CLAIMS

1. A normal incidence photodetector structure comprising:

a p-i-n mesa bonded to a semiconductor device layer of a semiconductor-on-insulator (SOI) substrate comprising the semiconductor device layer on top of an insulating undercladding, the p-i-n mesa comprising n-type, active, and p-type semiconductor layers;

metal contacts contacting the p-type and n-type semiconductor layers; and

a semiconductor waveguide formed in the semiconductor device layer of the SOI substrate and configured to operatively couple light into the p-i-n mesa.

2. The photodetector structure of claim 1, wherein the waveguide flares out from a width smaller than half of a diameter of the p-i-n mesa to a strip underneath the p-i-n mesa dimensioned and positioned to encompass at least half the diameter of the p-i-n mesa, the strip operatively to couple light through a bottom surface of the p-i-n mesa into the p-i-n mesa.

3. The photodetector structure of claim 1, wherein the waveguide comprises a wrap-around portion formed along and underneath an edge of the p-i-n mesa to operatively couple light at least one of directly into the p-i-n mesa or into a semiconductor structure formed in the semiconductor device layer underneath the p-i-n mesa.

4. The photodetector structure of claim 3, wherein the portion of the waveguide formed along and underneath the edge of the p-i-n mesa tapers down to a narrower width at a terminal end of the waveguide.

5. The photodetector structure of claim 3, wherein the semiconductor device layer is at least partially etched down in a region underneath the p-i-n mesa surrounded by the wrap-around portion of the waveguide.

6. The photodetector structure of claim 3, wherein the semiconductor device layer is left unetched in a region underneath the p-i-n mesa surrounded by the wrap-around portion of the waveguide.

7. The photodetector structure of claim 3, wherein the semiconductor device layer is patterned in accordance with a fill pattern in a region underneath the p-i-n mesa surrounded by the wrap-around portion of the waveguide.

8. The photodetector structure of claim 1, wherein the layers in the p-i-n mesa are arranged with one or more n-type layers closest to the SOI substrate, the active layer on top of the one or more n-type layers, and the one or more p-type layers on top of the active layer, and wherein the one or more p-type layers comprise at least a p-type contact layer.

9. The photodetector structure of claim 8, wherein the p-type contact layer is uniform.

10. The photodetector structure of claim 8, wherein the p-type contact layer is ring-shaped.

11. The photodetector structure of claim 1, wherein the p-i-n mesa is made from III-V materials.

12. An optical transceiver integrated on a semiconductor substrate, the optical transceiver comprising:

one or more optical transmitters formed at least in part in a device layer of the substrate;

a transmitter output port;

one or more optical receivers each comprising a normal incidence photodetector formed on the substrate by a p-i-n mesa with electrical connections, and a waveguide formed in a device layer of the substrate and configured to couple light into the p-i-n mesa; and

an optical switch configured to selectively couple the one or more optical transmitters either to the transmitter output port in a normal operation mode or to the waveguides of the one or more optical receivers in a self-test mode.

13. The optical transceiver of claim 12, comprising multiple optical transmitters and multiple respective optical receivers configured for multiple respective operating wavelengths, wherein the optical switch comprises a wavelength multiplexer further configured to multiplex optical signals received from the multiple optical transmitters.

14. The optical transceiver of claim 12, wherein the waveguide of at least one of the optical receivers flares out from a width smaller than half of a diameter of the p-i-n mesa to a strip underneath the p-i-n mesa dimensioned and positioned to encompass at least half the diameter of the p-i-n mesa, the strip operatively to couple light through a bottom surface of the p-i-n mesa into the p-i-n mesa.

15. The optical transceiver of claim 12, wherein the waveguide comprises a wrap-around portion formed along and underneath an edge of the p-i-n mesa to operatively couple light at least one of directly into the p-i-n mesa or into a semiconductor structure formed in the semiconductor device layer underneath the p-i-n mesa.

16. A method of testing an optical transceiver comprising an optical transmitter and an optical receiver integrated on a single substrate comprising a semiconductor device layer on top of an insulating undercladding, the optical receiver comprising a normal incidence photodetector (NIPD) bonded to the semiconductor device layer of the substrate and an associated waveguide structure formed in the semiconductor device layer of the substrate underneath the NIPD and configured to couple in-plane light into the NIPD, the method comprising:

generating an optical signal with the optical transmitter;

selectively coupling an output of the optical transmitter to the waveguide structure associated with the NIPD, whereby the optical signal is coupled vertically into the NIPD; and

measuring a photocurrent at the NIPD to determine a responsivity of the receiver.

17. The method of claim 16, further comprising:

modulating the optical signal to impart high-speed data on the optical signal; and

determining at least one of a bandwidth, a packet loss, or a bit error rate of data received at the optical receiver.

18. The method of claim 16,

wherein the optical transmitter comprises a transmitter laser and a transmitter modulator and the optical transceiver further comprises a multiplexer;

wherein the method further comprises calibrating a wavelength of the transmitter laser, measuring an output power of the transmitter laser, measuring an output power of the transmitter modulator, and measuring an output power of the multiplexer; and

wherein the responsivity of the NIPD is determined based on the measured photocurrent and the measured output power of the multiplexer.

19. The method of claim 16, wherein the waveguide structure flares out from a width smaller than half a diameter of the NIPD to a strip underneath the NIPD that encompasses at least half the diameter of the NIPD, and wherein the optical signal is coupled vertically from the strip into the NIPD.

20. The method of claim 16, wherein the waveguide structure comprises a wrap-around portion formed along and underneath an edge of the NIPD, and wherein the optical signal is coupled at least one of directly vertically into the NIPD or into a semiconductor structure formed underneath the NIPD from which the optical signal is coupled vertically into the NIPD.