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(54) Title: METHOD OF REDUCING VISIBILITY OF ILLIMINATION WHILE ACQUIRING HIGH QUALITY IMAGERY

(57) Abstract: A method of providing active illumination during biometry that utilizes pulsed lighting synchronized to frame acquisition. Two distinct illumination modalities are provided: the first maximizes the quality of images captured by the imaging system, and the second minimizes the overall illumination perceived by the user in combination with the first. The two modalities are provided substantially simultaneously. The first modality always includes a set of pulses synchronized with frame acquisition. The second modality may be either a second set of pulses not synchronized with frame acquisition or constant background illumination. The two modalities may be generated by two separate sources of illumination or by the same single illumination source. Adding the second modality to the first reduces user discomfort and the chances of an epileptic response as compared to using the first modality alone. The two modalities may have different wavelengths, pulse durations, or intensities.

METHOD OF REDUCING VISIBILITY OF PULSED ILLUMINATION WHILE ACQUIRING HIGH QUALITY IMAGERY

RELATED APPLICATIONS

Priority is claimed from i) U.S. Provisional Patent Application No. 61/075,817 filed June 26, 2008; and ii) U.S. Provisional Patent Application No. 61/185,417 filed June 9, 2009, the entire teachings of which are hereby incorporated by reference herein.

BACKGROUND OF THE INVENTION

Field of the Invention

The invention relates to biometry, the study of characteristics of people for identification purposes. More specifically, the invention relates to active illumination used during biometry, especially iris and facial recognition, for enhancing user experience while maintaining image quality.

Description of the Related Art

Active illumination has been widely used in the field of iris recognition, which is the field of recognizing individuals based on the patterns of the iris in the human eye. For example, Daugman describes a range of iris recognition deployments all using active infra-red illumination [J. Daugman / "The Importance of being Random : Statistical Principles of iris Recognition" / Pattern Recognition 26 (2003) 279-291]. A problem however is that the illumination is often noticed by the subject, which may cause them some temporary discomfort while using the system.

Moreover, figure 1 shows methods for iris recognition using pulsed lighting 11 synchronized to frame acquisition 10 that has been described in US 2003/0169334 A1 and US Patent 7,542,628, for example, as a means to stop the motion of an individual while performing iris recognition. The top graph on the horizontal axis shows time, and on the vertical axis it is shown whether a frame is being acquired or not. In this example three frames of a continuous sequence are shown being acquired, with each frame being acquired in a finite time period T.

The illumination in these systems is more noticeable to the user due to the repetitive on/off cycle of the illumination. Pulsed Light Emitting Diode (LED) lighting compared to constant LED lighting is preferable in these applications since for a given average heat dissipation capability of an LED, more power can be concentrated in the pulse during which the frame is being acquired, resulting in higher quality imagery with a lower signal to noise ratio, rather than wasting the power during the time period when the image is not being acquired.

In addition, as iris recognition devices have becomes smaller, a side effect is that the user is more likely to look directly at or near the light sources mounted within a compact case. As such, the impact of the illumination is perceptually much greater than if the illumination were placed elsewhere. Put simply, the illuminators are more noticeable to the user, even though the incident power to the eye is the same compared to when the illuminators are placed elsewhere.

Of equal importance, the power of Light Emitting Diode (LED) illumination has increased substantially in recent years so that the LEDs are that much more noticeable to the user even though the incident power is the same, compared to less powerful LEDs spread over a larger area. High power LEDs can now be pulsed at >=250mA. We have found that the use of pulsed illumination combined with the two factors above vastly increases the user's perception of the illumination. This very high perception of the illumination even given safe illumination intensity level can not only be annoying to a user, it can also create photosensitive epilepsy in certain subjects.

Wilkins in "Visual Stress", Oxford Univ Press, 1995 describes how the peak response for photosensitive epilepsy is approximately 15Hz, and the wavelength of light to which patients are most sensitive is in the red wavelength region, which is near the infra-red region used for iris recognition.

For all the aforementioned reasons therefore, it is important to reduce the visibility of illumination to the subject, while not impacting the quality of imagery acquired. This is a difficult problem since changing the characteristics of the illumination can potentially adversely impact the characteristics of the images being acquired.

SUMMARY

In light of these and other problems, we have devised a method of illuminating the subject and acquiring imagery for use in applications such as iris or facial recognition that that exploits differences between the characteristics of the imaging system and the characteristics of the human eye in order to maximize the quality of the images being acquired while minimizing the illumination being perceived by the user. We use four differences in the characteristics of the imaging system and the human eye: temporal persistence of the human visual system, background light level, spectral response, and asymmetric perceived pulse brightness. These methods can be used individually or collectively, depending on the constraints and specifications of the particular device.

The invention is a method of providing active illumination during biometry that utilizes pulsed lighting synchronized to the frame acquisition of an imaging system. The inventive method includes the steps of a) providing a first illumination modality that maximizes the quality of images captured by the imaging system; and b) providing a second illumination modality, substantially simultaneously as the first illumination modality, that, in combination with the first illumination modality, minimizes the overall illumination perceived by the user.

In one aspect, the first illumination modality is provided as a first set of periodic illumination pulses synchronized with the frame acquisition of an imaging system, and the second illumination modality is provided as a second set of periodic illumination pulses not synchronized with imaging system frame acquisition. Preferably, the pulse rate frequency of a combination of the first and second sets of illumination pulses is greater than a response frequency for photosensitive epilepsy and is 2-10 times the pulse rate of the first set of pulses alone. More preferably, the intensity of the second set of pulses is equal to or greater than the intensity of the first set. The frame acquisition rate of the imaging system may be set to a maximum value.

In another aspect, the first illumination modality is provided a first set of periodic illumination pulses, and the second illumination modality is provided as constant background illumination. The background illumination of the second modality is preferably in the range of from at least .02 times, up to but not equal to, the average illumination of the pulses of the first illumination modality. Optionally, the first and second modalities may be both provided by the same single illumination source, or they may each be provided by different illumination sources. Optionally, the wavelength of the light from the first illumination source is different from the wavelength of the light of the second illumination source. In this case, the first wavelength is substantially in the range of 700-900 nm and the second wavelength is substantially in the range of 400-700 nm. In addition or in the alternative, the intensity of the light from the second illumination source is substantially 0.1-10 times the intensity of the light from the first illumination source.

In another aspect of the invention, the first illumination modality is provided by a first illumination source that generates a first set of periodic illumination pulses, and the second illumination modality is provided by a second illumination source to generate a second set of periodic illumination pulses having a substantially inverse waveform of the first set of pulses. As before, the wavelength of the light from the first illumination source may be different from the wavelength of the light of the second illumination source. Again, the first wavelength is preferably substantially in the range of 700-900 nm and the second wavelength is preferably substantially in the range of 400-700 nm.

In yet another aspect of the invention, the first modality includes pulses of a first duration and having a first intensity synchronized with imaging system frame acquisition, while the second modality includes pulses not synchronized with imaging system frame acquisition and have a shorter duration but equal or greater intensity than the pulses of the first modality. Preferably, the second pulses are .001 to 1 times the duration and 1 to 100 times the intensity of the first pulses.

In all cases, it is preferred to include in the method the steps of sensing the actual output of at least one of the first and second illumination modalities, and adjusting the output of at least one of the first and second illumination modalities in response to the output sensed in the sensing step. One example is to provide at least one photodiode for detecting the output of one or more modalities and to connect the photodiode to the controller(s) of the one or more illumination sources to provide feedback to the controller(s).

More generally, the invention is a method of providing active illumination during the acquisition of high quality images of a person that utilizes pulsed lighting synchronized to imaging system frame acquisition. A first illumination modality is provided that maximizes the quality of images captured by the imaging system. Substantially at the same time, a second illumination modality is provided that, in combination with the first illumination modality, minimizes the overall illumination perceived by the user.

The invention also includes an image capturing apparatus that performs the abovementioned methods.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows, on the top, image frames being acquired at different time instants, and on the bottom, shows illumination pulses synchronized to the frame acquisition.

Figure 2 shows a first system implementation of the invention, comprising an illuminator, a lighting controller, a camera controller, a camera, an optional photodiode, with the camera and illuminator positioned facing the direction of a subject.

Figure 3 shows, on the top, image frames being acquired at different time instants, and on the bottom, shows a first modality of illumination synchronized to the frame acquisition and a second modality of illumination not synchronized with the frame acquisition.

Figure 4 shows, on the top, image frames being acquired at different time instants, and on the bottom, shows a first modality of illumination synchronized to the frame acquisition and a second modality of illumination not synchronized with the frame acquisition, whereby the combined frequency of the first and second modalities of illumination is x3 the frequency of the frame acquisition.

Figure 5 shows, on the top, image frames being acquired at different time instants, and on the bottom, shows a first modality of illumination pulses synchronized to the frame acquisition and a second modality of illumination that provides substantially constant background illumination.

Figure 6 shows a second system implementation of the invention, comprising two illuminators, a lighting controller, a camera controller, a camera, two optional photodiodes, with the camera and illuminators positioned facing the direction of a subject.

Figure 7 shows, on the top, image frames being acquired at different time instants, in the middle shows a first modality of illumination pulses synchronized to the frame acquisition being provided by a first illuminator, and on the bottom, shows a second modality of illumination comprising substantially constant background illumination being provided by a second illuminator.

Figure 8 shows, on the top, the spectral sensitivity of the human eye, on the bottom shows the spectrum of an infra-red LED source, and in the diagonally-marked area shows the overlap between these two spectrums.

Figure 9 shows on the top, shows the spectrum of an infra-red LED source, on the bottom shows the spectrum of a second LED source, and in the diagonally-marked area shows the overlap between these two spectrums.

Figure 10 shows on the top a first modality of illumination, and on the bottom shows a second modality of illumination that is substantially the inverse of the first modality of illumination

Figure 11 shows a first illuminator separated from a second illuminator by a distance D, such that the illuminators are positioned substantially facing a user at a distance R

Figure 12 shows, on the top, image frames being acquired at different time instants, and on the bottom, shows a first modality of illumination synchronized to the frame acquisition and a second modality of illumination not synchronized with the frame acquisition such that the intensity of the second modality is greater than or equal to the intensity of the first modality.

Figure 13 shows, on the top, image frames being acquired at different time instants, and on the bottom, shows a first modality of illumination synchronized to the frame acquisition and a second modality of illumination not synchronized with the frame acquisition such that the intensity of the second modality is greater than or equal to the intensity of the first modality, and whereby the combined frequency of the first and second modalities of illumination is x3 the frequency of the frame acquisition.

DETAILED DESCRIPTION OF THE DRAWINGS AND THE INVENTION

Description of the invention will now be given with reference to Figs. 1-13. It should be understood that these figures are exemplary in nature and in no way serve to limit the scope of the invention, which is defined by the claims appearing hereinbelow.

In the first aspect of the invention, we take advantage of the temporal persistence of the human visual system, such that individual pulses at higher frequencies are less discernible than individual pulses at lower frequencies. Figure 2 shows such a system implementation. An illuminator 22 is controlled by a lighting controller 20, which is synchronized by a camera controller 21 to a camera 25 that acquires frames. An optional photodiode 23 can also be connected to the lighting controller 20. The illuminator 22 projects light onto the optional photodiode 23 as well as on the subject 24, shown on the bottom of the figure. The illumination is reflected off the eye of the subject 24, and an image of the eye is captured using the camera 25 shown to the right of the figure.

Most camera sensors are capable of acquiring data at 5-30 frames per second or higher, depending on the resolution of the imager. As the resolution of the imager increases, the number of pixels per image that needs to be acquired also increases, and therefore the rate at which data can be acquired through a given data bandwidth channel reduces. Iris recognition typically uses high resolution cameras (for example, 1.3 Mpixel or greater) and such cameras often have frame rates limited to 5-15 frames per second as a result. US 2003/0169334 A1 and US Patent 7,542,628 describe methods whereby the frame acquisition is synchronized to the illumination pulse. If the acquired frame rate and illumination pulse rate is set too low, then the performance of the iris recognition device can be impacted since not enough frames are being acquired in a sufficient time period for reliable acquisition of eye imagery of the subject. On the other hand, if the acquired frame rate and illumination pulse rate is set at the highest possible rate for the sensor, which may be close to 15 frames and illumination pulses per second, then the illumination pulse rate is close to the peak response for photosensitive epilepsy.

The first aspect of the invention overcomes this problem by using a different pulse rate for the illumination compared to the frame acquisition rate of the sensor, such that a portion of the illumination pulses are still synchronized with frame acquisition but where the remaining portion of illumination pulses is not. Put another way, a first set of pulses coincide with frame/image capture (the synchronized pulses), while a second set of pulses are triggered at other times (the asynchronous pulses). The pulse rate of the illumination is set sufficiently high in order to take advantage of the persistence of the human visual system so that the illumination pulses appear almost unnoticed to the subject, but a subset of the pulses are still synchronized to the lower frame acquisition rate so that illumination is provided at the lower frequency in order to provide high-quality, well-illuminated imagery. In this way, photosensitive epilepsy or discomfort to the user is not a concern, even though images are being illuminated and acquired at a rate to which the human eye is much more sensitive.

Figure 3 shows an example of this method whereby frames are acquired as shown in 10, and whereby illumination is pulsed as shown in 30 and 31. The top graph shows time on the horizontal axis, and on the vertical axis shows by the value 1 that an image is being acquired during that time instant, and by the value 0 that imagery is not being acquired. The bottom graph shows time on the horizontal axis to the same scale as the first graph, and on the vertical axis shows the intensity of the illumination pulse. Note that the pulse rate of the illumination 30 in the bottom graph is different from the acquisition rate of the frames 10 in the top graph. A subset 30 of the illumination pulses are synchronized with the cameras in order to provide illumination during the time that the imagery is being acquired, but the remaining subset 31 of the illumination pulses occur between the times that images are acquired. By using this method, the pulse rate of the illumination is higher than the frame acquisition rate. For example, in the example shown in Figure 3, if the frame acquisition rate is 15 frames per second, then the illumination pulse rate is 30 pulses per second. While an illumination pulse rate of 15 pulses per second is very noticeable and is at the peak response for photosensitive epilepsy, a pulse rate of 30 pulses per second is much less noticeable to a user.

As shown in figure 4, note that arbitrary illumination pulses 41 can be inserted between the illumination pulses 40 that are synchronized with the illumination, as shown in Figure 4. In this case 2 pulses are inserted between the pulses that are synchronized with the frame acquisition, resulting in an illumination frequency that is x3 the frequency of frame acquisition. A Fourier analysis of the pulse train can show the decomposition of the output illumination pulse rate. Due to the limited response time of the human visual system, illumination pulses at 30Hz or higher are almost unnoticeable compared to pulses at 15Hz or lower, much in the same way as flickering of the display on a television set or fluorescent lights are generally not noticed because the flicker occurs at 30Hz or higher. A preferred pulse rate of the illumination is within the range of x2 to x 10 the frame acquisition rate. By "pulse rate" it is understood to mean the primary frequency of the respective pulses, since the pulses are square waves (which decompose into multiple frequencies).

The asynchronous pulse sets 31 and 41 are shown to be evenly periodic, and that is preferred. However, the asynchronous pulses need not be evenly periodic; they can be spaced unevenly in time.

The intensity of the illumination between frame acquisition does not necessarily need to be smaller than the intensity of the illumination that is synchronized with frame acquisition, in order to achieve optimal imagery. In fact, we have found it advantageous to use the same or higher intensity illumination between frame acquisition compared to during frame acquisition, as described further in the fourth aspect of the invention.

In the second aspect of the invention, we take advantage of another property of the human visual system such that the sensitivity of the eye is substantially consistent with Weber's law whereby for a given wavelength of light the minimum brightness *difference* that can be perceived is approximately proportional to the average brightness being perceived. In other words, the brighter the scene, then the less sensitive the human visual system is to a fixed difference in illumination either temporally or spatially. We impose this constraint with our iris recognition system using 2 methods.

The first method of the second aspect of the invention is shown in figure 5. We use a single illumination source 22 that uses illumination pulses 50 of intensity I (51) that are synchronized to frame acquisition 10, but using the lighting controller 20 we also add a constant background illumination signal B (52) to the same illuminator 22 so that the brightness of the illumination is non-zero between the pulses. An injection of even a small background illumination can greatly reduce the perceived brightness of the illumination pulse to the human visual system. Put simply, illumination is much more noticeable when pulsed in complete darkness compared to being pulsed with a background of even small, constant illumination. A preferred intensity of background illumination B (52) is in the range of from approximately 0.05 up to but not including 1 times the intensity peak I (51) of the pulsed illumination.

The second method of the second aspect of the invention is shown in figure 6, which is the same system shown in figure 1 except the lighting controller 20 is now controlling 2 illumination sources, 22A and 22B. As shown in figure 6 and 7, we use one illumination source 22A synchronized to frame acquisition 10 for illuminating the eye 24 using pulsed illumination 11, and a second illumination source 22B in order to provide the background illumination. The advantage of using 2 illumination sources instead of 1 is that more power can be projected to the user 24 since more illuminators are available, and also the illuminators can optionally be of different wavelengths, which has some advantages. For example, the preferred wavelength range of the first illumination source 22A for illuminating the eye for iris recognition is substantially 700-900nm which lies in the near infra-red spectrum. As described below a first preferred wavelength range of the second illumination 22B is within 400-700nm which lies in the spectrum to which humans are sensitive, with a second preferred wavelength range being near 660nm or in the spectrum that appears red to a human observer. Figure 8 on the top shows the spectral sensitivity 80 of the human eye, showing the strong response in the 400-700nm wavelength range. Figure 8 on the bottom shows an example of the spectrum 81 of an infra-red LED which in this case is centered about 830nm. While most of the infra-red illumination is invisible to the human eye, a portion of the illumination is visible as shown by the intersection 82 of the human response curve with the illumination response curve, shown by the diagonally-marked area in figure 8. This illumination appears red to the human eye. Figure 9 on the top shows the same spectrum 81 of the infra-red illuminator as shown in figure 8, but on the bottom shows the spectrum 90 of a second illuminator that in this case peaks in the region of 660nm, which also appears substantially red to the human eye. By projecting substantially red background illumination from the second illuminator of a similar color to the residual visible illumination from the infra-red illuminator, color differences are minimized and the infra-red illuminator becomes almost unnoticeable to a human observer. Notwithstanding this, a benefit is still achieved even if the second illuminator has a different color compared to the infra-red illuminator.

A preferred intensity of the second illuminator source is in the range of 0.1 to 10 of the peak intensity of the infra-red pulsed illumination.

In the third aspect of the invention, we again take advantage of the differences in the spectral response of the visual system compared to the spectral response of the camera system. Similarly to the method described above, in this embodiment of the invention we also introduce a second illumination module with wavelength characteristics that are substantially different from the wavelength characteristics of the first illumination module. In this case however, as shown in figure 10, we control each illumination module such that, at least for the most part, while one module (11) is illuminated, the other (100) is not, and vice versa; i.e., that illumination of one module has substantially the inverse waveform of the other module. Preferably, the two modules have precisely inverse waveforms, however as frequency increases, it rises above the threshold at which the human eye can detect a difference. For example, a waveform at 100Hz and a waveform at 200Hz are different, but to the human eye, they may look the same, since the eye cannot respond that quickly.

The wavelength spectrums of the first and second illuminators are also chosen such that the spectrum defined by the intersection 82 of the human-visible spectrum and the spectrum of the first illuminator, and the spectrum defined by the intersection of the human-visible spectrum and the spectrum of the second illuminator are substantially the same, as described earlier and shown in figure 8 & 9. The eye perceives substantially non time-varying illumination since the addition of the two signals in the two wavelength spectrums from the two illuminators results in substantially uniform perceived illumination both in terms of intensity and color. On the other hand, the camera perceives substantially pulsed illumination from the signal primarily from the first wavelength spectrum band.

While reducing or eliminating the magnitude of visible pulsed illumination observed by the subject substantially reduces discomfort, if the two or more illuminators are positioned substantially apart from each other, then spatial flickering may still be observed solely from the difference in position, even if the wavelength spectrum of each illuminator were identical. Figure 11 shows the two illuminators 22A and 22B separated by distance D (111) and observed at a viewing radius R (110) and at an angle Theta (112) with respect to the user. Angular sensitivity of the human visual system is essentially in two parts: (i) peripheral angular sensitivity and (ii) foveal angular sensitivity. The peripheral angular sensitivity or human ability to discern an object viewed in the periphery begins to reduce dramatically at approximately 1 line/pairs per 1/3 degree (approximately 0.006 Radians). Foveal angular sensitivity or ability to discern an object in the fovea begins to reduce dramatically at approximately 1 line/pairs per 1/30 degree (approximately 0.0006 Radians). From geometry, for small values of Theta, the separation of the first and second illuminators is given by D = R * Theta, where Theta is in Radians and R is the distance of the user from the illuminators. The arrangement of the illumination may be such that the fovea of the eye is directly facing the illumination, or the illumination be offset such that it is facing the periphery of the eye. In one preferred embodiment therefore, it is preferred that the maximum separation of the first and second illuminators is governed by D = R * 0.0006. In an exemplary system, R may range from 0.5 to 2m, which results in maximum separation range for D to range from 0.3 mm to 1.2 mm. In another preferred embodiment, it is preferred that the maximum separation is governed by D = R * 0.006. In a second exemplary system, R may range from 0.5 to 2m, which results in maximum separation range for D to range from 3 mm to 12 mm.

In the fourth aspect of the invention, we take advantage of another property of the human visual system such that the perceived temporal response of the eye is non-symmetric for illumination that transitions from off-to-on, compared to light that transitions from on-to-off. More specifically, the perceived response time of the eye has a decay time that is longer than the attack time. For example, a description of this property of the eye is given by Jinno et. al "Effective Illuminance Improvement of a Light Source by using Pulse Modulation and Its Physcophysical Effect on the Human Eye" in J. Light & Vis. Env. Vol.32, No.2, 2008.

As shown in figure 12, we take advantage of this by modifying the pulse intensities and pulse widths such that the pulses 121 that occur inbetween pulses 120 that are synchronized with the frame acquisition 10 have lower pulse widths but the same or higher intensities compared to the intensities and widths of the pulses 120 that are synchronized with the frame acquisition. The human eye perceives the very bright but short pulse, and perceives that the very short pulse lasts longer than it actually does. The advantage is that with only a very small amount of power applied to the LEDs between the pulses that are synchronized with frame acquisition, the user will perceive bright illumination. The less power that is applied to the pulses 121 between the pulses 120 that are synchronized to the frame acquisition 10, then the more power that can be applied to the pulses 120 applied during frame acquisition for a given heat dissipation level of the LEDs. A preferred pulse rate of the illumination is within the range of x2 to x 10 the frame acquisition rate. A preferred ratio of the width of the pulses that are synchronized to the frame acquisition compared to the width of the other pulses is within the range of 1 to 1000. A preferred ratio of the intensity of the pulses that are synchronized to the frame acquisition compared to the intensity of the other pulses is within the range of 0.1 to 1. As shown in figure 13, multiple pulses 122 can be introduced to occur inbetween pulses 120.

As described in the four aspects of the invention above, the characteristics of the illumination control signals (for example pulse width) are adjusted substantially within the preferred ranges to reduce or eliminate perceived flicker while maintaining high quality image acquisition. As shown in figure 2 and 6, in an additional optional embodiment, one or more photodiodes 23, and 23A, 23B monitor the illumination being presented by the one or more illuminators 22, and 22A,22B, in any of aspects of the inventions described above. The brightness and spectral properties of some illuminators change over time, and this method allows residual flicker from such changes to be minimized. A preferred embodiment is such that the photodiode(s) has a response curve similar to the spectral response of the human visual system. In this way, controlling the illuminators such that the flicker output from the photodiode(s) is minimized is substantially equivalent to minimizing the flicker observed by a user.

Having described certain embodiments of the invention, it should be understood that the invention is not limited to the above description or the attached exemplary drawings. Rather, the scope of the invention is defined by the claims appearing hereinbelow and any equivalents thereof as would be appreciated by one of ordinary skill in the art.

What is claimed is:

1. A method of providing active illumination during biometry that utilizes pulsed lighting synchronized to imaging system frame acquisition, comprising the steps of:

a) providing a first illumination modality that maximizes the quality of images captured by the imaging system; and

b) providing a second illumination modality, substantially simultaneously as the first illumination modality, that, in combination with the first illumination modality, minimizes the overall illumination perceived by the user.

2. A method of providing active illumination during biometry according to Claim 1, further comprising the step of providing a single illumination source, wherein:

said step a) further comprises the step of providing a first set of periodic illumination pulses synchronized with imaging system frame acquisition; and

said step b) further comprises the step of providing a second set of periodic illumination pulses not synchronized with imaging system frame acquisition.

3. A method of providing active illumination during biometry according to Claim 2, wherein a frequency of a combination of the first and second sets of illumination pulses is greater than a response frequency for photosensitive epilepsy.

4. A method of providing active illumination during biometry according to Claim 2, wherein a pulse rate of a combination of the first and second sets of illumination pulses falls substantially within the range of 2-10 times the pulse rate of the first set of pulses alone.

5. A method of providing active illumination during biometry according to Claim 2, wherein the intensity of the second set of pulses is equal to or greater than the intensity of the first set.

6. A method of providing active illumination during biometry according to Claim 1, further comprising the step of setting a frame acquisition rate of the imaging system to a maximum value.

7. A method of providing active illumination during biometry according to Claim 1, wherein:

step a) provides the first illumination modality as a first set of periodic illumination pulses, and

step b) provides the second illumination modality as constant background illumination.

8. A method of providing active illumination during biometry according to Claim 7, wherein the background illumination of the second modality is in the range of from at least .02 times, up to but not equal to, the average illumination of the pulses of the first illumination modality.

9. A method of providing active illumination during biometry according to Claim 7, wherein step a) and step b) are both provided by the same single illumination source.

10. A method of providing active illumination during biometry according to Claim 7, wherein step a) is performed by a first illumination source and step b) is performed by a second illumination source.

11. A method of providing active illumination during biometry according to Claim 10, wherein a first wavelength of the light from the first illumination source is different from a second wavelength of the light of the second illumination source.

12. A method of providing active illumination during biometry according to Claim 11, wherein the first wavelength is substantially in the range of 700-900 nm and the second wavelength is substantially in the range of 400-700 nm.

13. A method of providing active illumination during biometry according to Claim 10, wherein the intensity of the light from the second illumination source is substantially 0.1-10 times the intensity of the light from the first illumination source.

14. A method of providing active illumination during biometry according to Claim 1, wherein:

step a) further comprises the step of providing a first illumination source to generate a first set of periodic illumination pulses; and

step b) further comprises the step of providing a second illumination source to generate a second set of periodic illumination pulses having a substantially inverse waveform of the first set of pulses.

15. A method of providing active illumination during biometry according to Claim 14, wherein a first wavelength of the light from the first illumination source is different from a second wavelength of the light of the second illumination source.

16. A method of providing active illumination during biometry according to Claim 15, wherein the first wavelength is substantially in the range of 700-900 nm and the second wavelength is substantially in the range of 400-700 nm.

17. A method of providing active illumination during biometry according to Claim 15, wherein the maximum distance between the first and second illumination sources is D= .0006R.

18. A method of providing active illumination during biometry according to Claim 15, wherein the maximum distance between the first and second illumination sources is D= .006R.

19. A method of providing active illumination during biometry according to Claim 1, wherein:

said step a) further comprises the step of providing a first set of periodic illumination pulses of a first duration and having a first intensity synchronized with imaging system frame acquisition;

said step b) further comprises the step of providing a second set of periodic illumination pulses not synchronized with imaging system frame acquisition, said second set of pulses having a second duration shorter than the first duration and a second intensity equal to or greater than the first intensity.

20. A method of providing active illumination during biometry according to Claim 19, wherein the second pulses are .001 to 1 times the duration and 1 to 100 times the intensity of the first pulses.

21. A method according to Claim 1, further comprising the steps of:

sensing the actual output of at least one of the first and second illumination modalities; and

adjusting the output of at least one of the first and second illumination modalities in response to the output sensed in the sensing step.

22. A method according to Claim 21, further comprising the step of using the sensed output to minimize the difference in illumination between the first and second modalities of illumination.

23. A method of providing active illumination during the acquisition of high quality images of a person that utilizes pulsed lighting synchronized to imaging system frame acquisition, comprising the steps of:

a) providing a first illumination modality that maximizes the quality of images captured by the imaging system; and

b) providing a second illumination modality, substantially simultaneously as the first illumination modality, that, in combination with the first illumination modality, minimizes the overall illumination perceived by the user.

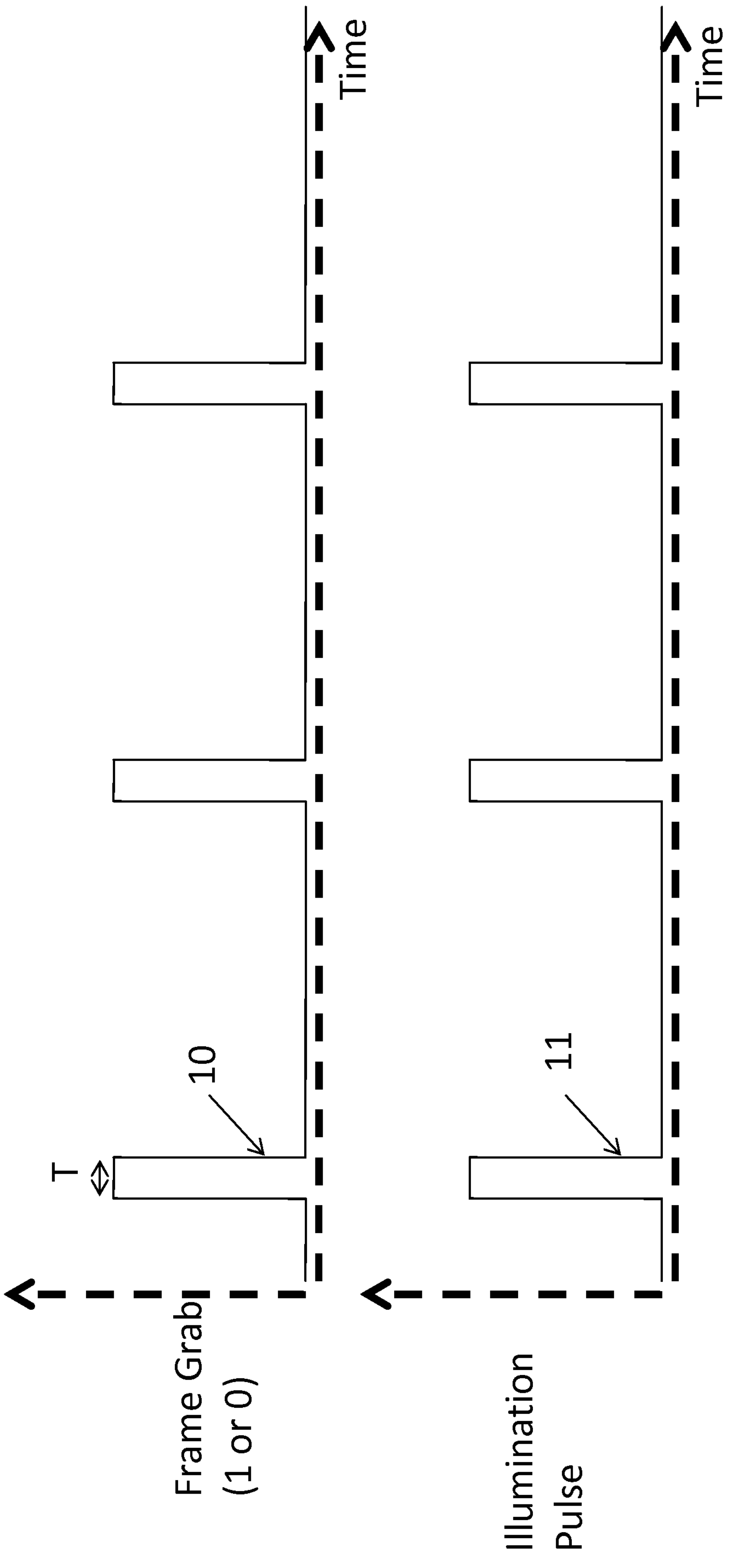

Figure 1

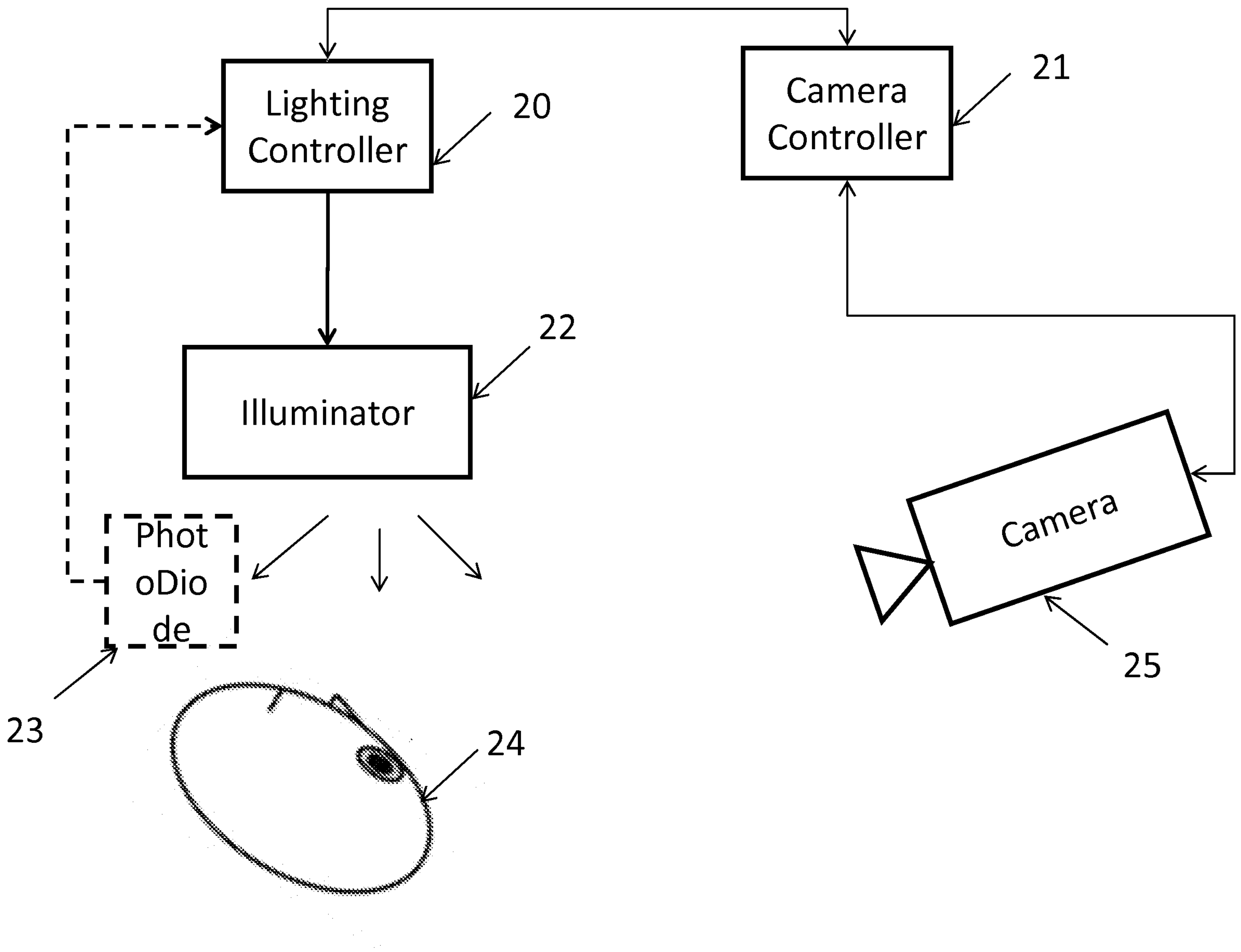
Lighting
Controller
20
Camera
Controller
21
Illuminator
22
Phot
oDio
de
23
24
Camera
25

Figure 2

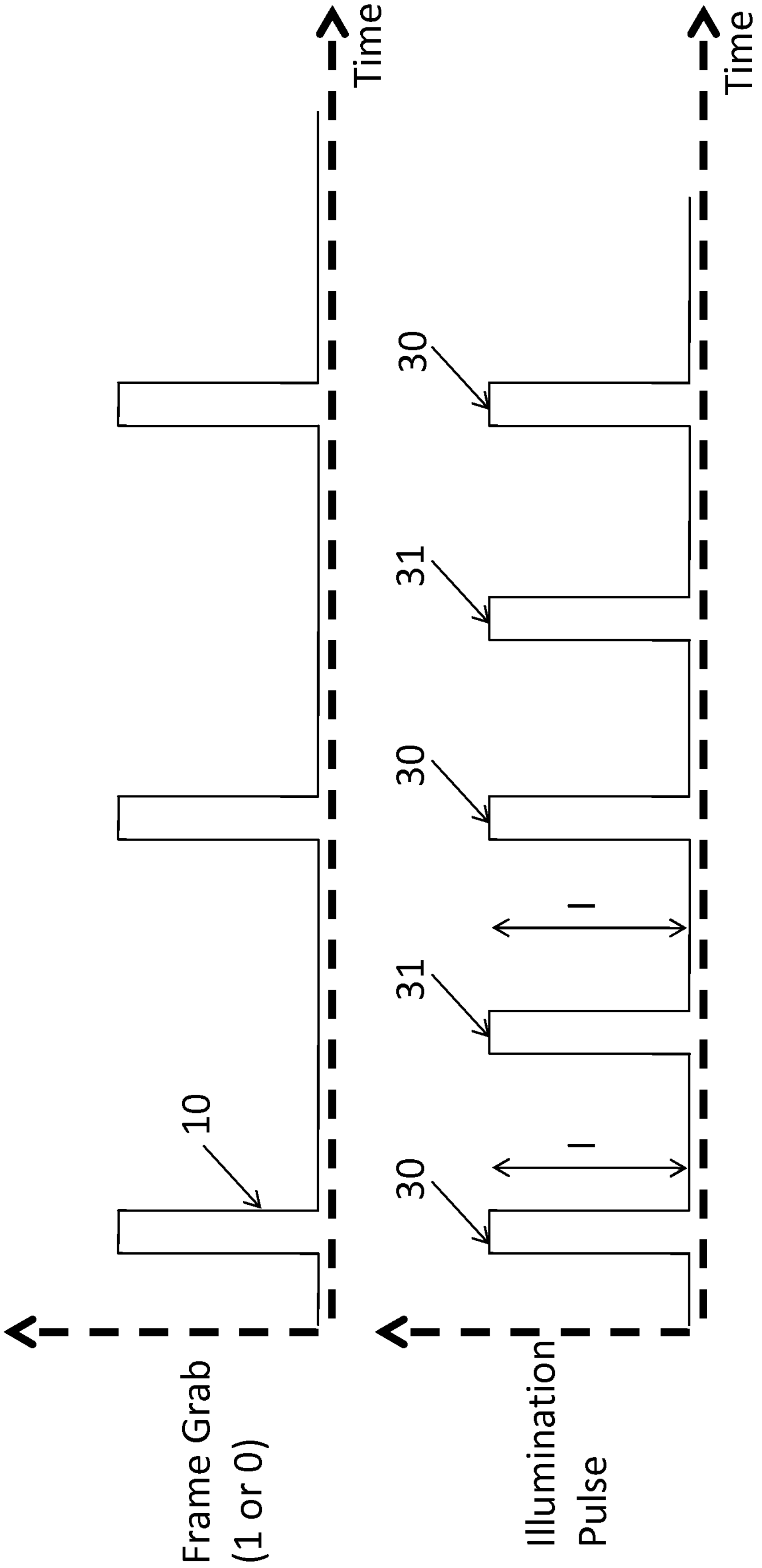
Frame Grab
(1 or 0)
Time
10
Illumination
Pulse
Time
30
31
30
31
30
I
I

Figure 3

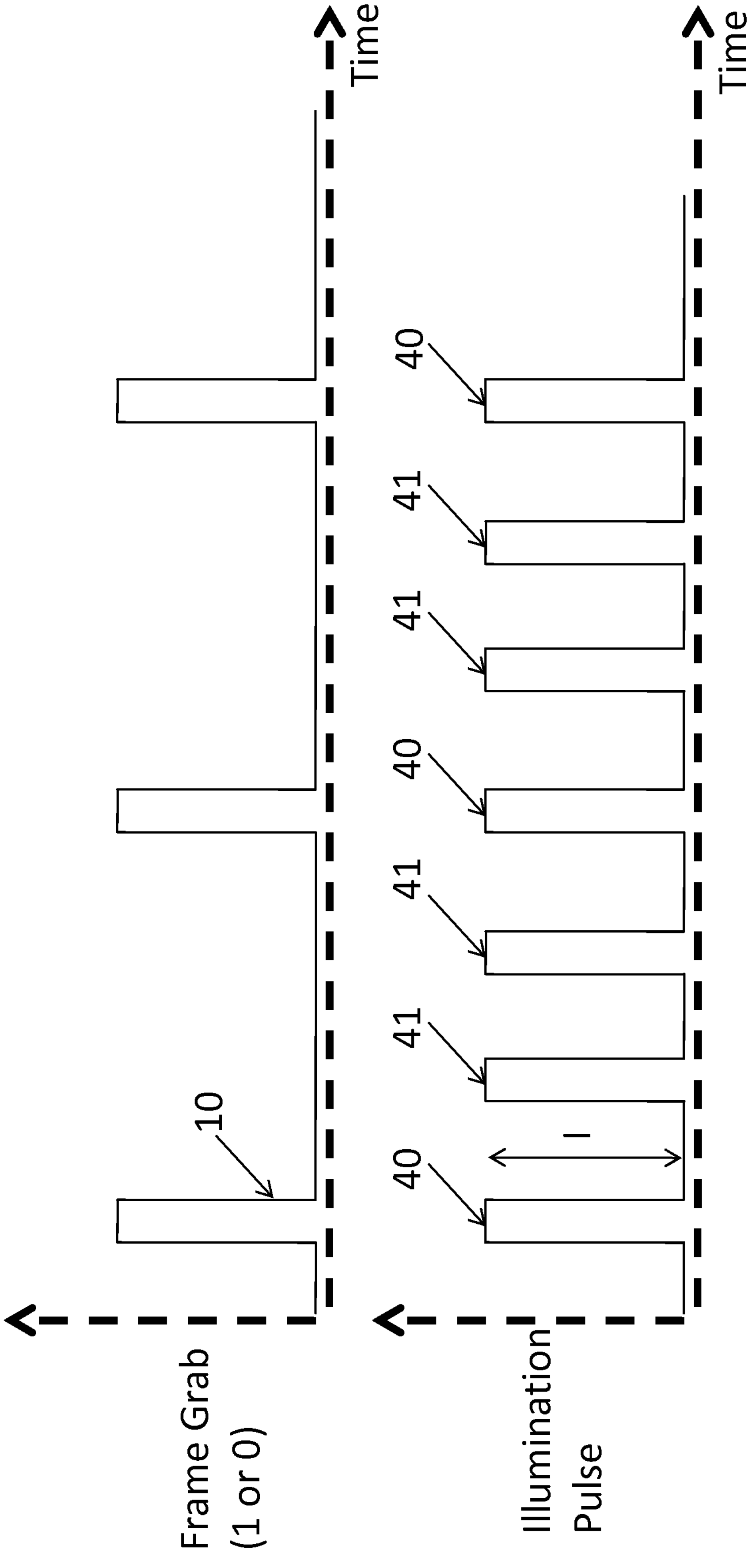
Frame Grab
(1 or 0)
Time
10
Illumination
Pulse
Time
40
41
41
40
41
41
40
I

Figure 4

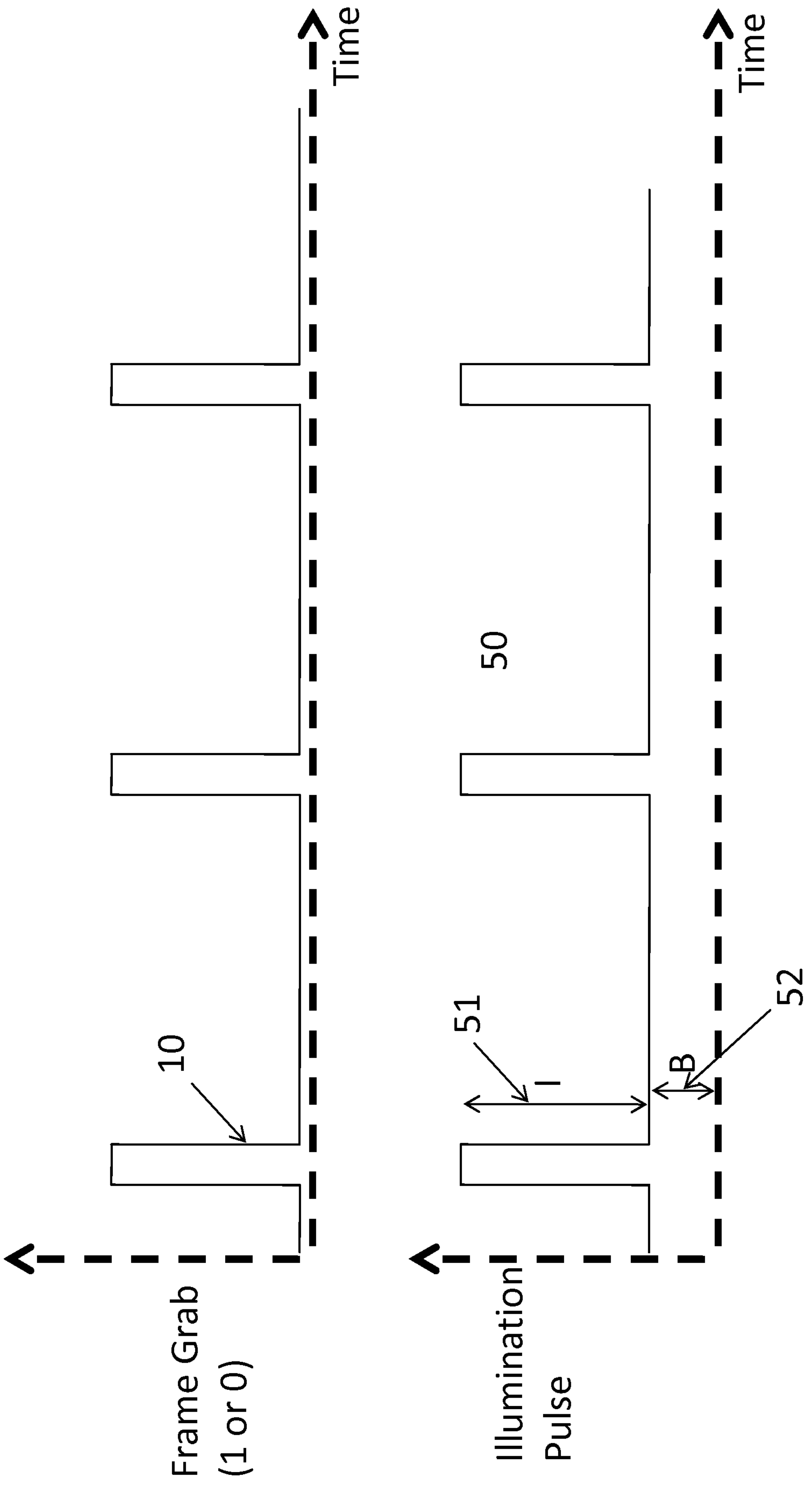

Figure 5

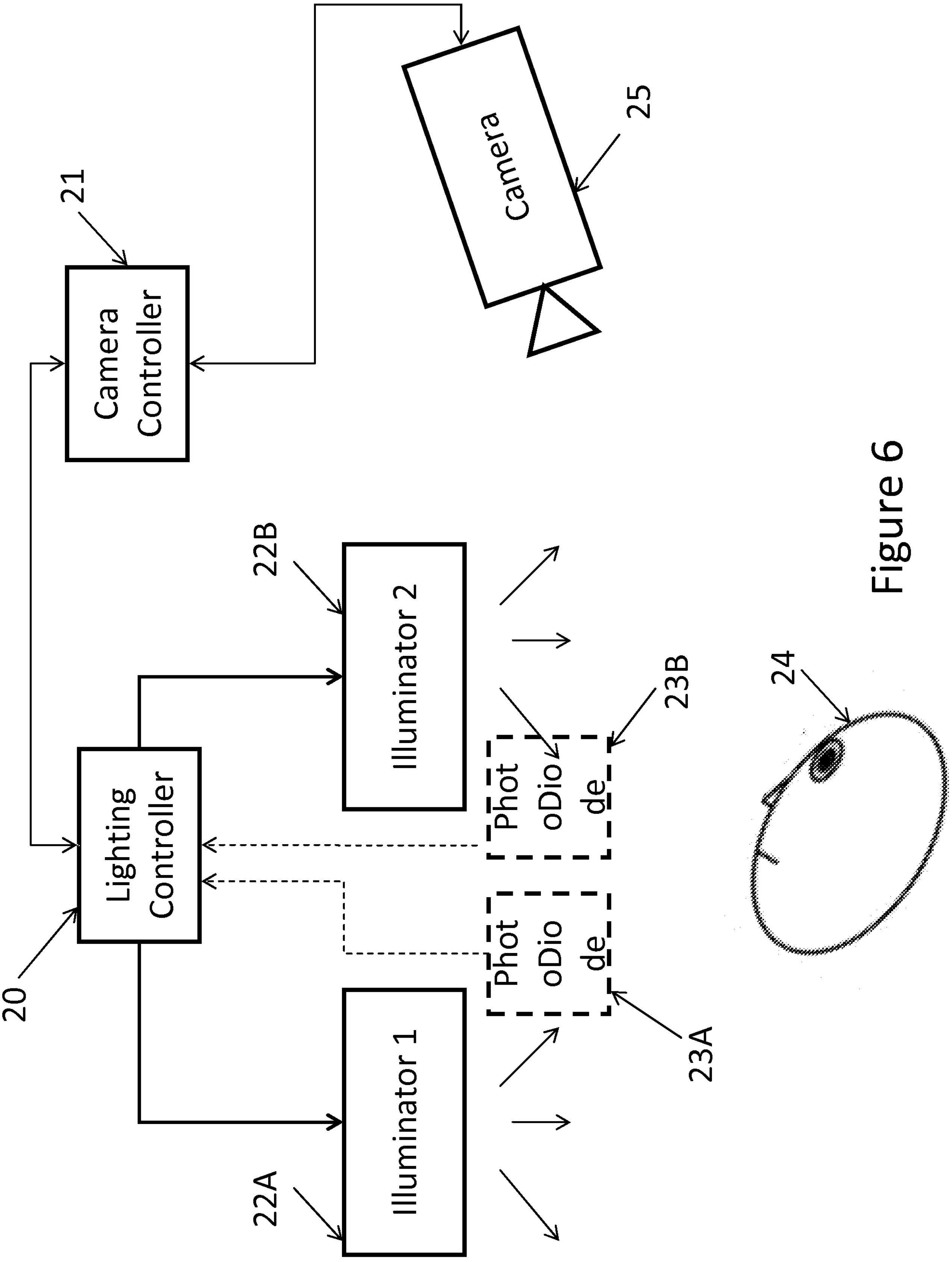
20
Lighting Controller
21
Camera Controller
25
Camera
22A
Illuminator 1
22B
Illuminator 2
23A
Phot oDio de
23B
Phot oDio de
24

Figure 6

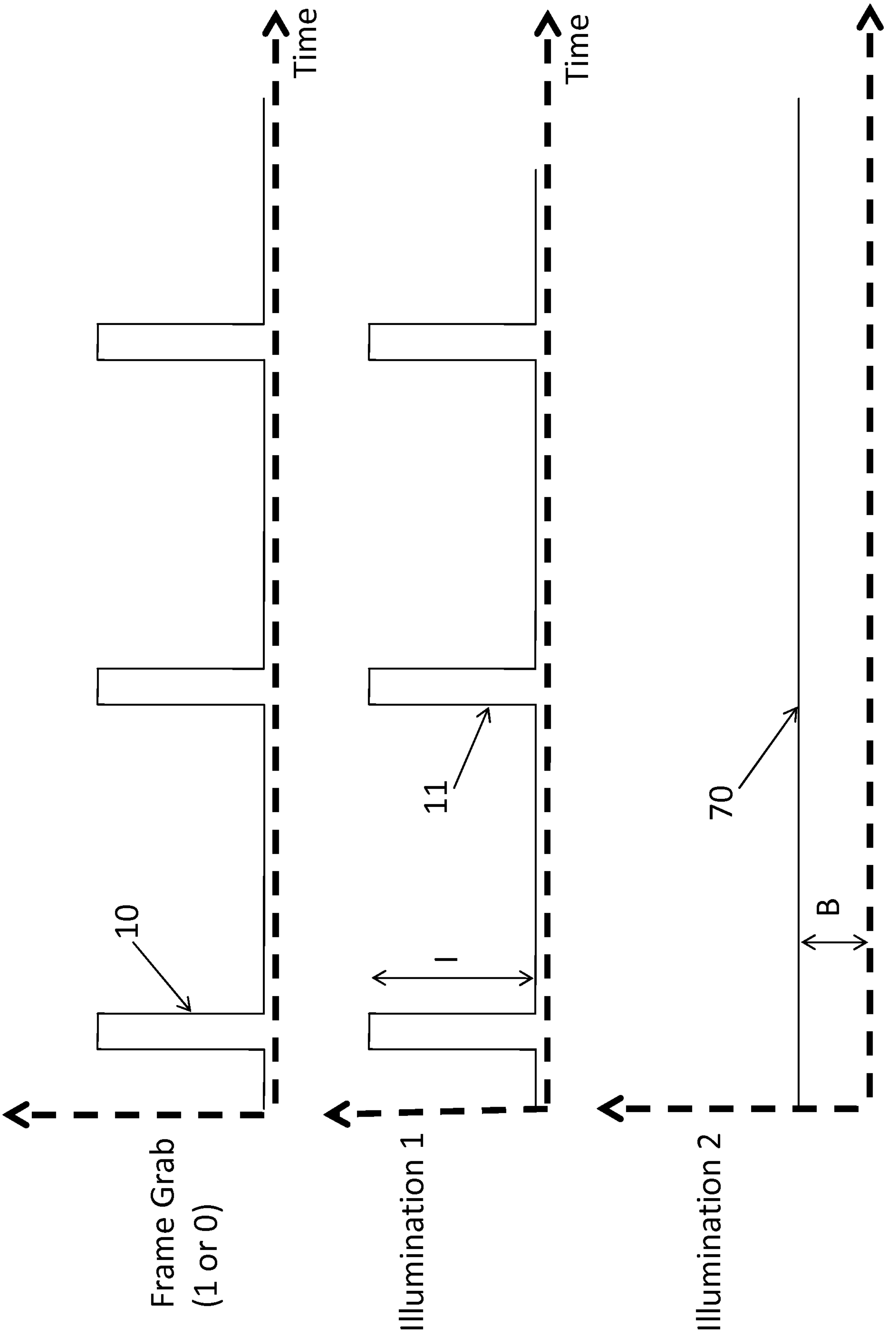
Frame Grab
(1 or 0)
Illumination 1
Illumination 2
Time
Time
10
11
70
I
B

Figure 7

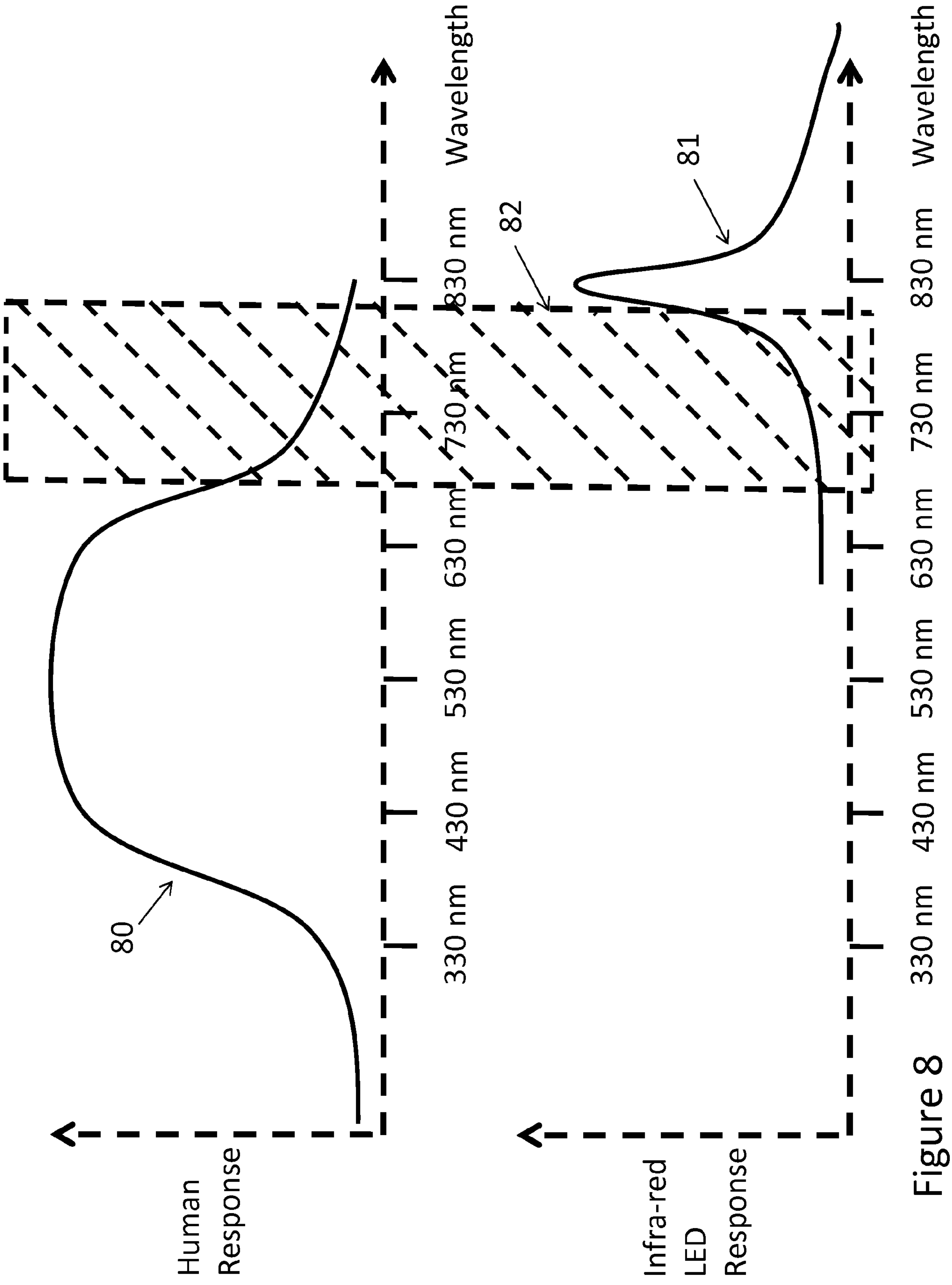
Human Response
80
330 nm
430 nm
530 nm
630 nm
730 nm
830 nm
Wavelength
Infra-red LED Response
81
82
330 nm
430 nm
530 nm
630 nm
730 nm
830 nm
Wavelength

Figure 8

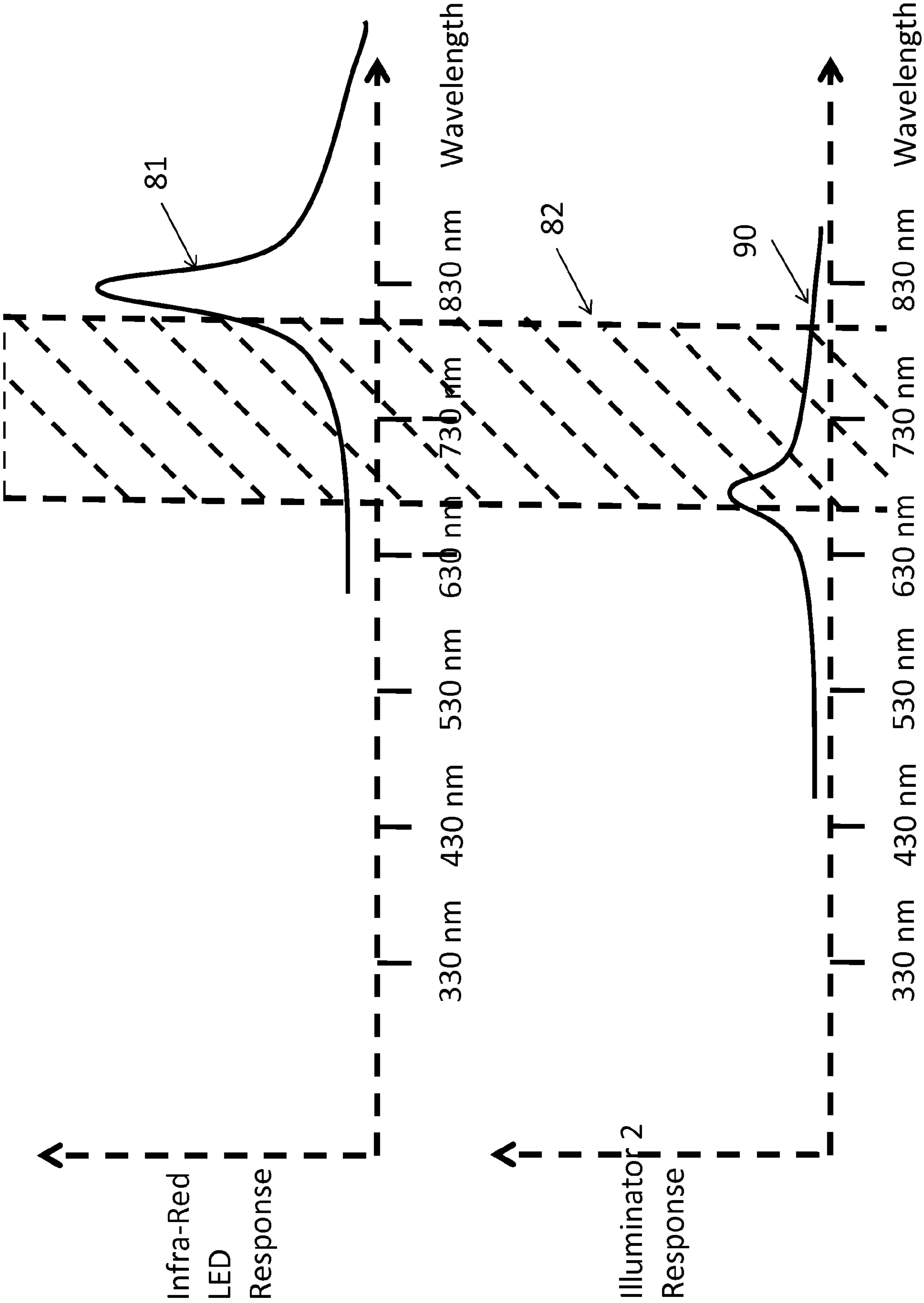
Infra-Red LED Response
81
82
330 nm
430 nm
530 nm
630 nm
730 nm
830 nm
Wavelength
Illuminator 2 Response
90
330 nm
430 nm
530 nm
630 nm
730 nm
830 nm
Wavelength

Figure 9

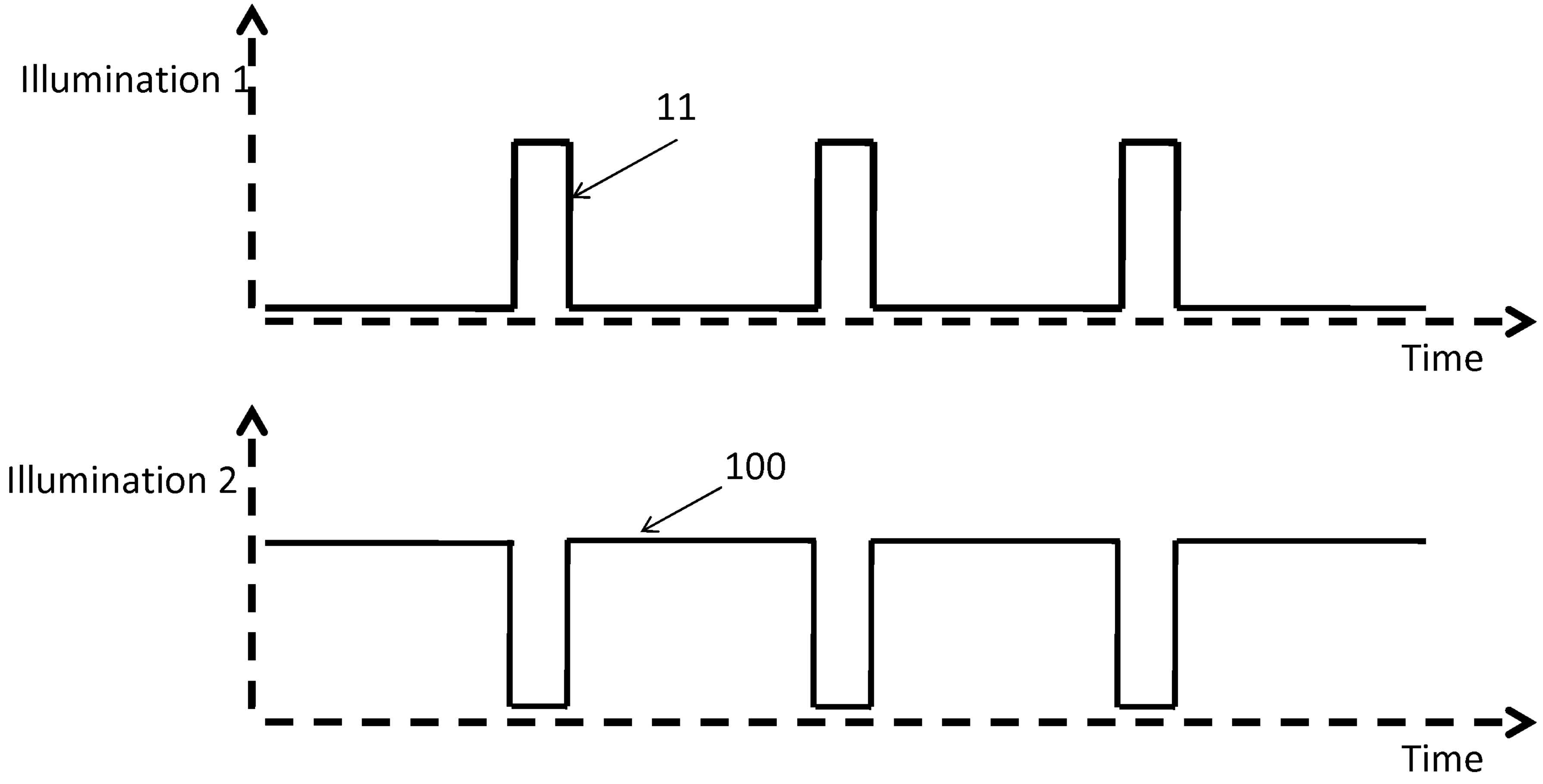

Figure 10

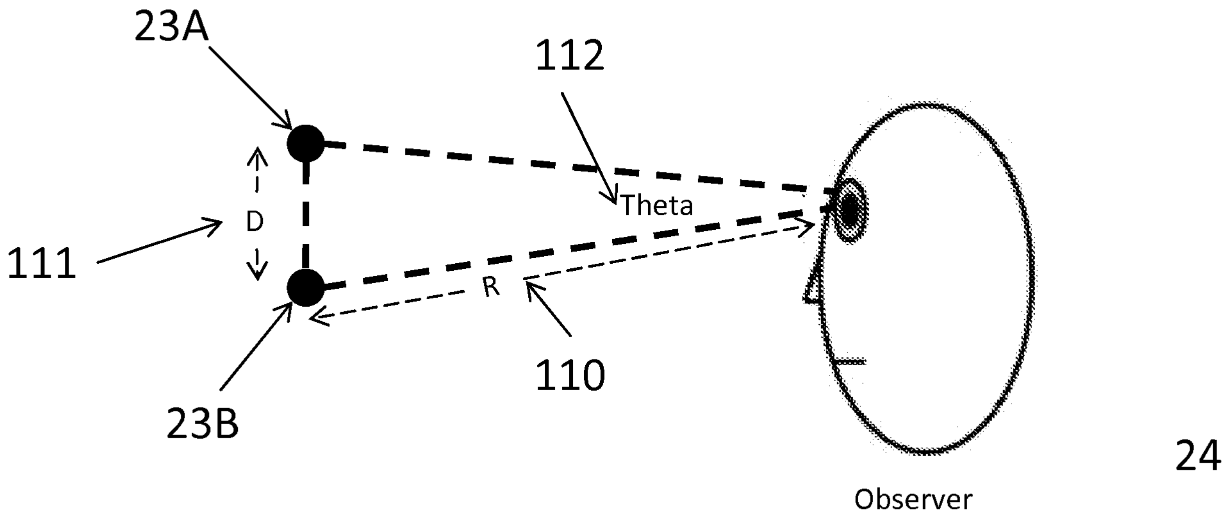

Figure 11

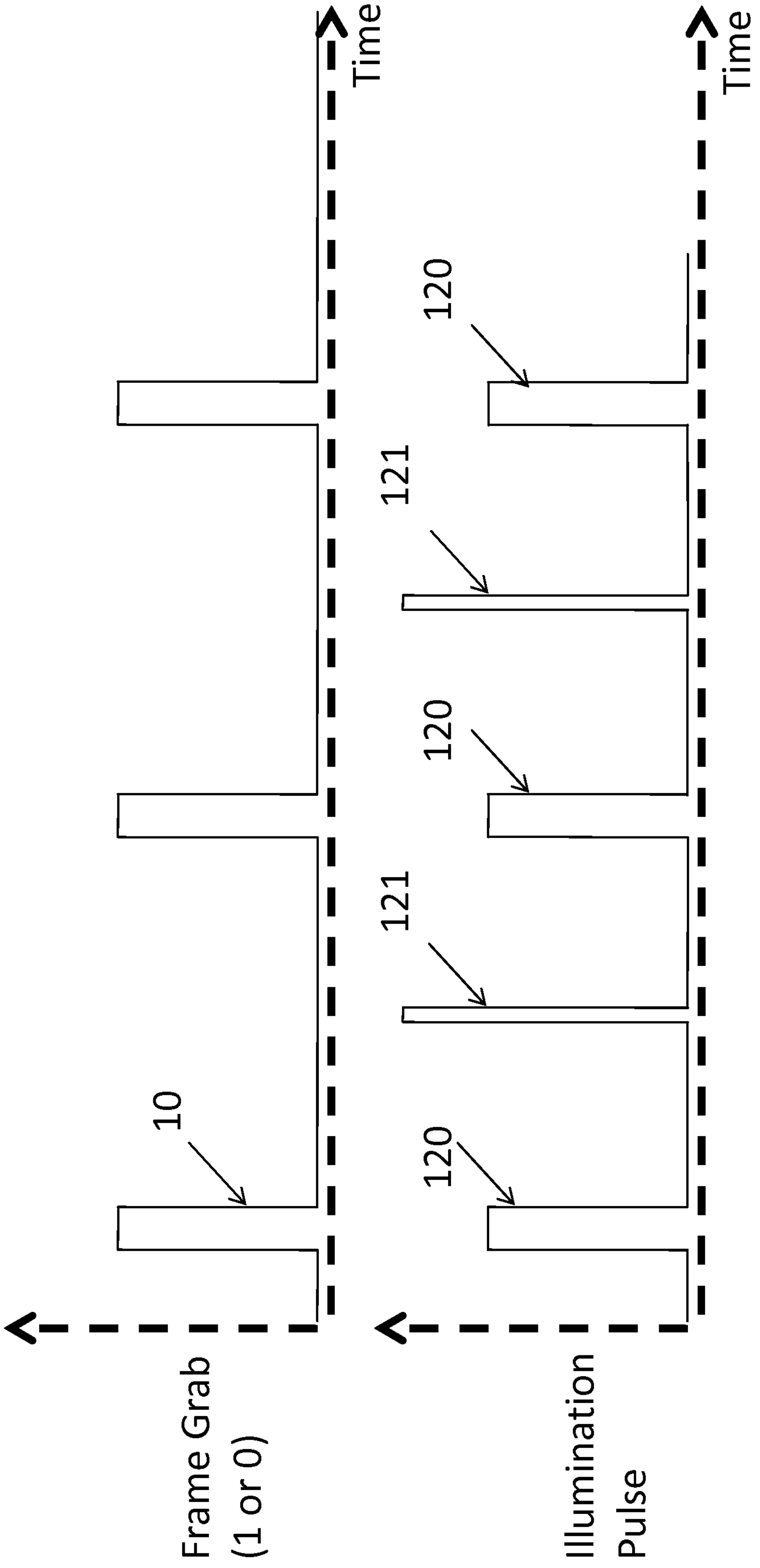
Time
Time
120
121
120
121
120
10
Frame Grab
(1 or 0)
Illumination
Pulse

Figure 12

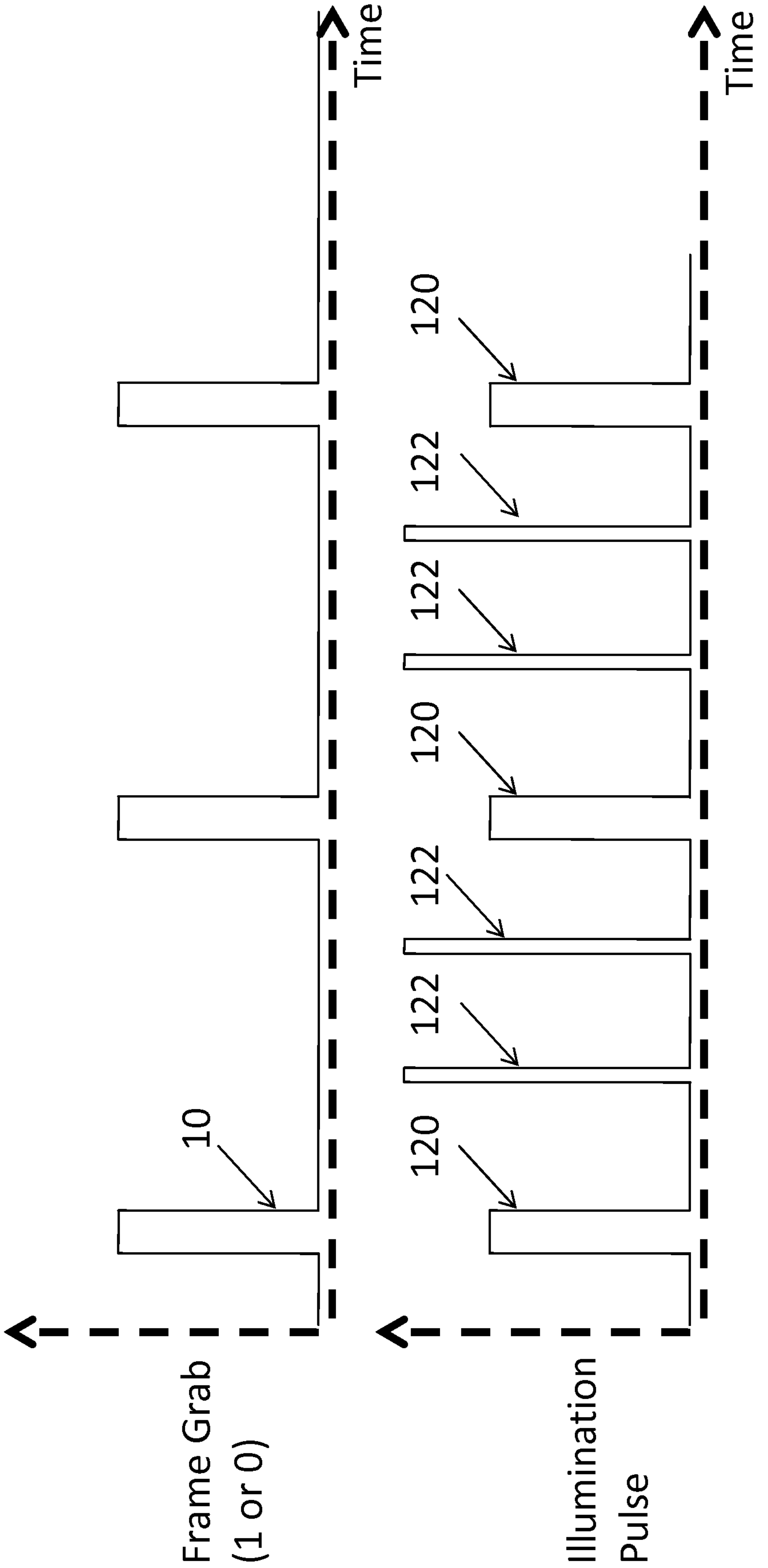
Frame Grab
(1 or 0)
Time
10
Illumination
Pulse
120
122
122
120
122
122
120
Time

Figure 13