Eye Refractometry by the Modified Foucault-knife Method

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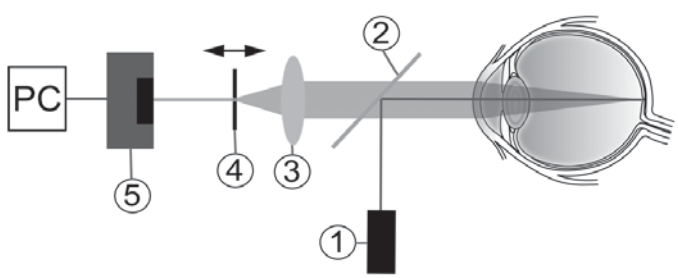
Abstract

The modified Foucault-knife method is a new direction in the ophthalmological refractometry for eye ametropy and astigmatism determination. The principal advantages of this method are relative simplicity of hardware and mathematical algorithm and low cost price. It also gives the potential possibility for the reconstruction of the wave aberration function by usage of the isodiopter zones images, video-recorded at the pupil plane.

Eye refractometry is a necessary condition for successful correction of vision aberrations. The accuracy in definition of eye aberrational parameters directly influences the efficiency of their correction. Ophthalmology refractometers or aberrometers are mostly used for the preliminary refractometric measuring. This equipment meets the requirements of the ophthalmologic practice but most of these devices have a number of disadvantages that hinder their use in the ordinary clinics and ophthalmological cabinets. Complexity of these devices and their high cost are the examples of such disadvantages. Thus, the creation of the ophthalmological refractometer which would allow to define the primary aberrations of eye optical system, such as ametropy and the primary astigmatism, by means of simpler hardware and also at a reasonable price, is an important task.

The essence of the method is definition of isodiopter zones in eye pupil plane, or areas in the pupil plane, which have identical optical force, by spatial filtration of the light rays that come out of the eye. The functional scheme of the refractometer based on the modified Foucault method is displayed in pic. 1.



Picture 1. The functional scheme of the refractometer based on the modified Foucault method: 1 – radiation source, 2 – the beam splitter, 3 – objective, 4 – the spatial filter, 5 – photodetector.

The refractometer consists of the lighting and measuring systems, whose optical axes are interfaced by the beam splitter 2. The lighting system contains a source of radiation 1 with an integrated optical system for shaping the light microstain from a laser beam on an eye retina. The measuring system includes the objective 3 for shaping out the shining area of the eye retina in the rays coming out of the eye. It also includes the spatial filter 4 designed as a microdiaphragm moving along the optical axis, the photodetector 5 for the eye pupil images registration and a computer for processing the received images. The objective 3 optically interfaces the photodetector plane with an eye pupil plane.

There are three stages of measuring device functioning: positioning the device relatively to a visual axis of an eye, videorecording of the eye pupil image at each fixed position of the spatial filter and the program processing of the received pictures. The refractometer has got two functional modes: eye ametropy and primary astigmatism determination with the use of luminosity distribution in the image of pupil and reconstruction of the wave aberration function, based on processing images of isodiopter zones.

The procedure of measurement of the eye ametropy consists of the spatial step-by-step filter moving with simultaneous photo-electric registration of the pictures of light exposure distribution in the eye pupil image. Every position of spatial filter corresponds a certain position of ‘further point of clear vision’, and, means, ametropy. The value of ametropy is defined by that position of a microdiaphragm where the total photo-electric signal from a photodetector is maximum. For the definition of a primary eye astigmatism it is necessary to find such positions of the spatial filter relatively to an optical axis of the refractometer when pupil plane zones, where the beams pass, form the images of astigmatic segments, are observed. The difference between spatial coordinates of these positions of a microdiaphragm allows to establish the value of a primary astigmatism of the eye optical system.

Refractometer functioning in a mode of reconstruction of the wave aberration function includes three steps. The first procedure should be digital filtering of video-images to allocate isodiopter zones of the photodetector light exposure. The appearance of such two-dimensional images is defined by wavefront aberration distribution in the specific eye’s optical system. The second procedure is to determine in the “in-front-of-the-eye space” the angular coordinates of rays, emanating from the eye. These rays form isodiopter zones in the pupil plane. Angular coordinates of each individual ray depend on its pupil coordinates and current position of a spatial filter. The third procedure is to reconstruct the wave aberration function in pupil coordinates. The approximation with Zernike polynomials is applied for this purpose. Amplitudes of aberration modes are reconstructed by means of the least-squares method or singular decomposition.

Computer simulation of the refractometer functioning in the mode of reconstruction of the wave aberration function has shown that the proposed algorithm enables to detect low-order aberration modes precisely enough for the ophthalmology practice, as well as to determine parameters of ametropy (defocusing), primary astigmatism, and primary coma.

These aberration modes have a dominant effect on visual acuity, therefore, information about these values is the most useful for ophthalmologists.

To confirmation the possibility of using an offered method for determination of ametropy and astigmatism and for renewal the function of eye wave aberration, it is necessary to realize the series of experimental researches.

The developed method is in detail described in the patent of Ukraine “Aberrometer with the analyzer of eye isodiopter zones of eye”, №56622, Pub. Bul. № 2, 25.01.2011.

Bibliography

1. Methods of eye refraction measuring with spatial resolution on the pupil. I.G.Chyzh, V.M.Sokurenko, Opticheskii journal, Vol. 68, № 3., P.19-25, 2001.

2. Refractometer with spatial resolution, I.G.Chyzh, V.M.Sokurenko, Patent 54570, Ukraine, A61B3/00, bull. № 3, Publ. 17.03.2003.

3. The method of wave aberration function recovery by isodiopter zones pictures on eye pupil. I.Chyzh, N.Afonchyna, T.Yakimenko // Bulletin of NTUU “KPI”, Instrument-making series, 2010, № 40, P.116-125.