Theoretical Background

During the introductory lecture you will get acquainted with electronic sources of information, which you will further be using for independent study to prepare for individual tasks. In the following paragraph you will find certain theoretical modifications and descriptions of methods and devices, which are not included in the basic biophysical practicum or the following textbooks:

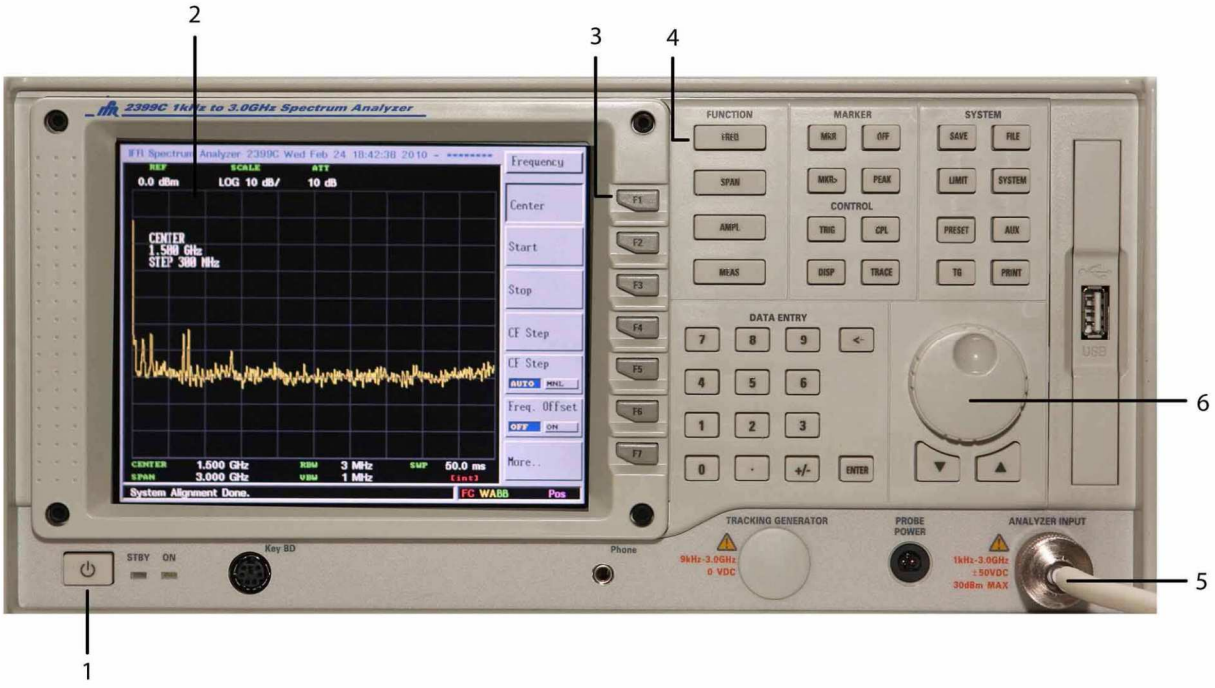
HRAZDIRA, Ivo, Vojtech MORNSTEIN, Aleš BOUREK and Jiřina ŠKORPÍKOVÁ. *Fundamentals of Biophysics and Medical Technology*. 1st edition 1st reprint. Brno: Muni Press, 2009. 317 p. ISBN 978-80-210-4228-5.

HRAZDIRA, Ivo and Vojtěch MORNSTEIN. *Medical Biophysics and Instrumentation*. 1st edition. Brno: Neptun, 2001. 395p. ISBN 80-902896-1-4.

A lot of information is available on the web pages of the Institute of Biophysical, Faculty of Medicine, MU under basic lectures.

Spectrum Analyzer

On principle a spectrum analyzer is a very sensitive, widely tunable receiver with a configurable bandwidth. This device enables measurement of frequency spectrum in the range from 1.0 kHz to 3.0 GHz. Description of spectrum analyzer controls can be found in the picture bellow.



1. STB/ON – power supply switch
2. LCD – displays the time course of signal, setting of parameters, and a menu of “soft” keys.

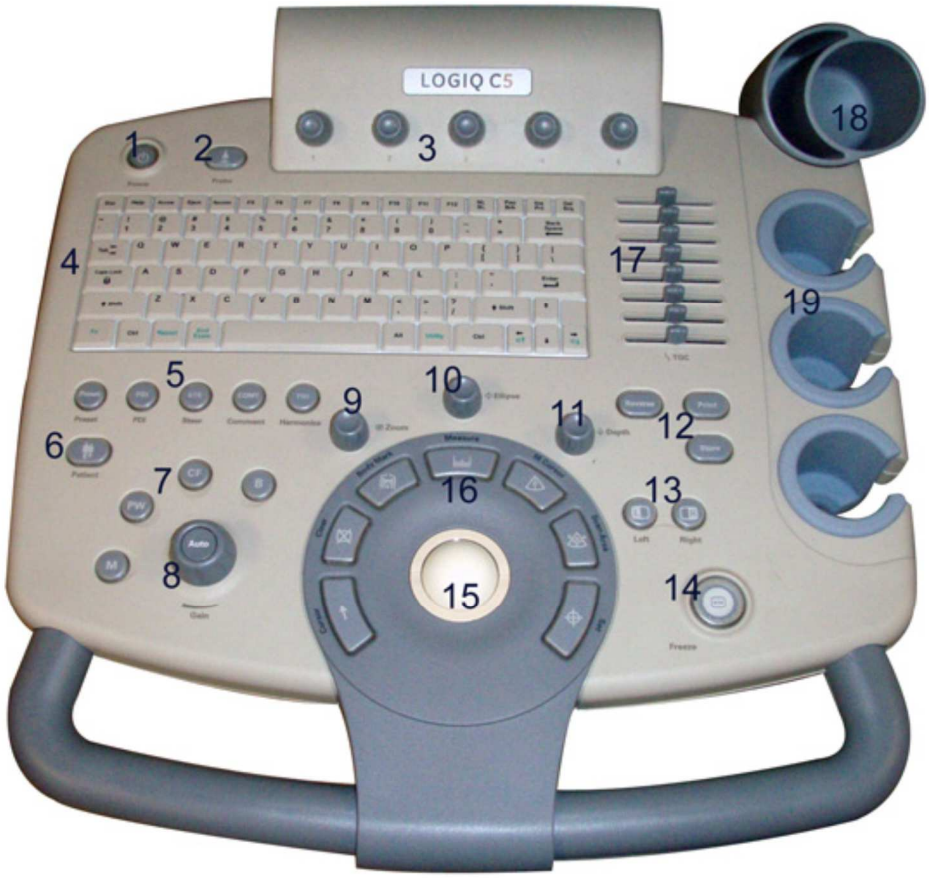
.

3. F1–F7 – Soft keys for selection from the corresponding menu, connected to the control of functions from the menu.
4. FUNCTION
   - FREQ – parameter or frequency, controls the setting of frequency values Center (middle), Start (beginning) and Stop (end) to display the course of signal. Center Freq. Step – describes how to set center frequency.
   - SPAN – parameter of span, controls the setting of span values (size of the frequency span controls display of the course of signal across the whole screen). Full Span – full frequency span. Zoom In/Zoom Out – change of frequency span from the current value to half of this value.
   - AMPL – parameter of amplitude, controls the setting of amplitude of the displayed signal.. Ref. Level – sets the reference level. Unit – amplitude units (dBm, dBmV, dBuV, V OLTS, WATTS, dBuV/m), for our measurement it is suitable to leave the unit of dBm.
   - MEAS – setting of measurement functions. X dB Down – bandwidth, Adjacent CH Power – power in the adjacent channels, Channel Power – power in the channel, Occupied BandWidth, Harmonic Distortion, Clear Measurement.
5. MARKER – activation of markers and their function setting.
   - MKR – marker activation and opening of marker menu.
   - OFF – turns of all active markers.
   - Mkr – setting of parameter using marker value.
   - PEAK – searches for the course peak using a marker. Peak – searches for the highest peak of the signal, Next Peak – searches for the next peak of the signal, NPeak Left/Right – searches for the course peak on the left/right.
6. Navigation rotation button for shifting in the list of parameters, markers, and value changes of parameter.
7. RF INPUT – device input.

DIAGNOSTIC ULTRASOUND

Ultrasonic diagnostic device LOGIQ C5 belongs to the upper middle class due to its properties and software equipment. It supports all basic imaging and Doppler examinations including both anatomical and Doppler measurements. It also has active software for 3D imaging using freehand scanning.

Device Control Panel



Description of individual elements of the control panel:

1. Main switch - Power On/Off

2. Probe selection

3. Main menu controls

4. Keyboard: use the keyboard to fill in patient information and description of images. F1 – F12 are function keys:: use F1, F2, F3, F4 and F5 to activate online operation instructions help, arrows, release, and activate Sub Menu. A user can define functions F6-F12. The following are available for F6-F12: worksheets, 3D, Logiq View, ECG on / off, Set Home, view previous, delete Word and cover text. [Utility] key serves to enter utility function and system configuration. Press [Report] to enter a working chart. Press [End exam] to end an examination.

5. Preset, PDI, routing, harmonic imaging

6. Patient key

7. Mode keys: B-Mode, M-Mode, PW-Mode (pulse doppler), PDI, CFMode (color coding)

8. Gain/Auto key: turn the key to set gain/amplification, press the key for de/activation of automatic optimization

9. **Zoom key**: increases the image's region of interest (ROI).

10. Ellipse key: activates measuring function of an area

11. Depth key: controls measurement of distance

12. Reverse, Print, Store keys: **Reverse key** turn the image by 180 degrees to the left / right. Use **Print key** to archive, print, or send an image. Use **Store key** to save images to the hard drive (factory setting)

13. **Left**, **Right key**: activation of the left or right image

14. **Freeze key**: freezes the image or returns to scanning

15. **Trackball**

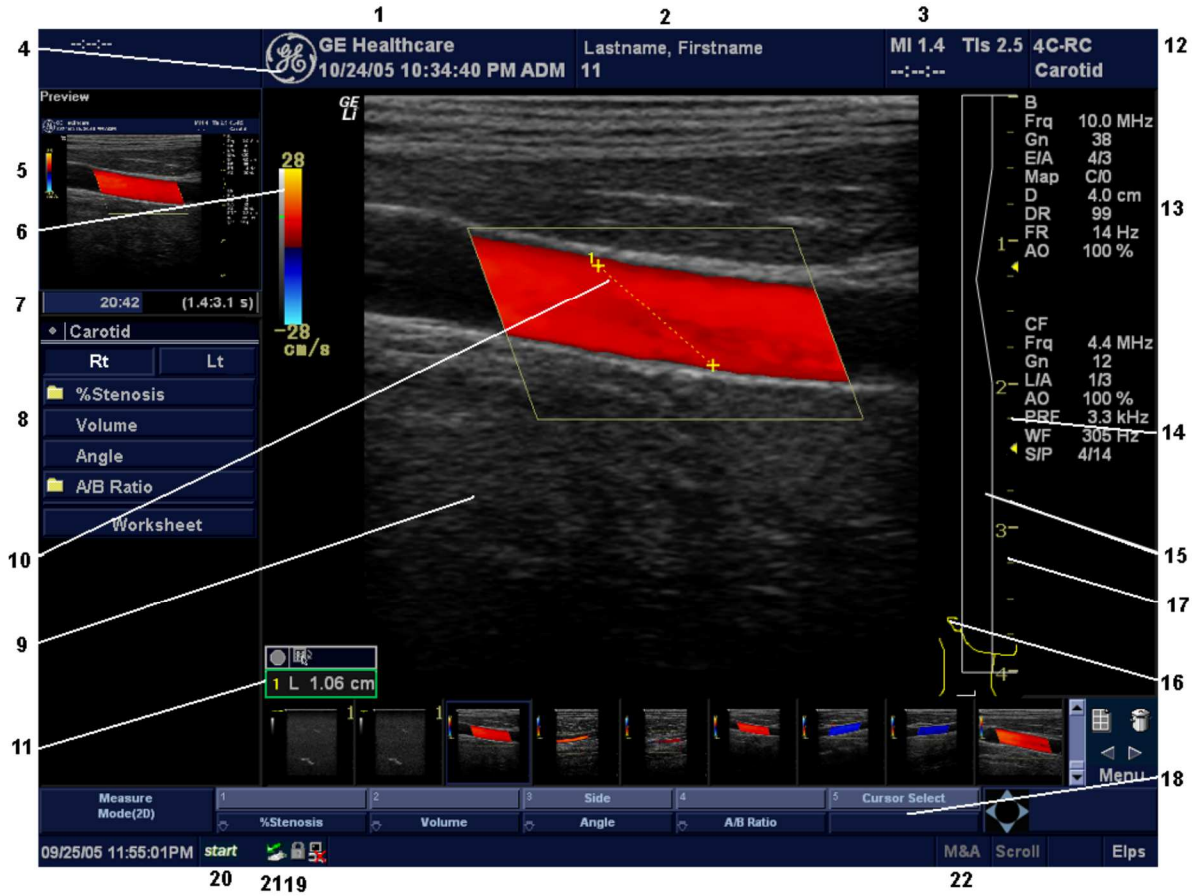
16. Imaging/Measurement keys

17. TGC (Time Gain Compensation): compensation of depth gain

18. Gel holder

19. Probe holder

Monitor Display



1. Institution/Hospital Name, Date, Time, Operator Identification, system status (real-time or frozen).

2. Patient Name, Identification.

3. Output – mechanic and thermal index .

4. GE Symbol: Probe Orientation Marker.

5. Image Preview.

6. Grey/Color Bar.

7. Cine Gauge.

8. Measurement Summary Window.

9. Image.

10. Measurement – Caliper.

11. Measurement Results Window.

12. Probe Identifier. Exam Study.

13. Imaging Parameters by Mode – current mode highlighted.

14. Focal Zone Indicator.

15. TGC.

16. Body Pattern.

17. Depth Scale.

18. SoftMenu – Main Menu, SubMenu.

19. Caps Lock: On/Off.

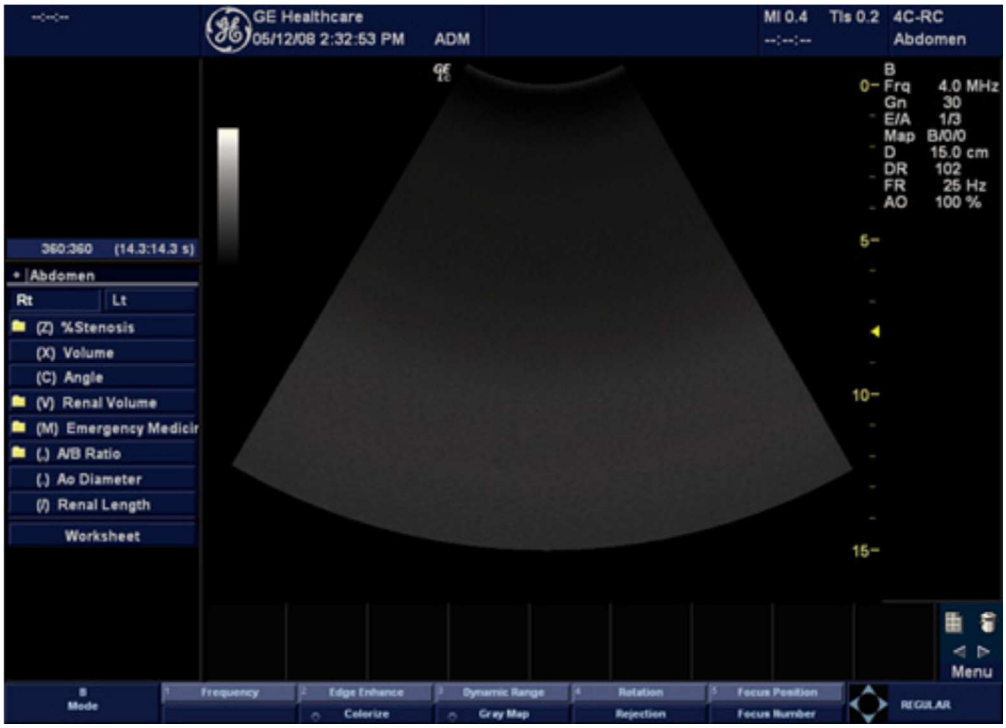
20. Start Menu Icon.

21. Card Icon.

22. Trackball Functional Status.

Optimization of B-image

B-image is designed for two-dimensional imaging and measurement of anatomical structures of soft tissues.



It is necessary to perform the following tasks to obtain typical B-imaging:

1. Mark patient data and check system settings (probes and preset/exam study).

2. Put the patient and system into an optimal position and perform the examination.

3. End examination and gather all necessary data.

Recommended Procedures for B – Imaging:

Harmonics – tissue harmonic oscillations: improves resolution in the close and middle fields, improves contract and reduces noise.

Frequency – changes system parameters to optimize a particular type of patient.

Gray Map – influences B-image information. It is necessary to select a suitable gray map prior to the examination. There is a mutual relationship between the gray map, gain and dynamic range. When gray map is changed, it is necessary to reset both gain and dynamic range.

Dynamic Range – influences the amount of displayed information in shades of gray. If you increase gain, you will need to decrease dynamic range.

Edge Enhance – influences contour sharpness

Average: averages frames together and as a results presents a smoother, softer image.

B – Softener –influences the degree of lateral smoothing.

TGC: sets depth gain.

Focus – Number / Position: the greatest sharpness of image is in the focal zone. Set the focal zones based on the area of interest so that they are in the middle of the anatomical structure to be scanned. Press the control to toggle between Focus Number and Focus Position. Press Up/Down Button to adjust the focal numbers.

Scan Area – adjust the scan area to the smallest size and thus maximize the image frequency.

Range Focus – improves the image quality in the close and middle field. Increases contrast and detail resolution.

Creating and Processing a 3D Image (Easy 3D)

Methods of Creating a 3D Image

Volume image can be created two ways:

SENSORLESS PARALLEL: When using this method, the probe must be shifted using movement in the same direction without tilting. Scanning time must fall within 2-4 seconds. Post-processing time depends on image frequency. Generally, there is long post-processing time when image frequency is low.

SENSORLESS SWEEP: When using this method, the probe must be positioned over the center of the scanned object. Then the probe is tilted at an angle of about 30 degrees until the scanned object disappears. At this moment, scanning under the total angle of 60 degrees is initiated and continues until the scanned object disappears again. Scanning time is the same as for the previous method: 2-4 seconds. Using this method, the probe must not be moved in a parallel way.

Selection of Scanning Plane

FRONT TO BACK: When using this method, the examined object is displayed from a frontal view.

SIDE TO SIDE: The examined object is displayed from a coronary view.

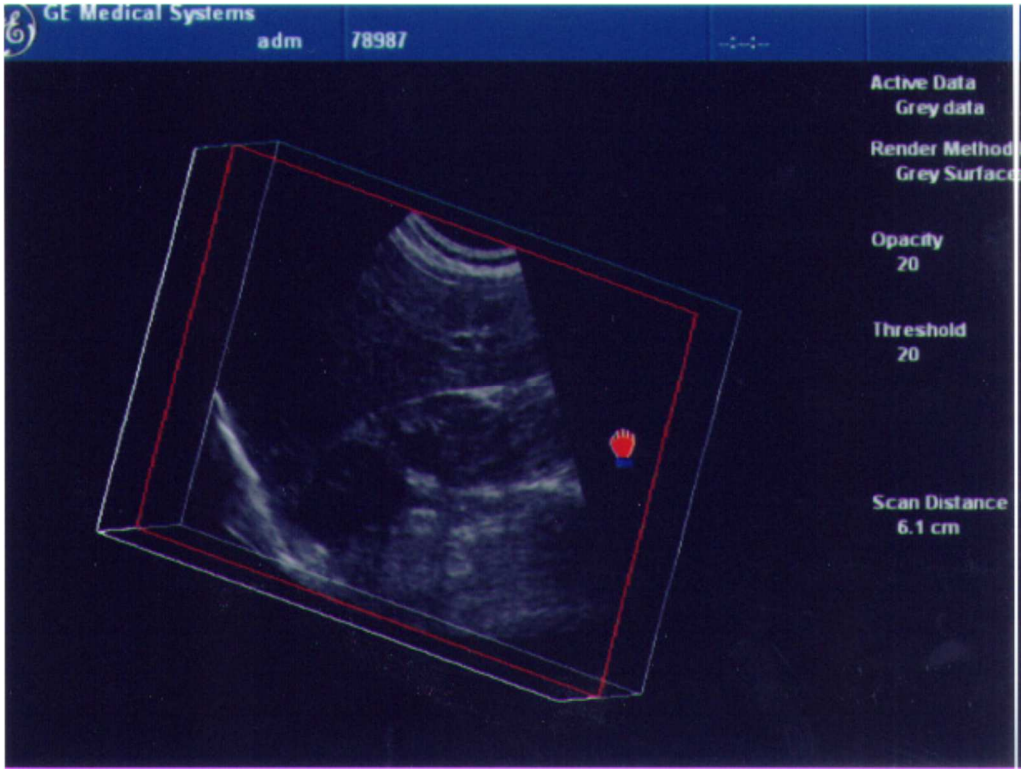
Processing Volume of Interest (VOI)

Displayed volume can be manipulated with using the ball-tracker and the SET key.

Move the cursor to various places of the volume image. Select color (white, red, yellow, or green). Press SET and process VOI using the displayed hand.

3D VOI – the image can be rotated to the right or left, front or back. Press the right key when the white hand is placed on the white box. By moving the white hand, you can manipulate the image.

S VOI – it is possible to move the red hand. Press the SET key when the red hand is placed on the red box.



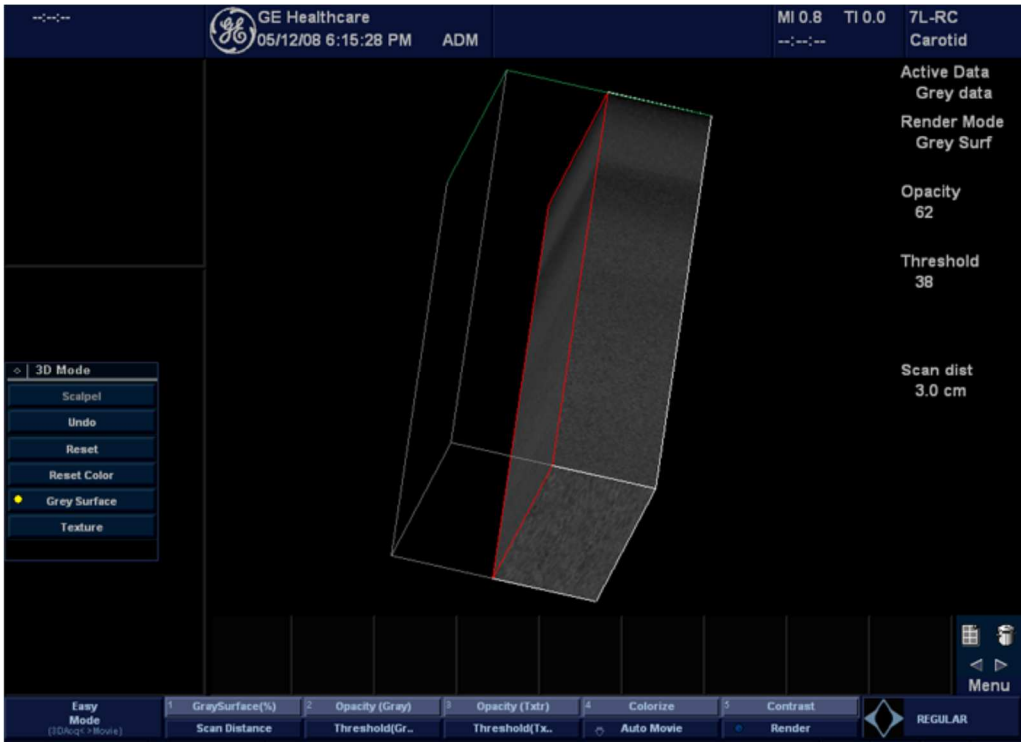
It is also possible to make specific anatomical structures visible. Using the yellow hand, it possible to remove selected structures. Press SET when the yellow hand is on the yellow box.

Using the green hand, it is possible to pull away the corner of the image to highlight a certain structure. Press SET when the green hand is placed on the green box.

Post-processing of the volume image is further possible by activating individual items in the left margin of the following picture:

- SCALPEL: enables cutting through a 3D image or cutting off a displayed structure. Selecting “erase inside“ will delete all structures inside a marked area. Selecting “erase outside“ will delete all structures outside a marked area. An area is demarcated by pressing the SET key. To close a contour, press the right SET key twice.

- UNDO: undoes previous manipulation with a 3D image.
- RESET: returns a 3D image into it original orientation.
- RESET COLOR: cancels image coloring.
- GRAY SURFACE: activates scanning mode of a gray surface. It results in a transparent look of the scanned object.
- TEXTURE: activates texture or photographic image of an object.

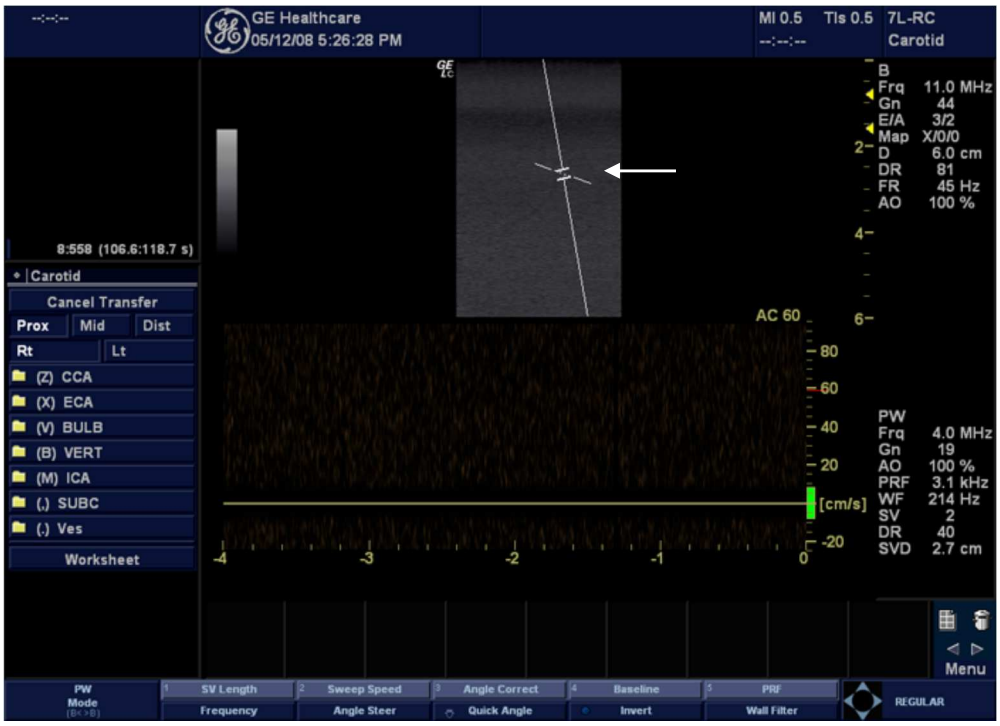


Doppler Mode

Optimization of Spectral Doppler Mode

Spectral Doppler mode provides information on movement velocity of tissues and fluids. Use PW (Pulse Wave) Doppler mode to analyze blood flow in a relatively small area, denoted as sample volume (arrow

In Pulse Wave Doppler mode (PW) the ultrasound signals are transferred from the probe into the patient's body in a similar way to B-mode, only their length is greater. The returning echoes of moving objects (blood elements) cause differences in the frequency of emitted and received signals. Resulting signals are presented both through audible sounds and graphically on the system display. Axis X of the record represents time, whereas axis Y represents a frequency shift which corresponds to the flow velocity. PW Doppler mode functions in two regimes: conventional PW and PW with high pulse repetition frequency (HPRF). The curve of spectral Doppler mode is recorded from the area of the position of sample volume. The cursor of sample volume can be shifted all over the B-Image using the ball-tracker.



Typical examination report using PW Doppler mode:

1. Select a suitable probe.

2. Put the patient in an examination position.

3. Press the “Patient” key. Fill in relevant patient data.

4. Select exam study (preset), application and probe.

5. Demarcate the anatomical area to be examined. Optimize B-Image. Press “CF” to display respective blood vessels.

6. Press “M / D Cursor” to display sample volume (gat). After you press the “PW” key, you will see the Doppler spectrum. The system works in combination with B+ Doppler mode. Set the volume of speakers to reproduce Doppler sounds.

7. You can shift the sample volume cursor using the ball-tracker. The sample volume size can be adjusted by pressing the “SV Length” key.

8. Optimize the Doppler spectrum gain as needed.

9. Press the “B Pause” key to switch between the B-Image and the Doppler mode.

10. Position the sample volume along the longitudinal axis of the examined blood vessel. The probe must be positioned parallel to the blood flow.

11. Press the FREEZE key to stop spectral scanning. D/M-CINE can be activated if needed.

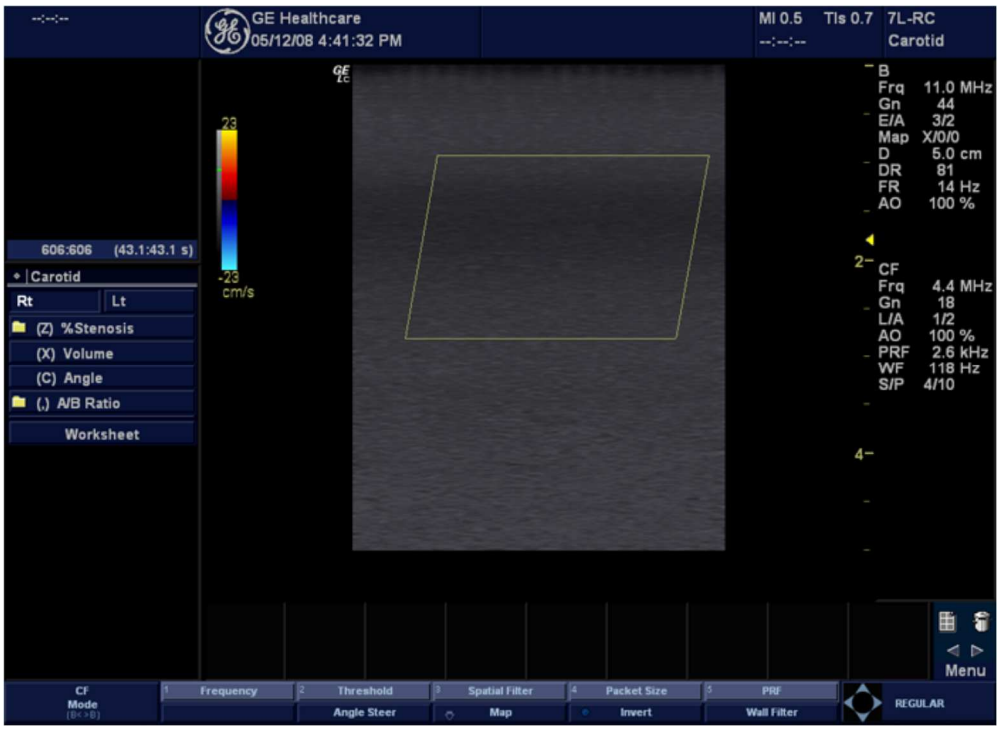
12. Perform measurements and calculations as needed.

13. Record the results by clicking the respective key.

14. Continue scanning by pressing the FREEZE key again.

Activation of Color Flow Doppler Mode

To activate color Doppler mode, it is necessary to press the CF key. The color sector (screen) is superimposed over a B-Image. Using a ball-tracker, it is possible to shift the color sector to a required position, most often to the center of the screen.



Color Doppler displays flow in the whole area of the selected color sector. Information on flow velocity is obtained from a small area of volume sample. Color coding often serves as the first step to identify arteries, in which velocity is subsequently measured using a spectral Doppler mode.

Controls of the Color Doppler Mode:

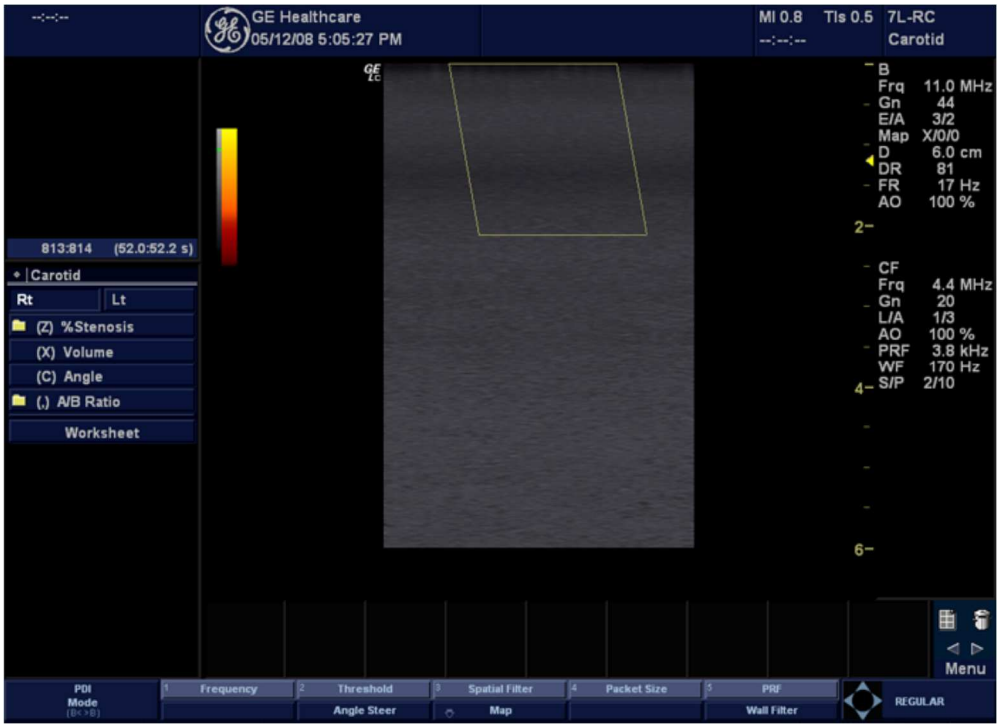
1. **Gain** – increases color coding intensity
2. **PRF** (pulse repetition frequency) – influences the range of measured velocities and thus also the color saturation of the coded flow
3. **Wall Filter** – removes signals of low flow velocity and thus decreases movement artifacts
4. **Scan Area** – determines size of a scanned area and position of the color box (window)
5. **Invert** – changes color-coding in the direction of flow (red → blue and blue → red).

6. **Baseline** – changes the basic line of color mapping or Doppler spectrum in such a way so that it is possible to record higher velocity flows.

Color Imaging Using Power Doppler Mode (PDI - Power Doppler Imaging)

Press the PDI key to activate this mode.

This mode uses full power of the Doppler signal to do color mapping. It is more sensitive that the classic method of color coding and much less dependent on the correct setting of the Doppler angle. There is one disadvantage – missing information on the direction of flow.



Duplex and Triplex Modes

Duplex mode enables simultaneous activation of two scanning modes (e.g. B + PW or B + CF). Triplex mode enables simultaneous activation of three scanning modes (B + PW + CF).

Activation of the Triplex Mode:

To start the triplex mode, first press CF, then PW. Doppler spectrum will be recorded along with artery color-coding in the B-image mode. It is possible to change the cursor position of the sample volume as well as its breadth. Spectral record of the flow is displayed together with the acoustic record.

Post-processing Options

Use the following controls for additional processing of frozen B-Images:

- Maps
- Zoom
- Rotation
- Inversion
- Deactivation
- Dynamic range
- Gain

The following controls serve to process color flow or Doppler images:

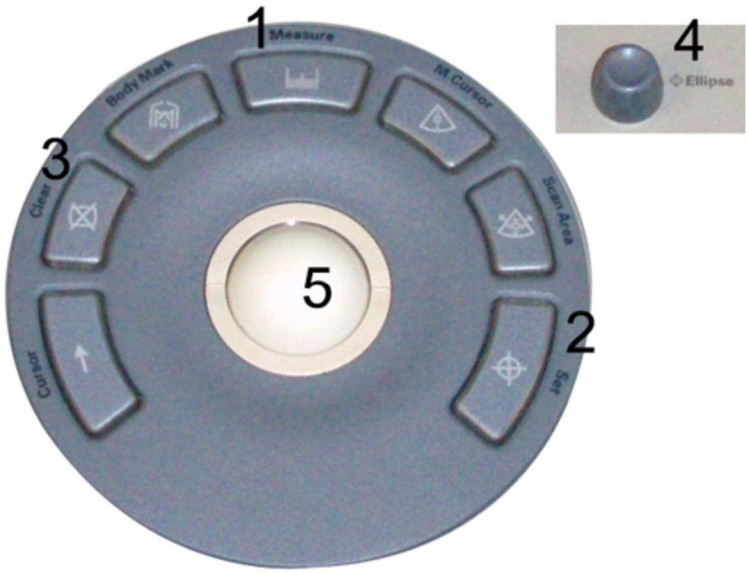
- Angle adjustment
- Inversion
- Additional coloring (PW)
- Threshold function
- Map (CF)
- Compression

AUTO OPTIMIZE – automatically optimizes B-Image or Doppler spectrum image.

Measurements and Calculations

Measurement and calculations based on ultrasound images represent a supplement of other clinical procedures. Accuracy of measurement is not determined solely by the accuracy of the system, but is also determined by using own data by the user. Formulas and databases used within the frame of system software are connected to individual examination procedures.

Position of regulation controls for measurements



1. MEASURE – Activates measuring with a caliper and a corresponding package of calculations.

2. SET – Fixes the caliper and end the measuring sequence.

3. CLEAR – Deletes the measuring caliper and measured data.

4. ELLIPSE – Activates measuring of the ellipse function after measurement with the first caliper and setting the second one are completed. While setting the ellipse, it is possible to change size of the ellipse by using a ball-tracker. Press *Cursor select* to set the measurement caliper.

5. TRACKBALL. Shifts the measuring caliper and can be used to select measurement.

X-ray Imaging

X-radiation is generated in the x-ray tube. Electrons emitted from a cathode, which is powered by electric current, are accelerated by anode voltage U of the strength of several hundreds of kV. In the area of their impact on the anode X-rays are formed. This radiation has a dual origin. First, there are the so-called braking X-rays, formed when the electrons hitting the anode brake in powerful electric fields of atomic nuclei; second, there are characteristic X-rays. It is generated when electrons jump within electron shells of atoms excited by impacting electrons.

Spectrum of braking X-rays is continuous and its wavelength depends on the energy of the impacting electrons. There is a certain minimum wavelength λ_m, which corresponds to the situation when the impacting electron hands over all its energy to the newly formed photon, which can be described as

$$E = U_a e = h f_m = \frac{hc}{\lambda_m} \tag{1}$$

Where E is kinetic energy of an electron, e elementary charge, h Planck's constant, f_m frequency corresponding to the wavelength of λ_m and c speed of light. Using this formula, we can experimentally determine Planck's constant.

Spectrum of characteristic X-rays is discrete – various wavelengths correspond to individual quantum jumps. Properties of radiation depend on the material of the anode. To calculate radiation wavenumber ν_{12} that corresponds to the jump from level n_1 to level n_2, we can use the following formula

$$\nu_{ab} = R\left(Z - s\right)^2 \left(\frac{1}{n_a^2} - \frac{1}{n_b^2} \right) \tag{2}$$

Originating from the Bohr's model of atom, where R is Rydberg's constant, Z atomic number of element and with the so-called shielding coefficient. Shielding coefficient is a unit that characterizes the influence of other electrons in an atom, which "shield" the atomic field. It increases with the distance from the nucleus. In our case, two jumps are significant – between levels 1-2 and 1-3, where corresponding wavelengths are denoted as K_α a K_β.

According to Bragg's interpretation of diffraction of x-rays on a crystal, radiation reflects off planes in which atoms within a crystal are organized. Where there is constructive interference of radiation reflected from various planes, we can observe interference maxima. If we consider that for reflected radiation the law of reflection is valid, we can formulate Bragg's condition for interference maximum

$$2d \sin \Theta = k\lambda \tag{3}$$

Where Θ is impact angle, d is inter-plane distance (grid constant) and k is the order of interference maximum. Figure 1 shows the situation of our examined crystal LiF with face-centered cubic grid.

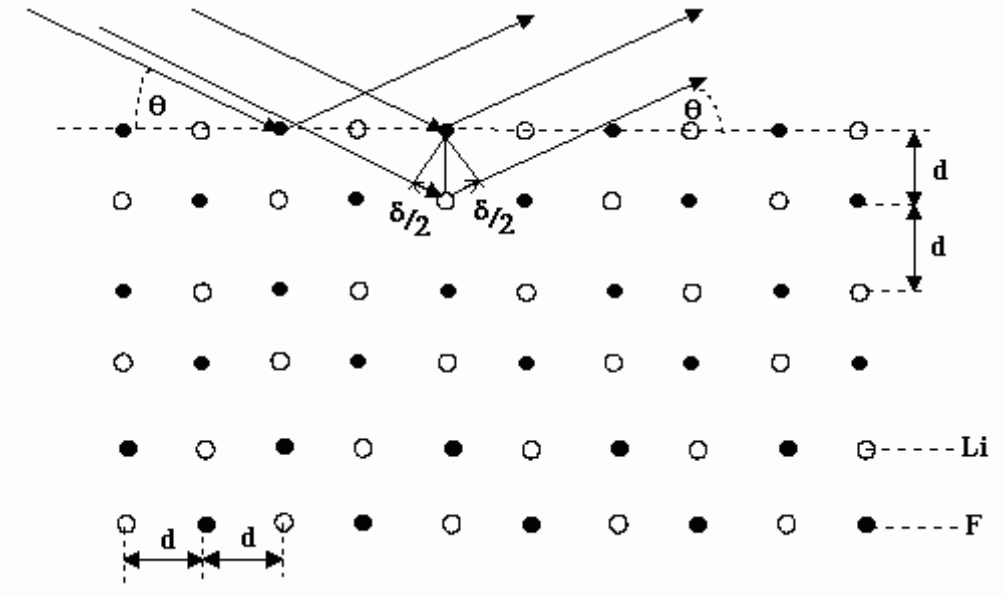


Figure 1: Reflection of X-rays on LiF crystal grid

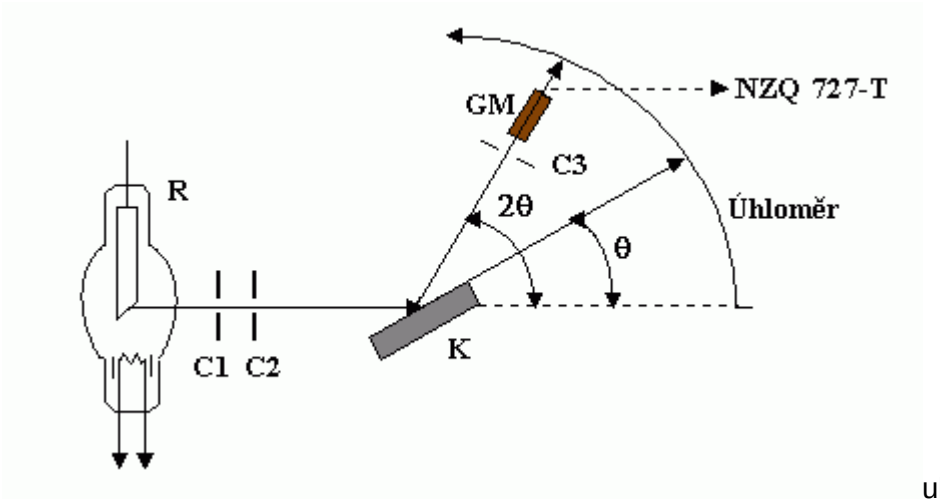
Based on the knowledge of the type of grid and crystal density ρ we can calculate inter-place distance d as

$$d = \sqrt[3]{\frac{(M_{Li} + M_F)}{2\rho N_A}} \tag{4}$$

Where M_{Li} and M_F represent molar weight of lithium and fluorine and N_A is Avogadr's constant. We reach this relationship by considering that ½ atom of lithium and ½ atom of fluorine accrues to 1 cell of d^3.

Measurement is performed on school X-ray device Phywe. Diffracted radiation emitted from the crystal was detected with Geiger-Müller's computer. Radiation intensity is directly

proportional to the number of impulses detected with the computer within a certain time period. The device uses an X-ray tube with copper anode (Z = 29). Its schema is depicted in Figure 2.



uhlomer = protractor

Figure 2: Schema of X-ray device PHYWE

Sources:
ŠTOLL, I., *History of Physics*, 1st ed., Praha, 584 p, Prometheus, 2009
KITTEL, Ch., *Introduction to Solid State Physics*, 1st ed., Praha, 600 p, Academia, 1986

Perimeter

Perimeters are generally used to examine visual field.

Computer perimeter, which uses a specialized software, enables selection of various programs for various examinations, in the range visual field that we want to examine (central and peripheral area tests) or according to diagnosis (glaucoma test, change of macula test). Individual changes of the visual field are typical for a particular disorder/illness and signal eye or other greater diseases. Examination of the visual field is often a necessary prerequisite that enables individuals to carry out certain professions (visual field test for the driver's license).

Visual field is part of space in front of an eye (monocular visual field) or in front of both eyes (binocular visual field). Light rays travel from the visual field and through the pupil into the eye (or both eyes). They bring about light sensations while the eye (or both eyes) fixate on one point.

The entire visual field is part of space, which is observable when both eyes are fixated at the same and right ahead. Clinically, the range of visual field is assessed separately for each eye. Physiologically, the range of monocular visual field is about 90° temporally, 60° nasally and upward, 70° downward. The range of visual field is also limited by eye sockets, nose, and eye lids. Visual fields of the left and right eye overlap in the central part of the binocular visual field.

We distinguish **central visual field and peripheral.**

We talk about central visual field when the light rays entering the eye fall on the central region, or fovea (macula lutea).

Central visual field serves sharp vision and color perception, which depends primarily on retinal cones. On the other hand, peripheral visual field mainly serves orientation in space and in the dark and provides colorless, achromatic vision attributable to rods. The eye first perceives movement in the visual field and then gradually white, blue, red, and green color.

The size of central visual field corresponds to only 1/5 of the whole visual field. In spite of that, we derive from it about 83% of all visual information. The ability to differentiate quickly diminishes as we move from the center to the periphery of the visual field; however, the periphery is highly sensitive to the perception of movement and is necessary for orientation in space and night vision. Therefore sharpness of vision, visual acuity, is not essential for peripheral vision, but range is. The image that falls on the retina is inverted so the upper parts of the retina correspond to the lower part of the visual field, temporal parts of the retina to the nasal part of visual field, etc. The range of visual field depends on the shape of the face – eye sockets, including eyebrows, eyelids, nose, cheeks and forehead. When simultaneously fixing the right and left eye, their visual fields completely overlap in an area of up to 60 degrees on each side and form the so-called binocular visual field. This area is important mainly for stereoscopic vision, which ensures the formation of high quality spatial perception. We see monocularly only in the most temporal half-moon parts of visual fields, that is in about 1/6.

Scotomas (positive, negative, absolute, and relative)

Scotomas are areas of diminished vision, or loss of vision, in the visual field. According to the patient's awareness of them, scotomas are divided into **positive** (e.g. macula disorders) and **negative** (e.g. physiological blind spot). In a **absolute** scotoma, the patient cannot differentiate anything, not even movement. In a **relative** scotoma, perception of movement is usually preserved and color perception is impaired. The patient can discern marks of larger size or higher intensity than in other parts of visual field.

Physiologic blind spot is the naturally occurring scotoma. We are not aware of the blind spots because both of them do not fall on the corresponding areas of the retina, so in the binocular visual field, the scotoma in one eye is compensated for by the other eye.

Factors that influence examination of the visual field:

- *Transparency of optical media.*

Cloudy optical media make examination more complicated; therefore it is important to know the status of cornea, lens, and vitreous humor.

- *Refractive disorders.*

A hypermetrope has a wider visual field than an emetrope, and by contrast a myope has a narrower visual field than an emetrope.

- *Non-corrected refractive errors* also influence the range of visual field.
- *Pupil width.*

Miosis causes narrowing of the visual field. This is especially important in glaucoma, as the patients are treated with miotics.

- *Patient cooperation/compliance.*

The patient should be informed of the course of examination in order to manage communication with the device so that there are no errors due to inability to comply.

- *Changes of the visual field as an effect of aging.*

As a result of aging, the visual field concentrically narrows. These changes are physiologic. They are not considered a disorder in the true sense of the word. Ptosis or sinking of the eye into the socket represents a common cause. We find deteriorated orientation in space in the elderly due to degenerative changes in the peripheral retina. A frequently mentioned disorder connected to aging is degeneration of the macula, which affects individuals after the age of 50 and affects central vision. It is important to take this into consideration when examining visual field. That is why modern perimeters take the patient's age into account and results are compared with norms for the given age group.

Methods of Visual Field Examination

- **Brief Examination**

Light projection test

It is an elementary test of the visual field. It is carried out when visual acuity is lowered to light perception or movement in front of the eye. The pupil is illuminated by ophthalmoscope from various directions and the examined subject reports from which direction he or she perceives light. The record then states only the quadrant in which the projection is preserved or is missing, or that the projection is uncertain or unreliable.

Confrontation Test

Monocular testing. The patient and physician sit opposite each other at a distance of approximately 1 m. The patient covers one eye with his/her hand, the physician closes the opposite eye and they look each other in the eye. The patient must be informed that it is necessary to concentrate and maintain fixation. The patient is to report as soon as he/she registers any movement in the periphery. The physician then slowly moves one or two fingers in the mid-distance, from the periphery to the center, and expects a signal from the examined subject the moment he himself registers movement. Movement is traced along eight meridians. It is necessary to repeatedly confirm any found pathological data.

- **Campimetry**

The method, on level surface parallel to the frontal plane, registers changes in the central visual field (up to 30°) and searches for minute losses in the centrocecal area. It used to be popular for examining neuro-ophthalmological disorders and glaucoma due to it simplicity and precision. In the age of automatic computer systems, campimetry is time-consuming, which is its main disadvantage.

- **White-Noise Field Campimetry**

White noise field campimetry (also called snowfield campimetry) is a method that directly reveals scotomas, which enables patients to immediately detect and interactively describe defects in their visual field. This is carried out using a display, which shows the same number of randomly located black and white squares flashing at a frequency of 30 Hz. Scotomas are usually described as “clouds,” which can be distinctly differentiated from the normal surrounding noise. The examined subjects react by drawing their scotoma on a touch screen using their fingertip. Subsequently, the examiner can ask questions that further characterize the given defect. Fixation is monitored with an infrared camera.

- **Perimetry**

At the present time two basic conventional types of perimeters are used – kinetic and static (computer-aided).

Kinetic Perimetry.

This method uses a mark that is progressively projected by movement from the periphery to the center along a given meridian. The process is repeated with the same stimulus along other meridians, usually at the interval of 15°. After connecting obtained points, there is an isoptera for a mark of particular size and brightness, which connects places in the retina that have the same sensitivity threshold. Then the size and brightness of the mark is changed in order to map out areas with different sensitivity to light. As soon as the examined subject detects the mark, he or she reacts. These patient reports are plotted in a graph, where the position of the mark in the visual field is indicated. Most kinetic perimeters require manual operation both when projecting the mark and when recording reactions. In view of the principle and demands of the technique, kinetic perimetry is less reliable than static.

Automatic Static Computer Perimetry.

It is much more modern and accurate. The size and localization of the tested mark stay constant. Sensitivity of the retina or sensitivity threshold in a given area is determined by change of brightness of the mark. By repeated measurement of threshold value in different areas of the visual field, the shape of the hill of vision is obtained. The measurement principle lies in projecting the light mark of standard size with various threshold and above-threshold levels onto individual point in the retina with the goal of determining sensitivity of these points. The computer determines sensitivity threshold in individual points of the visual field and subsequently also expected light sensitivity in corresponding parts of the retina. Comparison with normative database provides information on statistical significance of the obtained examination and the results are simultaneously correlated with those from previous examinations. The computer determines reliability the test. Even if the findings are reproducible, there are certain factors (e.g. variability in pupil size, presence or progression of cataracts) that can influence comparison.

In perimetry, brightness of the test mark is given in apostilbs (asb) = blondels – an older unit of light brightness.

[1 apostilb (blondel) = 0.31831 $cd.m^{-2}$].

The decibel scale is a relative inverted logarithmic scale used to determine threshold sensitivity in individual points of the retina. Zero value (0 db) corresponds when using various devices of different brightness.

Computer system enables us to express results either by using numeric expression (if there is a minus sign in front of the printed number, it means that for the particular point there is greater sensitivity by that number than an average value in a given age group) or the results are expressed using a graph, color map a scale of gray. The darker the colors, the greater effect we found in a particular point. Black color means an absolute scotoma. The degree of deformation of the visual field can be expressed using Bebie's curve. This curve represents the relationship between the location of tested area and the found defect of the visual field (in dB). Along with this curve we also get a normative curve and we can compare the degree of defects. In the area of 5 % around the normative curve, there is tolerance band. It is generally true that when a patient's curve falls outside the tolerance band and has the same shape as the normative curve, reduction of the visual field is even. The more the curve is deformed, the greater defects were found.

Static perimeters also monitor eye fixation. Loss of fixation should not be greater than 30 %. If the patient blinks or closes his eyes while the stimulus is being presented, it is registered with a supplementary camera and the computer presents the same stimulus once more. Patient simulation is detected thanks to the so-called false negative and false positive reactions. A false negative reaction means that a patient is not giving us information about a stimulus that he had already registered with a lower intensity before. If a patient reacts to an absent light stimulus solely based on the sound signal, it is a false positive reaction.

If a corrective lens is required for the examination (if a patient wears glasses), we place it in the holder in front of the examined eye. This way we ensure that the patient can see the projected stimuli clearly at an appropriate distance. Patients who wear contact lenses can keep them during the examination.

Examination technique varies from device to device.

Computer Perimeter Conterfield

Computer perimeter Conterfield is a compact device controlled with a desktop computer or laptop. In spite of its compact dimensions, it is able to measure vision in the periphery – up to 70° in all directions. It is possible to supply a mechanical or electric chinrest, an above standard part equipment. Computer perimeter CENTERFIELD is a full range perimeter 0 - 70° in both horizontal and vertical planes for normal static perimetry, color perimetry (blue-yellow) and automatic kinetic perimetry 0 – 36°. Stimulation points are displayed from behind (patented) using a new projection system. This way the same size and intensity of points are preserved. This type of perimeter contains a number of programs for tests in various areas of the visual field (e.g. screening, glaucoma, macula, incl. the option of creating own test program, etc.). Maximum number of tested points is 249, in the central area 0-30° max.188 tested points.

Measured data are stored in the PC memory, which enable future comparison with new results, including assessment of improvement, or worsening, of the patient's visual field. Results can be printed out using level symbols, dB, shades of gray, static curves, etc.

Corneal Topographer

Cornea is the transparent dome-curved layer covering the front of the eyeball. The cornea has considerable optical power which accounts for about two thirds of the total optical power of the eye (about 66%). Thus it constitutes the most important refractive part of the optical system of the eye. No blood vessels go through the cornea. Under normal circumstances it is completely clear and has a glossy surface. The cornea is also extremely sensitive. It contains more nerve endings than any other area in the human body. The adult cornea is only about half a millimeter thick and takes up approximately 1/6 of the eye surface. Normal diameter of the

cornea is 11,5 – 12,0 mm horizontally, 11,0 mm vertically. Average curvature radius is 7,7 mm on the exterior surface and 6,8 mm on the interior one. The cornea flattens towards the limbus. Average optical power of the anterior surface of the cornea is +48,83 D and of the posterior -5,88 D. Simply put, the cornea is considered to be the only optical system with an optical power of **+43,05 D.**

The course of the anterior surface of the cornea does not show sphericity. Peripherally, the curvature radius grows and the cornea flattens. The curvature radius changes during the course of a lifetime. After the age of 30 the cornea flattens by about 0,5 D and, on the contrary, after the age of 70 it gets a steeper shape by about 1D. In adulthood the horizontal meridian of the cornea shows a higher refraction by 0,5 D, which according to the rule corresponds to astigmatism (physiological astigmatism). This astigmatism of the cornea diminishes with age. On the contrary, the lens shows astigmatism against the rule, which grows with age. Corneal astigmatism is often compensated by lens astigmatism. Since the cornea constitutes about 66% of the optical power of the whole system, every change of the shape of cornea plays an important role in the optical system of the eye. Even a small change in the curvature radius and shape of the cornea has a significant impact on the resulting retinal image, e.g. bowing of the cornea, decrease in curvature radius causes myopia, and, if it is not even, also astigmatism. Corneal deformation can even bring about a very unpleasant effect of monocular diplopia (double vision), rarely even polyplopia. This condition is very irritating and is connected to difficulties like headache and nausea. This condition can prevent the patient from performing his job, driving a motor vehicle, and in more serious cases from performing everyday tasks.

Change of corneal shape can be caused by trauma, illness, degeneration, or refractive corneal procedure. Frequently, there is a post-surgery increase in corneal astigmatism caused by tension in the suture in the corneal limbus. The condition can spontaneously correct itself, or a different solution may be considered. We need to count with an increase in aberrations that come both with purposeful and undesired change of the corneal shape. Especially higher order aberrations, which cause subjective image deterioration, cannot be corrected with classic spectacle correction or contact lenses.

Any defect in the frontal surface of the cornea will immediately manifest as deterioration of eyesight. The worst pathology that can affect a cornea is the so-called keratoconus.

Keratoconus, irregular bowing of the cornea, is a degenerative disorder of the corneal stroma. There is conical bowing of the cornea in its center or paracentrally. An irregular astigmatism with corneal thinning is formed. Stroma is condensed, without any signs of inflammation, in about 85% cases bilaterally. Keratoconus often develops earlier in one eye than the other. .

Keratoglobus is a developmental disorder, which is usually diagnosed during adolescence. It is a bilateral disorder of the corneal stroma. Cause of this disorder in not clear yet. Prevalence is lower than of keratoconus. The whole cornea bows spherically. It causes corneal thinning in its entire diameter. The thinning is most apparent in the periphery. Thickness of corneal stroma decreases up to 1/5 of average thickness. The speed and seriousness of progression cannot be easily predicted. The condition worsens and is typically most serious between the ages of 20 and 30.

Corneal Cross Linking

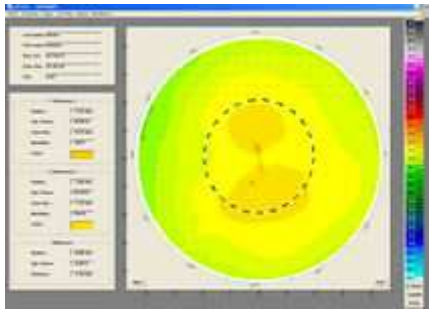
Corneal Cross Linking (CCL) is a relatively young method of keratoconus treatment. Corneal Cross Linking method was developed by Theo Seiler, a German physician, in cooperation with Professor Spoerl shortly before the year 2000. First they applied it using animals. After the year 2000 Siler and Spoerl used the method in humans for the first time. During the procedure, epithelium (upper part of the cornea 40microns thick) is removed and vitamin B2 is applied to the eye. The tissue of the eye is saturated with vitamin B2, then it is illuminated by a special lamp. During illumination light brakes when it reaches riboflavin molecules and it activates a chemical reaction. Oxygen radicals are formed, which we typically prevent in everyday life. However, in this case they are actually helpful. The radicals bring about the so-called crosslinking. Cross-links are transverse bonds between collagen strands, which make up the cornea. Formation of new collagen strands (cross-links) strengthens the cornea. New chemical bonds strengthen the eye without compromising transparency. Thanks to this many patients can avoid transplantation of the cornea and undergo keratoconus treatment that is much safer and minimally invasive method. CCL does not cure keratoconus completely; it only stabilizes it and stops further progress. This method stops the progress of keratoconus; however, it may be necessary to repeat the process in several years. Unfortunately for patients, health insurance companies do not cover this procedure. Patients need to pay fourteen thousand Czech crowns per procedure (i.e. for one eye) themselves.

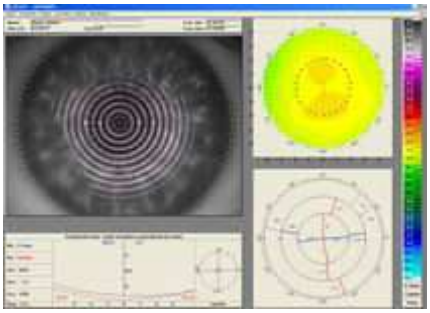
Corneal topography is a non-invasive imaging method of the frontal segment of the eye. It enables a quantitative and qualitative analyses of curvature radius of the front surface of the cornea in the entire diameter of the cornea. Corneal topographer is primarily a clinical device. It is not used during routine eye examination. It supplements autokeratometry. (Keratometry also focuses on measurement of curvature radius of the front surface of the cornea. Measuring range is however only between 2 – 4 mm. In this diameter, most corneas have a regular shape approximating a spherical surface.

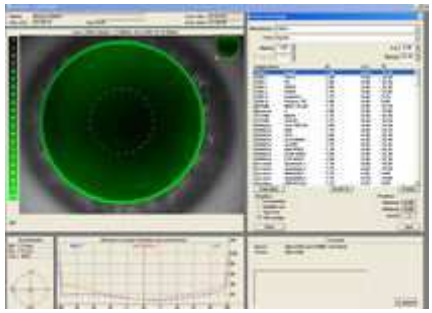
Compact Topographer OCULUS Easygraph.

It maps the surface of the front part of the cornea (the whole surface). Values of the curvature radius can be determined in any point in the area 7mm (πr^2), which is approx. ¾ of the surface of the cornea. The surface of the cornea, which takes part in the process of seeing, is fully measured (it is never more than 7mm), even at maximum mydriasis. Measurement is automatically started by reaching a measurement point, which shorten the overall examination time and ensures measurement repeatability. It is controlled with a supplied PC software (USB port) connection. The software enables monitoring changes in corneal curvature in time, e.g. during various corneal dystrophic diseases. It enables 3D imaging etc. It makes manipulation with client data easier thanks to Windows environment. A testing module for determining suitability of contact lens parameters based on obtained data is included. In practice it is used similarly to a keratometer. Measurement accuracy is the same, but provides much more information on geometry of the front part of the surface of the cornea. Therefore, it has greater importance in arriving at a correct diagnosis.

Measurement results: various maps of the frontal surface of the cornea showing values of curvature radius in different point.







Application of Corneal Topography in Clinical Practice

- Application of Contact Lenses.

With growing popularity of correcting common refractory defects with soft contact lenses, demands on equipment of contactology centers and knowledge of optometrists are also growing. Keratometry is sufficient for the majority of cases, but corneal topography expands the options of contact lenses applicators. Information on the course of corneal curvature in the whole diameter can explain difficulties in cases of atypically shaped corneas, where classic measurement in the center of cornea fails. Most corneal topographers offer special software equipment designed especially for work in contactology centers that help select contact lenses based on various parameters, suggest individual contact lenses, or simulate various tests of contact lenses. Demands on the patient and examination time are lower and the system enables

providing exhausting information that helps select suitable contact lenses. The option to save measured values and compare them at the next checkup represents another advantage of corneal topography.

- Diagnosis of astigmatism, keratoconus and other eye diseases.

The possibility of comparison with previously gathered data of the patient constitutes a great advantage even here. That is why it is used for example in monitoring progression of irregular astigmatism and in corneal diseases in the beginning stages, where it represents the only possibility of correct diagnosis. This way the disease can be detected at the beginning and hard contact lenses can be used to slow its progression.

Further possibility of usage comes when the values of astigmatism measured with an auto-refracto-keratometer are too great, or it is not possible to carry out objective measurement of refraction due to advanced stage of the cataract. Measurement error is caused by cataract of intraocular lens, which deflects the measurement beam. Even the selection of a suitable implant depends on the measurement of radius of curvature of the cornea.

- Refractive Surgery.

Corneal topography represents an indispensable examination method in preparing the patient for a refractive surgery procedure. Prior to surgery, all necessary information is gathered, e.g. irregular astigmatism, corneal degeneration and other abnormalities, which could contraindicate the surgery. Post-surgery, the corneal topography is used to monitor surgery results. It detects causes of visual difficulties and impairment and helps improve the procedure technique.

As every measurement, even corneal topography has its limits. It requires mainly the presence of intact corneal epithelium and a layer of tear film.