CLAIMS

1. A laser having a laser cavity comprising:

a first reflector at a first end of the laser cavity;

an intracavity NxM coupler arranged to receive light from the first reflector at a first port and distribute the light to N output ports, where N and M are both greater than 1;

Q optical amplifiers arranged to amplify light from at least some of the N output ports to produce amplified light, where $Q \geq 2$; and

at least one second reflector arranged to reflect the amplified light back to the NxM coupler, wherein the first reflector is located on a first photonic integrated circuit chip that includes a coherent optical receiver and an optical modulator arranged to receive power from the laser and the at least one second reflector is located on a second chip.

2. The laser of claim 1, further comprising at least one phase shifter in at least one optical path between the NxM coupler and the Q optical amplifiers.

3. The laser of claim 2, wherein the at least one phase shifter comprises at least one thermo-optic phase shifter.

4. The laser of claim 2, further comprising M-1 power ports connected to the NxM coupler, wherein the at least one phase shifter is adjustable to alter an amount of laser power from at least one of the M-1 power ports.

5. The laser of claim 4, further comprising:

a detector arranged to sense an optical power from one of the M-1 power ports; and

a feedback circuit arranged to receive a power signal from the detector and alter a phase of a phase shifter responsive to the received power signal.

6. The laser of claim 1, further comprising a tunable wavelength filter in the laser cavity and coupled to the NxM coupler.

7. The laser of claim 6, wherein the tunable wavelength filter comprises at least one ring resonator coupled to a waveguide.

8. The laser of claim 6, wherein the tunable wavelength filter is configured to tune a wavelength of the laser over a range of wavelengths, the range of wavelengths lying between 1200 nm and 1700 nm.

9. The laser of claim 1, wherein the NxM coupler is integrated on the first photonic integrated circuit chip and the Q optical amplifiers are integrated on the second chip.

10. The laser of claim 9, further comprising:

first microfabricated waveguides on the first photonic integrated circuit chip and second microfabricated waveguides on the second chip arranged to couple the N output ports of the NxM coupler to the Q optical amplifiers; and

mode-size adapters located between the first microfabricated waveguides and the second microfabricated waveguides.

11. The laser of claim 10, wherein the first microfabricated waveguides are butt-coupled to the second microfabricated waveguides.

12. The laser of claim 9, wherein the first photonic integrated circuit chip comprises a silicon photonics chip and the second chip comprises indium-phosphide.

13. The laser of claim 12, further comprising:

M-1 power ports connected to the NxM coupler,

wherein a first of the M-1 power ports is connected to the coherent receiver, and

wherein a second of the M-1 power ports is connected to the optical modulator.

14. A method of generating coherent light, the method comprising:

reflecting light from a first reflector located on a first photonic integrated circuit chip;

distributing the light, with an NxM coupler, to N optical paths, where N and M are both greater than 1;

producing amplified light by amplifying light in at least some of the N optical paths with Q optical amplifiers, where Q≥2;

returning the amplified light to the NxM coupler and first reflector with at least one second reflector located on a second chip;

receiving power from the NxM coupler at a coherent optical receiver located on the first photonic integrated circuit chip; and

receiving power from the NxM coupler at an optical modulator located on the first photonic integrated circuit chip.

15. The method of claim 14, wherein producing amplified light by amplifying light in at least some of the N optical paths comprises amplifying the light with indium-phosphide semiconductor optical amplifiers.

16. The method of claim 14, wherein returning the amplified light comprises returning the amplified light from a first semiconductor material to a second semiconductor material in which the NxM coupler is fabricated, wherein the first semiconductor material is different from the second semiconductor material.

17. The method of claim 16, wherein the first semiconductor material comprises indium phosphide and the second semiconductor material comprises silicon.

18. The method of claim 14, further comprising adjusting a tunable filter to select a wavelength of the light reflected from the first reflector, wherein the wavelength is between approximately 1200 nm and approximately 1700 nm.

19. The method of claim 14, further comprising:

providing portions of the coherent light out M-1 power ports connected to the NxM coupler; and

adjusting a phase of light in at least one of the N optical paths to alter an amount of power in at least one of the M-1 power ports.

20. The method of claim 19, further comprising:

providing a first signal from a first power port of the M-1 power ports to the coherent optical receiver; and

providing a second signal from a second power port of the M-1 power ports to the optical modulator, wherein the NxM coupler is located on the first photonic integrated circuit chip.

21. The method of claim 20, further comprising:

mixing the first signal as a local oscillator with a received optical signal; and

modulating the second signal as a carrier wave to encode at least a portion of a transmitted optical signal.

22. An optical receiving system comprising:

a first cavity reflector of a laser formed on a first substrate that is formed of a first semiconductor material;

at least one second cavity reflector of the laser formed on a second substrate that is formed of a second semiconductor material that is different from the first semiconductor material;

a plurality of optical paths within the laser extending between the first cavity reflector and the at least one second cavity reflector;

plural optical amplifiers formed on the second substrate in at least two optical paths of the plurality of optical paths; and

a coherent optical receiver formed on the first substrate and having an optical port connected to an output port from the laser.

23. The optical receiving system of claim 22, wherein the laser is configured to provide a local oscillator signal to the coherent optical receiver.

24. The optical receiving system of claim 23, wherein the coherent optical receiver comprises an integrated phase-diverse photonic circuit.

25. The optical receiving system of claim 23, wherein the coherent optical receiver comprises an integrated polarization-diverse photonic circuit.

26. The optical receiving system of claim 22, further comprising an N×M coupler arranged in the laser to receive light from the first cavity reflector at a first port of the N×M coupler and to distribute the light to N output ports of the N×M coupler, where N and M are both greater than 1.

27. The optical receiving system of claim 26, wherein plural output ports of the N output ports connect to the at least two optical paths.

28. The optical receiving system of claim 26, wherein the first substrate comprises a silicon photonics chip and the second substrate comprises an indium-phosphide chip.

29. The optical receiving system of claim 26, further comprising:
first microfabricated waveguides coupled to at least some of the N output ports; and
second microfabricated waveguides coupled to the plural optical amplifiers.

30. The optical receiving system of claim 29, further comprising mode-size adapters located between the first microfabricated waveguides and second microfabricated waveguides.

31. The optical receiving system of claim 29, wherein the first microfabricated waveguides are butt-coupled to the second microfabricated waveguides.

32. The optical receiving system of claim 29, wherein the N×M coupler and the first microfabricated waveguides are integrated on the first substrate and the second microfabricated waveguides are integrated on the second substrate.

33. The optical receiving system of claim 26, further comprising:
M-1 power ports connected to the N×M coupler; and

a phase shifter in a first optical path of the plurality of optical paths, wherein the phase shifter is adjustable to alter an amount of power from at least one of the M-1 power ports.

34. The optical receiving system of claim 33, further comprising:

a detector arranged to sense an optical power from one of the M-1 power ports; and

a feedback circuit arranged to receive a power signal from the detector and alter a phase of the phase shifter responsive to the received power signal.

35. The optical receiving system of claim 33, wherein a first of the M-1 power ports is connected to the coherent optical receiver, and wherein a second of the M-1 power ports is connected to an optical transmitter that is integrated on the first substrate.

36. The optical receiving system of claim 35, wherein the optical transmitter comprises a pair of nested Mach-Zehnder interferometers.

37. A method of receiving optical signals, the method comprising:

generating a local oscillator signal by a laser that includes a first cavity reflector formed on a first substrate of a first semiconductor material, at least one second cavity reflector formed on a second substrate of a second semiconductor material that is different from the first semiconductor material, a plurality of optical paths within the laser extending between the first cavity reflector and the at least one second cavity reflector, and plural optical amplifiers formed on the second substrate in at least two optical paths of the plurality of optical paths;

receiving the optical signals by a coherent optical receiver that is formed on the first substrate and connected to an output port from the laser; and

receiving the local oscillator signal by the coherent optical receiver.

38. The method of claim 37, further comprising providing the optical signals and the local oscillator signal to a phase-diverse photonic circuit of the coherent optical receiver.

39. The method of claim 37, further comprising providing the optical signals and the local oscillator signal to a polarization-diverse photonic circuit of the coherent optical receiver.

40. The method of claim 37, further comprising adjusting an amount of power in the local oscillator signal by adjusting at least one phase shifter located in at least one optical path of the plurality of optical paths.

41. The method of claim 37, further comprising:
generating a carrier wave with the laser; and
providing the carrier wave to an optical transmitter that is formed on the first substrate.