THE DIOPTRON II - IN THEORY

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MOST OF THE published studies seeking to evaluate automatic refractors are American. There have been some British studies but these have not always effectively separated subjective enthusiasm or cold water from hard, objective evidence. In the first of two articles we are looking mainly at the *theory* behind the Dioptron II—how and why it works. In the second (to be published in the next issue) we will be looking at the Dioptron II in practice—reporting objectively on our own experience at UMIST where the Ophthalmic Optics Department has been using the instrument routinely for over two years.

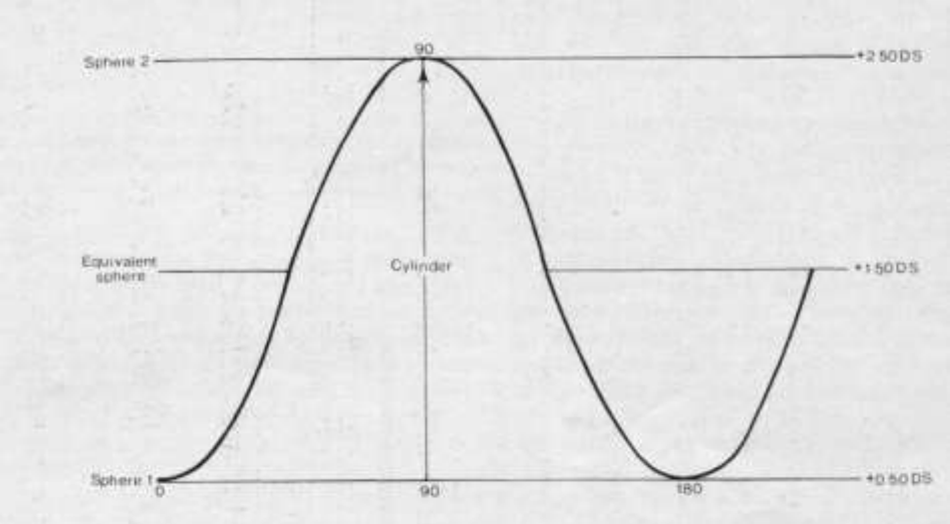

Figure 1: The graph of the sin^2^ function illustrates how the refractive data is analysed. Sphere 1 is the base line sphere of the refraction, eg +0.50 DS. Sphere 2 is the second sphere, eg +2.50 DS. The cylinder component is the difference between the two spherical components, ie +2.00 DC. The axis of this cylinder is determined from the 'zero points' on the base line sphere, eg axis 780. The equivalent sphere is half the sum of the base line sphere and the second sphere, eg + 1.50 DS. The sin^2^ function is fitted to the measurements from the relative position of the Badal lens. In our example the refraction is + 0.50/ + 2.00x 180.

INFRA-RED optometers are not new but it is only with the introduction of the microcomputer that they have become fully automatic. Although Collins built the first infra-red optometer in 1937, it was not until the mid-seventies that computer technology enabled Stanford Research Institute to develop Coherent's Dioptron. This instrument, the Acuity Systems Autorefractor and the Bausch and Lomb Ophthalmetron formed the first generation of automatic refractors. According to your viewpoint, these devices may be seen as useless, a threat, or a powerful tool for the optometrist or ophthalmologist.

Many have taken advantage of this new technology. There are around a thousand Dioptrons installed in the United States, about half that number in Europe and several hundred in the Far East. However, at the time of writing, the number in use by British opticians can be counted in tens rather than hundreds. It would appear that most of these have been acquired in recent months and this may herald an upsurge in their use in this country. Is it, therefore, just a matter of time before most practices in Britain will have computer-based instruments? As with most technological changes, the rapid increase in the use of computers first began in America. We still lag behind the Americans and perhaps even the Europeans in our use of microcomputers in other areas such as 'hobbies', education and business, but the upward trends in all these areas are very clear. Are we, therefore, going to follow the Americans with automatic refractors as well or is there something peculiar to the British scene which will prevent it? Certainly the optometrist's role varies worldwide as do associated social, financial and other factors. These considerations further prompted us to take a *British* look at the Dioptron II.

No doubt some resistance stems from a reticence of people to adopt new technology when little is known about it. So, in this first article we hope to explain how the instrument works.

The measurement principles of Dioptron II

The designers of infra-red optometers must cope with the problem of detecting the patient's far point in order to obtain a measurement of the static refraction. There are the well-known techniques of retinoscopy and Scheiner disc optometry for determining this- measurement, but more recently, the image analysis method has been developed. In this method of measurement the degree of modulation or change in contrast of the retinal image of a projected target is monitored by the eye, or in the case of a Dioptron, by an infra-red detector. The vergence of the incidental infra-red beam is altered thereby changing the focus of the projected target and its associated degree of modulation or contrast. When the vergence of the infra-red light is such that the modulation of the projected image is at maximum, the vergence of the incident infra-red beam is equal to the refraction of the eye under test. The Dioptron utilises this technique, the incident and reflected beams using the same light path. The incident beam is polarised at right angles to the returning beam, the phase occurring after reflection from the sclera. Because the infra-red light is reflected at the sclera and not the neural epithelium and empirical allowance has to be made when determining the refraction. A further allowance is made because the infra-red light renders an emmetropic eye hypermetropic by 1.1 DS (Tucker 1972). Both these correction factors are found in the $sin^2$0 computer program of the Dioptron which determines the final measurement of the refraction. The $sin^2$0 function is the best-fit function describing sphere, cyl and axis and is fitted to the data recorded from six meridional refraction measurements.

Precisely how the Dioptron utilises the image quality analysis to produce these six meridional refractions will be discussed in the later section on Dioptron II mechanics.

Instrument alignment

Having produced a system to carry out these refractive measurements, the measurement beam has to be correctly centred on the patient's pupil. An obvious solution is the good old fashioned sight hole. Unfortunately, the observer's eye requires visible light. For this reason the

continued on page 8

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continued from page 7

Dioptron's designer, G Munnerlyn, decided to use a night-sight to convert the infra-red into visible light. The light path of this observation system is angled to ensure that a vertex corrected measurement is made; if the patient's head is too far away, the patient's upper lid will be seen in the viewing tube, whereas if it is too low, the lower lid will be visible (see Figure 2).

This alignment system is used in conjunction with the visible star fixation target which the patient views. Therefore, when the instrument is correctly aligned the visible star target can be seen in the centre of the viewing tube, concentric with patient's pupil and bisected by the horizontal 'vertex line' on the viewing tube.

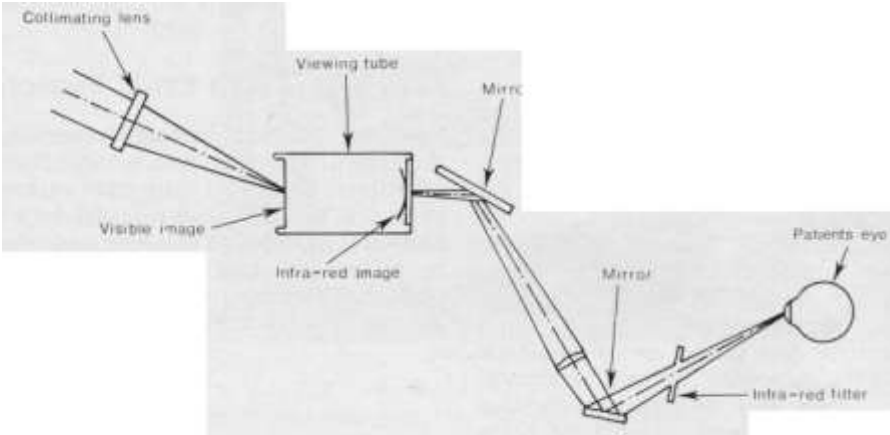

Figure 2: The viewing system of the Dioptron is angled by two mirrors so that the eye under test is set at the correct vertex distance when the pupil is bisected by the horizontal vertex line on the viewing tube.

The Dioptron examination procedure

As with any instrument there is a correct, standardised procedure to be used when operating the Dioptron. First, the patient is asked to sit comfortably with the chin in the chin-rest, with their mouth closed and teeth together. This ensures that the patient's head alignment and fixation do not vary during the course of head-rest adjustment and the rest of the examination.

After adjustment of the head-rest, the measuring head is moved to the rear of its table and the patient's right eye is lined up with the instrument by sighting along the groove on top of the instrument to give a coarse alignment. The viewing tube is then switched on and the measuring head finely adjusted until the operator can see that the star target is centred on the patient's pupil, both target and pupil being bisected by the horizontal line 'vertex target'. The patient is instructed to look 'through' the visible star target and not worry about blinking. After this, the operator initiates the scanning sequence and within a short period of time the printed result is obtained.

The Dioptron M's mechanics

In order to understand in detail how the instrument works it may be helpful to break our examination down into four parts to consider illumination system, the detector system, the scanning sequence and the print out.

Illumination system

A diagram of the illumination and detector system is shown in Figure 4.

The infra-red, filtered light source, S, produces a light beam which is subsequently plane-polarised by the reflecting prisms. The light is then focused by a condensing lens and a moving Badal lens at C to produce an aerial image of the rotating bar wheel, W, at I.

The position of this high contrast moving image, I, can be varied by the movement of the Badal lens stepper motor. As the name 'Badal' implies, it is calibrated in dioptres, and so the movement in millimetres of the lens from its zero position is recorded and converted by dioptres by the computer.

The light from the image, I, is re-collimated by the eye lens and is viewed as a generally blurred image, X, by the ametropic eye. This latter image, X, is focused and defocused by the movement.

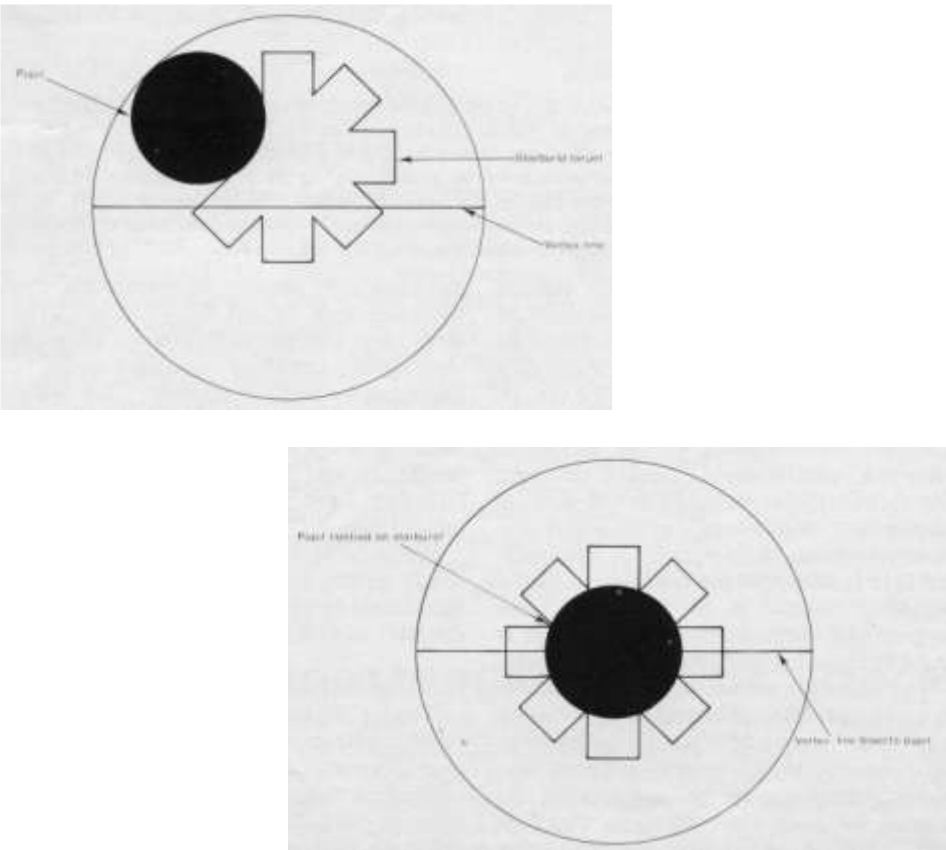

Figure 3: The upper diagram shows the appearance of the patient's eye in the viewing tube after initial alignment of the measuring head, while the lower shows the pupil centred on the Starburst target which is in turn bisected by the vertex line.

of the lens, C. Hence, when the image, X, is sharply focused for the ametropic eye, the change in the lens position is proportional to the dioptric power required to correct the ametropia present.

The detector system

The detector system is concerned with monitoring the degree of modulation or contrast of the image, X, present on the patient's retina. The photodiode, P, receives the returning beam which is focused by the moving lens, C, and the condensing lens on to a mask just in front of the photodiode. The width of this mask is the same as that of the bars of "the rotating wheel, W. Hence maximum modulation or change of contrast occurs when the returning beam is focused on this mask. This will occur when the retinal image, X, is in sharp focus.

A microcomputer controlled servo-loop couples the movement of the Badal lens, C, to the photodiode so that movement of the lens stops when a peak modulation or change in contrast is detected.

Scanning sequence

Having determined the position of the initial peak signal in the focusing scan, the sensing head is rotated 90 degrees to determine the position of the orthogonal astigmatic peak signal. This is the cylinder axis scan. The sensing head is then rotated and the focusing lens tracked in and out to determine the relative position and axes of these two peak signals in a series of six further scans. Each of these scan measurements is recorded in the microcomputer's memory, analysed by a special program stored within the computer, and then printed out on a card.

Print out

The card on which the results are printed is shown in Figure 5.

Here the 0.01 dioptre setting has been chosen although it is a simple matter to request the more conventional, but abridged, 0.25. The first four lines of the print out are of most interest to the practising optician as they show the sphere, cylinder, axis and equivalent sphere in that order.

The other lines are also important as they relate to the instrument's accuracy. The fifth line gives the instrument's internal consistency or 'confidence factor' which is concerned with the goodness of fit of a sine-squared function to the dioptric measurements received and analysed by the microcomputer. The numbers printed on this line vary from 0 to 999 according to how close the scatter of measurements are to the best-fit sine-squared function. The results we will be reporting have for the most part an internal consistency of between 0.01 and 1.00.

The sixth line gives the number of missed scans which have occurred during the instrument's operation. These may occur if a patient's blinks have interrupted the infra-red beam. The first two digits represent missed focusing and axis scans, but these do not appear crucial. However, the third digit is particularly important for accuracy and indicates the number of missed measurement scans. In this report we will mainly be concerned with results where there were three or fewer of these.

The seventh line is concerned with the number of times the optical sensing head has to rotate to find a peak signal in its search for the axis, but we will not be reporting on this information in our present study.

Line eight, which appears only for the right eye against 'Pupil Dist' on the print out, is of no interest to the user and for use only returned the number, 86.

The print out, although simple, is in fact an extremely valuable feature of the Dioptron as we hope to make clear later, but the cards themselves are not very well prepared. As well as the misleading 'Pupil Dist', there are a couple of pre-printed lines which occasionally appear beneath the computer printout disguising some figures.

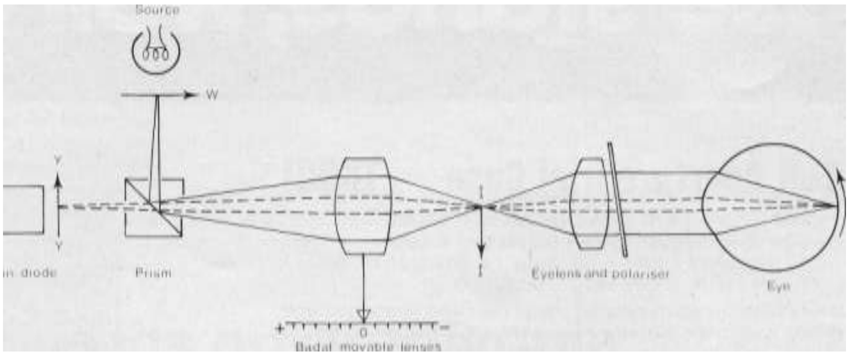

Figure 4: The illuminating beam (solid line) is produced at the infra-red, filtered source. This light passes through the bar wheel, W, and is polarised by a semi-reflecting prism. The Badal lens focuses the light to produce an image of the bar wheel at I. The eyelens and circular polariser refocus this real image, I, as image, X, on the patient's retina.

The repolarised light (dotted lines) is reflected from x and returns along the same optical path through the semi-reflecting prism to be focused on the mask of the photodiode.

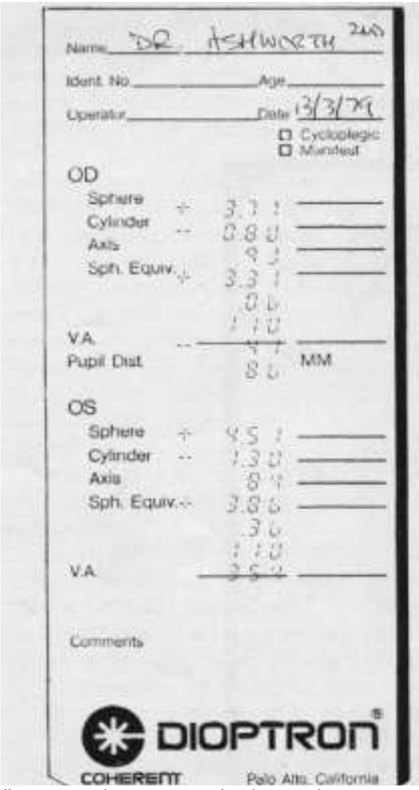

figure 5: Dioptron Card printout (See text for details.)

Consumer response

The whole process from making the patient comfortable through to the results being printed takes on average three minutes, although this may be longer when the patient blinks a great deal or fixates the target incorrectly. We found that the Dioptron did produce some rather indigestible figures as a response to a poor signal being returned to the infra-red detector.

continued on page 11

continued from page 9

This was usually due to a cataract or myopic pupil. For the most part, however, *our* general subjective impression was that the Dioptron's operation was free from 'hiccups'. We experienced no breakdowns.

Reference

TUCKER, j The chromatic aberration of the eye between wavelengths 200nm and 2,000nm: some theoretical considerations, *Brit J Physiol Optics.* 1974. **29.** 118-125.

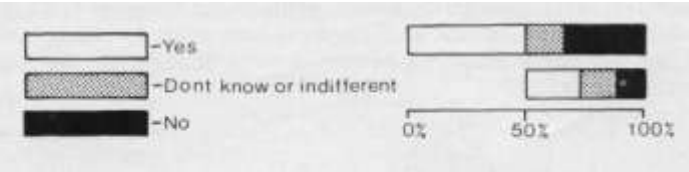

Figure 6 shows the proportions answering YES, DON'T KNOW or INDIFFERENT, or NO to the questions given. The second question was only asked of those who did not answer YES to the first. The respondents were 62 UMIST undergraduates who had actively used the Dioptron II in the course of their clinical work. They were mainly from successive final year groups.