

Conoscopic Measurement of Optic Angle and Orientation Optic Indicatrix

Method of Intersection

User Guide

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It needs to be known

Before you to start manual reading, it is necessary to familiarise with used terms and their letter designations.

Conoscopic method of intersection. So named by the author developed a conoscopic method to determine the optic angle and orientation of the optical indicatrix. In oblique sections of the direct measurement of the angle $2V$ using the Mallarda's method impossible, since the optical axes are out of field of view. Hence, it is required to define orientation of optical axes under those characteristics of an isogyre which can be measured in sight of a conoscope. This problem is similar to the definition of the origin inaccessible object by measuring the angles with the two points with known coordinates to be solved in geodesy "method of intersection". In conoscopy the similar problem also can be solved "intersections": measurement of angles of turn of a stage at which there is the overlap of an isogyre with three points in the field of view of the conoscope. Knowing the angles and coordinates of points, we can analytically calculate the coordinates of the optical axes and the angle between them.

Spherical coordinates. To determine the spatial orientation of optical axes and the symmetry elements of the optical indicatrix used spherical coordinates (polar system of coordinates) in a combination with the rectangular coordinates. The axes of rectangular coordinates X and Y coincide with threads of ocular cross, the orientation of which corresponds to directions of light oscillations in Nicol prisms (Fig. 1).

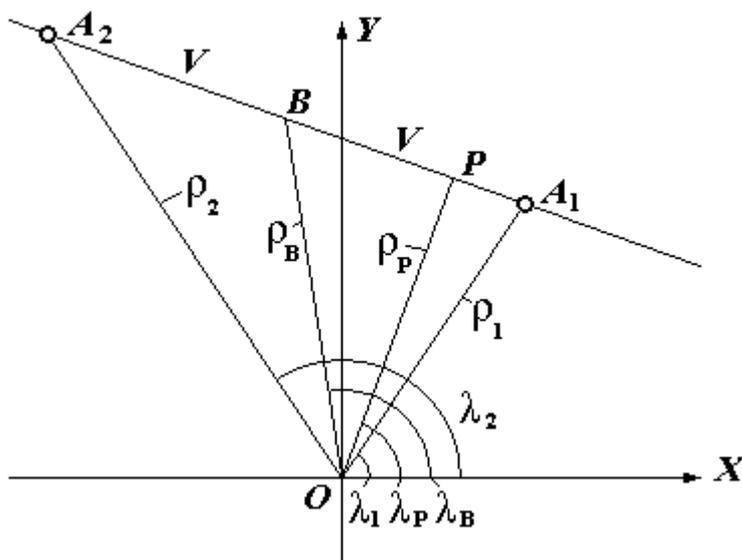


Fig. 1. Spherical coordinates of optical axes A_1 and A_2 , the axial plane $P (A_1PA_2)$ and bisectrix B of optical axial angle in an oblique cross section of a biaxial crystal (gnomonic projection). ρ - polar angle; λ - longitude.

The pole of spherical coordinates is combined with centre O of rectangular coordinates. For a zero meridian it is accepted positive half-axis X . Orientation of any directions, for example, optical axes A_1 and A_2 , is defined by their spherical coordinates: polar angles ρ_1 , ρ_2 and longitudes λ_1 and λ_2 , measured from the zero meridian. Longitudes λ are considered positive if they are measured in the direction counter-clockwise (from 0 to 180°), and negative, if in the opposite direction (from 0 to -180°). Knowing coordinates of optical axes, it is possible graphically or by calculation to define orientation of the optical indicatrix: spherical coordinates of an axial plane - ρ_p , λ_p and bisectrix B of optical axial angle - ρ_B , λ_B .

Angular radius of the conoscopic field of view (ρ_k) - a polar angle of edge of a field of view, depending on aperture A of an objective and a refractive index of a crystal. It pays off under the formula

$$\sin \rho_k = A/n,$$

where n - the average refractive index of the crystal, equal to $(n_g + n_m + n_p) / 3$.

Initial positions of optical axes. To calculate rotation angles of the stage are necessary starting points - some kind of reference points from which readout are made.

Standard position of optical axes - one of four positions of the extinction of crystal (in parallel light) at which near optical axis A_1 is in 1st quadrant. (Numbering of quadrants is shown in Fig. 3). Two variants of a locating of distant optical axis A_2 are thus possible: above the axis X (Fig. 2, a) - standard position A (SPA) or below (Fig. 2, b) - standard position B (SPB).

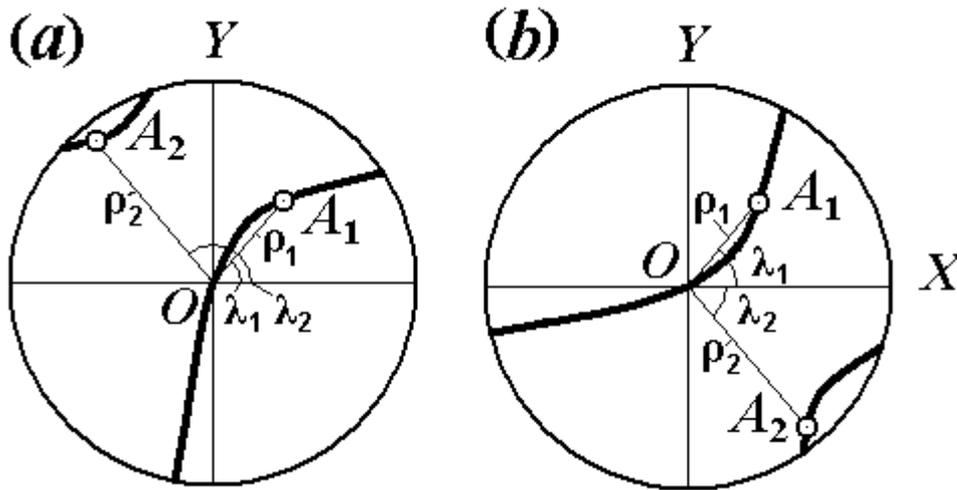
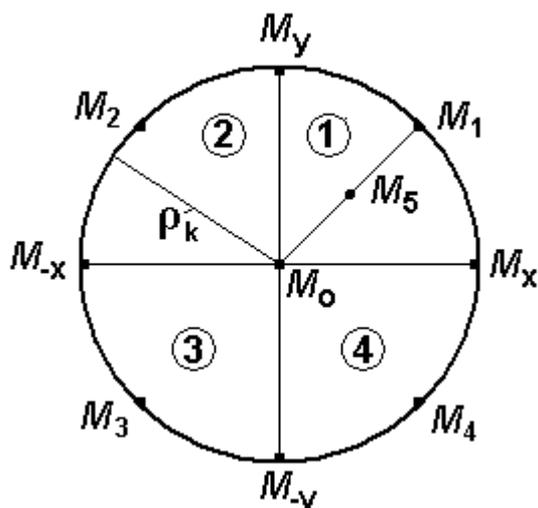


Fig. 2. Standard positions of optical axes. A_1 - the near optical axis; A_2 - the distant optical axis; ρ_1 and ρ_2 - polar angles of optical axes; λ_1 and λ_2 - longitudes of optical axes.

The isogyre in a standard position, crossing centre O , passes from 1st in 3rd quadrant. Narrow, less mobile end of an isogyre should be in 1st quadrant. If the standard position is chosen correctly at stage rotation clockwise the isogyre moves from the centre to the right.

Longitudes of optical axes in a standard position are connected by following dependences: $\lambda_1 = 180^\circ - \lambda_2$ (SPA); $\lambda_1 + \lambda_2 = 0$ (SPB).

Marks - points in the field of view with known coordinates. As the marks used ocular crosshair (M_0), points of intersection of threads of ocular cross with the edge of field of view (axial marks M_x , M_y , M_{-x} and M_{-y}) and points on the boundary of the field of view (diagonal marks M_1 , M_2 , M_3 , M_4), equidistant from threads of the cross (Fig. 3). Besides, for some cross sections in which it is impossible to use diagonal marks, the additional mark M_5 allocated visually by of division of line M_0M_1 half-and-half is required.



In marks M_{1-4} the bottom indexes specify in number quadrant in which they are located. To designate them, it is necessary to raise slightly the ocular, to turn it on 45° and to lower, so that the screw-clamp has appeared in nest specially intended for this purpose in the tube case.

Fig. 3. Marks. The numbers in circles - number of quadrants.

Table 1
Spherical coordinates of marks

| Mark s | Spherical coordinates of marks | | Angle of overlap of isogyre with marks |
|-----------|-----------------------------------|-------------|---|
| | ρ | λ | |
| M_0 | 0 | 0 | 0° |
| M_1 | ρ_k | 45° | ω_1 |
| M_5 | $\arcsin(\sin \rho_k / 2)$ | 45° | ω_5 |
| M_x | ρ_k | 0° | ω_x |
| M_{-x} | ρ_k | 180° | ω_{-x} |
| M_y | ρ_k | 90° | ω_y |
| M_{-y} | ρ_k | -90° | ω_{-y} |

Spherical coordinates of marks and a designation of angles of overlap with them isogyres are resulted in the table 1.

Angles of turn of the stage, counted from the standard position, isogyres necessary for overlap with a mark, are designated by the letter with a corresponding bottom index, for example, ω_3 for mark M_3 , ω_{-x} for mark M_{-x}

Angle of overlap of an isogyre with a mark - an angle of turn of the stage, counted from the standard position, necessary for overlap of an isogyre with a mark. Overlap angles are designated by the letter with a corresponding bottom index, for example, ω_3 for mark M_3 , ω_{-x} for mark M_{-x} .

Zero isogyre. Used in a method of intersection the gnomonic equation shows an isogyre as a line of the third order. It is the so-called "zero" isogyre which all points theoretically have zero intensity of light. Actually we it do not see, as the human eye perceives an isogyre in the form of some flat geometrical figure in which there passes a "zero" isogyre. The form and location of zero isogyre depending on coordinates of optical axes can be observed on the screen of the monitor by means of the program of its reproduction (Appendix A, program 3).

Preparing the microscope.

To work with conoscope great importance careful alignment of the microscope. Lowering usual checks and the adjustments which description is given in operation manuals of microscopes, we will stop on two procedures, which determine the accuracy of measurements: adjustment of illumination and centering conoscope.

Illumination adjustment. Clearness of an isogyre depends on illumination adjustment. At correct adjustment of illumination the light source image should be in a thin section plane.

For the lighter of a microscope the most suitable are lamps with a flask from the matte or milky-white glass, giving uniform soft illumination. At their absence before a lamp with a transparent flask it is necessary to put a plate from matte glass.

For illumination adjustment it is necessary:

- a) to establish a thin section on the stage, to include the lighter and with an objective 20^x to focus a microscope on a thin section;
- b) not deleting a thin section, completely to open an aperture diaphragm of a condenser and, lifting and lowering a condenser, and, if necessary, moving a bulb cartridge to achieve the sharp image of a light source (points, scratches on a flask of a bulb);
- c) to establish an objective 60^x and at the included Bertrand and Lazo lenses, whether to check up completely the field of vision is filled by light. If filling incomplete, it is necessary to move the cartridge bulb in either direction and repeat setting.

Centering of conoscope should be made by uniaxial minerals (e.g. quartz). To do this, pick up the grain of the mineral with the inclination of the optical axis of 35-50°. These cross sections have low displacement rate isogyre rotating stage. Angle of rotation stage, which isogyre passes through the entire field of view, must be not less than 60°. To determine the moment of maximum darkness using the exact method of installation on the extinction, which provides accuracy from 0,5 to 1,5°. For this purpose in parallel light from a "darkness" position slightly rotate a stage at first in one direction, then in opposite and fix the beginning of an enlightenment of grain, each time taking off the countdown to the limb's stage. Repeat several times, the mean value of the reference N_0 , sets him on the stage and in the converging light is isogyre, which must match the thread of an ocular cross is not only in the center, but also along its entire length (Fig. 4, a).

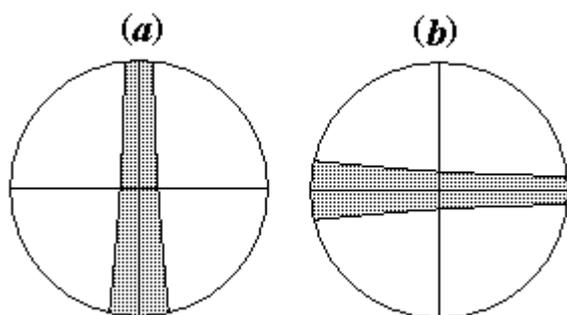


Fig. 4. Symmetric position of an isogyre an uniaxial crystal concerning threads ocular a cross in correctly centered conoscope.

a - isogyre in the position of extinction of the crystal is aligned with the vertical thread eyepiece cross;
b - isogyre aligned with the horizontal thread of ocular cross (after turning the stage on 90°).

At non-observance of this condition, rotating of centering screws on Bertrand lens, combine an isogyre with a thread. Having turned a stage on 90°, check, whether the isogyre coincides with other thread a ocular cross and, if necessary, in the same way make overlap of an isogyre with this thread the ocular cross (Fig. 4, *b*).

Requirements to quality of thin sections. Rough processing of thin sections at their manufacturing - the main reason of a poor quality of interference figures observed in a conoscope. Especially it is fatal for minerals with a high refractive index, curvilinear roughnesses on which surface cause strong light scattering, lighting and lowering contrast of a conoscopic picture. Therefore it is necessary to supervise observance of manufacturing techniques of the thin sections providing gradual transition from rough abrasive powders to more thin. It concerns first of all the bottom party of a thin section which, unlike the top party, is not leveled in the course of operational development till the necessary thickness. It is possible to order special thin sections with bilateral polishing. They give the high-quality image of an isogyre even for low birefringencing minerals.

Determining of the optical angle and the orientation of optical indicatrix

The process of determining the optical angle and the orientation of optical indicatrix in the following order:

1. Search sections of the crystal, suitable for measuring the optic angle.
2. Installation of the selected crystal in the initial (standard) position.
3. The choice of crossing of an isogyre with a mark.
4. Overlap of an isogyre with marks.
5. Calculation of angles of overlap.
6. Check (control) of results of calculation $2V$ and orientation of an optical indicatrix.
7. Drawing of optical axes and elements of symmetry of an optical indicatrix on a stereographic projection.

1. Search of cross sections of a crystal, suitable for optical axial angle measurement.

The method of intersection is suitable for any cross sections of crystals. However strongly oblique cross sections are not desirable because of the big errors of measurement $2V$. It is necessary to give preference to poorly oblique cross sections (one of optical axes is in sight of a conoscope) and to moderately oblique cross sections (one or both optical axes out of sight, but near to its edge). However thus it is necessary to avoid sections in which one or both optical axes are near to edge of a field of view as inside, and behind its limits. In them exact combination of an isogyre with the marks which are on the brink of a field of view that leads to rough errors at angle definition $2V$ is impossible. In such cases it is necessary to use mark M_5 instead of mark M_1 though it can lead to decrease in accuracy of calculations.

Among oblique cross sections it is necessary to select such which give the clear isogyre which is slowly passing through a field of view under rotation of stage. Low speed of movement of isogyre specifies in an arrangement of a near optical axis near to edge of a field of view. For them the narrow top end of an isogyre is characteristic.

2. Installation of the chosen crystal in an initial (standard) position. From four positions of extinction of the crystal (in parallel light) choose that in which the isogyre, crossing the center of the field of view, passes from 1st in 3rd quadrant (Fig. 2, *b*; 5, *a*), and its narrower and less mobile end is in 1st quadrant. At stage rotation clockwise the isogyre should be displaced on an axis X from the centre left to right.

In poorly oblique cross sections in an optical axis in the field of view choose extinction at which the branch of an isogyre which is not leaving a field of view, will cross the ocular cross-hair.

The finishing step - exact installation of a crystal in an initial standard position (on the maximum darkness) - can be executed in two ways: in parallel (see above *centering of conoscope*) and converging light. The first way gives good results for cross sections with high interference colour and the extent of its reduction setting accuracy is reduced. In isotropic cross sections (cuts perpendicular an optical axis) this way is not applicable.

The second way consists in serial and numerous overlap with the eyepiece crosshair and removal of readout for limb of stage at first for one edge of an isogyre, then for another (*the bilateral way* described more low). Average readout N_0 count as arithmetic-mean value of many readout. This way gives good results in cross sections with low interference colors, including and isotropic cuts. Conversely, cross sections with high interference colors yield less exact result, since they exhibit a broad vague isogyre.

The following step – a choice of marks: on an axis X (marks M_x and M_{-x}) or on axis Y (marks M_y and M_{-y}). Preference should be given marks M_x and M_{-x} , if isogyre in the center of the visual field makes with the horizontal thread eyepiece of cross (axis X) greater angle than with a vertical thread (axis Y). When it is visually difficult to estimate a parity of these angles, it is necessary to define angles of the "run" on these axes, i.e. to measure an angle of turn of the stage, necessary for passage by an isogyre of a field of view in horizontal and vertical directions. If the angle of "run" on an axis X appears smaller, than on axis Y , it is necessary to make definition of angles of displacement on marks on axis Y .

Mark M_5 is used in sections of crystals, in which one or both optical axes are in the field of view. In them the isogyre at rotation of a stage does not cross diagonal marks M_1 or, reaching a mark only one party, begins movement in the opposite direction.

3. The choice of crossing of an isogyre with a mark. At stage turn on 360° the isogyre depending on location of optical axes crosses the same mark 0, 2, 4 times (see table 2) and to each such crossing there corresponds the angle of overlap ω . In this connection the **question**

arises: what angle of overlap should be used in calculations? **The answer:** all angles of overlap equal in rights also any of them can be used for input in the computer. However for axial marks there is a restriction - absolute value of a difference of angles of overlap on opposite alignment marks should not be close to 180° , i.e. $|\omega_x - \omega_{-x}| \approx 180^\circ$, $|\omega_y - \omega_{-y}| \approx 180^\circ$. Such values of angles of overlap are conflicted and at their input in the computer the program will warn about inadmissibility of their use in calculations

At 4-fold cross isogyre with 3 marks the total number of angles combination is 12, from which it is possible to create 48 combinations of 3 angles. However, not all of them can give a good result, since among them there are the angles defined with low accuracy. To avoid confusion among these numerous combinations, we can recommend the following rule: of the 4 (or 2) the angles of overlap with the same mark for calculations to take only *the nearest* angles, i.e. such angles, which demand the minimum turn of a stage from an initial position.

Table 2

The dependence of the number of crossings isogyre marks when you turn the stage by 360° from the location of the optical axes

| The location of the optical axes | Number of intersections of an with marks by turning the stage on 360° | |
|---|--|--------------------------------|
| | diagonal marks M_{1-4} | axial marks $M_{x,y,-x,-y}$ |
| 1. Optical axes A_1 and A_2 in the field of view, $\rho_1 < \rho_k$; $\rho_2 < \rho_k$ a) A_1 near the center of the field of view. b) A_1 midway between center and edge of the field of view. c) A_1 and A_2 near the edge of the field of view. | 0 0 0, 2, 4 | 2 2, 4 2, 4 |
| 2. Optical axis A_1 in the field of view, A_2 out of the field of view, $\rho_1 < \rho_k$; $\rho_2 > \rho_k$ | 2, 4 | 2, 4 |
| 3. Optical axis out of the view, $\rho_1 > \rho_k$; $\rho_2 > \rho_k$ | 4 | 4 |

4. Overlap of isogyre with marks. Very good results are given by a *bilateral way* of definition of an angle of overlap of an isogyre with a mark. It consists in readout removal on limb of stage in two positions: at the isogyre approach to a mark when it concerns with its outer side, and at isogyre leaving when on a mark there is its inside (Fig. 5).

For the further calculations it is necessary to take an average from two readout. This way is suitable even for very wide isogyres and, that is especially important, at its use there is an overlap of a zero isogyre with a mark with the minimum errors.

Chosen visually mark M_5 is used instead of mark M_1 for cross sections with two axes in sight in which the isogyre is not combined with diagonal marks at any angle of turn of stage, and also in

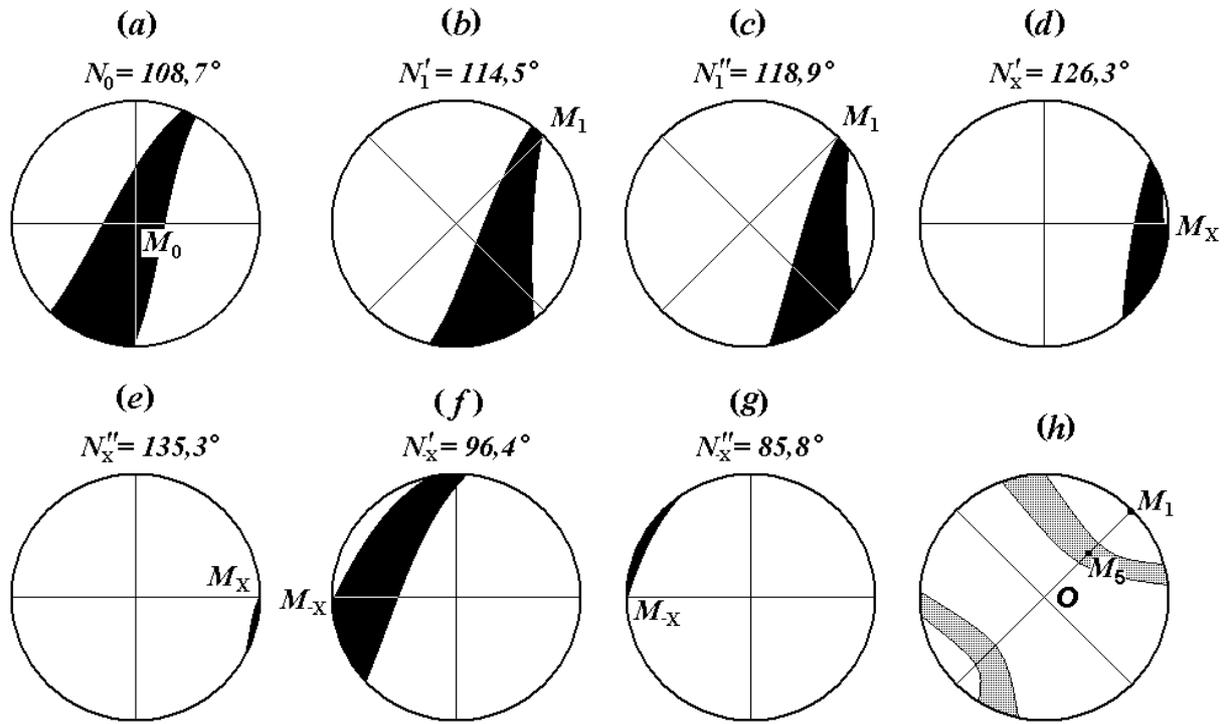


Fig. 5. Bilateral way of measurement of overlap angles the isogyre with marks: *a* – initial position; *b, c* – overlap with mark M_1 ; *d, e* – with mark M_x ; *e, f* – with mark M_x . *h* – overlap of isogyre with mark M_5 .

all other cases when overlap of isogyre with mark M_1 is not reliable (it often happens, when one of optical axes is located near to edge of a field of view).

For mark M_5 the bilateral way is difficult. To combine an isogyre with this mark, it is necessary to deduce an average point of isogyre on the middle of distance from the centre to mark M_1 . If isogyre wide, it is necessary to stay on a position at which distances from edges of an isogyre to the centre and mark M_1 will be identical.

5. Definition of angles of overlap. Readout for all marks is made repeatedly, to within 0.1° (on vernier), before reception of steady average value of readout N_1 , N_x and N_{-x} for each mark. Overlap angles are defined under formulas:

$$\omega_1 = N_1 - N_0; \omega_x = N_x - N_0; \omega_{-x} = N_{-x} - N_0; \omega_y = N_y - N_0; \omega_{-y} = N_{-y} - N_0,$$

where N_0 - average value of readout in an initial (standard) position.

For results of the measurements shown in drawing 5, average values of readout on limb microscope stage of a microscope for marks M_1 , M_x and M_{-x} the following ($^\circ$):

$$N_1 = (N_1' + N_1'') / 2 = (114.5 + 118.9) / 2 = 116.7;$$

$$N_x = (N_x' + N_x'') / 2 = (126.3 + 135.3) / 2 = 130.8;$$

$$N_{-x} = (N_{-x}' + N_{-x}'') / 2 = (96.4 + 85.8) / 2 = 91.1.$$

We count angles overlap of isogyre with marks:

$$\omega_1 = N_1 - N_0 = 116.7 - 108.7 = 8,0;$$

$$\omega_x = N_x - N_0 = 130.8 - 108.7 = 22,1;$$

$$\omega_{-x} = N_{-x} - N_0 = 91.1 - 108.7 = -17,6.$$

These angles of overlapping, and also the objective aperture 60^\times , equal 0.85, and an refractive index of a crystal $n = 1.7$, are entered into the computer program of calculation $2V$ and elements of orientation of an optical indicatrix. Following results for calculation are received ($^\circ$):

- 1) angular radius of a field of view of conoscope: $\rho_k = 30$;
- 2) spherical coordinates of optical axes A_1 and A_2 : $\rho_1 = 44.5$, $\lambda_1 = 53.9$, $\rho_2 = 67.4$, $\lambda_2 = 126.1$;

- 3) angle $2V$ and spherical coordinates of axial plane: $2V = 61.8$, $\rho_p = 44.3$, $\lambda_p = 60.1$;
 4) spherical coordinates acute (B_1) and obtuse (B_2) bisectrices: $\rho_{B1} = 50.2$, $\lambda_{B1} = 95.7$, $\rho_{B2} = 71.3$, $\lambda_{B2} = -10.6$.

6. Checking (control) of results of calculation $2V$ and orientation of an optical indicatrix.

Culling of clearly erroneous results. Gross errors in definitions $2V$ and orientations of an optical indicatrix become visible at comparison of isogyre really observed in a conoscope and its computer reproduction on the screen executed under the program 2 (Appendix A). At detection of appreciable differences in the form of an isogyre and its behaviour at rotation of a stage it is necessary to consider results of calculations doubtful.

If the calculated polar angle ρ_1 near optical axes more than angular radius ρ_k of field of view ($\rho_1 > \rho_k$), and in a conoscope one of isogyre branches constantly is in sight, or, on the contrary, a parity ρ_1 and ρ_k the return ($\rho_1 < \rho_k$), and both branches of an isogyre at stage rotation leave a field of view such results are ignored as obviously erroneous.

Subject to culling results indicating the presence of the cross interference figure in the field of view in his absence and, conversely, its absence in the actual presence. Verify the presence or absence of the cross can program 2 and 3 playback isogyre (Appendix A), that should be given an estimate of the coordinates of the optical axes and empirically find the angle of rotation stage, which yields a cross.

Not credible results if the computer reports the non-standard position, and the executor is assured, that it standard. Usually such a situation occurs when you enter the program 1 (Appendix A) conflict the angles of overlap of isogyre with axial marks.

Detailed control of results of the calculations is possible, if in the field of view conoscope visible cross. It is necessary to measure the angle of turn of the stage, which yields a cross and then on the this angle and the spherical coordinates of the optical axes and reproduce the zero isogyre (Program 3, Appendix A). One additional angle of rotation of the stage that will be required to obtain a cross on your screen, characterizes the accuracy of the calculations. This angle should not exceed a few degrees.

As mentioned above, on the same mark can be 2 or 4 angle overlap. Of these, one can choose different combinations and use them to control the calculations of the angle $2V$ and the orientation of the optical indicatrix. Comparing new data with previous ones, we may conclude that the accuracy of the work done.

Measurement errors $2V$ on a method of resection. Accuracy of definition of an optical axial angle a method of intersection has been checked up by control measurements on Fedorow's stage. It was thus found out, that method errors depend, basically, from clearness of an isogyre. If isogyre contours distinct, the error of the determination of $2V$ does not exceed $2-3^\circ$. At indistinct contours they increase to $5-6^\circ$.

7. Drawing of optical axes and elements of symmetry of an optical indicatrix on a stereographic projection.

Results of calculation of spherical coordinates of optical axes and elements of symmetry of an optical indicatrix can be taken out on a stereographic projection. Though all spherical coordinates are calculated in polar system coordinates, for this purpose it is possible to use Woolf's equatorial stereographic net.

Figure 6 shows the construction of the stereographic projection of the optical axes and the symmetry elements of the optical indicatrix of the data presented above. Preliminary negative longitudes it is translated in positive, having added to their value 360° . We impose on Woolf's

net a tracing-paper, combine a zero index on a tracing-paper with division of the big circle of the net, corresponding to a longitude of optical axis A_1 (Fig. 6, *a*). On zero meridian we mark a point

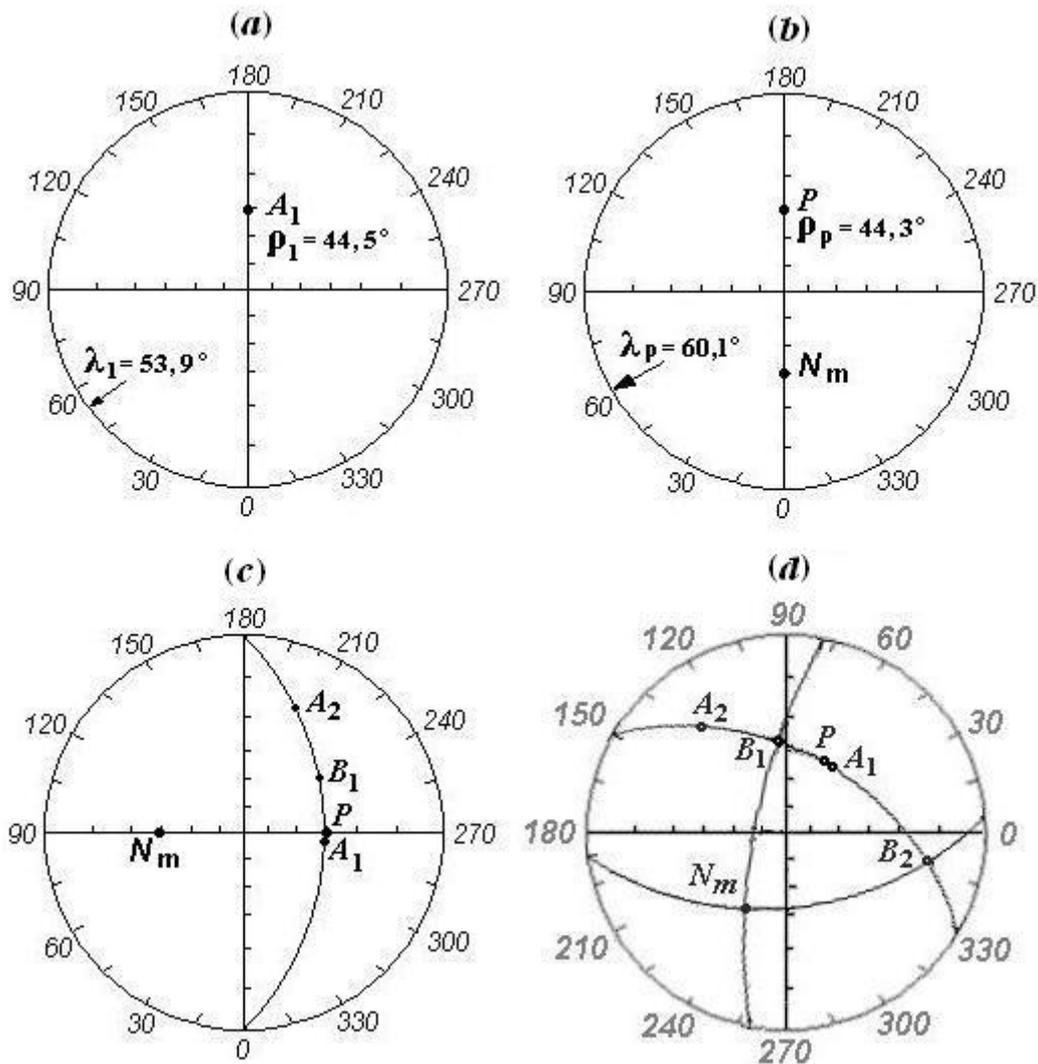


Fig. 6. Construction of a stereographic projection of optical axes and the symmetry elements of an optical indicatrix. *a* – drawing on a tracing-paper of optical axis A_1 ; *b* – drawing of axial plane P and its poles N_m ; *c* – construction of a axial plane; *d* – a stereographic projection of optical axes and symmetry elements of an optical indicatrix. A_1 and A_2 – optical axes; P – a point defining an angle of an inclination of axial plane; N_m – an axis of an optical indicatrix (the same pole of axial plane); B_1 and B_2 – acute and obtuse bisectrix of optical axes.

locked from the centre upwards on size of a polar angle of an optical axis ρ_1 . Likewise, apply a tracing of the second optical axis A_2 , acute (B_1) and obtuse (B_2) bisectrices and the axial plane (P). In the latter case you should keep in mind that the point P is located in the axial plane. To get the pole of this plane (with the same axis of optical indicatrix N_m), must at the same longitude mark a point on the zero meridian below the center corresponding to angle $90^\circ - \rho_p$ (Fig. 6, *b*).

Further, we combine points N_m and P with equator of net and on a meridian corresponding to a polar angle ρ_p , we draw the axial plane. In the same way, having combined with equator acute (B_1) and obtuse (B_2) bisectrices, we draw other two main sections of an optical indicatrix - B_1N_m and B_2N_m . As a result of drawing the stereographic projection of all elements of an optical indicatrix (Fig. 6, *d*) is received.

Research of cristal twins. In a conoscope it is impossible to measure an angle of an inclination of a plane of accretion twin individuals. Therefore it is necessary to search twins with a thin seam in which the accretion plane is perpendicular to a thin section surface. On a tracing-paper take out optical axes and elements of symmetry of an optical indicatrix of two twin strips, define position of a plane of accretion and a relative positioning of optical indicatrix on the basis of what the conclusion about the twinning law becomes.

Appendix A

Step by step instructions to conoscopic programs

The website contains 4 programs in different versions of the interface in Russian and English languages. They are written in Qbasic 4.5 and compiled into an executable EXE-files.

1. Measurement of optical axial angle and orientation of optical indicatrix on method of intersection.

1.1. With using the mark M_1

Ms2VM1En.exe

1.2. With using mark M_5

Ms2VM5En.exe

2. Computer synthesis of isogyre on the screen

IsogyrEn.exe

3. Computer synthesis of zero isogyre on the screen

ZeroIsEn.exe

Number of characters in the name of compiled files Qbasic 4.5 shall not be greater than 8. When naming files, the following abbreviations are accepted:

Ms – Measurement

2V – optical axial angle;

M1, M5 – using marks;

Isogyr – isogyre;

ZeroIs – zero isogyre;

En – English language of the interface.

In the programs written in language Qbasic, it is impossible to display the Greek letters. Therefore they are replaced by Latin letters, as shown lower:

| | | | |
|---------------|--------|-----------|----------|
| Greek letters | ρ | λ | ω |
| Latin letters | R | L | W |

Run of programs is possible under Windows XP, x86. Program compatibility of with other operational systems was not tested, but there are bases to believe, that they are functional under all earlier versions Windows. Before start of programs with a text screen mode it is necessary to establish the screen permission 800x600.

Screen mode (text or graphics) is automatically installed after you run the program. Adjourn the programs can be a combination of keys Ctrl + C and then press any key.

1. Measurement of optical axial angle and orientation of optical indicatrix of crystals on a method of intersection with use of marks M_1 (file Ms2VM1En.exe) and M_5 (file Ms2VM5En.exe).

Click the link and select "Run". In a window there will be inquiries about input of initial data.

1) Input the numerical aperture of objective (0.85 for 60x, 0.65 for 40x).

It is necessary to enter the value of the aperture engraved on lens mount.

2) Input the index of refraction of mineral $N=(N_g+N_m+N_p)/3$.

If the mineral is diagnosed, its refractive index can be taken from handbooks. For an unknown mineral it is necessary to define group and to enter average for group a refraction index (see Appendix B).

3) Select marks: on axis X - (0), on axis Y - (1).

The preference should be marks M_x and M_{-x} on axes X, if isogyre in the center of the visual field makes with the horizontal thread of ocular cross (axis X) greater angle than with a vertical filament (axis Y). When it is visually difficult to estimate a parity of these angles, it is necessary to define "run" angles on these axes, i.e. to measure an angle of turn of stage, necessary for passage by an isogyre of a field of view in horizontal and vertical directions. If the "run" angle on axis X appears smaller, than on axis Y, it is necessary to make definition of angles of displacement on marks on axis Y (marks M_y and M_{-y}).

4) Enter angles of overlap of isogyre with marks:

W1 (mark M1) or W5 (mark M5);

Wx (mark Mx) or Wy (mark My), if selected marks on axis Y;

W-x (mark M-x) or W-y (mark M-y), if selected marks on axis Y.

It is required to enter the average values of angles of turn of stage, isogyres necessary for overlap with specified marks.

If the axis with marks is chosen unsuccessfully, the computer will warn about it the message (example):

5) An angle between isogyre and axis X: 25.2

It is necessary to use marks on other axis of coordinates

You agree? (0 - No, 1 - Yes).

The angle between an isogyre and axis X has appeared less than a similar angle with axis Y. Here it is necessary to make a choice: to continue calculation or to pass to definition of angles of overlap with marks on axes Y.

6) There is a fear, that you have entered conflicting values Wy and W-y.

To enter new values Wy and W-y (0), to continue calculation (1).

Here we must make a choice: to enter other values ω_y and ω_{-y} (ω_y and ω_{-y}) or ignore the warning and continue the calculation.

At this initial data input is finished.

If at crystal installation the wrong initial position is chosen, the computer stops calculations, informs the reason and gives advice such as:

7) A non-standard position.

Optical axis A1 in 2nd quadrant.

Turn a stage on 90 degrees clockwise.

It is necessary to turn the stage on 90° clockwise and to define new angles overlap.

Next, the program gives results of calculation:

- a) angular radius of a field of view of conoscope R_k ;
- b) spherical coordinates of optical axes: R_1 and R_2 – polar angles, L_1 and L_2 – longitudes;
- c) angle $2V$ and spherical coordinates of optical axial plane (P) : R_p - a polar angle (angle of inclination of plane P concerning an optical axis of a microscope), L_p - longitude (i.e. azimuthal direction of inclination);

d) spherical coordinates acute (B1) and obtuse (B2) bisectrices of optical axes: polar angles RB1, RB2 and longitudes LB1, LB2.

At the end of the calculations the program offers a choice:

Continue (1), Exit (0)

Continue - to continue job (to enter new value of an index of refraction of a mineral and angles of overlap of an isogyre with marks;

Exit - exit the program.

2. Computer Synthesis of isogyre on the screen

(file IsogyrEn.exe)

Click the link and select "Run". In the window asks for the original data.

1) Input radius of conoscopic field of view (screen points).

Recommended values from 100 to 220. This indicator defines the size of the image on the screen. If you wish to see a map of the optical axes that are far beyond the field of view, it should reduce its size.

2) Input angular radius of a field of view conoscope, degree.

It is possible to take value of radius of a field of view of conoscope R_k from results of calculation of this indicator under the previous program. In it there can be a necessity if you intend to compare conformity of isogyre really observed in a conoscope to its display on the screen, constructed by results of calculation of spherical coordinates of optical axes and by that to estimate reliability of these calculations. In other cases at a choice of value R_k it is necessary to be guided on following data about dependence R_k on the refractive index a crystal n (60x lens):

| | | | | | | | | | | | |
|-------|-------|------|-------|------|-----|------|-----|------|-------|-------|-----|
| n | 1,4 | 1,45 | 1,5 | 1,55 | 1,6 | 1,65 | 1,7 | 1,75 | 1,8 | 1,85 | 1,9 |
| R_k | 37,5° | 36° | 34,5° | 33° | 32° | 31° | 30° | 29° | 27,5° | 26,5° | 26° |

And, at last, if you are curious and wish to see an isogyre outside of the visual field, set great values R_k , up to 90°.

3) Input boundary value light intensity (BI) of isogyre.

Estimated relative light intensity in the field of view conoscope ranges from 0 to 1. Apparently from the name, boundary intensity of light defines a contour of the image of an isogyre on the monitor. With intensity of light of the smaller set size the computer carries all points to an isogyre. Usually I enter size of intensity from 0.05 to 0.1. But if isogyre really observed in a conoscope is wider or already reproduced on the screen, you can increase or reduce size of boundary intensity accordingly.

4) Input spherical coordinates of optical axes A1(R1,L1) and A2(R2,L2)

(R – polar angle, L – longitude)

By this inquiry it is necessary to enter consistently spherical coordinates of optical axes R_1 , L_1 , R_2 , L_2 , taken of results of their calculation under the previous program, or to set at own discretion any other coordinates.

5) Input rotation angle (W) of stage

W = 999 – New R_1 , L_1 , R_2 , L_2 ; W = -999 – Exit

You can enter any angle of rotation of the stage from -360 to 360°, to see how the change in the shape and position isogyre in sight conoscope. On this step there is a possibility to change a direction of job of the program: to enter number "999" for input of new coordinates of optical axes or «-999» for an exit from the program. If an angle of turn not to enter and at once to press Enter the angle of turn of a stage will be equal 0°.

At this data entry is over. On the screen image is obtained the field of view conoscope (circle, gray background), the cross threads ocular graduations at 5° , isogyre (black), the optical axes (small light circles) and the marks M_{1-4} , designated by with small red rectangles.

Computer reproduction of an isogyre can useful in following cases:

- For comparison of an isogyre observed in a conoscope with its computer model constructed on coordinates of optical axes calculated on intersection method, for the purpose of an estimation of reliability of results of calculations.
- For the description of the form of an isogyre and its behaviour at rotation of a stage at various coordinates of optical axes (i.e. in various cross sections of an optical indicatrix).
- In experiments on perfection of a conoscopic method of research of crystals. For example, it is possible to check up, errors of measurement of angles of overlap of an isogyre with marks in the bilateral way, to develop a way of definition $2V$ using cross interference figure, etc.

2. Computer Synthesis of zero isogyre on the screen

(file ZeroIsEn.exe)

This program introduced by the spherical coordinates of the optical axes calculates the coordinates of points with zero light intensity and reproduces for them zero isogyre as a line on the screen.

The order of data input is the same as in the previous program. There is only one exception - point 3 «**Input boundary value light intensity (BI) of isogyre**» is passed.

Basic purpose of this program - demonstration of the form and position of an isogyre in field of view and its behaviour at stage rotation as the line which are a "true" isogyre which we is real in a conoscope we do not see, but we can reproduce on the screen. Changing an angle of turn of a stage, it is possible way «fitting» to achieve crossing of a zero isogyre with marks and thus with high accuracy to define angles of overlap of an isogyre with marks. If the cross interference figure on the screen it is possible to fix an angle of turn of stage at which the cross is formed is in sight visible, to compare it to the similar angle defined in a conoscope and to draw conclusions on accuracy of calculations under the program 1.

Classification of colourless minerals by an index of refraction (V. N. Lodochnikov, 1936)

| № groups | Index of refraction, <i>n</i> | Average value, <i>n</i> | Optical properties of minerals | Typical minerals |
|----------|-------------------------------|-------------------------|---|--|
| 1 | 1,41 – 1,47 | 1,44 | Clear the return a relief and shagreen surfaces. Sharp restrictions. Distinct dispersive effect - golden-yellow colouring on joints with other minerals | Opal, fluorite, tridymite |
| 2 | 1,47 – 1,53 | 1,5 | Relief and restrictions are appreciable, but weaker, than in 1st group. The shagreen surface is not clear or is absent. Clear dispersive effect on borders with balm - minerals get a golden-yellow shade | Zeolites, potassium feldspar, cancrinite |
| 3 | 1,535 – 1,545 | 1,54 | Restrictions and a relief are imperceptible. The dispersive effect and Becke line are caught hardly or in general are imperceptible | Chalcedony, acid plagioclase, nepheline |
| 4 | 1,55 – 1,60 | 1,575 | Restrictions and a relief are poorly appreciable. Index of refraction - on Becke line - is clear more than at balm. The clear dispersive effect on a joint with balm - a mineral gets a greenish-blue shade | Quartz, plagioclase № 15-100, muscovite |
| 5 | 1,61 – 1,66 | 1,635 | Distinct restrictions and relief. A clear shagreen surface. The dispersive effect and Becke line are easily caught | Apatite, andalusite, tremolite |
| 6 | 1,66 – 1,78 | 1,72 | Sharp restrictions and relief. Distinct a shagreen surface, Becke line and dispersive effect. | Carbonates, olivine, rhombic pyroxene |
| 7 | >1,78 | | Very sharp a relief, restrictions and a shagreen surface | Garnets, zircon, sphene |