CLAIMS

1. A waveguide, comprising:

a waveguide substrate, having a substrate refractive index (RI) n_{sub};

a slab waveguide layer disposed over the waveguide substrate, the slab waveguide layer having a slab RI n_{swg} and a slab depth d_{swg}, the slab depth d_{swg} from a lower surface to an upper surface of the slab waveguide layer;

a grating material disposed on the slab waveguide layer, wherein a material of the slab waveguide layer and the grating are different;

an incoupler grating defined by a first portion of a plurality of grating structures, the grating structures of the incoupler grating are disposed in the grating material and the slab waveguide layer such that the grating structures of the in-coupler grating include a layer of the grating material and a layer of the slab waveguide layer; a fold grating defined by a second portion of the plurality of grating structures, the grating structures of the fold grating are disposed in the grating material on the slab waveguide layer;

an outcoupler grating defined by a third portion of the plurality of grating structures, the grating structures of the outcoupler grating are disposed in the grating material on the slab waveguide layer; and a superstrate between and over the grating structures, the superstrate having a superstrate RI $n_{superstrate}$ and an interface with the slab waveguide layer, wherein the slab RI n_{swg} is greater than the substrate RI n_{sub} and the slab RI n_{swg} is greater than the superstrate RI $n_{superstrate}$.

2. The waveguide of claim 1, wherein the slab waveguide layer is disposed on the waveguide substrate.

3. The waveguide of claim 1, where the slab depth d_{swg} is from the lower surface to the upper surface of the slab waveguide layer between grating structures disposed in the slab waveguide layer.

4. The waveguide of claim 1, wherein waveguide substrate comprises glass, silicon (Si), silicon dioxide (SiO_2), germanium (Ge), silicon germanium (SiGe), indium phosphide

(InP), gallium arsenide (GaAs), gallium nitride (GaN), fused silica, quartz, sapphire (Al_2O_3), silicon carbide (SiC), lithium niobate ($LiNbO_3$), indium tin oxide (ITO), or combinations thereof.

5. The waveguide of claim 1, wherein the slab waveguide layer comprises one or more of silicon oxycarbide (SiOC), titanium dioxide (TiO_2), silicon dioxide (SiO_2), vanadium (IV) oxide (VOx), aluminum oxide (Al_2O_3), aluminum-doped zinc oxide (AZO), indium tin oxide (ITO), tin dioxide (SnO_2), zinc oxide (ZnO), tantalum pentoxide (Ta_2O_5), silicon nitride (Si_3N_4), zirconium dioxide (ZrO_2), niobium oxide (Nb_2O_5), cadmium stannate (Cd_2SnO_4), titanium silicon oxide (TiSiOx) or silicon carbon-nitride (SiCN) containing materials.

6. The waveguide of claim 1, wherein the substrate RI n_{sub} at 620 nm is 1.8 to 2.10.

7. The waveguide of claim 1, wherein the substrate RI n_{sub} at 620 nm is greater than 2.77.

8. The waveguide of claim 1, wherein the slab RI n_{swg} at 620 nm is 1.8 to 2.6.

9. The waveguide of claim 1, wherein the slab depth d_{swg} is:
75 nm to 110 nm when the slab RI n_{swg} at 620 nm is 2.1;
55 nm to 100 nm when the slab RI n_{swg} at 620 nm is 2.2;
35 nm to 85 nm when the slab RI n_{swg} at 620 nm is 2.3;
30 nm to 70 nm when the slab RI n_{swg} at 620 nm is 2.4;
25 nm to 60 nm when the slab RI n_{swg} at 620 nm is 2.5; and
15 nm to 50 nm when the slab RI n_{swg} at 620 nm is 2.6.

10. The waveguide of claim 1, wherein the waveguide has a diffraction efficiency ratio of a diffraction efficiency of blue channel light to the diffraction efficiency of red channel light of 1.1:1.0.

11. The waveguide of claim 1, wherein the grating structures are blazed grating structures.

12. The waveguide of claim 1, wherein the grating structures have sidewalls parallel to each other and angled relative to the waveguide substrate.

13. The waveguide of claim 1, wherein the grating structures have two-dimensional periodicity.

14. The waveguide of claim 1, wherein the superstrate is a coating.

15. The waveguide of claim 1, wherein the waveguide has a resonance condition of

$$2n_{swg}k_0\cos(\theta)d + \phi_{sub} + \phi_{grating} = 2\pi m$$

wherein, n_{swg} is the slab RI, m is the diffracted order, k_0 is the wavenumber of light ($2\pi/\lambda_0$), d is the slab depth d_{swg}, θ is the angle of propagation of light in the slab waveguide layer, ϕ_{sub} is a phase accumulated upon reflection at the interface, and $\phi_{grating}$ is the phase accumulated upon reflection at a the interface.

16. The waveguide of claim 15, wherein a change in slab depth d_{swg} between resonance peaks, Δd, is determined by solving

$$\Delta d = \frac{\lambda_0}{2n_{swg}\cos(\theta)}$$

wherein λ_0 corresponds to a wavelength of a blue channel light, a green channel light, or a red channel light.

17. A waveguide, comprising:

a waveguide substrate, having a substrate refractive index (RI) n_{sub};

a slab waveguide layer disposed over the waveguide substrate, the slab waveguide layer having a slab RI n_{swg} and a slab depth d_{swg}, the slab depth d_{swg} from a lower surface to an upper surface of the slab waveguide layer;

a grating material disposed on the slab waveguide layer, wherein a material of the slab waveguide layer and the grating are different;

an incoupler grating defined by a first portion of a plurality of grating structures, the grating structures of the incoupler grating are disposed in the grating material and the slab waveguide layer such that the grating structures of the in-coupler grating include a layer of the grating material and a layer of the slab waveguide layer; a fold grating defined by a second portion of the plurality of grating structures, the grating structures of the fold grating are disposed in the grating material on the slab waveguide layer;

an outcoupler grating defined by a third portion of the plurality of grating structures, the grating structures of the outcoupler grating are disposed in the grating material on the slab waveguide layer; and

a superstrate between and over the grating structures, the superstrate having a superstrate RI $n_{superstrate}$ and an interface with the slab waveguide layer, wherein the slab RI n_{swg} is greater than the substrate RI n_{sub} and the slab RI n_{swg} is greater than the superstrate RI $n_{superstrate}$, and the slab depth d_{swg} is:

75 nm to 110 nm when the slab RI n_{swg} at 620 nm is 2.1;

55 nm to 100 nm when the slab RI n_{swg} at 620 nm is 2.2;

35 nm to 85 nm when the slab RI n_{swg} at 620 nm is 2.3;

30 nm to 70 nm when the slab RI n_{swg} at 620 nm is 2.4;

25 nm to 60 nm when the slab RI n_{swg} at 620 nm is 2.5; and

15 nm to 50 nm when the slab RI n_{swg} at 620 nm is 2.6.

18. A waveguide, comprising:

a waveguide substrate, having a substrate refractive index (RI) n_{sub};

a slab waveguide layer disposed over the waveguide substrate, the slab waveguide layer having a slab RI n_{swg} and a slab depth d_{swg};

a grating material disposed on the slab waveguide layer, wherein a material of the slab waveguide layer and the grating are different;

an incoupler grating defined by a first portion of a plurality of grating structures, the grating structures of the incoupler grating are disposed in the grating material and the

slab waveguide layer such that the grating structures of the in-coupler grating include a layer of the grating material and a layer of the slab waveguide layer;

an outcoupler grating defined by a second portion of the plurality of grating structures, the grating structures of the outcoupler grating are disposed in the grating material on slab waveguide layer; and

a superstrate between and over the grating structures, the superstrate having a superstrate RI $n_{superstrate}$ and an interface with the slab waveguide layer, wherein the slab RI n_{swg} is greater than the substrate RI n_{sub} and the slab RI n_{swg} is greater than the superstrate RI $n_{superstrate}$.