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 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. 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; 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.

15. The apparatus of claim 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.

16. The apparatus of claim 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.

17. The apparatus of claim 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.

18. The apparatus of claim 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.

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