

CLAIMS

What is claimed is:

1. An apparatus, comprising:
 - a collimator at an input end positioned to receive an input beam from a fiber beam source and to produce a substantially collimated beam;
 - a beam shaping group comprising one or more optical elements and positioned to receive the substantially collimated beam from the collimator and format the substantially collimated beam into a shaped propagation beam having a substantially rectangular cross-section in a far field; and
 - a focusing objective stage including an objective pupil for receiving the shaped propagation beam and positioned to transform the shaped propagation beam into a substantially rectangular cross-section sampling beam at or near a focal plane of the focusing objective stage for optically probing a sample.
2. The apparatus of claim 1, further comprising:
 - an optical relay stage positioned between the beam shaping group and the focusing objective stage for imaging the shaped propagation beam from the beam shaping group onto or near the objective pupil of the focusing objective stage.
3. The apparatus of claim 2, wherein the optical relay stage comprises an input lens stage positioned to receive the shaped propagation beam from the beam shaping group and an output lens stage positioned to produce the shaped propagation beam to the objective pupil of the focusing objective stage.
4. The apparatus of claim 3, wherein the input lens stage and the output lens stage form a focusing element pair defining an intermediate image plane within the optical relay stage.
5. The apparatus of claim 4, the optical relay stage having a beam affecting element at the intermediate image plane.
6. The apparatus of claim 5, wherein the beam affecting element is an optical mask.
7. The apparatus of claim 5, wherein the beam affecting element is a despeckling element.

8. The apparatus of claim 3, wherein a position of at least one of the input lens stage and the output lens stage is adjustable.

9. The apparatus of claim 2, further comprising a Powell lens positioned before to the optical relay stage.

10. The apparatus of claim 2, further comprising a Lineman lens positioned before to the optical relay stage.

11. The apparatus of claim 2, wherein the optical relay stage is afocal.

12. The apparatus of claim 2, wherein the optical relay stage is a fixed magnification relay.

13. The apparatus of claim 2, wherein the optical relay stage is a variable magnification relay.

14. The apparatus of claim 1, wherein the beam shaping group is an integrator.

15. The apparatus of claim 14, wherein the integrator is an imaging integrator formed of two arrays of microlenses positioned in series.

16. The apparatus of claim 15, wherein the microlenses are cylindrical lenses.

17. The apparatus of claim 15, wherein the microlenses each have different focal lengths along an x-direction and along a y-direction.

18. The apparatus of claim 14, wherein the integrator is a non-imaging integrator formed of one array of microlenses.

19. The apparatus of claim 18, wherein the microlenses are cylindrical lenses

20. The apparatus of claim 18, wherein the microlenses each have different focal lengths along an x-direction and along a y-direction.

21. The apparatus of claim 14, wherein the beam shaping group comprises integral diffractive features.

22. The apparatus of claim 14, wherein the beam shaping group comprises integral diffuser features.
23. The apparatus of claim 22, wherein the integrator is an imaging integrator formed of microlenses, wherein the microlenses are cylindrical lenses.
24. The apparatus of claim 23, wherein the cylindrical lenses are configured to impose divergence in one axial direction of the microlenses and not in an orthogonal direction of the microlenses.
25. The apparatus of claim 1, wherein the beam shaping group comprises a diffractive optical element.
26. The apparatus of claim 1, wherein the beam shaping group comprises a refractive optical element, a combination of a refractive optical element and a diffractive optical element, or a refractive optical element with integral diffractive or diffusive features.
27. The apparatus of claim 1, wherein the beam shaping group transforms the collimated beam into the shaped propagation beam having a uniform illumination in the far field over a rectangle having a ratio 8 to 1.
28. The apparatus of claim 1, wherein the beam shaping group transforms the collimated beam into the shaped propagation beam having a uniform illumination in the far field over a rectangle having a ratio of between about 10 to 1 and about 20 to 1.
29. The apparatus of claim 1, wherein the beam shaping group transforms the collimated beam into the shaped propagation beam having a uniform illumination in the far field over a rectangle having a ratio 24 to 1.
30. The apparatus of claim 1, wherein the beam shaping group transforms the collimated beam into the shaped propagation beam having a uniform illumination in the far field over a rectangle having a ratio that matches a profile of a Time Delay and Integration (TDI) line sensor.
31. The apparatus of claim 1, further comprising the fiber beam source.

32. The apparatus of claim 31, wherein the fiber beam source is a two-input beam source to generate the input beam having a first beam over a first wavelength range and having a second beam over a second wavelength range, different than the first wavelength range.

33. The apparatus of claim 32, wherein the fiber beam source comprises two dedicated input fibers each corresponding to one of the first beam and the second beam.

34. The apparatus of claim 33, wherein output ends of the two dedicated input fibers are presented to the collimator with fixed spacing and with rotation about fiber cores and a collimator axis.

35. The apparatus of claim 31, 32, or 33, wherein each input fiber has a substantially rectangular cross-section at an exit face.

36. The apparatus of claim 31, wherein the fiber beam source is a light pipe.

37. The apparatus of claim 1, further comprising: an optical compensator positioned to receive the shaped propagation beam and having two compensation positions, a first compensation position such that the focusing objective stage is to produce the substantially rectangular cross-section sampling beam to probe an upper surface of the sample and a second compensation position such that the focusing objective stage is to produce the substantially rectangular cross-section sampling beam to probe a bottom surface of the sample.

38. The apparatus of claim 36, wherein the optical compensator is electro-mechanically controllable between the first compensation position and the second compensation position.

39. The apparatus of claim 36, wherein the optical compensator is electrically controllable between the first compensation position and the second compensation position.

40. The apparatus of claim 36, wherein the optical compensator is insertable between the beam shaping group and the focusing objective stage.

41. The apparatus of claim 36, further comprising:

an optical relay stage positioned between the beam shaping group and the focusing objective stage, the optical relay stage comprising an input lens stage positioned to receive the shaped propagation beam from the beam shaping group and an output lens stage positioned to produce the shaped propagation beam to the objective pupil of the focusing objective stage,

wherein the optical compensator is positioned within the optical relay stage.

42. The apparatus of claim 36, wherein the optical compensator is an optical element electrically controllable to switch from a first optical state to a second optical state to affect optical compensation.

43. The apparatus of claim 36, further comprising:

an optical relay stage positioned between the beam shaping group and the focusing objective stage, the optical relay stage comprising an input lens stage positioned to receive the shaped propagation beam from the beam shaping group and an output lens stage positioned to produce the shaped propagation beam to the objective pupil of the focusing objective stage,

wherein the optical compensator is positioned before the optical relay stage.

44. The apparatus of claim 36, further comprising:

an optical relay stage positioned between the beam shaping group and the focusing objective stage, the optical relay stage comprising an input lens stage positioned to receive the shaped propagation beam from the beam shaping group and an output lens stage positioned to produce the shaped propagation beam to the objective pupil of the focusing objective stage,

wherein the optical compensator is positioned after the optical relay stage.

45. The apparatus of claim 1, further comprising:

an optical compensator; and

a positioner coupled to the optical compensator to controllably (i) insert the optical compensator into a beam path for receiving the shaped propagation beam and for affecting the shaped propagation beam path to probe one of an upper surface or a lower surface of the sample and (ii) remove the optical compensator from the beam path for affecting the shaped propagation beam path to probe the other of the lower surface or upper surface of the sample.

46. The apparatus of claim 44, wherein the optical compensator is a plane-parallel plate of refractive material.
47. The apparatus of claim 44, wherein the optical compensator is a lens.
48. The apparatus of one of claims 45 and 46, wherein the optical compensator is inserted before an optical relay stage in the beam path.
49. The apparatus of one of claims 45 and 46, wherein the optical compensator is inserted within an optical relay stage in the beam path.
50. The apparatus of one of claims 45 and 46, wherein the optical compensator is inserted after an optical relay stage in the beam.
51. The apparatus of claim 1, further comprising:
an optical relay stage positioned between the beam shaping group and the focusing objective stage, the optical relay stage comprising an input lens stage positioned to receive the shaped propagation beam from the beam shaping group and an output lens stage positioned to produce the shaped propagation beam to the objective pupil of the focusing objective stage,
wherein the input lens stage is movable between a first position such that the focusing objective stage is to produce the substantially rectangular cross-section sampling beam to probe an upper surface of the sample and a second position such that the focusing objective stage is to produce the substantially rectangular cross-section sampling beam to probe a bottom surface of the sample.
52. The apparatus of claim 1, further comprising:
an optical relay stage positioned between the beam shaping group and the focusing objective stage, the optical relay stage comprising an input lens stage positioned to receive the shaped propagation beam from the beam shaping group and an output lens stage positioned to produce the shaped propagation beam to the objective pupil of the focusing objective stage,
wherein the output lens stage is movable between a first position such that the focusing objective stage is to produce the substantially rectangular cross-section sampling beam to probe an upper surface of the sample and a second position such that the focusing objective stage is to produce the substantially rectangular cross-section sampling beam to probe a bottom surface of the sample.

53. The apparatus of claim 1, further comprising the fiber beam source, the apparatus having a first spacing distance between the collimator and the fiber beam source to produce the substantially rectangular cross-section sampling beam to probe an upper surface of the sample and having a second spacing distance between the collimator and the fiber beam source to produce the substantially rectangular cross-section sampling beam to probe a bottom surface of the sample.

54. A method of optically probing a sample, the method comprising:
generating a collimated beam from an input beam;
formatting, using a beam shaping group, the collimated beam into a shaped propagation beam having a substantially rectangular cross-section in a far field;
providing the shaped propagation beam to an optical relay stage producing the shaped propagation beam at an objective pupil of a focusing objective stage;
transforming, using the focusing objective stage, the shaped propagation beam into a substantially rectangular cross-section sampling beam at a focal plane of the focusing objective stage;
probing the sample at a first position for the focal plane; and
affecting optical compensation of the optical relay stage such that the focusing objective stage transforms the shaped propagation beam into substantially rectangular cross-section sampling beam at a second position for the focal plane and probing the sample at the second position.

55. The method of claim 54, wherein affecting optical compensation of the optical relay stage comprises adjusting a position or an optical property of an affecting element within the optical relay stage.

56. The method of claim 54, wherein affecting optical compensation of the optical relay stage comprises adjusting a position of an input lens stage of the optical relay stage or a position of an output lens stage of the optical relay stage.

57. The method of claim 54, wherein the beam shaping group comprises two arrays of microlenses.

58. The method of claim 54, wherein the beam shaping group comprises a diffractive optical element.

59. The method of claim 54, wherein the beam shaping group comprises a refractive optical element, a combination of a refractive optical element and a diffractive optical element, or a refractive optical element with integral diffractive features.

60. The method of claim 54, wherein the beam shaping group transforms the collimated beam into the shaped propagation beam having a uniform illumination in the far field over a rectangle having a ratio 8 to 1.

61. The method of claim 54, wherein the beam shaping group transforms the collimated beam into the shaped propagation beam having a uniform illumination in the far field over a rectangle having a ratio of between about 10 to 1 and about 20 to 1.

62. The method of claim 54, wherein the beam shaping group transforms the collimated beam into the shaped propagation beam having a uniform illumination in the far field over a rectangle having a ratio 24 to 1.

63. A method, comprising:
receiving, at a collimator, an input beam from a fiber beam source;
producing, by the collimator, a substantially collimated beam from the input beam;
receiving the substantially collimated beam from the collimator at a beam shaping group comprising one or more optical elements;
formatting, by the beam shaping group, the substantially collimated beam into a shaped propagation beam having a substantially rectangular cross-section in a far field;
receiving the shaped propagation beam at a focusing objective stage including an objective pupil;
transforming the shaped propagation beam into a substantially rectangular cross-section sampling beam at or near a focal plane of the focusing objective stage; and
optically probing a sample using the focusing objective stage.

64. The method of claim 63, further comprising generating the input beam having a first beam over a first wavelength range and having a second beam over a second wavelength range, different than the first wavelength range.

65. The method of any one of claims 63 – 64, further comprising generating the input beam using a two-input beam source.

66. The method of claim 65, wherein the fiber beam source comprises two dedicated input fibers each corresponding to one of the first beam and the second beam.

67. The method of claim 66, wherein output ends of the two dedicated input fibers are presented to the collimator with fixed spacing and with rotation about fiber cores and a collimator axis.

68. The method of claim 63, wherein affecting optical compensation of the optical relay stage comprises adjusting a position or an optical property of an affecting element within the optical relay stage.

69. The method of claim 63, wherein the beam shaping group comprises two arrays of microlenses.

70. The method of claim 63, wherein the beam shaping group comprises a diffractive optical element.

71. The method of claim 63, wherein the beam shaping group comprises a refractive optical element, a combination of a refractive optical element and a diffractive optical element, or a refractive optical element with integral diffractive features.

72. The method of claim 63, wherein the beam shaping group transforms the collimated beam into the shaped propagation beam having a uniform illumination in the far field over a rectangle having a ratio 8 to 1.

73. The method of claim 63, wherein the beam shaping group transforms the collimated beam into the shaped propagation beam having a uniform illumination in the far field over a rectangle having a ratio 10 to 1.

74. The method of claim 63, wherein the beam shaping group transforms the collimated beam into the shaped propagation beam having a uniform illumination in the far field over a rectangle having a ratio 24 to 1.

75. The method of claim 63, wherein the beam shaping group transforms the collimated beam into the shaped propagation beam having a uniform illumination in the far field over a rectangle having a ratio of between about 10 to 1 and about 20 to 1.

76. The method of claim 63, wherein the beam shaping group transforms the collimated beam into the shaped propagation beam having a uniform illumination in the far field over a rectangle having a ratio of approximately 1.