CLAIMS:

1. A dual-mode waveguide antenna comprising:

   a straight section configured to receive an optical signal;

   a periodic sinusoidal tapered section optically coupled to the straight section, the periodic sinusoidal tapered section being configured to project the optical signal into an optical beam,

   whereby a period Λ of the periodic sinusoidal tapered section is longer than an operating wavelength λ of the optical signal,

   whereby a width W_{WG} of the straight section is smaller than a maximum width W_{MAX} of the periodic sinusoidal tapered section and larger than a minimum width W_{MIN} of the periodic sinusoidal tapered section,

   whereby a width at a midpoint of each period Λ of the periodic sinusoidal tapered section is equal to the width W_{WG} of the straight section, and

   whereby the dual-mode waveguide antenna is configured to produce a single emission angle when two separate optical signals with differing wavelengths are beamed through the dual-mode waveguide antenna.

2. The dual-mode waveguide antenna according to claim 1 whereby a width $W(x)$ along a longitudinal distance of the periodic sinusoidal tapered section is determined based on the width W_{WG} of the straight section, the maximum width W_{MAX} and the minimum width W_{MIN} of the periodic sinusoidal tapered section.

3. The dual-mode waveguide antenna according to claim 2 whereby the width $W(x)$ along a longitudinal distance of the periodic sinusoidal tapered section is defined as:

$$W(x) = (W_{WG} + \frac{W_{max} - W_{min}}{2}) \cos(2\pi x) + \frac{W_{max} + W_{min}}{2} \, |\cos(2\pi x)|$$

   where x is a position along the longitudinal distance of the periodic sinusoidal tapered section, W_{WG} is the width of the straight section, W_{MAX} is the maximum width and W_{MIN} is the minimum width of the periodic sinusoidal tapered section.

4. The dual-mode waveguide antenna according to claim 2 wherein optimal parameters for the maximum width W_{MAX}, the minimum width W_{MIN}, the width W_{WG}, the width

$W(x)$ along a longitudinal distance of the periodic sinusoidal tapered section and period Λ of the periodic sinusoidal tapered section are determined based on iterations of these parameters that are able to produce a largest main to highest side lobe ratio of the operating wavelength λ of the optical signal and a smallest angular difference between main lobes of a first wavelength λ_1 and a second wavelength λ_2 that are associated with the optical signal.

5. The dual-mode waveguide antenna according to claim 4 whereby the parameters for the maximum width W_{MAX}, the minimum width W_{MIN} and the width W_{WG} are recursively generated in each iteration.

6. The dual-mode waveguide antenna according to claim 5 whereby the period Λ of the periodic sinusoidal tapered section is determined by obtaining an initial period Λ_0 of the periodic sinusoidal tapered section and by varying the initial period Λ_0 in a numerical simulation of a far field projection of the dual-mode waveguide antenna based on the width $W(x)$ along a longitudinal distance of the periodic sinusoidal tapered section, the width W_{WG}, the minimum width W_{MIN} and the maximum width W_{MAX} until a variation of the initial period Λ_0 that produces an optimum far field projection of the dual-mode waveguide antenna is determined.

7. The dual-mode waveguide antenna according to claim 6 whereby an initial period Λ_0 of the periodic sinusoidal tapered section is determined based on the first wavelength λ_1 and the second wavelength λ_2, a high order diffraction q_1 of the first wavelength λ_1, a high order diffraction q_2 of the second wavelength λ_2, and an effective index difference $\Delta n_{eff,integ}$ across all N parts of the period Λ of the periodic sinusoidal tapered section.

8. The dual-mode waveguide antenna according to claim 7, wherein the effective index difference $\Delta n_{eff,integ}$ across all N parts of the period Λ of the periodic sinusoidal tapered section is defined as:

$$\Delta n_{eff,integ} = \frac{1}{N}\sum_{j=1}^{N} |n_{eff,\lambda 1}(x_j) - n_{eff,\lambda 2}(x_j)|$$

where $n_{eff,\lambda 1}(x_j)$ is an effective index of the first wavelength λ_1 at part x_j of the N parts of the period Λ of the periodic sinusoidal tapered section and $n_{eff,\lambda 2}(x_j)$ is an effective index of the second wavelength λ_2 at part x_j of the N parts of the period Λ of the periodic sinusoidal tapered section.

9. The dual-mode waveguide antenna according to claim 8, wherein the initial period Λ_0 of the periodic sinusoidal tapered section is defined as:

$$\Lambda_0 = q_1 \frac{\lambda_1}{\Delta n_{eff,integ}} - q_2 \frac{\lambda_2}{\Delta n_{eff,integ}}$$

where q_1 is the high order diffraction of the first wavelength λ_1, and q_2 is the high order diffraction of the second wavelength λ_2.

10. The dual-module waveguide antenna according to claim 1 whereby the straight section and the periodic sinusoidal tapered section comprises Aluminum Nitride (AlN) formed on a Silicon Dioxide (SiO_2) substrate and cladded in a Silicon Dioxide (SiO_2) superstrate.

11. A method of forming a dual-waveguide antenna, the method comprising:

forming a straight section of the dual-waveguide antenna, the straight section being configured to receive an optical signal;

forming a periodic sinusoidal tapered section of the dual-waveguide antenna such that the periodic sinusoidal tapered section is optically coupled to the straight section, the periodic sinusoidal tapered section being configured to project the optical signal into an optical beam,

whereby a period Λ of the periodic sinusoidal tapered section is formed such that the period Λ is longer than an operating wavelength λ of the optical signal,

whereby a width W_{WG} of the straight section is formed such that the width W_{WG} is smaller than a maximum width W_{MAX} of the periodic sinusoidal tapered section and larger than a minimum width W_{MIN} of the periodic sinusoidal tapered section,

whereby a width at a midpoint of each period Λ of the periodic sinusoidal tapered section is formed such that the width at the midpoint of each period Λ is equal to the width W_{WG} of the straight section, and

whereby the dual-mode waveguide antenna is configured to produce a single emission angle when two separate optical signals with differing wavelengths are beamed through the dual-mode waveguide antenna.

12. The method according to claim 11, further comprising the step of determining a width $W(x)$ along a longitudinal distance of the periodic sinusoidal tapered section based on the width W_{WG} of the straight section, the maximum width W_{MAX} and the minimum width W_{MIN} of the periodic sinusoidal tapered section.

13. The method according to claim 11 whereby the width $W(x)$ along a longitudinal distance of the periodic sinusoidal tapered section is defined as:

$$W(x) = (W_{WG} + \frac{W_{max} - W_{min}}{2}) \cos(2\pi x) + \frac{W_{max} + W_{min}}{2} \, |\cos(2\pi x)|$$

where x is a position along the longitudinal distance of the periodic sinusoidal tapered section, W_{WG} is the width of the straight section, W_{MAX} is the maximum width and W_{MIN} is the minimum width of the periodic sinusoidal tapered section.

14. The method according to claim 12 wherein optimal parameters for the maximum width W_{MAX}, the minimum width W_{MIN}, the width W_{WG}, the width $W(x)$ along a longitudinal distance of the periodic sinusoidal tapered section and period Λ of the periodic sinusoidal tapered section are determined based on iterations of these parameters that are able to produce a largest main to highest side lobe ratio of the operating wavelength λ of the optical signal and a smallest angular difference between main lobes of a first wavelength λ_1 and a second wavelength λ_2 that are associated with the optical signal.

15. The method according to claim 14 further comprising the step of recursively generating the parameters for the maximum width W_{MAX}, the minimum width W_{MIN} and the width W_{WG} in each iteration.

16. The method according to claim 15 whereby the period Λ of the periodic sinusoidal tapered section is determined by obtaining an initial period Λ_0 of the periodic sinusoidal tapered section and by varying the initial period Λ_0 in a numerical simulation of a far field projection of the dual-mode waveguide antenna based on the width $W(x)$ along a

longitudinal distance of the periodic sinusoidal tapered section, the width W_{WG}, the minimum width W_{MIN} and the maximum width W_{MAX} until a variation of the initial period Λ_0 that produces an optimum far field projection of the dual-mode waveguide antenna is obtained.

17. The method according to claim 16 whereby an initial period Λ_0 of the periodic sinusoidal tapered section is determined based on the first wavelength λ_1 and the second wavelength λ_2, a high order diffraction q_1 of the first wavelength λ_1, a high order diffraction q_2 of the second wavelength λ_2, and an effective index difference $\Delta n_{eff,integ}$ across all N parts of the period Λ of the periodic sinusoidal tapered section.

18. The method according to claim 17, wherein the effective index difference $\Delta n_{eff,integ}$ across all N parts of the period Λ of the periodic sinusoidal tapered section is defined as:

$$\Delta n_{eff,integ} = \frac{1}{N}\sum_{j=1}^{N} |n_{eff,\lambda 1}(x_j) - n_{eff,\lambda 2}(x_j)|$$

where $n_{eff,\lambda 1}(x_j)$ is an effective index of the first wavelength λ_1 at part x_j of the N parts of the period Λ of the periodic sinusoidal tapered section and $n_{eff,\lambda 2}(x_j)$ is an effective index of the second wavelength λ_2 at part x_j of the N parts of the period Λ of the periodic sinusoidal tapered section.

19. The method according to claim 18, wherein the initial period Λ_0 of the periodic sinusoidal tapered section is defined as:

$$\Lambda_0 = q_1 \frac{\lambda_1}{\Delta n_{eff,integ}} - q_2 \frac{\lambda_2}{\Delta n_{eff,integ}}$$

where q_1 is the high order diffraction of the first wavelength λ_1, and q_2 is the high order diffraction of the second wavelength λ_2.

20. An optical phased array system comprising:
    a plurality of dual-mode waveguide antennas,
    whereby each dual-mode waveguide antenna comprises:
        a straight section configured to receive an optical signal;

a periodic sinusoidal tapered section optically coupled to the straight section, the periodic sinusoidal tapered section being configured to project the optical signal into an optical beam,

whereby a period Λ of the periodic sinusoidal tapered section is longer than an operating wavelength λ of the optical signal,

whereby a width W_{WG} of the straight section is smaller than a maximum width W_{MAX} of the periodic sinusoidal tapered section and larger than a minimum width W_{MIN} of the periodic sinusoidal tapered section,

whereby a width at a midpoint of each period Λ of the periodic sinusoidal tapered section is equal to the width W_{WG} of the straight section, and

whereby each dual-mode waveguide antenna is configured to produce a single emission angle when two separate optical signals with differing wavelengths are beamed through the dual-mode waveguide antenna.