CLAIMS

We Claim:

1. A waveguide neural interface device, comprising:

a) a neural device that is implantable in tissue and ~~including~~ comprises a neural device sidewall extending from a proximal neural device portion that is connectable to a pulse generator to a distal neural device portion;

b) an array of electrode sites ~~that~~ supported by the neural device sidewall, wherein the array of electrode sites are configured to electrically communicate with their surroundings~~, wherein the array of electrode sites includes~~ and at least one recording electrode site located on a first face of the distal neural device portion; ~~and~~

c) a first waveguide ~~formed separately from and coupled to the neural device~~extending from a proximal first waveguide portion that is connectable to a light source to a distal first waveguide portion having a distal first waveguide end, wherein the distal first waveguide ~~carries light along a longitudinal axis and includes a light directing element that redirects the carried light from the waveguide~~ portion is supported by a second face of the distal neural device portion;

d) an aperture extending from the first face through the neural device sidewall to the second face in the distal neural device portion; and

e) a light redirecting element supported by the distal first waveguide portion adjacent to the aperture,

f) wherein the light redirecting element serves to redirect light traveling along the distal first waveguide portion through the aperture in the neural device portion to thereby illuminate selectively targeted tissue~~;~~

~~• wherein at least a portion of the redirected light is directed laterally away from the longitudinal axis; and~~

~~• wherein the recording electrode site is configured to sample illuminated tissue~~ adjacent to, but in a manner that avoids direct illumination of, the at least one recording electrode site on the first face of the distal neural device portion, and

wherein the at least one recording electrode site is configured to sample illuminated tissue.

2. The waveguide neural interface device of Claim 1, wherein the neural device is a neural probe.

3. The waveguide neural interface device of Claim 1, wherein the redirected light is aimed substantially in a direction perpendicular to ~~the~~ a longitudinal axis of the light redirecting element.

4. The waveguide neural interface device of Claim 1, wherein ~~at least a portion of the array of electrode sites is located on a first face of the neural device and the waveguide is~~

~~coupled to a second face of the neural device, wherein~~ the second face is opposite the first face of the distal neural device portion.

~~5. The waveguide neural interface device of Claim 4, wherein the neural device includes an aperture extending between the first face and the second face.~~

~~6~~5. The waveguide neural interface device of Claim ~~5~~1, wherein the light redirecting element of the waveguide includes at least one selected from the group consisting of: a refractor that refracts light through the aperture ~~of~~ in the neural device sidewall, a reflector that reflects light through the aperture ~~of~~ in the neural device sidewall, and a lens that focuses light through the aperture ~~of~~ in the neural device sidewall.

~~7~~6. The waveguide neural interface device of Claim 1, wherein at least a portion of the electrode sites and the waveguide are mounted on the same face of the distal neural device portion.

~~8~~7. The waveguide neural interface device of Claim 1, wherein at least a portion of the waveguide extends laterally beyond the neural device so that a first portion of the redirected light travels out through the aperture and a second portion of the redirected light is redirected laterally away from the waveguide.

~~9~~8. The waveguide neural interface device of Claim 1, wherein the light redirecting element of the waveguide includes a refractor that refracts light away from ~~the~~ a longitudinal axis of the light redirecting element.

~~10~~9. The waveguide neural interface device of Claim 1, wherein the light redirecting element of the first waveguide includes a reflector that reflects light away from ~~the~~ a longitudinal axis of the light redirecting element.

~~11~~10. The waveguide neural interface of Claim ~~9~~8, wherein the reflector includes a roughened surface that scatters light.

~~12~~11. The waveguide neural interface device of Claim 1, wherein the light redirecting element of the waveguide includes a lens that manipulates light away from ~~the~~ a longitudinal axis of the light redirecting element.

~~13~~12. The waveguide neural interface device of Claim 1, wherein the light redirecting element of the waveguide includes an optically dissipating portion that dissipates the ~~carried~~ light to illuminate tissue.

~~14~~13. The waveguide neural interface device of Claim 1, wherein the waveguide includes a plurality of light redirecting elements, wherein each light redirecting element redirects a portion of the ~~carried~~ light from a different point ~~on~~ along the distal first waveguide portion.

~~15~~14. The waveguide neural interface device of Claim ~~14~~13, wherein each light redirecting element redirects a portion of the ~~carried~~ light at a different distance along ~~the~~ a length of the distal first waveguide portion.

~~16~~15. The waveguide neural interface device of Claim 1, further comprising a second waveguide coupled to the neural device.

~~17~~16. The waveguide neural interface device of Claim ~~16~~15, wherein the neural device includes at least a first neural device branch and a second neural device branch.

~~18~~17. The waveguide neural interface device of Claim ~~17~~16, wherein the first waveguide is coupled to the first neural device branch and the second waveguide is coupled to the second neural device branch.

~~19~~18. The waveguide neural interface device of Claim 1, wherein the waveguide is rigid.

~~20~~19. The waveguide neural interface device of Claim 1, wherein the waveguide further includes an inner core and a cladding layer over the core, and wherein the cladding layer is patterned to selectively expose the core, and the light redirecting element includes the exposed core.

~~21~~20. The waveguide neural interface device of Claim 1, further comprising a circuit board that interfaces with the waveguide and the at least one recording electrode of the array of electrode sites ~~and the waveguide~~.

~~22~~21. The waveguide neural interface device of Claim ~~21~~20, wherein the circuit board is double-faced and includes an electrical face having electrical components that interface

with the array of electrode sites and an optical face having components that interface with the waveguide.

~~23~~22. The waveguide neural interface device of Claim ~~22~~21, wherein the ~~array of~~ at least one recording electrode ~~sites~~ in communication with the electrical face of the circuit board is located on ~~a front~~the first face of the neural device ~~that is in communication with the electrical face of the circuit board~~, and the waveguide ~~is located on a back face of the neural device that is~~ in communication with the optical face of the circuit board is located on the second face of the neural device.

~~24~~23. The waveguide neural interface device of Claim ~~23~~22, wherein the circuit board further includes a light source that provides light to the waveguide.

~~25~~24. The waveguide neural interface device of Claim 1, wherein the array of electrode sites further includes at least one stimulation electrode site.

~~26~~25. A waveguide neural interface device, comprising:

- a) a neural device that is implantable in tissue and ~~including~~ comprises a neural device sidewall extending from a proximal neural device portion that is connectable to a pulse generator to a distal neural device portion, wherein at least the distal neural device portion extends along a first longitudinal axis;
- b) an array of electrode sites ~~that~~ supported by the neural device sidewall, wherein the array of electrode sites are configured to electrically communicate with their surroundings~~, wherein the array of electrode sites includes~~ and include at least one recording electrode site located on a first face of the distal neural device portion; ~~and~~
- c) a first waveguide ~~coupled to the neural device~~extending from a proximal first waveguide portion that is connectable to a light source to a distal first waveguide portion having a distal first waveguide end, wherein the distal first waveguide

~~carries light along a longitudinal axis and includes an optically dissipating portion that dissipates the carried light~~portion extends along a second longitudinal axis and is supported by a second face of the distal neural device portion in a side-by-side, co-axial relationship;

d) a first aperture extending from the first face through the neural device sidewall to the second face in the distal neural device portion; and

e) a light redirecting element supported by the distal first waveguide portion adjacent to the first aperture,

f) wherein the light redirecting element serves to redirect light traveling along the distal first waveguide portion away from the second longitudinal axis and through the first aperture in the neural device sidewall to thereby illuminate selectively targeted tissue~~;~~

- ~~wherein at least a portion of the dissipated light travels laterally away from the longitudinal axis from the optically dissipating portion; and~~
- ~~wherein the recording electrode site is configured to sample illuminated tissue~~adjacent to, but in a manner that avoids direct illumination of, the at least one recording electrode site on the first face of the distal neural device portion, and wherein the at least one recording electrode site is configured to sample illuminated tissue.

~~27~~26. The waveguide neural interface device of Claim ~~26~~25, wherein the neural device is a neural probe.

~~28~~27. The waveguide neural interface device of Claim ~~26~~25, wherein the neural device includes an electrode substrate that is layered over the waveguide, wherein at least a portion of the array of electrode sites is located on the electrode substrate.

~~29~~28. The waveguide neural interface device of Claim ~~28~~27, wherein the waveguide is mounted to the electrode substrate such that the ~~optically dissipating portion~~light redirecting element is adjacent to at least a portion of the array of electrode sites.

~~30~~29. The waveguide neural interface device of Claim ~~28~~27, wherein at least a portion of the ~~optically dissipating portion~~light redirecting element extends laterally beyond the electrode substrate.

~~31~~30. The waveguide neural interface device of Claim ~~28~~27, wherein the electrode substrate is wrapped around the waveguide.

~~32~~31. The waveguide neural interface device of Claim ~~28~~27, wherein the electrode substrate includes ~~an~~ a substrate aperture that corresponds to the ~~optically dissipating portion~~first aperture adjacent to the light redirecting element of the waveguide such that ~~dissipated~~ redirected light ~~is scattered~~travels through the first aperture and the substrate aperture.

~~33. The waveguide neural interface device of Claim 32, wherein the recording electrode site is adjacent to the aperture.~~

~~34~~32. The waveguide neural interface device of Claim ~~32~~31, wherein the waveguide includes a second ~~optically dissipating portion~~light redirecting element and the neural device includes a second aperture ~~that corresponds~~adjacent to the second ~~optically dissipating portion~~light redirecting element of the waveguide, such that ~~dissipated~~ redirected light ~~is scattered through~~travels from the second ~~optically dissipating portion~~light redirecting element and through the second aperture to thereby illuminate tissue.

~~35~~33. The waveguide neural interface device of Claim ~~32~~31, wherein the first aperture is elongated in the direction of the second longitudinal axis of the waveguide.

~~36~~34. The waveguide neural interface device of Claim ~~28~~27, wherein the ~~waveguide~~ light redirecting element includes a reflector tip that reflects carried light along the second longitudinal axis of the distal first waveguide portion.

~~37~~35. The waveguide neural interface device of Claim ~~36~~34, wherein the reflector ~~may include~~comprises a selectively roughened surface that modulates the path of reflected light.

~~38~~36. The waveguide neural interface device of Claim ~~26~~25, wherein the ~~dissipated~~ light ~~passing through the optically dissipating portion~~redirected by the light redirecting element has a substantially uniform intensity as a function of distance along the second longitudinal axis of the ~~optically dissipating~~distal first waveguide portion.

~~39~~37. The waveguide neural interface device of Claim ~~26~~25, wherein the waveguide further includes an inner core and a cladding layer over the core.

~~40~~38. The waveguide neural interface device of Claim ~~39~~37, wherein the cladding layer is patterned to selectively expose the core, wherein the ~~optically dissipating portion of the waveguide~~distal first waveguide portion includes the exposed core.

~~41~~39. The waveguide neural interface device of Claim ~~40~~38, wherein the ~~optically dissipating portion of the waveguide~~distal first waveguide portion further includes a layer of optically dissipating material patterned on the exposed core.

~~42~~40. The waveguide neural interface device of Claim ~~41~~39, wherein the optically dissipating material is aluminum oxide.

~~43~~41. The waveguide neural interface device of Claim ~~40~~38, wherein the exposed core is embedded with optically dissipating molecules.

~~4442~~. The waveguide neural interface device of Claim ~~4038~~, wherein the waveguide is a thin-film structure.

~~4543~~. The waveguide neural interface device of Claim ~~4038~~, wherein the waveguide is an optical fiber.

~~4644~~. The waveguide neural interface device of Claim ~~4038~~, wherein the neural device includes an electrode substrate that is wrapped around the waveguide, and wherein at least a portion of the array of electrode sites is located on the electrode substrate.

~~4745~~. The waveguide neural interface device of Claim ~~4644~~, wherein the electrode substrate includes at least one substrate aperture that corresponds to the exposed core, such that ~~dissipated~~ redirected light ~~is scattered~~travels through the first aperture and the substrate aperture.

~~4846~~. The waveguide neural interface device of Claim ~~4745~~, wherein the electrode substrate includes an optically dissipating material.

~~4947~~. The waveguide neural interface device of Claim ~~4745~~, wherein the waveguide includes a second ~~optically dissipating portion~~light redirecting element and the neural device includes a second aperture ~~that corresponds~~adjacent to the second ~~optically dissipating portion~~light redirecting element of the waveguide, such that ~~dissipated~~ redirected light ~~is scattered through~~travels from the second ~~optically dissipating portion~~light redirecting element and through the second aperture to thereby illuminate tissue.

~~50~~48. The waveguide neural interface device of Claim ~~26~~25, further comprising a circuit board that is double-faced and includes an electrical face having electrical components that interface with the array of electrode sites and an optical face having components that interface with the waveguide.

~~51~~49. The waveguide neural interface device of Claim 1, wherein the ~~optically dissipating portion~~light redirecting element includes an optically diffusive portion that diffuses light.

~~52~~50. The waveguide neural interface device of Claim 1, wherein the ~~optically dissipating portion~~light redirecting element includes an optically scattering portion that scatters light.

~~53. A method of assembling a waveguide neural interface device, comprising the steps of:~~

- ~~providing a neural device that includes a plurality of electrode sites;~~
- ~~providing a waveguide, separate from the neural device, that is configured to carry light along a longitudinal axis and includes a light directing element that redirects the carried light away from the waveguide;~~
- ~~providing a circuit board, separate from the neural device and the waveguide, that is configured to interface with the plurality of electrode sites and the waveguide;~~

- ~~orienting the light directing element of the waveguide to a predetermined angular orientation relative to the neural device, wherein the predetermined angular orientation is based on a selected direction of redirected light; and~~
- ~~coupling each structure of the group comprising the neural device, the waveguide, and the circuit board to at least one of the other structures in the group, wherein coupling includes fixing the waveguide at the predetermined angular orientation relative to the neural device.~~

~~54. The method of Claim 53, wherein orienting the light directing element includes rotating the waveguide about the longitudinal axis of the waveguide to the predetermined angular orientation.~~

~~55. The method of Claim 53, wherein coupling includes coupling the waveguide to the circuit board and coupling the neural device to the circuit board.~~

~~56. The method of Claim 55, wherein coupling the waveguide to the circuit board includes coupling the waveguide to a multi-faced circuit board including an optical face and an electrical face, wherein coupling the waveguide to a multi-faced circuit board includes:~~

- ~~coupling the waveguide to the optical face of the circuit board having optical components; and~~

~~• coupling the neural device to the electrical face of the circuit board having electrical components.~~

~~57. The method of Claim 53, wherein coupling including coupling the waveguide and the circuit board to form a waveguide-circuit board structure and coupling the neural device to the waveguide-circuit board structure.~~

~~58. The method of Claim 53, wherein coupling includes coupling the neural device and the circuit board to form a neural device-circuit board structure and coupling the waveguide to the neural device-circuit board structure.~~

~~59. The method of Claim 53, wherein coupling includes coupling the waveguide to the neural device to form a waveguide-neural device structure and coupling the circuit board to the waveguide-neural device structure.~~

~~60. The method of Claim 53, wherein coupling the waveguide to the neural probe includes layering the neural device over the waveguide.~~

~~61. The method of Claim 60, wherein layering the neural device over the waveguide includes wrapping the neural device around the waveguide.~~

51. The waveguide neural interface device of claim 38 wherein the neural device includes an electrode substrate that is wrapped around the waveguide, and wherein at least a portion of the array of electrode sites is located on the electrode substrate.

52. The waveguide neural interface device of claim 51 wherein the electrode substrate includes at least one substrate aperture that corresponds to the exposed core, such that redirected light travels through the first aperture and the substrate aperture.

53. The waveguide neural interface device of claim 52 wherein the electrode substrate includes an optically dissipating material.

54. The waveguide neural interface device of claim 1 wherein the neural device has a first length from a proximal neural device end to the distal neural end and the waveguide has a second length from a proximal waveguide end to the distal waveguide end and wherein the light redirecting element resides at the distal waveguide end with the second length being less than the first length to thereby position the light redirecting element opposite the aperture in the neural device sidewall of the distal neural device portion.

55. The waveguide neural interface device of claim 1 wherein the light redirecting element is supported by the waveguide at the distal waveguide end.

56. The waveguide neural interface device of claim 1 wherein the light redirecting element is supported by the distal waveguide portion at a location that is proximal the distal neural end.

57. The waveguide neural interface device of claim 25 wherein at least a portion of the redirected light is directed laterally away from a second longitudinal axis of the distal waveguide portion.

58. The waveguide neural interface device of claim 1 wherein the neural device includes an electrode substrate that is layered over the waveguide, wherein at least a portion of the array of electrode sites is located on the electrode substrate.

59. The waveguide neural interface device of claim 58 wherein the waveguide is mounted to the electrode substrate such that the light redirecting element is adjacent to at least a portion of the array of electrode sites.

60. The waveguide neural interface device of claim 58 wherein at least a portion of the light redirecting element extends laterally beyond the electrode substrate.

61. The waveguide neural interface device of claim 58 wherein the electrode substrate is wrapped around the waveguide.

62. The waveguide neural interface device of claim 58 wherein the electrode substrate includes a substrate aperture that corresponds to the first aperture adjacent to the light redirecting element of the waveguide such that redirected light travels through the first aperture and the substrate aperture.

63. The waveguide neural interface device of claim 1 wherein the waveguide includes a second light redirecting element and the neural device includes a second aperture adjacent to the second light redirecting element of the waveguide, such that redirected light travels from the second light redirecting element and through the second aperture to thereby illuminate tissue.

64. The waveguide neural interface device of claim 1 wherein the first aperture is elongated along a longitudinal axis of the waveguide.

65. The waveguide neural interface device of claim 5 wherein the reflector comprises a selectively roughened surface that modulates the path of reflected light.

66. The waveguide neural interface device of claim 25, wherein the light redirected by the light redirecting element has a substantially uniform intensity as a function of distance along the distal first waveguide portion.

67. The waveguide neural interface device of claim 19 wherein the distal first waveguide portion further includes a layer of optically dissipating material patterned on the exposed core.

68. The waveguide neural interface device of claim 67 wherein the optically dissipating material is aluminum oxide.

69. The waveguide neural interface device of claim 19 wherein the exposed core is embedded with optically dissipating molecules.

70. The waveguide neural interface device of claim 1 wherein the waveguide is a thin-film structure.

71. The waveguide neural interface device of claim 1 wherein the waveguide is an optical fiber.

72. The waveguide neural interface device of claim 1 wherein the light redirecting element includes an optically diffusive portion that diffuses light.

73. A waveguide neural interface device, comprising:

a) a neural device that is implantable in tissue and comprises a neural device sidewall extending from a proximal neural device portion that is connectable to a pulse generator to a distal neural device portion, wherein at least the distal neural device portion extends along a first longitudinal axis;

b) an array of electrode sites supported by the neural device sidewall, wherein the array of electrode sites are configured to electrically communicate with their surroundings and include at least one recording electrode site located on a first face of the distal neural device portion;

c) a waveguide extending from a proximal waveguide portion that is connectable to a light source to a distal waveguide portion having a distal waveguide end, wherein the distal waveguide portion extends along a second longitudinal axis and is supported by a second face of the distal neural device portion in a side-by-side, co-axial relationship;

d) an aperture extending from the first face through the neural device sidewall to the second face in the distal neural device portion;

e) a double-faced circuit board that includes an electrical face having electrical components that interface with the at least one recording electrode site and an optical face having components that interface with the waveguide; and

f) a light redirecting element supported by the distal first waveguide portion adjacent to the aperture,

g) wherein the light redirecting element serves to redirect light traveling along the distal first waveguide portion away from the second longitudinal axis and through the aperture in the neural device sidewall to thereby illuminate selectively targeted tissue adjacent to, but in a manner that avoids direct illumination of, the at least one recording electrode site on the first face of the distal neural device portion, and

h) wherein the at least one recording electrode site is configured to sample illuminated tissue and the circuit-board is configured to transmit information recorded by the recording electrode site to the proximal neural device portion.

74. The waveguide neural interface device of claim 73 wherein the at least one recording electrode site in communication with the electrical face of the circuit board is located on a front face of the neural device, and the waveguide in communication with the optical face of the circuit board is located on a back face of the neural device.

75. The waveguide neural interface device of claim 73 wherein the circuit board further includes a light source that provides light to the waveguide.