Estimation of eye retina exposition during the laser attack

František Racek, Teodor Baláž, Jan Komenda

***Abstract*—** The direct laser attack of the eye can cause a significantly serious after-effect, which can inflict strong decrease of ability of the operator to control the mean of transport. The physiological reaction of human organism is to turn round the head or quicker reaction like eye closing or eyewink. To determine the quantity of light energy that passes through the eye, illuminates the eye retina and causes the physiological reaction has to be taken into account. Therefore the paper deals with measurement of eye reaction on laser attack and model of it for eye retina illumination computation.

***Keywords*—** eye illumination, eye reaction measurement, laser attack, retina.

I. Introduction

Nowadays; the lasers are widely utilized in the industry, traffic management [14, 15], etc. The utilization of the lasers is connected with keeping of safety rules [1, 3,13]. Besides the professional utilization of the lasers, the lasers are used unprofessionally or for fun. The powerful semiconductor lasers with continual radiation are easily obtainable, now. The power of said semiconductor lasers reaches up to hundreds mW (falls into 2A laser class [1]). Either unprofessional utilization or premeditated misuse of those lasers can produce significant threat, especially when used against means of transport (aircraft, train, bus, car, boat). The laser radiation can cause glaring of the operator (pilot, driver, etc.) of the transport mean. The direct attack of the laser radiation can cause a significantly serious after-effect at night low-light conditions especially, when eye is adapted for scotopic vision [2], see Fig. 1. The after-effects caused by attack of laser radiation can inflict strong decrease of ability of the operator to control the mean of transport. The ability to control recovers back with the process of regeneration of the retina of the exposed eye. It is presumed that the eye prevention is ensured by physiological reaction of the organism (valid for the 2nd class lasers). The physiological reaction of the organism is to turn round the head or quicker reaction like eye closing or eyewink. The physiological reaction, the eye reaction especially, are widely investigated [e.g. 16, 17, 18, 19]. However, these experiments and researches are not useable for said problem. The eye prevention reaction is not instantaneous, but it is delayed. Time delay between laser radiation attack and eye closing is 0.25s [3]. However the run of eye closing is specific. During the eyelid closing, the energy impacting on the eye retina is simultaneously decreasing. Knowledge of the running of the eye closing would allow determination of eye retina exposition exactly.

Fig. 1 Laser beam track seen from airplane cockpit; laser distance 2.7km; power of the laser 50mW

II. Eye retina illumination

The flux incident on eye retina [21] can be expressed

$$\Phi = \frac{\pi \cdot \tau_{0,\lambda} \cdot D_0^2 \cdot I}{4s^2} \quad , \tag{1}$$

where $\tau_{0,\lambda}$ is eye spectral transmittance, D_0 is eye pupil diameter, I is a laser luminance intensity and s is a laser - eye distance. In this equation, the laser luminance I characterizes the source of light, its power especially. Equation (1) is valid for circle aperture only. Since the laser power is often expressed in radiometric units, it has to be recomputed to photometric units. According [11], it is valid that for photopic vision 1 lm $=147\cdot10^{-5}$ W. Therefore 1W = 680 lm. Likewise, for scotopic vision 1 lm = $574.7\cdot10^{-5}$ W. Therefore 1W = 1740 lm. Both, the parameters $\tau_{0,\lambda}$ and D_0 characterize the optical qualities of the eye. It can be claimed that the eye spectral transmittance is constant during the light attack. The eye spectral transmittance can partially change over the age of the human [11]. However, the eye aperture changes during the light attack, as mentioned above, as a physiological reaction of the organism via the eye closing.

To determine the quantity of light energy that passes through the eye and illuminates the eye retina with consideration of physiological reaction, all following events have to be determined:

- the eye spectral transmittance,
- the real eye aperture as a function of the light conditions and time,
- total time of eye closing.

The eye spectral transmittance is well known [12] and its characteristic course is presented in Fig. 2.

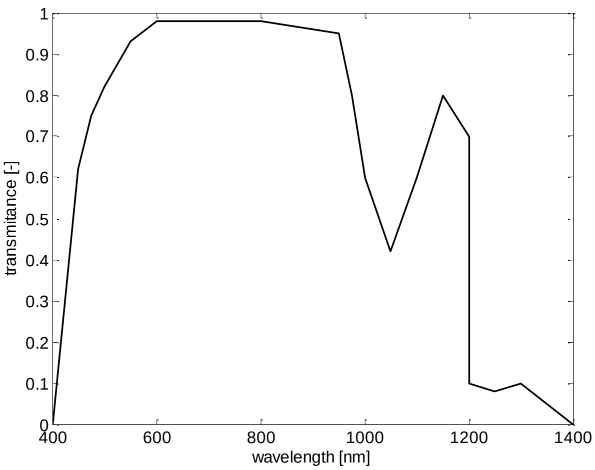

Fig. 2 The eye spectral transmittance as a function of wavelength

On the other hand, the eye aperture problematic is more complicated. The real eye aperture can be assumed as a result of overlap of eye pupil by upper eyelid. The eye pupil diameter changes with light conditions. Again, this question is well known and described in the number of publications [e.g. 8,9,10,11]. Dependebility of an eye diameter [10] on the field luminance L is ilustrated in Fig. 3 and the dependence is expressed by

$$D_0 = 5 - 3\tanh(0.4 \log L) \quad (2)$$

As it is seen in Fig. 3, the diameter variates from 2mm to 8mm.

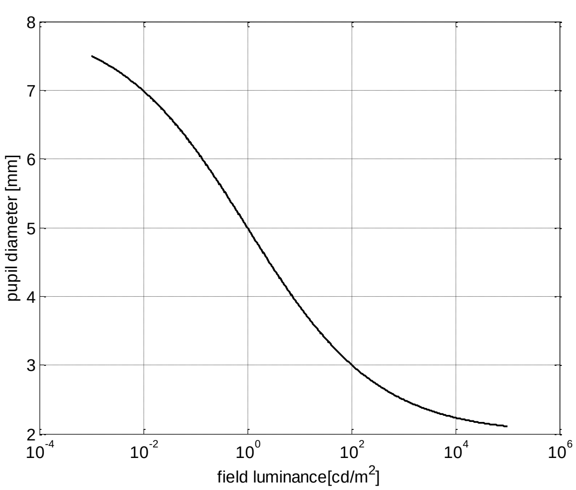

Fig. 3 The eye pupil diameter as a function of field luminance

Via the algebra of sets, the real eye aperture area D as a result of overlap of the eye pupil by the upper eyelid can be expressed as

$$D = A - B, \quad (3)$$

where set A represents the eye pupil area and set B represents upper eyelid area. It is too complicated to exactly determine said diference of sets, because of:

- the upper eyelid contour is rugged and
- the upper eyelid contour variates during the eye closing.

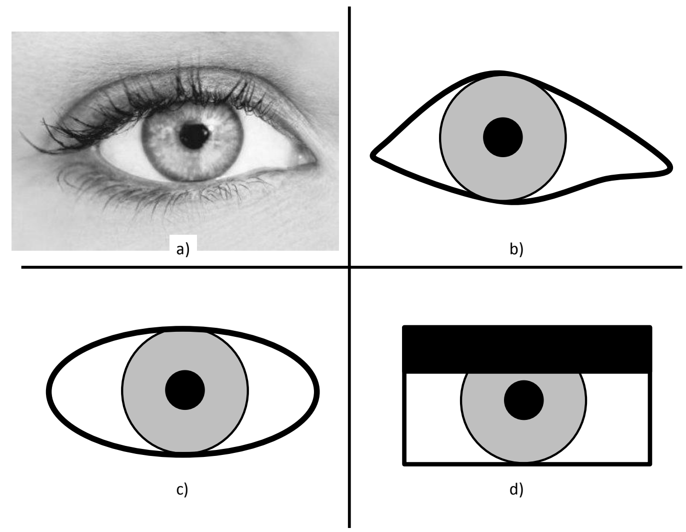

Fig. 3 The possible eye shapes. 3a) photo of the eye, 3b) complex eye shape, 3c) eliptical eye shape, 3d) simplified eye model when the upper eyelid is closing down

The shape of the eye is ilustrated in Fig. 3a. The contour of the eye or upper eyelid respectively is presented in Fig. 3b. The rugged upper eyelid contour could be reduced using eliptical model of eye shape as it is presented in Fig. 3c. The upper eyelid contour is than simplier and can be mathematicaly expressed. However, the other problem, the variation of upper eyelid during eye closing, is stil atendant. To model the movement of upper eyelid, we should respect the variation of the upper eyelid curvature from maximum on the begining, through the linear shape in the aproximately centre of eye, up to reverse curvature on the end of its movement. The said mathematical model should be highly complex without effect of enhanced accuracy. The eye shape is still aproximated and the upper eyelid contour variation is unaccurate, too. Therefore, we use a simplified model presented in Fig. 3d. The upper eyelid is replaced by rectangle shutter in that model. Thus, the eye closing can be figured as an overlaying of eye pupil by sunblind. The area of the eye pupil, overlapped by rectangular upper eyelid, has the shape of circular segment, during the eye closing. According to [20] the area of circular segment A_{CS} can be expressed as

$$A_{CS} = \frac{D_0^2}{4}\cos^{-1}\left(\frac{D_0 - 2h}{D_0}\right) - \left(\frac{D_0}{2} - h\right)\sqrt{hD_0 - h^2}\ , \qquad (4)$$

where h is the height of the arced portion. The height of the arced portion is than function of the time $h(t)$ and represents the eye closing run. Finally, the real eye aperture area $D(t)$ as a function of the time is

$$D(t) = D_0 - A_{CS}(t)\ . \qquad (5)$$

Equation (1) of the flux incident on retina is valid for circle aperture. The shape of the real aperture with consideration of physiological reaction is not to be a circle. Therefore, we have to assume following expression for flux incident on eye retina

$$\Phi(t) = \frac{\tau_{0,\lambda} \cdot D^2(t) \cdot I}{s^2}\ . \qquad (6)$$

III. Experiment for eye reaction estimation

To know the problem of eye closing run, we prepared an experiment. The experiment consists of both experimental measurement and data post processing. An experimental workspace for measurement had to be prepared for measurement of eye reaction time.

Eye reaction time T_R is the time between moment of activation event t_a and moment when eye is closed t_c. Time of eye reaction can be divided into two phases:

- eye response time and
- time of eyelid movement.

Eye response time T_{re} is a time between moment of activation event t_a and moment when eyelid begins the movement t_b. Time of eyelid movement T_{em} is the time between moment when eyelid begins movement t_b and moment when the eye is closed t_c. Simply; it is a time necessary for eyelid closing.

The activation event should be close to the real condition, where the observer is to be glared. Therefore we decided to use a flashing of photographic speed lamp as an activation event. The reasons for photographic speed lamp are:

- it gives glaring light and
- time of its flashing is suitably short, so it can represent a “moment”.

To measure said times (moments respectively) we have chosen a contactless measuring method via the High Speed Camera (HSC). Thus the experimental workspace, ready for measurement, consists of 4 main elements of measuring equipment as it is seen in Fig. 4.

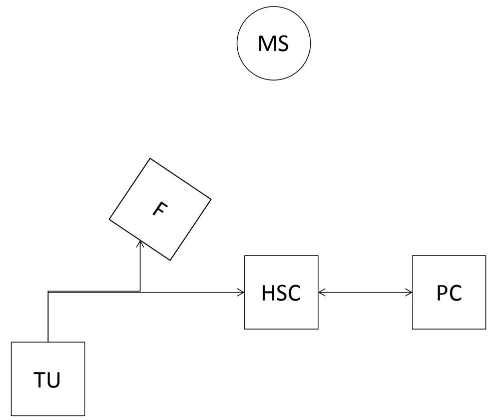

Fig. 4 Experimental workspace, F – speed lamp, TU – trigger unit, HSC – high speed camera, PC – personal computer, MS – measured subject

The speed lamp F represents, as mentioned, an activation event. Trigger unit TU produces a starting signal that starts both speed lamp and HSC. The HSC, as a most important element of measuring equipment, records the reaction of measured subject MS after and also before the activation event. Personal computer PC is used for controlling the HSC, for data storage and finally for data post processing. Measured subject is to be a person, its eye especially.

The experimental measurement is prepared for measurement of eye reaction under two different conditions – conscious and unconscious. A conscious condition means that the person knows when the speed lamp flashing comes. It implies that the person is waiting for the event. Simultaneously it is ordered to close the eye as quickly as possible after it saw the speed lamp flashing. Unconscious conditions means that the person does not know when the speed lamp flashing comes and it implies that the person does not expect it. It can be noticed here that it is extremely difficult to set the experimental measurement under the unconscious condition.

The running of the experimental measurement under the both condition was the same. After the signal from trigger unit the speed lamp flashed and the HSC recorded the video-sequence. Time interval recorded in the video-sequence takes pre-trigger and post-trigger time intervals as it is peculiar to HSCs. The timeline with highlighted moments and intervals is presented in Fig. 5.

Taking the video-sequences finishes the experimental measurement and appropriate eye reaction parameters have to be evaluated from video-sequences by the special data post processing.

IV. Processing of experimental data

The video-sequence from HSC is in the form of sequence of unique frames with specified uniform delay. The first task is to determine moment of activation event t_a. The signal of normalized exposition in any image of the video-sequence was used for t_a determination. The signal of normalized exposition

e_{iN} was computed using

$$e_{iN} = \frac{e_i}{e_{max}}, \quad (7)$$

where e_i is an exposition of i^{th} frame of the video-sequence and e_{max} is the maximal exposition among the all frames of the video-sequence. The exposition e_i was set

$$e_i = \sum_j \sum_k I_{ijk}, \quad (8)$$

where I_{ijk} is the intensity of j^{th} pixel of k^{th} line of i^{th} frame of the video-sequence.

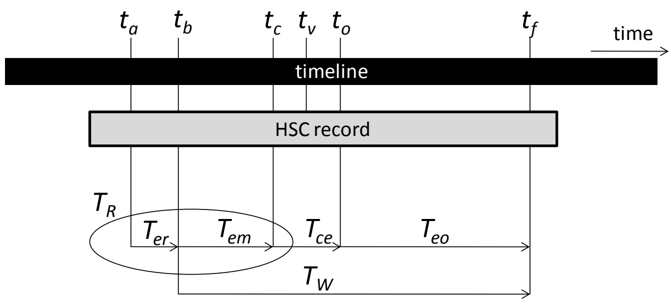

Fig. 5 Timeline with important moments and intervals during eye reflex

The typical signal of normalized exposition is presented in Fig. 6. The moment of activation event is defined as the moment of greatest exposition increment.

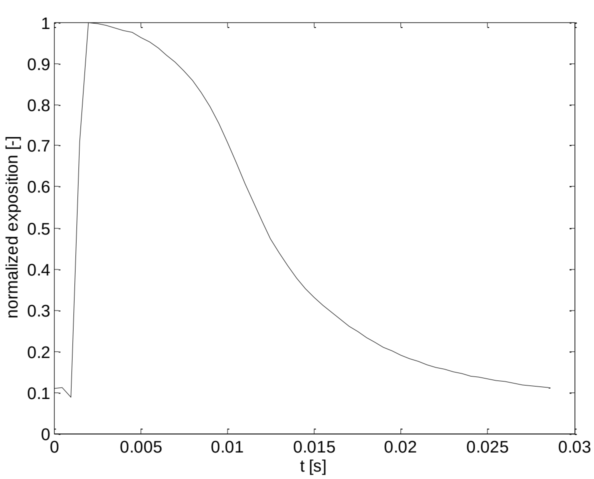

Fig. 6 Typical signal of the normalized exposition in the video-sequence as a function of time

The determination of both moments t_b and t_c was done via the MRI [4]. The MRI is the Movement Record Image [4] taken from initial image processing of the video-sequence. Simply described; the movement of tracked point on eyelid is recorded in the said MRI. The vertical axis of the image represents the spatial coordinate in meters or pixels. The horizontal axis of the image represents the time line. The time line can be scaled in seconds or in frame numbers. The conversion between time line in the frame number and seconds is defined as

$$t = n \cdot T, \quad (9)$$

where t is a time [s], n is a frame number [-], T is a period of high speed camera image scanning [s].

It is valid for the period of high speed camera image scanning that

$$T = \frac{1}{f_{ps}}, \quad (10)$$

where f_{ps} is a high speed camera image scanning frequency [s^{-1}]. The description of the MRI creation follows. A column of special-interest is selected in the first image of the processed video-sequence. The said column of the special-interest is located in the horizontal centre of the eye. The required MRI is than created by inserting of the current image column of special-interest into the MRI as a new column. Thus the i^{th} column of the MRI matches with column of special-interest of i^{th} video-sequence frame. Typical MRI from experimental video-sequence you can see in Fig. 7.

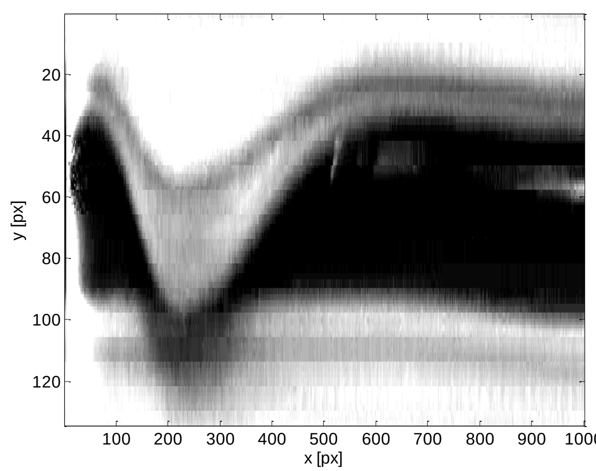

Fig. 7 MRI from the video-sequence of upper eyelid movement

A typical additional problem in experimental video-sequence processing is the eyelashes. The eyelashes produce blurring of said edges representing the movement of tracked point on eyelid. Thus the determination of tracked point trajectory is more complicated. Therefore the Sobel operator [5] was used for improving the finding of the edges in the image. The output image after the Sobel operator application is presented in Fig. 8. The original image was image in Fig. 7.

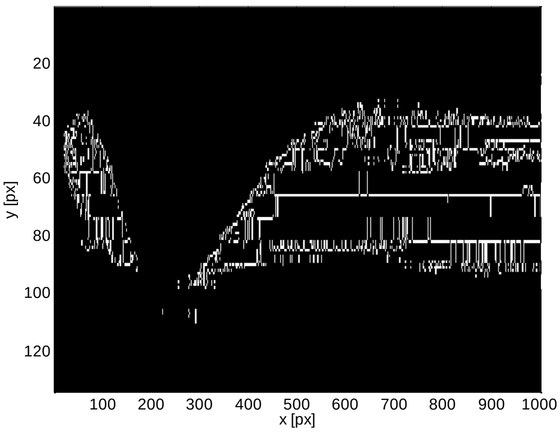

Fig. 8 MRI after the Sobel operator application

At this phase of image processing, the operator input is still necessary. The operator has to manually specify the edges, both descending and ascending. Notice that the y-axis in the image is conversely oriented. The vector of predictors and observations manually specified is illustrated in Fig. 9 by cross symbols. For further processing, the vector is approximated by model of tracked point movement. Following model [6] of tracked point movement was used

$$y_m(t) = a \cdot e^{-\left(\frac{\ln(t)-b}{c}\right)^2} , \qquad (11)$$

where a is a parameter characterizing value of the vertex of tracked point trajectory, b is a parameter characterizing moment when the trajectory reaches the vertex and c is a parameter characterizing width of the trajectory model. Presented here function of the model of the tracked point movement utilizes a modified lognormal distribution function [7]. The model of the tracked point movement, fitted to the manually specified vector of predictors and observers, is presented in Fig. 9 by dashed line. The model of tracked point movement in the MRI you can see in Fig 10. It is seen in the figure that the model fits with the nature. The model is finally utilized for further determination of eyelid movement parameters.

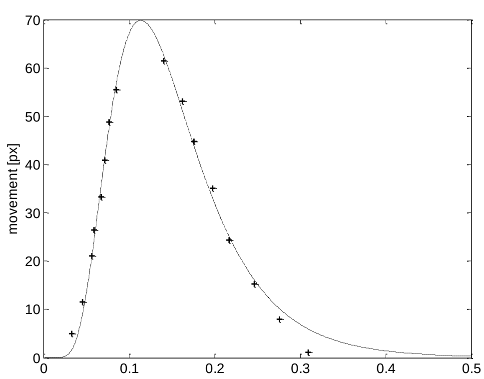

Fig. 9 Model of tracked trajectory of upper eyelid fitted to the vector of manually specified predictors and observers

Knowing the tracked point position in explicit time, the velocity and the acceleration of it can be estimated. The velocity is computed

$$v_m = \frac{\Delta y_m}{T} \qquad (12)$$

and acceleration

$$a_m = \frac{\Delta v_m}{T} \ . \qquad (13)$$

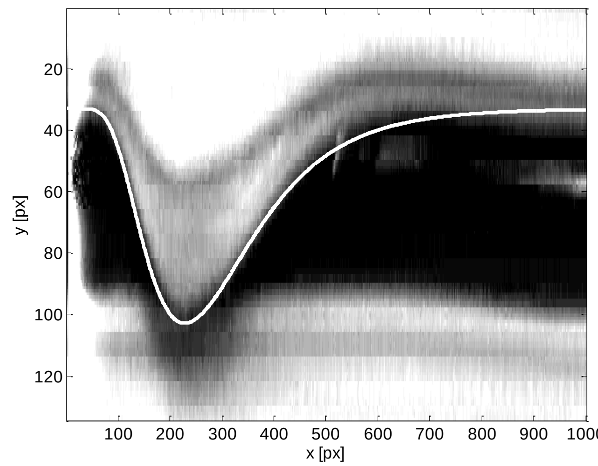

Fig. 10 MRI and the model of movement upper eyelid

Typical curve of tracked point velocity is presented in Fig. 11. Notice that the movement parameters are expressed either in pixels [px] in the case of position or in pixels per second [px/s] in the case of velocity. To obtain the said parameters in standard units [m; m/s], they have to be multiplied by image scale. The estimation of the image scale is described in [4].

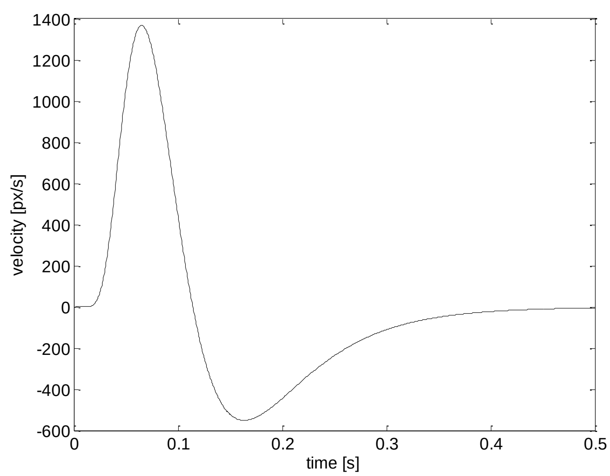

Fig. 11Velocity of the upper eyelid movement

Following circumstance was stated for estimation of the moment when eyelid begins the movement t_b. The moment when eyelid begins the movement is the moment when the rise of normalized tracked point velocity is equal to 0.1dB.

Simply; the minimal detectable movement is looked for. The circumstance is expressed as

$$20\ log\left(\frac{1}{1-v_{mN}(t_b)}\right) = 0.1\ . \tag{14}$$

The normalized velocity is computed similarly to normalized exposition

$$v_{mN}(t) = \frac{v_{m(t)}}{max(v_m)}. \tag{15}$$

The moment, when the movement of eyelid stops, can be simply estimated from the model as the moment of the vertex. However, this moment is not identical with the moment when the eye is closed t_c. Eye is closed when the upper eyelid touches the lower eyelid. This moment t_c can be estimated from MRI and eyelid movement model. The operator specifies this position y_{le} in image manually. The moment t_c is estimated than under the circumstance

$$y_m(t_c) = y_{le}\ \ . \tag{16}$$

Knowing the moments (t_a, t_b, t_c), the eye response time and time of eyelid movement can be determined. Time of eye response is equal to

$$y_m(t_c) = y_{le}\ \ . \tag{17}$$

Time of eyelid movement

$$y_m(t_c) = y_{le}\ . \tag{18}$$

Finally; total time of eye reaction is

$$y_m(t_c) = y_{le}\ . \tag{19}$$

Recorded video-sequence and described data processing method allows determination of additional interesting eye movement characteristics:

- time of closed eye T_{ce},
- time of eye re-opening T_{eo} and
- total time of eyewink T_W.

Time of closed eye starts in the moment t_c and ends in the moment when the upper eyelid separates out of lower eyelid t_o. The moment t_o is estimated under the condition

$$y_m(t_o) = y_{le}\Big|_{t_o > t_c}\ . \tag{20}$$

Time of eye re-opening begins in the moment to and finishes in the moment t_f when the eyelid again reaches the same position as in the moment t_b

$$y_m(t_f) = y_m(t_b)\Big|_{t_f > t_b}\ . \tag{21}$$

Time of closed eye is

$$y_m(t_f) = y_m(t_b)\Big|_{t_f > t_b}\ . \tag{22}$$

Time of eye re-opening

$$y_m(t_f) = y_m(t_b)\Big|_{t_f > t_b}\ . \tag{23}$$

Total time of eyewink is

$$y_m(t_f) = y_m(t_b)\Big|_{t_f > t_b}\ . \tag{24}$$

The discussed moments and time intervals are evident from Fig. 12. The moment of activation event is identical with zero time; the moment when eyelid begins the movement pertains to the moment where the curve of movement model begins rise up; the moment when eye is closed pertains to the moment when the curve of movement model crosses the line representing the lower eyelid position (horizontal line) on the ascending edge; the moment when eye re-opens pertains to the moment when the curve of movement model crosses the line representing the lower eyelid position on the descending edge; the moment of the end of eyewink pertains to the moment where the curve of movement model comes close to time axis.

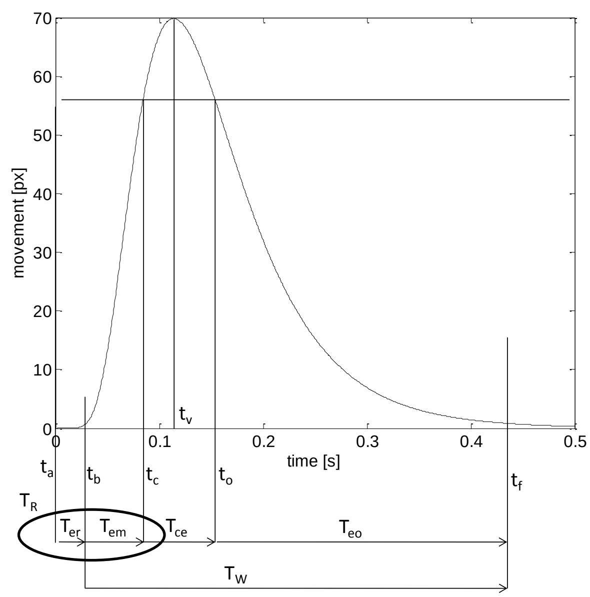

Fig. 12 Important moments and time interval during upper eyelid movement

V. Exposition of Eye Retina

The eye closing run *h(t)* as a mathematical model of upper eyelid movement (11) was developed in the previous chapter. The exposition of the eye retina can be estimated now. Thus, the exposition of eye retina [11] with consideration of (5) can be expressed

$$S = \int_{t_a}^{t_c} \Phi(t)dt = K\int_{t_a}^{t_c}\left(D_0 - A_{CS}(t)\right)^2 dt, \qquad (25)$$

where K is a constant and it is valid

$$K = \frac{\tau_{0,\lambda} \cdot I}{s^2}\ . \qquad (26)$$

Using (4, 11) for expression of $A_{cs}(t)$ and (2) for eye pupil diameter D_0, the integral (25) can be numerically integrated. Since the eye pupil does not occupy whole area between upper and lower eyelid, the pupil is overlapped when eyelid is moved over it, only. Assume that centre of eye pupil is positioned in y_{cp}, y_u is initial position of upper eyelid and y_l is position of lower eyelid as illustrated in Fig. 13. The eye pupil than lies between its vertex y_{up} and bottom y_{lp}. The moments t_{lp} and t_{up} match with positions y_{lp} and y_{up} when eylid is evelapping the eyepupil.

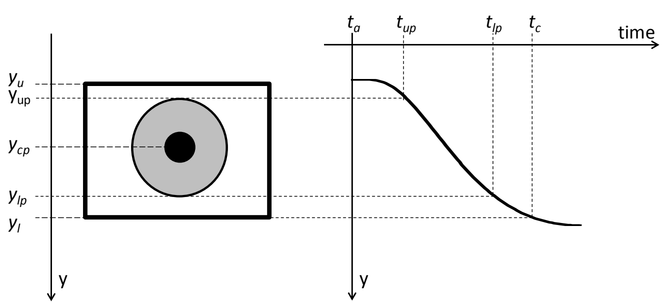

Fig. 13 Spatial and time relations during eye closing

Equation (25) than can be redefined as

$$S = K\int_{t_{up}}^{t_{lp}}\left(D_0 - A_{CS}(t)\right)^2 dt. \qquad (27)$$

VI. Conclusion

The experimental measurement for eye reaction and eyelid movement is prepared as well as the data processing for eyelid movement characteristics estimation. That will allow us to determine exact and accurate time intervals of eye reaction. Moreover, the exact estimation of eye retina exposition, after laser radiation attack, is possible, too. Pursuant to the proposed eye retina illumination model and eye reflex measurement results, the safety areas for laser device utilization can be precisely re-determined.

Acknowledgment

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References

[1] *Safety of laser productsPart 1: Equipment classification, requirements and user's guide*, IEC 60825-1:2007, International Electrotechnical Commission, 2007.

[2] L.O. Bjorn, *Photobiology – The Sience of Life and Light*, Springer Science + Business Media LLC, 2008, ISBN 978-0-387-72654-0.

[3] *American National Standard for Safe Use of Lasers*, ANSI Z136.1, American National Standard Institute, Vol. 38, #23, 2007.

[4] Racek, F., Červenka, M., Macko, M., Baláž., " Measuring and modeling of initiation mechanisms of small arms, " in *RECENT ADVANCES in APPLIED COMPUTER SCIENCE*, 2009, pp. 167-172.

[5] M.S. Nixon, A.S. Aguado, *Feature Extraction and Image Processing*, Newnes, 2002, ISBN 0750650788.

[6] Racek, F., Macko, M., Baláž., Třešňák, J., Benedik., "Determination of band position for evaluation of DNA/RNA molecular weight from electrophoretic gels, " in *6th WSEAS International Conference on SYSTEM SCIENCE and SIMULATION in ENGINEERING*, 2007, pp. 212-216..

[7] Weisstein, Eric W. *Log Normal Distribution*, From MathWorld--A Wolfram Web Resource. Available: http://mathworld.wolfram.com/LogNormalDistribution.html.

[8] Levi, L., *Applied optics*, New York: John Wiley & Sons, 1980, ISBN 0 471 05054-7

[9] Kopeika, N., S., *A system engineering approach to imaging*, Bellingam: SPIE, 1998, ISBN 0-8194-2377-7

[10] *Handbook of optics*, New York: Mcgraw-Hill book company, 1978, ISBN 0-07-047710-8

[11] Shober, H., *Das Sehen*, Leipzig: Fachbuchverlag, 1958

[12] Wissensspeicher Lasertechnik, Leipzig: VEB Fachbuchverlag, 1982

[13] El-Hofy, H., Youssef, H., "Environmental Hazards of Nontraditional Machining, " in *Proceedings of the 4th IASME / WSEAS International Conference on ENERGY & ENVIRONMENT (EE'09)*, pp. 140-145.

[14] Salerno, M., Constatntini, G., Carota, M., Casali, D., Todisco, M., "A Simulation Tool for a Laser Based Air Traffic Management System, " in *RECENT ADVANCES in CIRCUITS, SYSTEMS, ELECTRONICS, CONTROL and SIGNAL PROCESSING*, pp. 122-127

[15] Salerno, M., Constatntini, G., Carota, M., Casali, D., Todisco, M.,Bocchetti, S., "A Laser Rangefinder for Air Traffic Management: Statistical Analysis of Acquired Test Session Data, " in *Proceedings of the 8th WSEAS International Conference on APPLIED ELECTRO-MAGNETICS, WIRELESS and OPTICAL COMMUNICATIONS*, pp. 49-54

[16] Naucer, D., Bougherira, H., Assad, Z., Guessoum, A., "A MOEMS architecture for a bionic retina, " in *Proceedings of the 7th WSEAS Int. Conf. on Signal Processing, Computational Geometry & Artificial Vision*, pp. 241-245.

[17] Nowak, W., Nakayama, M., "Spectral Analysis of the Pupillary Light Reflex to Chromatic Stimuli Mediated by Intrinsically Photosensitive Retinal Ganglion Cells, " in *Proceedings of the 10th WSEAS International Conference on MATHEMATICS and COMPUTERS in BIOLOGY and CHEMISTRY*, pp. 42-47.

[18] Ando, S., "Effects of Exercise on Reaction Time to Peripheral Visual Stimuli, " in *ADVANCES IN BIOMEDICAL RESEARCH*, pp. 260-263 , ISBN: 978-960-474-164-9

[19] Nowak, W., Nakayama, M., "Preliminary Examination of Chromatic Flicker Light Stimulation EEG and Pupil Size for Observing Human Activity Levels, " in *Proceedings of the 10th WSEAS International Conference on MATHEMATICS and COMPUTERS in BIOLOGY and CHEMISTRY*, pp. 48-52.

[20] Weisstein, Eric W. "*Circular Segment*." From MathWorld--A Wolfram Web Resource. http://mathworld.wolfram.com/CircularSegment.html

[21] Staněk, S., Vizuální fotometrie a fyziologická optika. Praha: SNTL, 1980

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The main books:

Baláž, T., Racek, F., Řehoř, Z., Melša, P., *The Sights II.* Textbook, University of Defence, Brno, 2009

Baláž, T., Racek, F., Řehoř, Z., Melša, P., *Optical devices I*. Textbook, University of Defence, Brno, 2009

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The main book:

Baláž, T., Racek, F., Řehoř, Z., Melša, P., *The Sights II.* Textbook, University of Defence, Brno, 2009

Baláž, T., Racek, F., Řehoř, Z., Melša, P., *Optical devices I*. Textbook, University of Defence, Brno, 2009

Fischer, P., Baláž, T., Racek, F., Řehoř, Z., Melša, P., *Optical devices I.* Textbook , University of Defence, Brno, 2009

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The main books:

Komenda,J., *et al*. *Non-lethal weapon systems*. Textbook, University of Defence, Brno, 2006

Komenda,J., *et al*. *Wound ballistics*. Textbook, Military Academy, Brno, 2003

Komenda,J., *et al*. *Insidious weapons*. Textbook, TT, Modřice, 2002

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