AN AUTOMATIC INTERFERENCE REFRACTOMETER

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AN AUTOMATIC INTERFERENCE REFRACTOMETER[1]

by

W. Kinder and H. Plesse

Dedicated to Dr. K. Räntsch on the occasion of his 65th birthday

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ABSTRACT

An automatic interference refractometer. The paper describes an interferometer for measuring liquids and gases, in which the path difference to be measured is compensated automatically and the amount of compensation determined photo-electrically by counting fringes. A time-division multiplex system with pulse-amplitude modulation is used for this purpose. The output of measured values is analog and digital form in units of 0.01 interference fringe.

1 Read before the meeting of the DGaO held in 1968 at Baden/Vienna

An earlier paper (1) described an interference refractometer for visual use and mentioned a device developed for this purpose in which all interference settings, including zero setting, measurement, correction and read-out of the measurement values, are made photo-electrically. The further development of this device (2) has resulted in the automatic interferometer, about which the Deutsche Gesellschaft für angewandte Optik (DGaO = German Society for Applied Optics) was informed at its meeting at Baden/Vienna.

Electronic means have repeatedly been used in the interferometric refractometry of gases in order to simplify measurement or increase its accuracy. In this connection, Kinder (3) widened the range of measurement by means of additional pairs of auxiliary chambers which produce substantially less fringe drift than the pair of measuring chambers; Namba (4) fixed the zero fringe electronically as the gas flowed in; Peck and Khanna (5) counted the passing monochromatic interference fringes during the inflow or evacuation of the gas. Whereas pressure fluctuations can be used in gas refractometry, such a procedure is impossible in the measurement of liquids. Special problems arise which will be discussed in this paper.

The principle of measurement of an interference refractometer is illustrated in Fig. 1. A light source provides two coherent beam components which are made to interfere after each has passed through a measuring chamber of length L. If the refractive power is the same for both chambers, zero interference occurs in the centre of the field of measurement, e.g. on a mark. If the refractive powers are different, the interferences shift in proportion to the difference $(n_2 - n_1)$ between the refractive indices. The fringe drift can be reversed by means of a compensator (consisting, for instance, of fixed and rotating glass plates). The measurement value is then given by the number of compensated interference fringes. This number is determined by the angular rotation of the compensator plates and, in the case of the automatic interference refractometer, ascertained by an interference fringe count.

Fig. 2 shows how this principle is put into practice. The actual interferometer consists of the beam divider T and the mirror Sp. Below the measuring beam path, in which the light passes through the measuring chambers on its outward and return journeys, there is a second beam path which is not affected by the contents of the chambers and is used both as a fiducial and a counting beam path. In its simplest form, the compensator K is of the Jamin or Löwe (7) type, since there is no need here for linearization (8). Wide dispersion ranges can be dealt with by means of a "double compensator" consisting of four plates, and "discontinuities" (1) can be thereby avoided. The compensator, however, affects not only the measuring beam path illuminated with white light, but also, at the same time, according to a proposal by R. Torge, the monochromatically illuminated fiducial and counting beam path. It is possible in this way to make an exact count, in monochromatic light, of the number of interference fringes needed for compensation in the measuring beam path.

In both beam paths, the image of the associated light source L appears on the aperture diaphragm A in the focal plane of a collimator, so that the interferometer is penetrated in what is called the "parallel beam path". A further light source image L" appears in the focal plane of a telescopic lens. The interference phenomenon can also be visually observed via a cube with a partly transparent plane. The interferences are localized on mirror Sp and conjugate to the field diaphragm S, the field of view SF and field of measurement MF. In the (upper) measuring beam path, two slits perpendicular to the image plane are fitted in the field of measurement. The distance between them is half that between the interference fringes (3). The two slits are thus so oriented with respect to the interference fringes that, with symmetrically adjusted fringes, they cut in a straight line from the left and from the right into the sides of the interference fringe maximum. Using an intensity-variation method, the luminous fluxes traversing the two slits are taken to a multiplier via rhombic prisms and a chopper diaphragm B. In the case of the (lower) counting beam path, three slits perpendicular to the image plane are fitted in the field of measurement. The distance between slits is exactly one-third of the distance between interference fringes. The three slits thus receive three signals at 120° from one another. A rotating slit diaphragm R sends these three signals in close succession to a second multiplier for fringe counting and interpolation.

The operation is as follows: first the compensator is made to rotate at a constant speed by means of a motor in order to seek the white light zero interference in the measuring beam path. At this juncture, the chopper diaphragm is at rest, because only <u>one</u> slit aperture is needed to find the point of greatest amplitude. Once the zero fringe has been found, the two partial luminous fluxes are precisely balanced by the intensity-variation method using the chopper diaphragm. At the same time, a change-over is made in the measuring beam path from white to monochromatic light in order to rid the zero fringe of dispersion and to intensify it. While, during the seeking and measuring beam path balancing, the compensator is rotated from an initial into a measuring position, the monochromatic interference fringes are counted and interpolated in the counting beam path. The measurement value is obtained to an accuracy of 1/100 of the distance between fringes; this corresponds at the same time to the accuracy with which the refractive index is determinated.

The electronic circuit for detecting zero interference in white light, as indicated by J. Neumann, is shown in Fig. 3. When the interference field passes the measuring slit Sp in front of the photoelectric cell Ph, fluctuations in the photoelectric current I_a occur on the transition from the practically unmodulated light of the higher-order fringe range to the zero-order interference fringe, which charge the capacitor C behind the rectifier G to the corresponding maximum voltage U_a. The charging current pulses produce voltage pulses U_b at the resistor R; these are amplified in amplifier V and converted into defined rectangular pulses U_c in the trigger Tr. If the amplitude of the fringes drops again, the voltage remains stored in capacitor C, since the rectifier prevents the charge from draining away, and the pulses disappear, as shown in the time chart. The negative leading edges of the rectangular pulses set a flip-flop K to its initial position (position of rest), if it is not already so set, while the positive trailing edges set it to its working position, i.e. signal voltage flows through the output contact at d. During the seeking process, the appearance of the negative edge of the first pulse causes the compensator driving motor to switch over to the output of the or-gate at e, via which, from this moment on, the motor receives its control voltage for the actual detection process. The control voltage is thus supplied to the motor via the or-gate either as a pulsed voltage directly through the trigger or through the flip-flop, the built-in tripping time T of which is about 1.5 times the pulse sequence time. The result of this is that the motor turns the compensator as long as pulses arrive. Once the pulses disappear, the flip-flop is automatically restored to its initial position after a time T, so that the voltage at e disappears and the motor stops, the zero fringe being then at about 1.5 fringe widths from the fiducial mark which is analogous to the scanning slit. With the automatic resetting of the flip-flop, the actual process of detection as described above is initiated; with the aid of a time switch, the motor then takes first of all the zero fringe to the immediate vicinity of the fiducial mark by means of the compensator.

Fig. 4 is a diagram of the electronic circuit for fringe counting and interpolation. The light passing through the three measuring slits Sp, which are staggered by one-third of a fringe width, is successively modulated at 1.2 kHz by the rotating sector disc S and taken to a single photoelectric cell. After having been amplified, the resulting photoelectric pulses charge three capacitors C1, C2 and C3 allocated to the three slits via a three-way switch Sch controlled by the sector disc. The voltages of these capacitors thus provide a measure of the phase position of the interference field in relation to the measuring slit. The use of only one photoelectric cell or photomultiplier in the so-called "time division multiplex system" ensures that the measuring voltages are drift-free to a high degree.

In order to give a numerical indication of the phase relationship, the capacitor voltages are cophasally modulated with the aid of a 400 Hz generator G and fed to the three stator windings of a 400 Hz function generator D. After amplification and phase-selective rectification, the voltage induced in the rotor is used by a d.c. motor to drive the rotor in a conventional tracking circuit until the induced voltage is zero. The angular position of rotor R now corresponds to the phase position of the interference field. The movement of the rotor and its position after balancing are indicated in a numerical table by means of an analog-digital converter ADU; this table shows the 100th part of the signal period. The entire range covers 250 fringes. The constancy of the sum of the three photoelectric currents obtained in the interference field by the 120° phase shift is checked on an instrument.

Fig. 5 shows the time sequence of the measurement process. In the interference field there are the three slits I to III which are displaced through 120° with reference to the spatial sum signal. The sector disc, the sector width of which is twice that of the measuring slits, travels past them, so that the light taken to the electron multiplier is constant for a brief period. During this time, photodiodes control switches by means of which the corresponding charging currents I, II and III flow to the three measuring capacitors in fig. 4.

Fig. 6 shows the spatial arrangement. On the left may be seen the measuring apparatus for the interference fringes, and on the right the photodiodes for the switch control.

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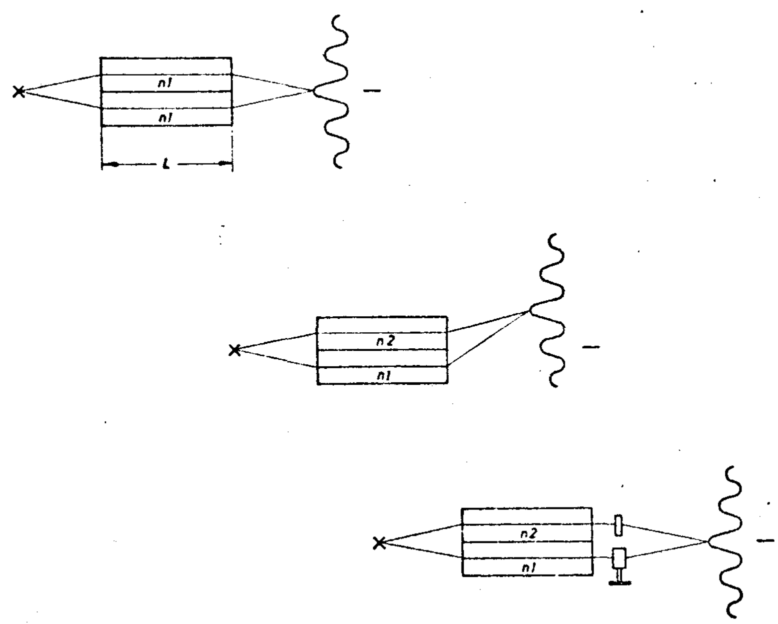


Fig. 1. Principle of measurement of an interference refractometer.

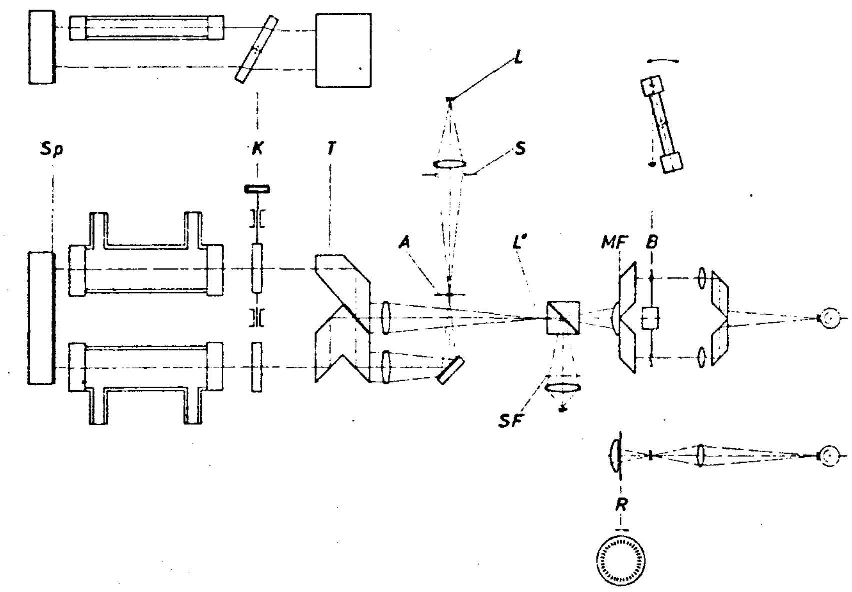


Fig. 2. Diagram of the optical structure.

Compensator

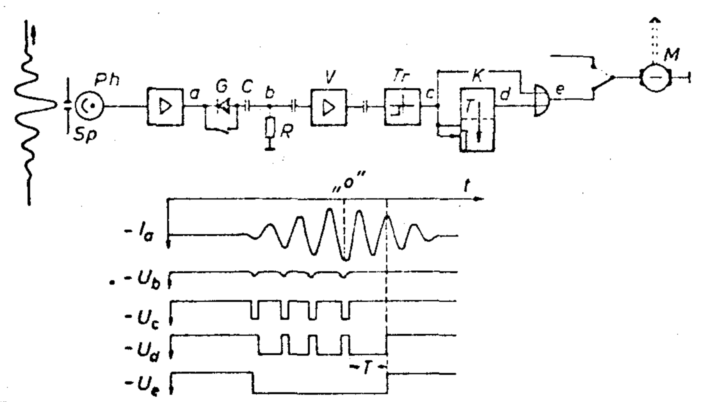
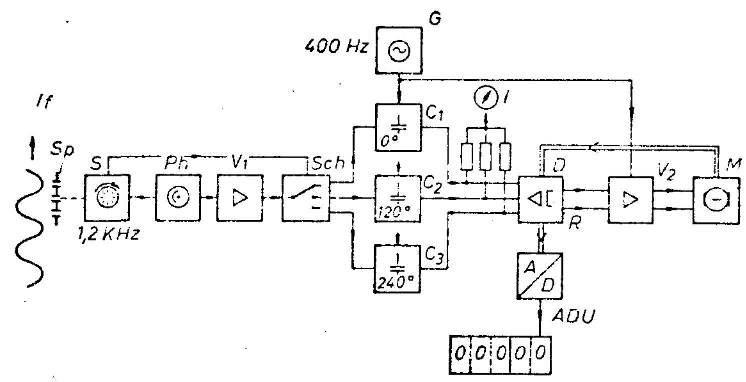
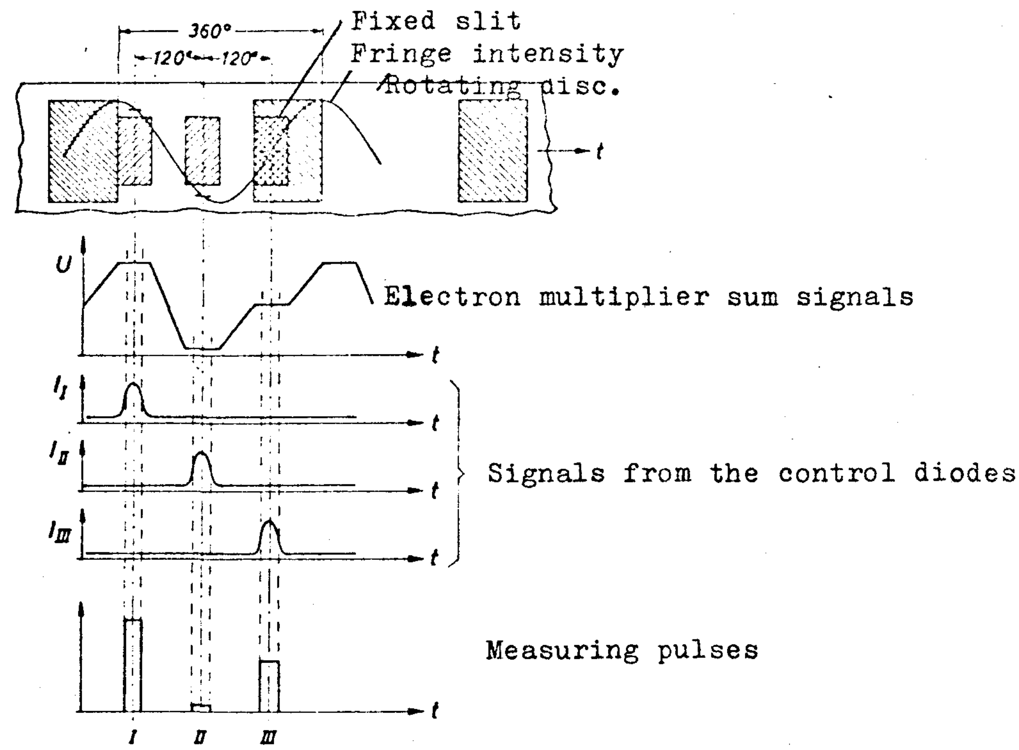


Fig. 3. Zero fringe detection circuit.



<u>Fig. 4.</u> Digital measuring apparatus for interference fringe displacement.



<u>Fig. 5.</u> Generating the measuring pulses.

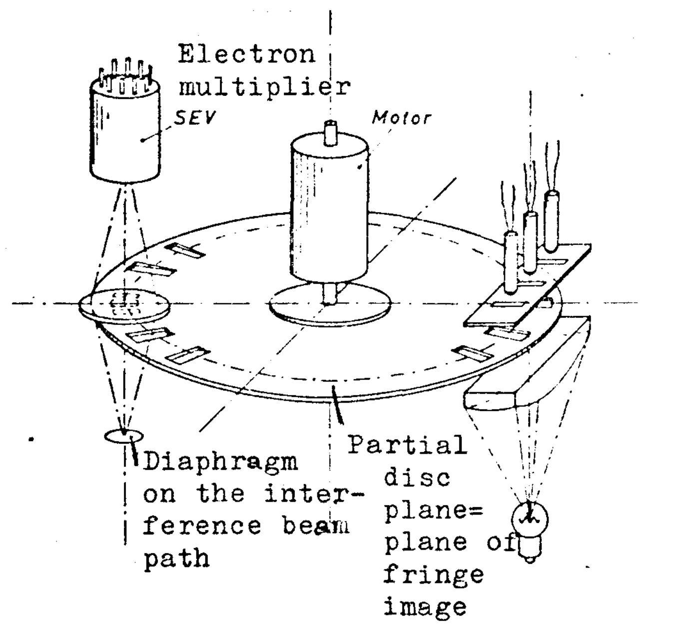


Fig. 6. Arrangement for generating the measuring pulses