismus kann zur Folge haben, daß Elektronen- und Gastemperatur (Temperatur der schweren Teilchen) und die Reaktionsprozesse im Plasmastrahl nicht im Gleichgewicht sind. Man muß deshalb allgemein die eine Strömung beschreibenden Erhaltungssätze für jede Teilchensorte formulieren [1].

Die Kontinuitätsgleichung hat dann die Form

$$\partial \varrho_s / \partial t + \operatorname{div}(\varrho_s \boldsymbol{u}_s) = \dot{w}_s \tag{1 a}$$

($\boldsymbol{u}_s$ und ϱ_s = Strömungsgeschwindigkeit bzw. Dichte der Komponente s, t = Zeit), wobei $\dot{w}_s$ die Summe der die Teilchensorte s erzeugenden und vernichtenden Prozeßraten ist.

Vernachlässigt man von vornherein alle Reibungs- und Kontaktwärmeleitungsphänomene, sowie sämtliche elektrischen Ströme und äußeren Kräfte, und läßt nur ein inneres elektrisches Feld $\boldsymbol{E}^{(i)}$ zu, das die Gleichheit von Elektronen- und Ionengeschwindigkeit bewirkt, so vereinfacht sich die entsprechende Impuls- oder Kraftgleichung wie folgt

$$\boldsymbol{R}_s + \boldsymbol{u}_s \dot{w}_s + \varrho_s \frac{D \boldsymbol{u}_s}{D t} = -\operatorname{grad} p_s + \boldsymbol{C}_s + n_s q_s \boldsymbol{E}^{(i)} \tag{2 a}$$

[$\boldsymbol{R}_s$ = Reibungsglied (Impulsaustausch durch elastische Stöße); $\boldsymbol{C}_s$ = Impulserzeugung bzw. Vernichtung durch unelastische Stöße; p_s, n_s und q_s = Druck, Teilchendichte und Ladung der Komponente s].

Die Energiegleichung mit den zu Gl. (2 a) eingeführten Voraussetzungen lautet für stationäre Strömungen

$$\operatorname{div}\left[\varrho_s \boldsymbol{u}_s \left(h_s + \frac{\boldsymbol{u}_s^2}{2}\right)\right] = S_{ss} + n_s q_s \boldsymbol{u}_s \boldsymbol{E}^{(i)} \tag{3 a}$$

(h_s = spezifische Enthalpie der Sorte s, in S_{ss} sind für die Sorte alle Energien berücksichtigt, die durch Stöße und Strahlung allgemein gebildet oder vernichtet werden).

Damit sind alle Gleichungen formuliert, die zur Beschreibung einer Strömung, auf die die eingeführten Vernachlässigungen zutreffen, benötigt werden.

Setzt man eine gemeinsame Geschwindigkeit aller Komponenten und eine gemeinsame Temperatur der schweren Teilchen (Gastemperatur) voraus, so sind die Unbekannten des Systems die Gradienten der Geschwindigkeit der Teilchendichten und der Gas- und Elektronentemperatur. Vorausgesetzt, daß im Parallelstrahl an jedem Ort derselbe Druck p herrscht und dieser dem meßtechnisch leicht zugänglichen Umgebungsdruck entspricht, so folgt aus dem eindimensionalen Gesamtimpulssatz

$$\varrho\, u \frac{\mathrm{d}u}{\mathrm{d}x} = -\frac{\mathrm{d}p}{\mathrm{d}x} \tag{4}$$

[Summation der Gl. (2 a) über alle Teilchensorten, p = Gesamtdruck, u = gemeinsame Strömungsgeschwindigkeit, ϱ = Gesamtdichte], daß die Geschwindigkeitsänderung Null ist.

Gibt man Geschwindigkeit, Teilchendichten und Temperaturen vor, so kann man zunächst die Teilchendichtegradienten aus der vereinfachten Kontinuitätsgleichung (1 a) bei bekannten Prozeßraten

$$u \frac{\mathrm{d}\varrho_s}{\mathrm{d}x} = \dot{w}_s(1) \tag{1 b}$$

sofort berechnen. Hierbei ist berücksichtigt worden, daß bei den bisher in diesem Zusammenhang untersuchten Geschwindigkeiten von einigen 10^5 cm/sec nur die Relaxationserscheinungen des Grundzustandes „1" maßgeblich sind [2, 3]. Der Verlauf der Elektronentem-

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