Claims

1. A waveguide display element comprising:

a plurality of waveguide layers stacked on top of each other, and
an in-coupler associated with each waveguide layer for coupling light within a predefined wavelength band into the waveguide layer,

wherein:

each of the in-couplers includes:

an intermediate layer arranged on the waveguide layer, the intermediate layer having intermediate layer properties, and

an in-coupling grating arranged on the intermediate layer, the grating having grating properties, and

the combination of intermediate layer properties and grating properties of each in-coupler is different with respect to other in-couplers.

2. The element according to claim 1, wherein the in-couplers have the same intermediate layer properties and different grating properties with respect to other in-couplers.

3. The element according to claim 2, wherein in-couplers associated with different waveguide layers have different in-coupling grating periods.

4. The element according to claim 3, wherein the grating period increases from a top waveguide layer on the incoming light side of the element towards a bottom waveguide layers on the opposite side of the element.

5. The element according to claim 2, wherein the grating period increases from a top waveguide layer on the incoming light side of the element towards a bottom waveguide layers on the opposite side of the element.

6. The element according to claim 2, wherein the intermediate layers of each in-coupler have a thickness of 20 μm or less, in particular 10 μm or less, such as 1-10 μm.

7. The element according to claim 2, wherein:

the waveguide layers have an index of refraction which is 1.7 or more, such as 2.0 or more, and the intermediate layers have an index of refraction which is less than 1.8, such as 1.7 or less.

8. The element according to claim 2, wherein the in-couplers have the same shape and are aligned with each other in the lateral plane of the element.

9. The element according to claim 1, wherein in-couplers associated with different waveguide layers have different in-coupling grating periods.

10. The element according to claim 9, wherein the grating period increases from a top waveguide layer on the incoming light side of the element towards a bottom waveguide layers on the opposite side of the element.

11. The element according to claim 9, wherein the grating period increases from a top waveguide layer on the incoming light side of the element towards a bottom waveguide layers on the opposite side of the element.

12. The element according to claim 1, wherein the in-couplers have the same grating properties and different intermediate layer properties with respect to other in-couplers.

13. The element according to claim 12, further comprising one or more optical bandpass filters or dichroic mirrors between the waveguide layers.

14. The element according to claim 1, wherein the intermediate layers of each in-coupler have a thickness of 20 μm or less, in particular 10 μm or less, such as 1-10 μm.

15. The element according to claim 1, wherein:

the waveguide layers have an index of refraction which is 1.7 or more, such as 2.0 or more, and

the intermediate layers have an index of refraction which is less than 1.8, such as 1.7 or less.

16. The element according to claim 1, wherein the in-couplers have the same shape and are aligned with each other in the lateral plane of the element.

17. A personal display device, such as a head-mounted display or head-up display, comprising:

a waveguide display element according to claim 1, and

a multicolor laser projector adapted to project light rays in different angles of incidence to in-couplers of the display element.

18. A method of coupling propagating light rays into a waveguide display, comprising:

providing a waveguide display element according to claim 1, and
directing light rays in different angles of incidence to the display element in order to selectively couple said rays into the different waveguide layers of the display element.

19. The method according to claim 18, wherein said light rays comprise light rays in at least three different wavelength bands, each of the wavelength bands being directed to the display element in a different angle of incidence.

20. The element according to claim 1, wherein each intermediate layer has a thickness and index of refraction smaller than that of the waveguide layer it is associated with.