have been proposed to treat myopia associated with axial length growth, these treatments can have less than ideal results and have not been shown to safely treat refractive error at least some instances. Although light has been proposed as a stimulus to alter the growth of the eye, at least some of the prior devices can provide less than ideal results. Also, the time of treatment can be longer than would be ideal, and at least some of the prior approaches may be more complex than would be ideal.

[0006] Therefore, new approaches are needed to treat refractive error of the eye that ameliorate at least some of the above limitations of the prior approaches.

SUMMARY

[0007] In an aspect, the present disclosure provides ~~A~~an apparatus to treat refractive error of an eye, the apparatus comprising~~es~~ an optic comprising an optical zone and a peripheral defocus optical structure to form images of a plurality of stimuli anterior or posterior to a peripheral portion of a retina of the eye.~~. In some embodiments,~~ the peripheral defocus optical structure located outside the optical zone. In some embodiments, the peripheral defocus optical structure comprises optical power to focus light to a different depth of the eye than the optical zone. In some embodiments, the optic comprises one or more of a lens, an optically transparent substrate, a beam splitter, a prism, or an optically transmissive support.

INCORPORATION BY REFERENCE

[0008] All patents, applications, and publications referred to and identified herein are hereby incorporated by reference in their entirety, and shall be considered fully incorporated by reference even though referred to elsewhere in the application.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] A better understanding of the features, advantages and principles of the present disclosure will be obtained by reference to the following detailed description that sets forth illustrative embodiments, and the accompanying drawings of which:

[0010] FIG. 1 shows a side view of a vision apparatus to treat refractive error of an eye, in accordance with some embodiments;

[0011] FIG. 2 shows an apparatus to treat refractive error of an eye, in accordance with some embodiments;

[0012] FIG. 3A shows the apparatus of FIG. 2 in use, in accordance with some embodiments;

CLAIMS

WHAT IS CLAIMED IS:

1. An apparatus to treat refractive error of an eye, the apparatus comprising:

an optic comprising an optical zone; and

a peripheral defocus optical structure to form images of a plurality of stimuli anterior or posterior to a peripheral portion of a retina of the eye, the peripheral defocus optical structure located outside the optical zone.

2. The apparatus of claim 1, wherein the peripheral defocus optical structure comprises optical power to focus light to a different depth of the eye than the optical zone.

3. The apparatus of claim 1, wherein the optic comprises one or more of a lens, an optically transparent substrate, a beam splitter, a prism, or an optically transmissive support.

4. The apparatus of claim 1, wherein peripheral defocus optical structure comprises a Fresnel lens.

5. The apparatus of claim 1, wherein peripheral defocus optical structure comprises a plurality of lenslets.

6. The apparatus of claim 5, wherein a plurality of lenslets is arranged in one or more circular arrays about the optical zone.

7. The apparatus of claim 1, wherein peripheral defocus optical structure comprises one or more of a diffractive optical structure or echelettes.

8. The apparatus of claim 1, further comprising a filter within the optical zone to decrease light transmission therethrough.

9. The apparatus of claim 8, wherein the filter is configured to decrease an intensity of a central image formed on a fovea of the eye and provide an increased intensity of the plurality of stimuli in relation to the intensity of the central image.

10. The apparatus of claim 8, wherein the filter extends into the peripheral defocus optical structure.

11. The apparatus of claim 8, wherein the filter comprises a neutral density filter.

12. The apparatus of claim 8, wherein the filter reduces transmission of visible light by a factor of between 5 and 30.

13. The apparatus of claim 8, wherein the filter reduces transmission of visible light by an amount within a range from 5 percent to 99 percent.

~~14. The apparatus of claim 1, further comprising a display that is configured to provide light through the optical zone to form a central image on a macula and through the peripheral defocus optical structure to provide the plurality of stimuli with defocus on the peripheral portion of the retina.~~

~~15. The apparatus as in claim 14, wherein plurality of stimuli is formed with lenslets of the peripheral defocus optical structure.~~

~~16. The apparatus of claim 1, wherein the peripheral defocus optical structure further comprises a plurality of stimuli generating structures.~~

~~17. The apparatus of claim16, further comprising a filter aligned with one or more apertures of the peripheral defocus optical structure.~~

~~18. The apparatus of claim 17, wherein the plurality of stimuli generating structures are within the aperture.~~

~~19. The apparatus of claim 18, wherein each of the plurality of stimuli generating structures comprise a mask.~~

~~20. The apparatus of claim 1, wherein the each of the plurality of stimuli comprises spatial frequencies.~~

~~21. The apparatus of claim 20, wherein the spatial frequencies comprise frequencies within a range from 0.1 cycles per degree to 180 cycles per degree and optionally within a range from 1 cycle per degree to 180 cycles per degree.~~

~~22. The apparatus of claim 20, wherein the spatial frequencies comprise frequencies of at least 1 line pair per mm (lp/mm) on the retina and optionally at least 50 lp/mm on the retina.~~

~~23. The apparatus of claim 1, wherein the plurality of stimuli comprise contrast within a range 99.9% to 2.5%.~~

~~24. The apparatus of claim 1, wherein the peripheral defocus optical structure comprises an optical power within a range from -2 D to -6 D or within a range from +2D to +6D.~~

~~25. The apparatus of claim 1, wherein the peripheral defocus optical structure comprises an optical power within a range from -3 D to -5 D or within a range from +3 D to +5 D.~~

~~26. The apparatus of claim 1, further comprising a base, wherein the peripheral defocus optical structure is coupled to the base.~~

~~27. The apparatus of claim 26, further comprising adhesive on a surface of the base.~~

~~28. The apparatus of claim 27, wherein the optic comprises a spectacle lens and a filter and peripheral defocus optical structure are coupled to the lens.~~

~~29. The apparatus of claim 1, wherein the optic comprises an adhesive.~~

~~30. The apparatus of claim 1, wherein the optic comprises a plurality of layers.~~

~~31.~~14. The apparatus of claim 1, further comprising:

a display; and

a processor operatively coupled to the display, wherein the processor comprises instructions to provide the plurality of stimuli on the display at a plurality of locations to form the images at a plurality of locations anterior or posterior to the retina.

~~32.~~15. The apparatus of claim ~~31~~14, wherein the peripheral defocus structure comprises a plurality of lenslets, and wherein the each of the plurality of stimuli on the display is aligned with a corresponding lenslet to form an image at a location anterior or posterior to a peripheral portion of the retina.

~~33.~~16. The apparatus of claim ~~32~~15, further comprising:

a plurality of substantially transparent electrodes; and

a liquid crystal material between the plurality of substantially transparent electrodes;

wherein the liquid crystal material and the plurality of lenslets are positioned between the plurality of electrodes to activate and deactivate optical power of the plurality of lenslets.

~~34.~~17. The apparatus of claim ~~33~~16, wherein the plurality of lenslets is substantially transparent in a deactivated configuration and wherein the plurality of lenslets is configured to provide the plurality of stimuli in a deactivated configuration.

~~35.~~18. The apparatus of claim ~~33~~16, wherein the plurality of electrodes is configured to change an index of refraction of the liquid crystal material in response to a voltage between the electrodes.

~~36.~~19. The apparatus of claim ~~33~~16, wherein the processor is operatively coupled to the plurality of electrodes to activate the plurality of lenslets to provide the plurality of stimuli.