Technology Offer

High-Efficiency Photodetector for Visible and Infrared Light

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Abstract

A novel photodetector apparatus is presented, capable of detecting light in the visible and infrared spectrum with exceptional efficiency. The design integrates a waveguide and a detector section separated by a cladding layer, enabling gradual and low-loss optical power transfer. This structure allows for compact device dimensions, high sensitivity, and fast detection speeds. By optimizing the distance between the waveguide and the detector and utilizing materials such as silicon nitride and silicon, the system ensures minimal coupling losses and improved manufacturing processes. Applications span optical communications, biosensing, and integrated photonics, offering substantial performance improvements over traditional end-fire coupled photodetectors.

Background

Traditional integrated photodetectors often struggle with high coupling losses, large device sizes, and limited operation in the visible light spectrum due to material absorption. Silicon-based waveguides, commonly used in telecommunications, are unsuitable for visible light applications without significant modifications. Furthermore, existing solutions for visible light detection, like end-fire coupling designs, suffer from considerable inefficiencies and large physical footprints, restricting their performance and applicability. Therefore, there is a strong need for compact, highly efficient photodetectors with minimal light loss and high operational speeds, especially for emerging fields like biosensing, quantum optics, and miniaturized imaging systems.

Technology

The photodetector apparatus consists of a substrate, a cladding layer, a light-guiding waveguide, and a detector section with p-doped and n-doped regions. The waveguide, made preferably of silicon nitride,

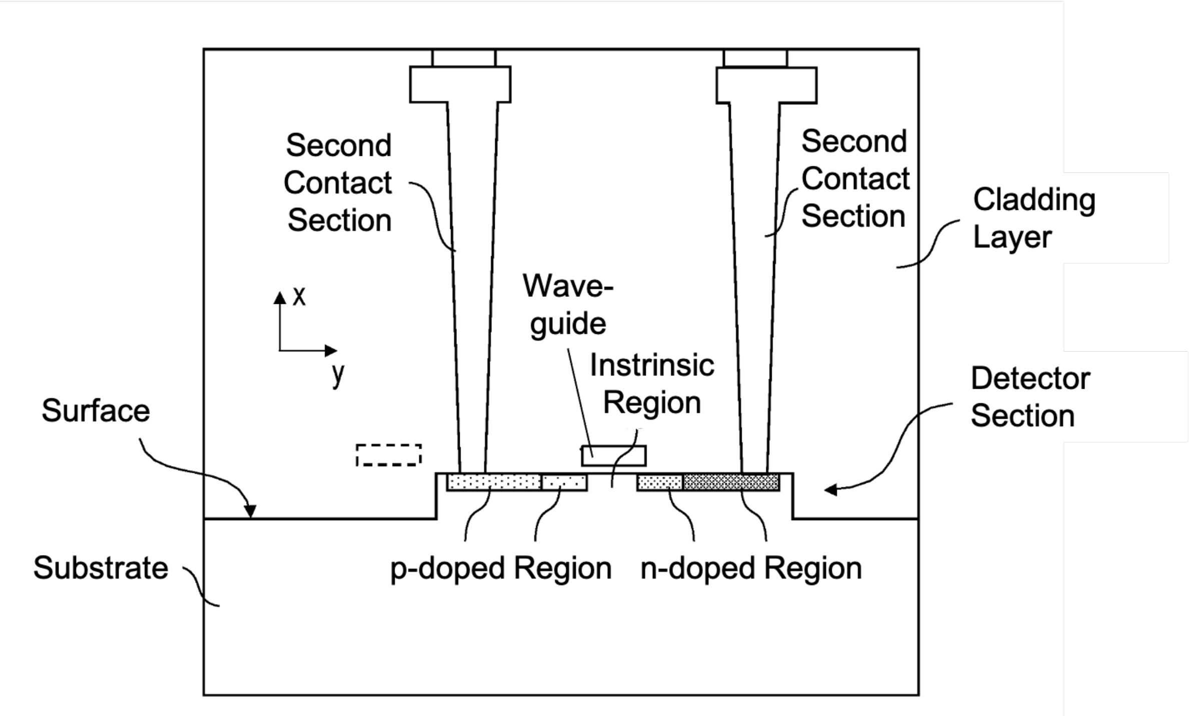

Figure 1: Cross-section of the photodetector showing the waveguide above a p-i-n junction detector. Light is coupled evanescently from the waveguide into the detector, enabling efficient charge generation and signal extraction via the contact sections.

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is positioned above the detector, with a carefully engineered gap maintained by the cladding layer. Light traveling through the waveguide gradually couples into the detector section via evanescent field interaction, enhancing absorption efficiency while minimizing optical losses. A tapered portion of the waveguide narrows the mode field, optimizing light transfer into the detector without the need for direct contact or phase-matching.

The detector employs a pn-junction or a pin-junction design, allowing efficient generation and collection of charge carriers created by incoming photons. The arrangement enables high-speed operation and low dark noise by maintaining a compact active volume. The use of intrinsic regions between doped zones allows operation in avalanche mode, further boosting sensitivity for single-photon detection. Manufacturing is simplified as the waveguide and detector are vertically aligned but separated, allowing greater tolerance in lithographic processes. Dimensions such as detector thickness (2–3 µm) and waveguide width (150–500 nm) are optimized for maximal performance across visible and near-infrared wavelengths. Overall, the design offers a scalable, foundry-compatible solution for next-generation integrated photonic systems.

Advantages

- **High absorption efficiency**: Achieves over 96% light absorption with minimal coupling loss through gradual optical transfer.
- **Compact and fast**: Small device size enables high-speed detection with reduced dark current and increased bandwidth.
- **Broad wavelength operation**: Efficient for both visible and near-infrared light (380–1500 nm), suitable for diverse applications.
- **Foundry-compatible fabrication**: Design tolerates standard CMOS processes and allows scalable, cost-effective manufacturing.
- **Flexible design parameters**: Adjustable waveguide-detector distance and geometry for optimized performance across specific application needs.

Potential applications

- **Integrated optical communication systems**: For high-speed data transfer in next-generation photonic networks.
- **Advanced biosensors**: Detecting biological signals (e.g., fluorescent markers) with high sensitivity for medical diagnostics and environmental monitoring.
- **Quantum photonics**: Single-photon detection for quantum computing, quantum key distribution, and fundamental physics experiments.
- **Neural probes and brain-machine interfaces**: Optical signal detection within neural systems for advanced neuroscience research and medical therapies.
- **Miniaturized imaging devices**: High-resolution, low-light imaging solutions for portable microscopes, AR/VR displays, and micro-projectors.

Patent Information

PCT application (*WO2022238320A1*, 09.05.2022), pending in EP, US

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