

INDIGO LIGHT EYEWEAR**CROSS REFERENCE TO RELATED CASES**

This application claims the benefit of and priority to U.S. Patent Application
5 No. 63/641,327 filed on 1 May 2024, entitled "INDIGO LIGHT EYEWEAR," the
contents of which are incorporated by reference in their entirety herein.

**STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR
DEVELOPMENT**

10 This invention was made with government support under grant number EY027077
awarded by the National Institutes of Health. The government has certain rights in this
invention.

BACKGROUND

15 The prevalence of myopia has reached epidemic levels impacting quality of life
and increasing both the vision-related health care burden and the risk for associated
blinding diseases such as glaucoma and retinal detachment. It is widely accepted that
the myopia epidemic has an environmental origin and that time spent outdoors in
sunlight reduces myopia risk. While sunlight includes wavelengths far into the
20 ultraviolet spectrum, violet and indigo light with wavelengths below 440nm is mostly
absent in indoor lighting environments. The absence of violet light indoors may be
related to environmental myopia and when added, can effectively prevent myopia.

SUMMARY

25 In accordance with the purpose(s) of this disclosure, as embodied and broadly
described herein, the disclosure, in various aspects, relates to indigo light eyewear and

methods of use thereof. The solutions described herein combine various aspects of mechanical, electrical, biological, and ophthalmological principles to arrive at novel solutions for treating and preventing eye diseases.

Aspects of the present disclosure provide for systems and methods of exposing
5 the eye to indigo light at specific wavelengths in order to treat and prevent various eye diseases and disorders, such as, for example, myopia. Embodiments of the present disclosure include: indigo-light producing eyewear which can be programmed to deliver indigo light to the eye at specific wavelengths, at various intensities and for various durations. For example, a system is provided having eyewear configured to be worn by a
10 subject, at least one LED disposed on the eyewear and configured to produce indigo light, and one or more light sensors disposed on the eyewear, where the light sensors are electrically coupled to the LED. In at least one example, the LED of the system is configured to produce light with a wavelength in the range of about 400 nm to 450nm. In some examples, the LED of the system is configured to produce light with a wavelength
15 in the range of about 414 nm to 449 nm. The system can further include a power switch electrically coupled to the LED and configured to activate and deactivate the LED. The system can further include at least one touch sensor electrically coupled to the LED and configured to activate and deactivate the LED.

The system can further include a processor, a memory, and machine-readable
20 instructions stored in the memory that, when executed by the processor, cause the system to at least receive an ambient light input from the one or more light sensors. The machine-readable instructions can further cause the system to determine an indigo light intensity based at least in part on the ambient light input and cause the LED to produce the indigo light intensity. In some examples, the machine-readable instructions further
25 cause the processor to at least activate the LED, set the intensity of the LED, adjust the

intensity of the LED, determine that a specified amount of time has passed since the at least one LED was activated, and in response to the determination that the specified time has passed, deactivate the at least one LED.

In some examples, the eyewear of the system can include a frame configured to
5 fit a subject's face and one or more lenses disposed within the frame. The LED can be disposed within the frame and adjacent to the one or more lenses. The LED can be positioned such that the indigo light produced is directed toward at least one eye of the subject. The LED can be directed through a diffuser such that diffused indigo light reaches at least one eye of the subject. In some examples, the LED can be positioned
10 such that indigo light produced is emitted to a fiber optic and/or diffuser and the diffused indigo light is emitted toward at least one eye of the subject. In some examples, the eyewear further includes a strap configured to hold the frame to the subject's face. The one or more light sensors can be disposed on an outer side of the frame and directed away from the subject's face. In some examples, the one or more light sensors are
15 disposed on an outer side of the eyewear.

In some examples, a system is provided which includes a device configured to be worn on a head of a subject, an indigo LED disposed on the device and directed toward an eye of the subject, and a power switch electrically coupled to the indigo LED and configured to activate and deactivate the indigo LED. The device can further include an
20 ambient light sensor disposed on the device, where the ambient light sensor is electrically coupled to the indigo LED. In some examples, the device further includes a strap configured to hold the device to the head of the subject.

The system can further include a processor, a memory, and machine-readable instructions stored in the memory that, when executed by the processor, cause the
25 system to at least set a light intensity for the indigo LED and activate the indigo LED at

the light intensity. The machine-readable instructions, when executed by the processor, can further cause the system to at least receive an ambient light input from the ambient light sensor and adjust the light intensity based at least in part on the ambient light input. In some examples, the machine-readable instructions, when executed by the processor,

5 further cause the system to at least determine a specified amount of time has passed since activating the indigo LED and deactivate the indigo LED.

Other systems, methods, devices, features, and advantages of the devices and methods will be or become apparent to one with skill in the art upon examination of the following drawings and detailed description. It is intended that all such additional systems,

10 methods, devices, features, and advantages be included within this description, be within the scope of the present disclosure, and be protected by the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Further aspects of the present disclosure will be more readily appreciated upon

15 review of the detailed description of its various embodiments, described below, when taken in conjunction with the accompanying drawings. The components in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the present disclosure. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

20 FIG. 1 is an example of a pair of indigo light therapy glasses according to various embodiments of the present disclosure.

FIG. 2 is a network diagram according to various embodiments of the present disclosure.

FIG. 3. is a flowchart illustrating one example of functionality implemented as portions of an application executed in the network environment of FIG. 2 according to various embodiments of the present disclosure.

FIG. 4A shows a schematic of the proposed mechanism. Sunlight that includes
5 indigo light is protective. White indoor lighting, where indigo light is absent, is a risk factor. When added to white indoor lighting, indigo light can suppress myopia.

FIG. 4B shows preliminary data showing that 1h of indigo light treatment using a narrowband LED with a peak wavelength of 421nm can completely inhibit the myopic effect of -10D lens wear in tree shrews according to various embodiments of the
10 present disclosure.

FIG. 5A shows normalized absorbance of OPN5 and transmission of tree shrew lenses at different ages according to various embodiments of the present disclosure. The lens transmission changes over age, where the transmission near the peak absorbance of OPN5 (360-380nm) decreases rapidly during early development. From
15 1 month of age to adulthood (2 years of age), the transmission of short wavelength light with wavelengths lower 400 nm decreases as the transmission curve shifts to higher wavelengths with age. FIG. 5B shows optimal peak wavelength for slowing myopia in tree shrews over age. The optimal indigo LED peak wavelength was computed by maximizing ONP5 activation while accounting for the age-dependent
20 change in lens transmission. The shaded area represents the juvenile age range at which tree shrews are highly susceptible to induced myopia: 45 to 121 days of age (24 to 100 days of visual experience (DVE)). FIG. 6C shows normalized absorbance of OPN5, lens transmission of different species (mouse, juvenile tree shrew, and a 23 year old human), and the calculated optimal LEDs irradiance for each species.

FIGS. 6A-6I show the effect of different short wavelength LEDs on induced myopia in tree shrews, according to various embodiments of the present disclosure. All groups were treated with a -10D lens in one eye. All groups received 4 hours of ambient short wavelength light supplementation following the *Pre-Dawn* protocol illustrated in FIG. 8C. FIGS. 6A, 6B, 6C, 6D, 6E, 6F, 6G, 6H, and 6I show the results of groups using LEDs with peak wavelengths 366 nm, 395 nm, 400 nm, 410nm, 421 nm, 432 nm, 441 nm, 454 nm, and 468 nm, respectively. The first column shows the irradiance of the respective short wavelength light LED and the warm white (WW) LED. The second and third columns show the longitudinal changes in refraction and axial length of the -10D lens treated eye, respectively. The fourth column shows the longitudinal changes in refraction and axial length of the control eye (no lens). In columns two to four, solid lines and shade areas represent the mean and SEM, respectively. Two reference groups (*Warm White (WW) Light with -10D lens* and *no lens*) are also shown in columns two to four. * represents significant time-group interactions between each short wavelength light group and the *White Light* group with $p < 0.05$. FIG. 8J shows the efficacy of each short wavelength LED to suppress induced myopia in the tree shrew. * represents significant differences between short wavelength light group with $p < 0.05$.

FIG. 7 shows the wavelength dependent total efficacy and effective OPN5 absorbance at the retina in tree shrews, according to various embodiments of the present disclosure. Circles represent the total efficacy of individual tree shrew experiments using short wavelength LEDs with peak wavelengths at 366 nm, 395 nm, 400 nm, 410 nm, 421 nm, 432 nm, 441 nm, 454nm, and 468 nm. All groups received 4 hours of ambient short wavelength light supplementation following the *Pre-Dawn* protocol illustrated in FIG. 8C. A skewed Gaussian function was fitted to the efficacy

data. The peak (429 nm) and upper quartile values of the Gaussian function are highlighted identifying that short wavelengths in the indigo range 414-449 nm are most effective in suppressing induced myopia. The shape and peak of the effective OPN5 absorbance matches the shape and peak of the fitted efficacy function supporting the proposed hypothesis and mechanism.

FIGS. 8A-8H show the effect of different times of day used for violet light treatment with a peak wavelength of 400 nm in juvenile tree shrews, according to various embodiments of the present disclosure. All groups were treated with a -10D lens to induce high myopia in one eye. The Dawn Till Dusk, Pre-Dawn, Post-Dusk groups received ambient violet light treatment, while the Midday group wore miniature violet light emitting glasses. FIG. 8A shows the miniature violet light emitting glass used for the Midday group. FIG. 8B shows a tree shrew wearing the miniature violet light emitting glass. FIG. 8C shows the lighting conditions used for the different experimental groups. FIGS. 8D, 8E, 8F, and 8G show the effect of violet light treatment during different times of day on longitudinal refraction changes (first column) and axial length changes (second column) of the -10D lens treated eye. The reference groups (*Warm White (WW) Light with -10 lens* and *no lens*) are also shown. * represents significant time-group interactions between each violet light group and the *Warm White Light* group with $p < 0.05$. FIG. 8H shows the total efficacy of violet light treatment at different times of day. * represent significant group differences with $p < 0.05$.

FIGS. 9A-9C show the effect of reduced indigo light treatment duration and intensity, according to various embodiments of the present disclosure. FIG. 9A shows the lighting conditions of the two indigo light groups that are compared here. Both indigo light groups were exposed to 421 nm centered indigo light and treated with a -10D in one eye. The other eye served as control eye. The refractive and axial length

results of the “Warm White + 4h Indigo Light” using 4h indigo light at $250\mu\text{W}/\text{cm}^2$ are presented in FIG 6E. FIG. 9B shows the results of the low-level indigo light group using 1h indigo light at $50\mu\text{W}/\text{cm}^2$. The first column shows the irradiance of the low-level indigo light and the warm white (WW) LED. The second and third columns show the longitudinal changes in refraction and axial length of the -10D lens treated eye, respectively. The fourth column shows the longitudinal changes in refraction and axial length of the control eye (no lens). FIG. 9C shows total efficacy of the two indigo light treatment groups. n.s. represents a not significant group difference. In FIGS. 9B, solid lines and shade areas represent the mean and SEM, respectively. * represent significant time-group interactions between the indigo light group and the *White Light* group with $p < 0.05$.

DETAILED DESCRIPTION

Before the present disclosure is described in greater detail, it is to be understood that this disclosure is not limited to particular embodiments described, as such may, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting, since the scope of the present disclosure will be limited only by the appended claims.

Where a range of values is provided, it is understood that each intervening value, to the tenth of the unit of the lower limit (unless the context clearly dictates otherwise), between the upper and lower limit of that range, and any other stated or intervening value in that stated range, is encompassed within the disclosure. The upper and lower limits of these smaller ranges may independently be included in the smaller ranges and are also encompassed within the disclosure, subject to any

specifically excluded limit in the stated range. Where the stated range includes one or both of the limits, ranges excluding either or both of those included limits are also included in the disclosure.

Unless defined otherwise, all technical and scientific terms used herein have
5 the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. Although any methods and materials similar or equivalent to those described herein can also be used in the practice or testing of the present disclosure, the preferred methods and materials are now described.

As will be apparent to those of skill in the art upon reading this disclosure, each
10 of the individual embodiments described and illustrated herein has discrete components and features which may be readily separated from or combined with the features of any of the other several embodiments without departing from the scope or spirit of the present disclosure. Any recited method can be carried out in the order of events recited or in any other order that is logically possible.

15 Embodiments of the present disclosure will employ, unless otherwise indicated, electrical, mechanical, biological, and ophthalmological techniques and the like, which are within the skill of the art. Such techniques are explained fully in the literature.

The following examples are put forth to provide those of ordinary skill in the art with a complete disclosure and description of how to perform the methods and use the
20 compositions and compounds disclosed and claimed herein. Efforts have been made to ensure accuracy with respect to numbers (e.g., amounts, measurements, *etc.*), but some errors and deviations should be accounted for.

Before the embodiments of the present disclosure are described in detail, it is to be understood that, unless otherwise indicated, the present disclosure is not limited
25 to particular materials, machines, computing processes, or the like, as such can vary.

It is also to be understood that the terminology used herein is for purposes of describing particular embodiments only and is not intended to be limiting. It is also possible in the present disclosure that steps can be executed in different sequence where this is logically possible.

5 All publications and patents cited in this specification are cited to disclose and describe the methods and/or materials in connection with which the publications are cited. Publications and patents that are incorporated by reference, where noted, are incorporated by reference as if each individual publication or patent were specifically and individually indicated to be incorporated by reference. Such incorporation by
10 reference is expressly limited to the methods and/or materials described in the cited publications and patents and does not extend to any lexicographical definitions from the cited publications and patents. Any lexicographical definition in the publications and patents cited that is not also expressly repeated in the instant application should not be treated as such and should not be read as defining any terms appearing in the
15 accompanying claims. Any terms not specifically defined within the instant application, including terms of art, are interpreted as would be understood by one of ordinary skill in the relevant art; thus, is not intended for any such terms to be defined by a lexicographical definition in any cited art, whether or not incorporated by reference herein, including but not limited to, published patents and patent applications. The
20 citation of any publication is for its disclosure prior to the filing date and should not be construed as an admission that the present disclosure is not entitled to antedate such publication by virtue of prior disclosure. Further, the dates of publication provided could be different from the actual publication dates that may need to be independently confirmed.

It should be noted that ratios, amounts, and other numerical data can be expressed herein in a range format. It is to be understood that such a range format is used for convenience and brevity, and thus, should be interpreted in a flexible manner to include not only the numerical values explicitly recited as the limits of the range, but

5 also to include all the individual numerical values or sub-ranges encompassed within that range as if each numerical value and sub-range is explicitly recited. To illustrate, a numerical range of "about 0.1% to about 5%" should be interpreted to include not only the explicitly recited values of about 0.1% to about 5%, but also include individual values (e.g., 1%, 2%, 3%, and 4%) and the sub-ranges (e.g., 0.5%, 1.1%, 2.2%, 3.3%,

10 and 4.4%) within the indicated range. Where the stated range includes one or both of the limits, ranges excluding either or both of those included limits are also included in the disclosure, e.g., the phrase "x to y" includes the range from 'x' to 'y' as well as the range greater than 'x' and less than 'y'. The range can also be expressed as an upper limit, e.g., 'about x, y, z, or less' and should be interpreted to include the specific ranges

15 of 'about x', 'about y', and 'about z' as well as the ranges of 'less than x', less than y', and 'less than z'. Likewise, the phrase 'about x, y, z, or greater' should be interpreted to include the specific ranges of 'about x', 'about y', and 'about z' as well as the ranges of 'greater than x', greater than y', and 'greater than z'. In some embodiments, the term "about" can include traditional rounding according to significant figures of the

20 numerical value. In addition, the phrase "about 'x' to 'y'", where 'x' and 'y' are numerical values, includes "about 'x' to about 'y'".

Discussion

Disclosed are various approaches for providing indigo light therapy glasses for

25 the treatment and prevention of various eye disorders such as myopia. The prevalence

of myopia has reached epidemic levels impacting quality of life and increasing both the vision-related health care burden and the risk for associated blinding diseases such as glaucoma and retinal detachment. Existing treatments are only partially effective and/or show significant adverse effects. The mechanism underlying the dramatic increase in myopia prevalence over the past 60 years is unclear but may be related to reduced short wavelength light with wavelengths between 360 nm and 450 nm. Short wavelength light is largely absent in indoor environments as it is partially filtered out by windows, glasses and contact lenses and only limited amount of short wavelength light is emitted by typical indoor light sources including fluorescent and LED lighting as well as displays, monitors, and phones/tables. Recent findings suggest that ultraviolet-A (UV-A) light in the range of 360-400 nm plays an important role in preventing myopia progression in mice, chicks, and humans. Findings in mice support this hypothesis and show that UV-A light with wavelengths of 360-400 nm can suppress experimental myopia by activating the atypical opsin OPN5 (neuropsin, peak absorbance 360-380 nm). However, due to the different lens transmission properties of the human eye, existing technologies are limited to wavelengths (<400nm) that are not ideal for myopia treatment in humans. Rather, indigo light, or light having a wavelength of approximately 400 nm to 450 nm, is a better alternative to activate OPN5 in humans and treat myopia.

The proposed system and method described herein use visible indigo light to treat and prevent myopia with greatly increased effectiveness compared to other available treatments, as well as decreased risk of side effects.

Accordingly, various embodiments of the present disclosure are directed to systems and methods for indigo light producing eyewear. This system allows for easy-to-implement therapeutic application of indigo light while a subject is occupied doing other activities. By including indigo light producing LEDs on eyewear, a subject can go

about their day while receiving treatment. Additionally, various features can be included with the system to improve comfort for the subject. For example, light sensors can be included in the system to detect ambient light near the subject. The intensity of the LEDs can be adjusted based on the detected ambient light so that the user can

5 have a comfortable light intensity based on their environment.

In the following discussion, a general description of the system and its components is provided, followed by a discussion of the operation of the same. Although the following discussion provides illustrative examples of the operation of various components of the present disclosure, the use of the following illustrative examples does not exclude other

10 implementations that are consistent with the principles disclosed by the following illustrative examples.

With reference to FIG. 1, shown is an example of indigo light eyewear 100 according to various embodiments. As shown in FIG. 1, the indigo light eyewear 100 can comprise a glasses frame 103 and lenses 106. However, in other examples, the indigo

15 light eyewear 100 can comprise other forms of eyewear (e.g., sunglasses, goggles, monocles, eyepatches, sleep masks, face masks, headsets, sport glasses, virtual reality headsets, etc.).

The indigo light eyewear 100 includes one or more light-emitting diodes (LEDs) 109 for producing indigo light. In some examples, the indigo light eyewear 100 can include

20 other indigo colored lights, such as fluorescent, halogen, laser, or incandescent lights. As shown in FIG. 1, the LEDs 109 can be included on the frame 103 of the indigo light eyewear 100 and directed toward the subject's eye(s). While the LEDs 109 shown in FIG. 1 are disposed along a bottom of the frame 103, the LEDs 109 can be positioned at various locations on the frame 103, in the lenses 106, or at other positions in the system.

25 The LEDs 109 can emit light directly toward the subject's eye(s) or oriented such that the

emitted light enters the eye indirectly. For example, the LEDs 109 can be directed into the lenses 106 to illuminate the lenses 106 or the LEDs 109 can be disposed on the frame 103 behind the subject's field of vision and directed parallel to the subject's line of sight or, in another example, the LEDs 109 can be directed into a diffuser that is attached or integrated into to the frame 103 and the diffuser can emit diffused indigo light toward the subject's eye(s), as well as many other configurations. According to various examples, the diffuser can comprise a fiber optic. In some embodiments, there can be one LED 109 per eye. However, in other examples, there can be multiple LEDs 109 per eye. Each LED 109 can be configured to produce indigo light in the range of 400 nm to 450nm. In some examples, the LED(s) 109 can be configured to produce indigo light in the range of 414-449nm, 421-441nm, 425-435nm, or at approximately 430nm.

As shown in FIG. 1, the indigo light eyewear 100 can further include one or more light sensors 113 for detecting ambient light in the subject's environment. In some examples, the light sensors 113 comprise photodiodes, phototransistors, photoelectric sensors, photovoltaic devices, or other photosensors which are capable of detecting and measuring ambient light intensity. The light sensors 113 can be positioned at various locations on the frame 103 of the indigo light eyewear 100, or on the lenses 106, or another part of the indigo light eyewear 100. In some examples, the light sensors 113 are directed parallel to the subject's field of vision for detecting ambient light as it would enter the subject's eye(s). In some embodiments, the indigo light eyewear 100 includes a single light sensor 113 for detecting ambient light. In some embodiments, the indigo light eyewear 100 includes more than one light sensor 113 for detecting ambient light. In some examples, the indigo light eyewear 100 can include one or more touch or proximity sensors. These touch or proximity sensors can be disposed on either side of the nose piece of the eyewear, on either ear piece of the eyewear, or at another location such that

the touch or proximity sensors can signal that the subject is wearing the indigo light eyewear 100.

According to various examples, the indigo light eyewear 100 includes a computing device 116. The computing device 116, described further in the discussion of FIG. 2, can be disposed on the frame 103 of the indigo light eyewear 100 and in data communication with the various components of the indigo light eyewear 100. The computing device 116 can include a switch 119, or an on/off button. The switch 119 can be electrically coupled to the LEDs 109 as well as the light sensors 113 in some examples. The subject can use the switch 119 to activate or deactivate the LEDs 109 and/or the light sensors 113.

According to some examples, the computing device 116 further includes a power source 123. The power source 123 can be representative of a battery or other source of electricity which is used to power the indigo light eyewear 100. In some embodiments, the power source 123 is electrically coupled to the LEDs 109 and/or the light sensors 113.

Moving to FIG. 2, shown is a network environment 200 according to various embodiments. The network environment 200 can include a computing device 116, the indigo light eyewear 100, a power source 123, and a client device 203, which can be in data communication with each other via a network 206.

The network 206 can include wide area networks (WANs), local area networks (LANs), personal area networks (PANs), or a combination thereof. These networks can include wired or wireless components or a combination thereof. Wired networks can include Ethernet networks, cable networks, fiber optic networks, and telephone networks such as dial-up, digital subscriber line (DSL), and integrated services digital network (ISDN) networks. Wireless networks can include cellular networks, satellite networks, Institute of Electrical and Electronic Engineers (IEEE) 802.11 wireless networks (*i.e.*, Wi-Fi®), BLUETOOTH® networks, microwave transmission networks,

as well as other networks relying on radio broadcasts. The network 206 can also include a combination of two or more networks 206. Examples of networks 206 can include the Internet, intranets, extranets, virtual private networks (VPNs), and similar networks.

5 The computing device 116 includes at least one processor circuit, for example, having a processor 126 and a memory 129, both of which can be coupled to a local interface 133. To this end, each computing device 116 may include, for example, at least one server computer or like device. The local interface 133 may include, for example, a data bus with an accompanying address/control bus or other bus structure as can be
10 appreciated.

 Stored in the memory 129 are both data and several components that are executable by the processor 126. In particular, stored in the memory 129 and executable by the processor 126 are an eyewear application 136, and potentially other applications. Also stored in the memory 129 can be a data store 139 and other data. In addition, an
15 operating system can be stored in the memory 129 and executable by the processor 126.

 The eyewear application 136 includes a number of machine readable instructions that cause the computing device 116 to perform various functions. For example, the eyewear application 136 can maintain data communication with the indigo light eyewear 100. This can allow the eyewear application 136 to gather ambient light inputs from the
20 light sensors 113 and store the inputs in the data store 139. This can also allow the eyewear application 136 to send commands to the indigo light eyewear 100 (e.g., capture sensor readings, adjust light intensity, activate/deactivate LEDs, etc.) and receive responses or reports from the indigo light eyewear 100 (e.g., sensor readings, duration of LED activation, current ambient light intensity, current LED light intensity, adjust LED
25 intensity, etc.). The eyewear application 136 can also send commands to a power source

123 in order to control the activation, adjust the LED intensity, or deactivation of the indigo light eyewear 100. For example, the eyewear application 136 could send a command to the power source 123 to apply a current, thereby inducing the activation of the indigo light eyewear 100. Similarly, the eyewear application 136 could send a command to the power
5 source 123 or another electric power source to stop the current in order to deactivate the indigo light eyewear 100. Similarly, the eyewear application 136 could send a command to the power source 123 or another electric power source to modulate the current in order to adjust the intensity of the LED(s) 109 of the indigo light eyewear 100. The eyewear application 136 is described further in the discussion of FIG. 3.

10 It is understood that there may be other applications that are stored in the memory 129 and are executable by the processor 126 as can be appreciated. Where any component discussed herein is implemented in the form of software, any one of a number of programming languages may be employed such as, for example, C, C++, C#, Objective C, Java®, JavaScript®, Perl, PHP, Visual Basic®, Python®, Ruby, Flash®, or other
15 programming languages.

A number of software components are stored in the memory 129 and are executable by the processor 126. In this respect, the term "executable" means a program file that is in a form that can ultimately be run by the processor 126. Examples of executable programs may be, for example, a compiled program that can be translated
20 into machine code in a format that can be loaded into a random access portion of the memory 129 and run by the processor 126, source code that may be expressed in proper format such as object code that is capable of being loaded into a random access portion of the memory 129 and executed by the processor 126, or source code that may be interpreted by another executable program to generate instructions in a random access
25 portion of the memory 129 to be executed by the processor 126, *etc.* An executable

program may be stored in any portion or component of the memory 129 including, for example, random access memory (RAM), read-only memory (ROM), hard drive, solid-state drive, Universal Serial Bus (USB) flash drive, memory card, optical disc such as compact disc (CD) or digital versatile disc (DVD), floppy disk, magnetic tape, or other
5 memory components.

The memory 129 is defined herein as including both volatile and nonvolatile memory and data storage components. Volatile components are those that do not retain data values upon loss of power. Nonvolatile components are those that retain data upon a loss of power. Thus, the memory 129 may include, for example, random access memory
10 (RAM), read-only memory (ROM), hard disk drives, solid-state drives, USB flash drives, memory cards accessed via a memory card reader, floppy disks accessed via an associated floppy disk drive, optical discs accessed via an optical disc drive, magnetic tapes accessed via an appropriate tape drive, or other memory components, or a combination of any two or more of these memory components. In addition, the RAM may
15 include, for example, static random access memory (SRAM), dynamic random access memory (DRAM), or magnetic random access memory (MRAM) and other such devices. The ROM may include, for example, a programmable read-only memory (PROM), an erasable programmable read-only memory (EPROM), an electrically erasable programmable read-only memory (EEPROM), or other like memory device.

20 Also, the processor 126 may represent multiple processors 126 or multiple processor cores and the memory 129 may represent multiple memories 129 that operate in parallel processing circuits, respectively. In such a case, the local interface 133 may be an appropriate network that facilitates communication between any two of the multiple processors 126, between any processor 126 and any of the memories 129, or between
25 any two of the memories 129. The local interface 133 may include additional systems

designed to coordinate this communication, including, for example, performing load balancing. The processor 126 may be of electrical or of some other available construction.

The client device 203 is representative of a plurality of client devices that can be coupled to the network 206. The client device 203 can include a processor-based
5 system such as a computer system. Such a computer system can be embodied in the form of a personal computer (e.g., a desktop computer, a laptop computer, or similar device), a mobile computing device (e.g., personal digital assistants, cellular telephones, smartphones, web pads, tablet computer systems, music players, portable game consoles, electronic book readers, and similar devices), media
10 playback devices (e.g., media streaming devices, BluRay® players, digital video disc (DVD) players, set-top boxes, and similar devices), a videogame console, or other devices with like capability. The client device 203 can include one or more displays 209, such as liquid crystal displays (LCDs), gas plasma-based flat panel displays, organic light emitting diode (OLED) displays, electrophoretic ink (“E-ink”) displays,
15 projectors, or other types of display devices. In some instances, the display 209 can be a component of the client device 203 or can be connected to the client device 203 through a wired or wireless connection.

The client device 203 can be configured to execute various applications such as a client application 213 or other applications. The client application 213 can be
20 executed in a client device 203 to access network content served up by the computing device 116 or other servers, thereby rendering a user interface 216 on the display 209. To this end, the client application 213 can include a browser, a dedicated application, or other executable, and the user interface 216 can include a network page, an application screen, or other user mechanism for obtaining user input. In addition, the
25 client application 213 can be executed to control the indigo light eyewear 100. For

example, the client application 213 can be used to change the settings of the indigo light eyewear 100 (e.g., the treatment time, the light intensity of the indigo LEDs 109, the wavelength, etc.) as well as collect data about the subject (e.g., date of birth, gender, existing ocular conditions, etc.). In some examples, the client application 213
5 can be used to present the subject with a log of usage for tracking treatment as well as remind the subject to use the indigo light eyewear 100 if needed. The client device 203 can be configured to execute applications beyond the client application 213 such as email applications, social networking applications, word processors, spreadsheets, or other applications.

10 Next, at FIG. 3, shown is a flowchart that provides one example of the operation of a portion of the eyewear application 136. The flowchart of FIG. 3 provides merely an example of the many different types of functional arrangements that can be employed to implement the operation of the depicted portion of the eyewear application 136. As an alternative, the flowchart of FIG. 3 can be viewed as depicting
15 an example of elements of a method implemented within the computing device 116.

Beginning with block 300, the eyewear application 136 can activate the one or more LEDs 109. In some examples, the eyewear application 136 can cause a signal to be sent to the one or more LEDs 109 to activate at least one of the LEDs 109. The eyewear application 136 can cause a signal to be sent to the LED(s) 109 to activate the
20 LED(s) 109 at a specified indigo light intensity.

Next, at block 303, the eyewear application 136 can receive an ambient light input from the one or more light sensors 113 on the indigo light eyewear 100. In some examples, the eyewear application 136 can send a read request to the light sensors 113 on the indigo light eyewear 100 and receive the ambient light input in response. In some

examples, the eyewear application 136 can receive the ambient light input from a data store 139 or other source.

Next, at block 306, the eyewear application 136 can determine an indigo light intensity. The eyewear application 136 can determine a comfortable indigo light intensity to set for the LEDs 109 based at least in part on the ambient light input received at block 303. For example, if there is a high ambient light intensity received at block 303, the eyewear application 136 can determine a correspondingly high indigo light intensity for the LEDs 109. Similarly, in another example, if the ambient light intensity received at block 303 is low, the eyewear application 136 can determine a correspondingly low indigo light intensity for the LEDs 109. The eyewear application 136 can use various additional data to determine the indigo light intensity, such as, for example, data about comfortable light intensities for the eye.

Moving to block 309, the eyewear application 136 can adjust the indigo light intensity for the LEDs 109. In some examples, the eyewear application 136 can send a command to adjust the indigo light intensity determined at block 306 for the LEDs 109. In some embodiments, the eyewear application 136 can cause the LEDs to emit indigo light at the determined indigo light intensity from block 306 by causing an electrical current to be sent to the LEDs. In some examples, the eyewear application 136 can store the determined indigo light intensity in a data store 139 to be used by another system or application for setting the light intensity of the LEDs 109.

Moving to block 313, the eyewear application 136 can determine that a specified time has passed since the LED(s) 109 were activated at block 300. In some examples, the eyewear application 136 can include a timer which is triggered by the activation signal sent at block 309. The timer can be set for a specific amount of time such as, for example, one hour. According to various examples, the specified amount of time can be determined

based at least in part on a treatment plan. For example, the specified amount of time may be one hour based on a treatment plan for the subject which recommends one hour of indigo light therapy per day. In other examples, the timer is set for a specified amount of time based at least in part on other factors such as, for example, battery life of a power source 123, the indigo light intensity determined at block 303, or other factors. In some examples, when the eyewear application 136 determines that the specified amount of time has not passed since the LED(s) were activated at block 300, the eyewear application 136 can default back to block 303 and repeat the steps recited in blocks 303 to 309. If the eyewear application 136 determines that the specified amount of time has passed, then the eyewear application 136 can proceed to block 316.

Next, at block 316, the eyewear application 136 can deactivate the one or more LEDs 109. In some examples, the eyewear application 136 can cause a signal to be sent to the one or more LEDs 109 to deactivate at least one of the LEDs 109. In some examples, the eyewear application 136 can send a deactivation signal in response to a positive determination from block 313 that a specified amount of time has passed since the LED(s) 109 were activated at block 309. After block 316, the flowchart of FIG. 3 comes to an end.

Although the eyewear application 136 and other various systems described herein may be embodied in software or code executed by general purpose hardware as discussed above, as an alternative the same may also be embodied in dedicated hardware or a combination of software/general purpose hardware and dedicated hardware. If embodied in dedicated hardware, each can be implemented as a circuit or state machine that employs any one of or a combination of a number of technologies. These technologies may include, but are not limited to, discrete logic circuits having logic gates for implementing various logic functions upon an application of one or more data

signals, application specific integrated circuits (ASICs) having appropriate logic gates, field-programmable gate arrays (FPGAs), or other components, *etc.* Such technologies are generally well known by those skilled in the art and, consequently, are not described in detail herein.

5 Also, any logic or application described herein, including the eyewear application 136, that includes software or code can be embodied in any non-transitory computer-readable medium for use by or in connection with an instruction execution system such as, for example, a processor 126 in a computer system or other system. In this sense, the logic may include, for example, statements including instructions and declarations that
10 can be fetched from the computer-readable medium and executed by the instruction execution system. In the context of the present disclosure, a "computer-readable medium" can be any medium that can contain, store, or maintain the logic or application described herein for use by or in connection with the instruction execution system.

 The computer-readable medium can include any one of many physical media such
15 as, for example, magnetic, optical, or semiconductor media. More specific examples of a suitable computer-readable medium would include, but are not limited to, magnetic tapes, magnetic floppy diskettes, magnetic hard drives, memory cards, solid-state drives, USB flash drives, or optical discs. Also, the computer-readable medium may be a random access memory (RAM) including, for example, static random access memory (SRAM)
20 and dynamic random access memory (DRAM), or magnetic random access memory (MRAM). In addition, the computer-readable medium may be a read-only memory (ROM), a programmable read-only memory (PROM), an erasable programmable read-only memory (EPROM), an electrically erasable programmable read-only memory (EEPROM), or other type of memory device.

Further, any logic or application described herein, including the eyewear application 136, may be implemented and structured in a variety of ways. For example, one or more applications described may be implemented as modules or components of a single application. Further, one or more applications described herein may be executed
5 in shared or separate computing devices or a combination thereof. For example, a plurality of the applications described herein may execute in the same computing device 116.

In addition to the foregoing, the various embodiments of the present disclosure include, but are not limited to, the embodiments set forth in the following clauses.

10 Clause 1. A system, comprising: eyewear configured to be worn by a subject; at least one LED disposed on the eyewear and configured to produce indigo light; one or more light sensors disposed on the eyewear, the light sensors electrically coupled to the at least one LED; a processor; a memory; and machine-readable instructions stored in the memory that, when executed by the processor, cause the
15 system to at least: receive an ambient light input from the one or more light sensors; determine an indigo light intensity based at least in part on the ambient light input; and cause the at least one LED to produce the indigo light intensity.

 Clause 2. The system of clause 1, wherein the at least one LED is configured to produce light with wavelengths in a range of about 400 nm to 450nm.

20 Clause 3. The system of clause 1 1, wherein the at least one LED is configured to produce light with wavelengths in the range of about 414 to 449 nm.

 Clause 4. The system of clause 1, wherein the at least one LED is configured to produce light with a peak and nominal wavelength in the range of about 421 to 441nm.

25 Clause 5. The system of any one of clauses 1 to 4, further comprising a

power switch electrically coupled to the at least one LED and configured to activate and deactivate the at least one LED.

Clause 6. The system of any one of clauses 1 to 5, wherein the eyewear further comprises: a frame configured to fit a subject's face; one or more lenses
5 disposed within the frame; and wherein the at least one LED is disposed within the frame and adjacent to the one or more lenses.

Clause 7. The system of clause 6, wherein the eyewear further comprises a strap configured to hold the frame to the subject's face.

Clause 8. The system of any one of clauses 6 or clause 7, wherein the at
10 least one LED is positioned such that the indigo light produced is directed toward at least one eye of the subject.

Clause 9. The system of any one of clauses 6 to 8, wherein the at least one LED is directed through a diffuser such that diffused indigo light reaches at least one eye of the subject.

15 Clause 10. The system of any one of clauses 6 to 9, wherein the one or more light sensors are disposed on an outer side of the frame and directed away from the subject's face.

Clause 11. The system of anyone of clauses 1 to 10, wherein the one or more light sensors are disposed on an outer side of the eyewear.

20 Clause 12. The system of any one of clauses 1 to 11, wherein the machine-readable instructions further cause the processor to at least: activate the at least one LED; determine a specified amount of time has passed since the at least one LED was activated; and in response to the determination that the specified amount of time has passed, deactivate the at least one LED.

25 Clause 13. A method, comprising: receiving, from one or more light sensors

disposed on eyewear, an ambient light input; determining, by a processor, an indigo light intensity based at least in part on the ambient light input; and causing, by the processor, at least one LED to produce the indigo light intensity, the at least one LED disposed on the eyewear.

5 Clause 14. The method of clause 13, further comprising: activating, by a processor, the at least one LED; setting, by the processor, an intensity of the at least one LED; determining, by the processor, a specified amount of time has passed since the at least one LED was activated; and in response to determining the specified amount of time has passed, deactivating, by the processor, the at least one LED.

10 Clause 15. The method of clause 13 or clause 14, wherein the eyewear further comprises: a frame configured to fit a subject's face; one or more lenses disposed within the frame; and wherein the at least one LED is disposed within the frame and adjacent to the one or more lenses.

 Clause 16. A system, comprising: a device configured to be worn on a head
15 of a subject; an indigo LED disposed on the device and directed toward an eye of the subject; and a power switch electrically coupled to the indigo LED and configured to activate and deactivate the indigo LED.

 Clause 17. The system of clause 16, further comprising: a processor; a memory; and machine-readable instructions stored in the memory that, when
20 executed by the processor, cause the system to at least: set a light intensity for the indigo LED; and activate the indigo LED at the light intensity.

 Clause 18. The system of clause 17, wherein the device further comprises an ambient light sensor disposed on the device, the ambient light sensor electrically coupled to the indigo LED.

25 Clause 19. The system of clause 18, wherein the machine-readable

instructions, when executed by the processor, further cause the system to at least: receive an ambient light input from the ambient light sensor; and adjust the light intensity based at least in part on the ambient light input.

Clause 20. The system of clauses 17 to 19, wherein the machine-readable
5 instructions, when executed by the processor, further cause the system to at least: determine a specified amount of time has passed since activating the indigo LED; and deactivate the indigo LED.

Clause 21. The system of any one of clauses 16 to 20 wherein the device further comprises a strap configured to hold the device to the head of the subject.

10 Clause 22. The system of clauses 16 to 20, wherein the indigo LED is configured to produce light with peak and nominal wavelength in the range of about 421 to 441nm.

Disjunctive language such as the phrase “at least one of X, Y, or Z,” unless specifically stated otherwise, is otherwise understood with the context as used in
15 general to present that an item, term, *etc.*, can be either X, Y, or Z, or any combination thereof (*e.g.*, X; Y; Z; X or Y; X or Z; Y or Z; X, Y, or Z; *etc.*). Thus, such disjunctive language is not generally intended to, and should not, imply that certain embodiments require at least one of X, at least one of Y, or at least one of Z to each be present.

It should be emphasized that the above-described embodiments of the present
20 disclosure are merely possible examples of implementations set forth for a clear understanding of the principles of the disclosure. Many variations and modifications can be made to the above-described embodiments without departing substantially from the spirit and principles of the disclosure. All such modifications and variations are intended to be included herein within the scope of this disclosure and protected by
25 the following claims.

EXAMPLE A**Indigo light can completely suppress a strong myopiagenic stimulus in tree shrews.**

It is widely accepted that the myopia epidemic has an environmental origin and
5 that time spent outdoors in sunlight reduces myopia risk. While sunlight includes
wavelengths far into the ultraviolet (UV) spectrum, violet light and indigo light with
wavelengths below 440 nm are mostly absent in indoor lighting environments. The
absence of indigo light indoors may be related to environmental myopia and when
added, can effectively prevent myopia. This hypothesis was tested in a preclinical
10 animal model of myopia, the tree shrew. A -10D lens was fitted in front of one eye of
juvenile tree shrews to induce a strong myopiagenic stimulus. Two groups of tree
shrews were exposed to either warm white (3000k) LED light (n=10) or warm white
LED light supplement for 1 hour with indigo LED light with a peak wavelength of 421nm
(n=5). The -10D lens treated eye developed high levels of myopia in tree shrews that
15 were housed in normal white lightning conditions without indigo LED light (FIG. 4B).
In contrast, the -10D lens treated eye maintained normal refractive values in the
second group of animals showing that 1 hour of indigo light can completely suppress
a strong myopiagenic stimulus in tree shrews (FIG. 4B). These findings are entirely
consistent with the environmental causation of the myopia epidemic, where sunlight,
20 with its abundant indigo wavelengths, is protective and time spent inside, where indigo
photons are absent, is a risk factor (FIG. 4A). Tree shrews are closely related to
primates and experimental results obtained in tree shrews are likely to translate to
humans. Therefore, embodiments of the present disclosure include the utilization of
indigo light-emitting eyewear to treat human myopia.

EXAMPLE B**The light transmission of the lens changes with age and differs across species**

Mouse experiments showed that the activation of the atypical opsin OPN5 (neuropsin, peak absorbance between 360 nm to 380 nm) within the retina can suppress induced myopia. However, ultraviolet UV-A light with wavelengths near the absorbance peak of OPN5 (360-380nm) might not be transmitted efficiently through the lens of tree shrews and humans. To assess which violet and indigo wavelengths can reach the retina in tree shrews, the lens transmission was measured at different ages (FIG. 5A). In tree shrews, the lens transmission changes rapidly during development (FIG. 6A). At 10 days of age (~11 days before eye opening) the lens is cloudy and transmits little light overall but allows UV-A light to pass. While overall transmission increases at 24 days of age (3 days after eye opening), transmission near the absorbance peak of OPN5 (360-380nm) λ_{max} decreases. This trend continues with age, where most of the light below 400nm is filtered out by the juvenile lens (1.5 months).

To identify the optimal narrow-band LED, the peak wavelength, $\lambda_{opt_{max(age)}}$ was calculated (Equation 1) that maximizes ONP5 activation in tree shrews while accounting for age-dependent lens transmission.

$$\lambda_{opt_{max(age)}} = \max \int I(\lambda, \lambda_{max}) \tau(\lambda, age) A_{OPN5}(\lambda) d\lambda \quad (\text{Equation 1})$$

In Equation 1, $I(\lambda, \lambda_{max})$ represents the irradiance of a narrow-band LED with a peak at the wavelength λ_{max} ; $\tau(\lambda, age)$ represents the age-dependent transmission of the lens; and $A_{OPN5}(\lambda)$ is the absorbance of OPN5. This calculation identified a λ_{max} between 435 nm and 440 nm to be ideal for OPN5 activation at the retina (FIG. 5B) in juvenile tree shrews that are most susceptibility to induced myopia. FIG. 5C summarizes species dependent differences in lens transmission and optimal LED

peak wavelengths for OPN5 activation. The lens of mice allows UV-A light to pass leading to an optimal peak wavelength (369 nm) near to λ_{max} of OPN5 (360-380 nm). In contrast, low transmission of the human and juvenile tree shrew lens below 400 nm requires higher wavelengths to maximize OPN5 activation with λ_{max} of 421 nm and
5 435 nm, respectively (FIG. 5C). This finding is an example where data obtained in mice can be refined, using tree shrews, to enhance human relevance. Therefore, embodiments of the present disclosure account for species-dependent differences in the lens transmission by utilizing indigo light that is transmitted by the human lens and are optimal for myopia treatment in humans.

10

EXAMPLE C

Suppression of induced myopia in the tree shrew is exquisitely wavelength sensitive.

Based on the findings from EXAMPLE B, different narrow-band short
5 wavelength LEDs were investigated for myopia suppression (FIG. 6) in tree shrews. Light units consisting of warm white LEDs (3000k) and nine different narrow-band LEDs emitting short wavelength light were built. The short wavelength LEDs had peak wavelengths in the range of 366 nm to 468 nm, dominant wavelengths that were close to the peak wavelength (less than 2nm difference), and a spectral line half width
10 between 8 nm and 21 nm.. LED light units were placed on top of each tree shrew cage and the irradiance was measured at the bottom of the cage (first column in FIG. 6A-I). To induce myopia, all tree shrews were fitted with spectacles at 24 days after their eyes open (24 days of visual experience, DVE). All spectacles have one control side that is open without a lens and an experimental side that incorporates a -10D lens to
15 induce myopia. Juvenile tree shrews were randomly assigned to one *reference* group raised in *warm white (WW)* LED lighting set to 400 lx and nine experimental groups, where the *WW* light was supplemented for 4 hours with one of the short wavelength LEDs. The intensity of the short wavelength LEDs was set to 250 mW/cm² for all short wavelength LEDs. The *4h Pre-Dawn* lighting regimen (FIG. 8A) was used in all
20 experimental groups, where short wavelength light treatment started at 6:30 am and lasted 4 hours. This timing was chosen as an initial condition based on the success of violet light suppression of induced myopia when applied at the beginning of the activity phase in mice. Furthermore, this light pattern mimics the high violet/indigo light content of dawn. All experiments were conducted between 24 and 60 days of visual experience
25 (DVE), which represents an age range at which tree shrews are most susceptible to induced myopia. Refraction and axial length were measured every 3 days in fully

awake animals using the Nidek ARK-700A autorefractor and Lenstar LS-900 biometer following established protocols. A general linear mixed-effects model was used to test for significant time-group interaction differences in refraction and axial length between experimental groups with short wavelength light supplementation and the reference group with WW light. FIG. 6 shows the finely tuned wavelength sensitivity of short wavelength light supplementation on induced myopia in tree shrews. The longitudinal development of refraction and axial length of the -10D lens treated eye is shown in the second and third column of FIG 6A-I, respectively. Supplementing WW light with UV-A LED light centered at 366 nm and 395 nm showed no or a very small treatment effect, where animals developed high levels of myopia and axial elongation like the WW group with -10D lens (FIG 6A, B). Violet LEDs centered at 400 nm and 410 nm had a modest, wavelength-dependent effect in suppressing myopia and axial elongation (FIGS. 6C, 6D), where the violet light treated eyes had significant less myopic refraction and shorter axial length compared to the WW group with -10D lenses. All indigo LEDs with peak wavelengths at 421 nm, 432 nm, and 441 nm completely suppressed the induced myopia, where the -10D lens treated eyes developed a refraction similar or higher than the control eye (no lens) of the WW group (FIGS. 6E-6G, second column). Indigo wavelength supplementation also eliminated the exaggerated axial elongation of induced myopia and resulted in a slightly reduced axial length change throughout the DVE24-60 time-course compared to WW controls (FIGS. 6E-6G, third column). These treatment effects in suppressing induced myopia decreased with higher wavelengths in the blue spectrum using LEDs with peak wavelengths at 454 nm and 468nm (FIGS. 6H, 6I). Efficacy was calculated based on the final refractive and axial length values at 60 DVE, where 0% and 100% efficacy represent values that match the eyes of the WW light group with and without -10D lens

treatment, respectively. The total efficacy was defined as the average efficacy for refraction and axial length. Total efficacy was highest for indigo light centered at 432 nm and at 100% or higher for all indigo LEDs using 421 nm, 432 nm, and 441 nm centered indigo light (FIG. 6J). Compared to indigo light, a wavelength-dependent
5 decrease in efficacy occurred with shorter wavelengths toward the violet spectrum and with higher wavelengths towards the blue spectrum (FIG. 6J).

While violet/indigo/blue light had a remarkable treatment effect on the -10D lens treated eye, the effect on the control eye (no lens) was limited (fourth column in FIG. 6A-I). Compared to the WW light group, 432 nm centered indigo light (the most
10 effective indigo light group) induced a hyperopic shift of 12.8D in the -10D lens treated eye at DVE60 (FIG. 6F, second column). However, the same indigo light induced a much smaller hyperopic shift of 2.9D in the control eye (FIG. 6F, fourth column). This contrasts with the effect of red-light treatment: some studies have shown that red light can inhibit the impact of a myopiagenic stimulus in an experimental eye but also
15 causes the control eye to shift into hyperopia by a similar amount. The indigo light can produce a mild hyperopia in eyes without a myopiagenic stimulus (no lens).

The total efficacy of all short wavelength light treated animals across all tested wavelengths was plotted in FIG. 7. A Gaussian function was fitted to the efficacy data showing that the predicted optimal wavelengths (435-440nm, FIG. 5B) lie within the
20 empirically identified high efficacy range of 414 nm to 449 nm (FIG. 7). Furthermore, the effective OPN5 absorbance (OPN5 absorbance multiplied by the lens transmission) was calculated and plotted in FIG. 7. The shape and peak of the effective OPN5 absorbance curve matches the shape and peak of fitted efficacy curve closely. These data support the hypothesis that species-dependent differences in lens
25 transmission determine the optimal short wavelengths for OPN5 activation and myopia

suppression.

In summary, suppression of induced myopia using short wavelength light in the tree shrew is exquisitely wavelength sensitive. While UV-A is ineffective and violet and blue light are moderate effective, indigo light can completely suppress a strong
5 myopiagenic stimulus in tree shrews. These data are consistent with species-dependent differences in lens transmission, environmental myopia causation, the documented role of OPN5 in myopia suppression, and human epidemiology showing that sunlight is protective and inside time a risk factor. Embodiments of the present disclosure account for the wavelength-dependent difference in efficacy by utilizing
10 indigo light that is highly effective for myopia suppression.

EXAMPLE D**Suppression of myopia by short wavelength light is time-of-day dependent in tree shrews.**

Previous experiments in the mouse suggest that evening UV-A light is most effective for myopia suppression. Preliminary experiments were conducted to test if a similar preference exists in tree shrew (FIG. 8). Experimental design was identical to experiments described under **EXAMPLE C**, but instead of using different short wavelengths, violet light was delivered at four different times of the day: (i) *Pre-Dawn*, (ii) *Midday*, (iii) *Post Dusk*, and (iv) *Dawn Till Dusk* (FIG. 8C). Note that 400 nm centered violet light was used in these experiments as they were performed before the discovery of the superior efficacy of indigo light. Monocular -10D lens treatment was used to induce a strong myopiagenic stimulus in one eye leaving the other eye as control. The same *warm white (WW)* light group with and without a -10D lens treated eyes was used as reference group and the same statistical analysis was performed as explained under **EXAMPLE C**. All violet light groups received ambient violet light treatment except the *Midday* group, where violet light was directly delivered to the eye using violet light emitting miniature glasses (specially designed for tree shrews: FIG. 8 A, B) matching the same irradiance used for ambient violet light ($250 \mu\text{W}/\text{cm}^2$). The effect of violet light delivered at different times of the day on the -10D lens treated eye is shown in FIG. 8D-G. Delivering 4 hours of violet light at Pre-Dawn, Midday, and Post Dusk resulted in a significant difference in the time-group interaction of refraction and axial length when compared to the *WW Light* group (8D-F). In contrast, delivering violet light from *Dawn Till Dusk* is ineffective for myopia suppression as this group showed no significant difference compared to the -10D lens treated eye of the *WW* light group (FIG. 8G). This finding is consistent with previous experiments in mice. The

Pre-Dawn and Midday groups showed a significant increase in total efficacy when compared to the Dawn Till Dusk group (FIG. 8H). These results confirm that the time of day used for short wavelength light treatment is important. Embodiments of the present disclosure account for time passed since the indigo LED(s) can be activated
5 and deactivated at various times by a processing unit to effectively treat myopia.

EXAMPLE E**Eyewear and treatment protocols for the delivery of violet light to the eyes of tree shrews and children**

Existing light therapy glasses are designed for adults and use blue light to help
5 with circadian rhythm disorders. No commercially available light therapy glasses exist
for children or for small animals like tree shrews. Here, the first short wavelength light
emitting glasses were designed and built for hypothesis testing in tree shrews (FIG.
8A). Based on a comparison of all 4h exposure conditions (FIG. 8D-G) there is some
indication that glasses may provide a superior myopia suppression. The proposed
10 system consists of an aluminum frame with a -10D lens to induce myopia and eight
surface mount violet light LEDs of type 0603 that are placed into grooves around each
lens. These LEDs are wired to a miniature processing unit to regulate the daily lighting
duration, a voltage control unit to maintain stable illumination while the battery
discharges, and a potentiometer to regulate the light intensity. Finally, the violet light
15 glasses are powered by two replaceable cell batteries. The design of these glasses
was modified multiple times until the system was able to function for three consecutive
days without user interference and the weight was low enough so that tree shrews
would accept it (FIG. 8B).

Results presented in FIG. 6E show that 4 hours of indigo light centered at 421 nm
20 and at an intensity of 250 $\mu\text{W}/\text{cm}^2$ completely suppressed a strong myopiagenic stimulus
(-10D lens) in tree shrews. This indigo light intensity may not be applicable for indigo light
eyewear in children as it may be perceived as too bright. Furthermore, children may not
be compliant to wear the eyewear for 4 hours daily. Using the tree shrew model of high
myopia, reducing the indigo light treatment duration from 4h to 1h and the indigo light
25 intensity from 250 $\mu\text{W}/\text{cm}^2$ to 50 $\mu\text{W}/\text{cm}^2$ was tested to determine if doing so would

compromise efficacy. A new indigo light group was treated with a -10D lens on one eye as a strong myopiagenic stimulus and exposed to indigo light centered at 421 nm using the *Pre-Dawn* lightning regimen, where indigo light treatment started at 6:30 am and lasted 1 hour (FIG. 9A). The same LED arrays have been used that were also used to generate the data shown in FIG. 6E. However, the indigo light intensity has been lowered to a low-level of 50 $\mu\text{W}/\text{cm}^2$ using pulse wave modulation. The warm white LED light remained the same. FIG. 9B shows the results of the new low-level indigo light group (with reduced light intensity and exposure time). The *Warm white (WW)* light group used in FIG 6 was also replotted, where the *WW* group was also treated with a -10D lens in one eye but not indigo light. The low-level indigo group showed significant treatment effects in refraction and axial length (FIG. 9B) that were very similar to the existing indigo light group (FIG 6E). Reducing the indigo light intensity 5-fold (from 250 $\mu\text{W}/\text{cm}^2$ to 50 $\mu\text{W}/\text{cm}^2$) and the duration 4-fold (from 4h to 1h) caused no significant reduction of the efficacy of indigo light (FIG. 9C) suggesting that short-term exposure of low-level indigo light is sufficient to completely suppress a strong myopiagenic stimulus.

Safety considerations were also investigated. A low-level indigo light irradiance of 50 $\mu\text{W}/\text{cm}^2$ is proposed for the indigo light eyewear. This light intensity is well below the retinal blue light hazard exposure limit for small light sources of $1\text{Wm}^{-2} = 100\ \mu\text{Wcm}^{-2}$ (Equation 2), falling under the *exempt risk group* (IEC 62471).

$$E_B = \sum_{300}^{700} E_\lambda \cdot B(\lambda) \cdot \Delta\lambda = 0.34\ \text{Wm}^2 < 1\text{Wm}^2 \quad (\text{Equation 2})$$

In Equation 2, E_λ represents the spectral irradiance, $B(\lambda)$ the hazard weighting function, and $\Delta\lambda$ the bandwidth. In summary, these data provide evidence that a short indigo light exposure time (1 hour) that is practical for children and parents, and a low indigo light intensity (50 $\mu\text{W}/\text{cm}^2$) that is safe (Equation 2) are sufficient to completely suppress a strong myopiagenic stimulus in a near-primate model. These findings support

the usage of indigo light eyewear for effective and safe myopia treatment in children.

Preliminary tests have revealed that existing designs of light therapy glasses are not practical for children as they were designed for adults. A prototype of indigo eyewear has been developed that uses a sport glasses design with elastic straps. This design is
5 ideal for children that are active. The prototype uses LEDs (SMD type 0603, flat lens) with wavelengths in the range of 418-446 nm, which has been identified to be highly effective in tree shrews (FIG. 7). The prototype uses an elastic strap that ensures secure placement during indigo light therapy. Micro-LEDs are integrated into the frame. The lenses can be replaced with prescription lenses if desired. The prototype
10 uses a processing unit to determine the specified amount of time that has passed since activating the indigo LEDs and deactivates them after the here determined treatment duration of 1h. Preliminary tests have shown that indigo light intensity of $52.5 \mu\text{W}/\text{cm}^2$ or higher may be perceived as bright and hinder the subject to perform normal activities in a dim ambient lighting environment. To the best knowledge of the inventors, no
15 existing light therapy glasses account for ambient light intensity. The proposed indigo eyewear will use light sensors to measure the ambient light intensity and adjust the indigo LED intensity using a processing unit to comfortable intensity levels providing indigo treatment that is safe without compromising the subject's ability to perform daily activities.

20 Furthermore, the indigo eyewear can incorporate a Bluetooth sensor to communicate with a smartphone and smartphone application. The processing unit of the indigo eyewear can communicate with the smartphone app via the Bluetooth connection, which can be used to change the settings of indigo eyewear (e.g., the treatment duration), track the daily usage of the eyewear including the indigo light
25 intensity, and remind the subjects to use the indigo eyewear if needed.

Embodiments of the present disclosure include a processing unit to set the indigo light intensity (e.g., 50 $\mu\text{W}/\text{cm}^2$), activate the indigo LED(s), determines a specified amount of time that has passed since activating the indigo LED(s), deactivates the indigo after the set treatment duration (e.g., 1h), obtain the ambient

5 light intensity from one or more light sensors and adjust the emitted indigo light based on the ambient light intensity. Furthermore, the embodiments of the present disclosure may include a Bluetooth sensor that allows the communication between the processing unit and a smartphone application to adjust settings, track usage, and providing reminders to the subject.

10

EXAMPLE F**Advantages of Indigo Light Eyewear over existing light therapy modalities for myopia treatment**

Existing violet light emitting glasses for myopia suppression used violet light in the range of 360 to 400nm. The associated randomized pilot clinical trial investigates the safety of the violet light emitting eyeglasses in 41 subjects (8- to 10-year old children) over a period of 6 months. A longer clinical study is required to assess the efficacy of these glasses. Our results suggest that violet light in the 360-400 nm range is ineffective in suppressing myopia in tree shrews (FIG. 6A,6B) and not optimal for retinal OPN5 activation in humans (FIG 5C). The design of existing violet light emitting glasses was based on experimental results in mice and disregarded the specie-dependent differences in lens transmission (FIG. 5C). The proposed indigo eyewear accounts for specie-dependent differences in lens transmission and will include indigo light in the high efficacy range of 418 nm to 446nm, which was identified to be highly effective in a near-to-primate model (FIG. 7).

A series of clinical trials reported that 'repeated low-level red light' (RLRL) therapy can slow myopia progression in children. In these reports, red laser light (635 to 650nm) was delivered directly into the eyes twice a day (3 min exposure times with a minimum of 4h gap between exposures) through an enclosed device. Several RLRL studies reported a prominent anti-myopia effect. A meta-analysis showed that RLRL therapy effectively promoted hyperopia, shortened axial length, and thickened the choroid. Concerns were raised by experts in the field regarding the study designed of existing RLRL studies and the long-term safety of RLRL. The concern was raised that existing RLRL system exceed safety limits (ANSI Z136.1-2014, sections 3.2.3-3.2.4). Similar safety concerns do not exist with the proposed indigo light eyewear, which produces indigo LED light at safe

intensity levels (Equation 2, EXAMPLE E). Furthermore, animal experiments have shown that red light can suppress induced myopia and induces hyperopia in normally developing eyes by a similar amount. Consequently, red light may not be ideal for myopia prevention. In contrast, indigo light had a limited effect on control eyes in tree shrews (FIG. 6E-G, last
5 column). Furthermore, it has been shown that spectral purity is important for effective red therapy. This means the subject has to stare into a device that just emits red light for this treatment modality to be effective. In contrast to red light, the treatment effect of indigo light does not require “spectrally pure light” to be effective (FIG. 6E-G, FIG. 9B). This means, the subject that uses the proposed indigo light eyewear can continue with its
10 daily activities while receiving indigo light treatment. In summary, the proposed indigo light eyewear has significant advantages over existing light therapy modalities including high efficacy levels, no known safety concerns, and practical advantages.

EXAMPLE G**Tunable indigo LED light source for patient-specific treatment**

Results presented in FIG. 5, FIG. 6, and FIG. 7 suggest that the treatment efficacy of short wavelength light depends on the exact wavelength of the light source, the lens transmission of the subject's eyes, and the age of the subject as the lens transmission profile changes with age. In various examples, indigo LEDs that can produce a tunable indigo light can be used to fine-tune the indigo spectrum for each subject and his/her age. As an example: the tunable LED can be used to expose a young patient (*e.g.*, 6 years old) to indigo light at the lower end of the high efficacy range (*e.g.*, indigo LED light with a peak wavelength of 421nm). As this patient is aging, the tunable indigo LED can be used to adjust the indigo spectrum such that peak wavelength increases with age (*e.g.*, indigo LED light with a peak wavelength of 430nm) until the patient becomes a young adult (*e.g.*, 18 years old). To accomplish this, the birthday of the patient can be entered into the smartphone app and transmitted to the processing unit of the indigo light eyewear. The processing unit can calculate the current age and set the spectrum of the tunable indigo LED based on the patient's age before activation of the tunable indigo LED.

CLAIMS

Therefore, the following is claimed:

1. A system, comprising:
 - eyewear configured to be worn by a subject;
 - at least one LED disposed on the eyewear and configured to produce indigo light;
 - one or more light sensors disposed on the eyewear, the light sensors electrically coupled to the at least one LED;
 - a processor;
 - a memory; and
 - machine-readable instructions stored in the memory that, when executed by the processor, cause the system to at least:
 - receive an ambient light input from the one or more light sensors;
 - determine an indigo light intensity based at least in part on the ambient light input; and
 - cause the at least one LED to produce the indigo light intensity.
2. The system of claim 1, wherein the at least one LED is configured to produce light with wavelengths in a range of about 400 nm to 450nm.
3. The system of claim 1, wherein the at least one LED is configured to produce light with wavelengths in the range of about 418 nm to 446nm.

4. The system of claim 1, wherein the at least one LED is configured to produce light with a peak and nominal wavelength in the range of about 421 to 441nm.
5. The system of claim 1, further comprising a power switch electrically coupled to the at least one LED and configured to activate and deactivate the at least one LED.
6. The system of claim 1, wherein the eyewear further comprises:
a frame configured to fit a subject's face;
one or more lenses disposed within the frame; and
wherein the at least one LED is disposed within the frame and adjacent to the one or more lenses.
7. The system of claim 6, wherein the eyewear further comprises a strap configured to hold the frame to the subject's face.
8. The system of claim 6, wherein the at least one LED is positioned such that the indigo light produced is directed toward at least one eye of the subject.
9. The system of claim 6, wherein the at least one LED is directed through a diffuser such that diffused indigo light reaches at least one eye of the subject.
10. The system of claim 6, wherein the one or more light sensors are disposed on an outer side of the frame and directed away from the subject's face.

11. The system of claim 1, wherein the one or more light sensors are disposed on an outer side of the eyewear.

12. The system of claim 1, wherein the machine-readable instructions further cause the processor to at least:

activate the at least one LED;

determine a specified amount of time has passed since the at least one LED was activated; and

in response to the determination that the specified amount of time has passed, deactivate the at least one LED.

13. A method, comprising:

receiving, from one or more light sensors disposed on eyewear, an ambient light input;

determining, by a processor, an indigo light intensity based at least in part on the ambient light input; and

causing, by the processor, at least one LED to produce the indigo light intensity, the at least one LED disposed on the eyewear.

14. The method of claim 13, further comprising:
- activating, by a processor, the at least one LED;
 - setting, by the processor, an intensity of the at least one LED;
 - determining, by the processor, a specified amount of time has passed since the at least one LED was activated; and
 - in response to determining the specified amount of time has passed, deactivating, by the processor, the at least one LED.
15. The method of claim 13, wherein the eyewear further comprises:
- a frame configured to fit a subject's face;
 - one or more lenses disposed within the frame; and
 - wherein the at least one LED is disposed within the frame and adjacent to the one or more lenses.
16. A system, comprising:
- a device configured to be worn on a head of a subject;
 - an indigo LED disposed on the device and directed toward an eye of the subject; and
 - a power switch electrically coupled to the indigo LED and configured to activate and deactivate the indigo LED.

17. The system of claim 16, further comprising:
- a processor;
 - a memory; and
 - machine-readable instructions stored in the memory that, when executed by the processor, cause the system to at least:
 - set a light intensity for the indigo LED; and
 - activate the indigo LED at the light intensity.
18. The system of claim 17, wherein the device further comprises an ambient light sensor disposed on the device, the ambient light sensor electrically coupled to the indigo LED.
19. The system of claim 18, wherein the machine-readable instructions, when executed by the processor, further cause the system to at least:
- receive an ambient light input from the ambient light sensor; and
 - adjust the light intensity based at least in part on the ambient light input.
20. The system of claim 17, wherein the machine-readable instructions, when executed by the processor, further cause the system to at least:
- determine a specified amount of time has passed since activating the indigo LED; and
 - deactivate the indigo LED.
21. The system of claim 16, wherein the device further comprises a strap configured to hold the device to the head of the subject.

22. The system of claim 16, wherein the indigo LED is configured to produce light with a peak and nominal wavelength in the range of about 421 to 441nm.