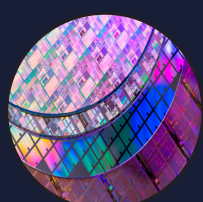
OPTO DIODE
*An ITW Company*

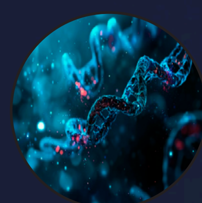
Illuminate. Detect. Innovate.
Since 1981

# Product Catalog



Semiconductors

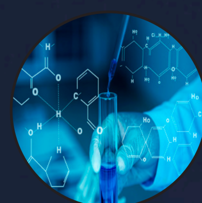
Industrial



Medical

Aerospace & Defense

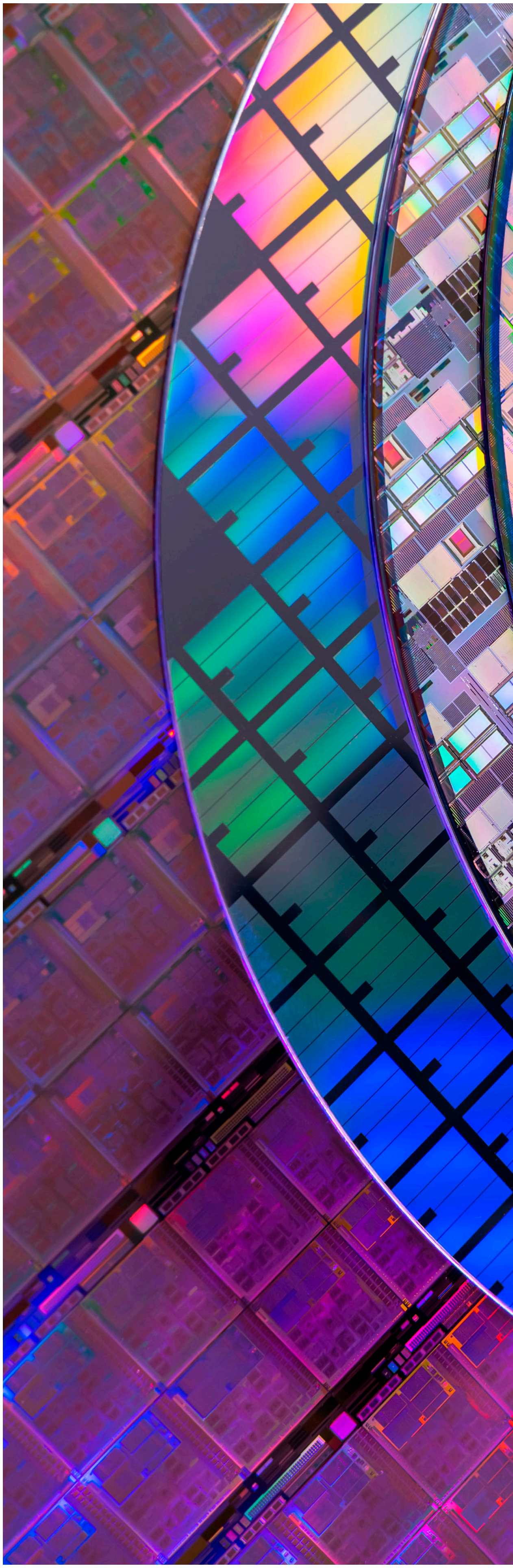
Environmental Monitoring



Food Analysis

www.OptoDiode.com

# WELCOME TO OUR PRODUCT CATALOG

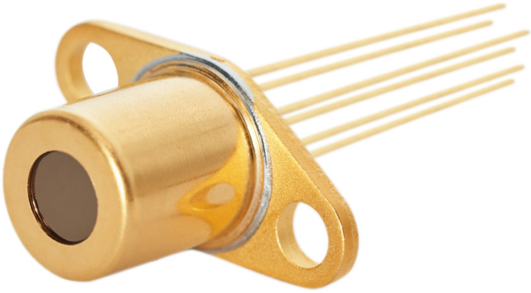


## ABOUT US

### Who are we?

Opto Diode Corporation delivers high performance photonic solutions built for precision, stability and long term reliability. We manufacture a broad portfolio of photodetectors, infrared detectors, IR emitters and LEDs, engineered to meet the performance demands of advanced optical systems.

Our technologies support critical applications across Aerospace, Defense, Medical, Automotive and Industrial Automation. From environmental monitoring and biomedical imaging to night vision, LiDAR and other mission driven systems, Opto Diode components provide the accuracy and consistency required for today's most demanding platforms. Backed by decades of expertise and a commitment to quality, we help customers build smarter, more capable and more dependable products.

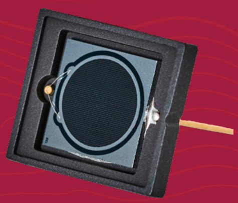


# TABLE OF **CONTENTS**

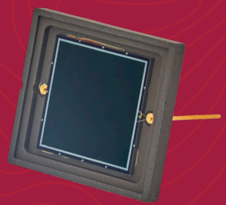
Discover innovation, page by page.

# SXUV Series

## EUV Enhanced Photodiodes



SXUV20HS1



SXUV100

## KEY FEATURES

- TO-18 and TO-5 Packaging
- Low Dark Current
- Fast Rise TImes
- Various Active Area Sizes
- Low Capacitance

## APPLICATIONS

- EUV Power Monitoring
- Metrology and Inspection
- Process Control
- EUV Qualification Processes

The SXUV family of Extreme Ultraviolet (EUV) optimized photodetectors offer exceptional 13.5nm photolithography capabilities and stable responsivity across extreme UV exposure wavelengths ranging from 1nm to 190nm. This makes them indispensable tools for the most critical EUV light measurement tasks, ensuring reliable and accurate results in demanding environments.

Available in a wide range of sizes, the SXUV series can be customized with bandpass filters optimized for specific wavelength ranges or incident power attenuation. This versatility allows users to select the most suitable configuration for their applications, whether in metrology and inspection, power monitoring, exposure systems, or process control.

Where speed and precision are paramount, low capacitance, high-speed versions of the SXUV detectors such as the **SXUV20HS1** deliver enhanced response times while maintaining low dark current. These features make them ideal for speed-critical applications such as high-throughput manufacturing, real-time process control, and advanced diagnostic systems.

## Product Lineup

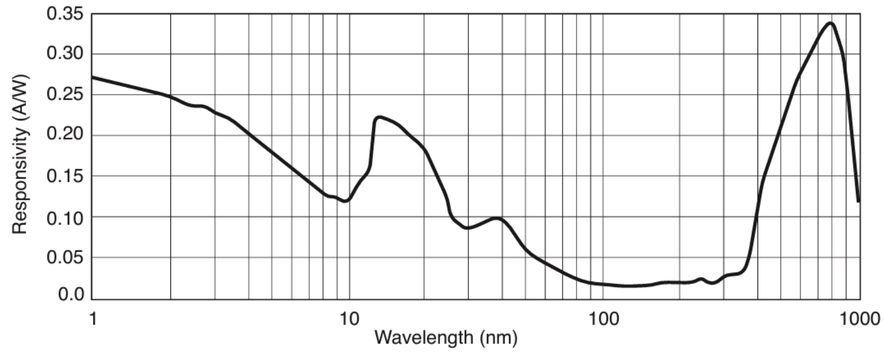
| Model Number | Part Number | Active Area Size (mm²) | Typical Responsivity (A/W) | Detection Range (nm) |
|---|---|---|---|---|
| SXUV100 | ODD-SXU-001 | 100 | See Responsivity Graph | 1-190 |
| SXUV20C | ODD-SXU-051 | 19.7 | See Responsivity Graph | 1-190 |
| SXUVHS1 | ODD-SXU-004 | 19.7 | See Responsivity Graph | 1-190 |
| SXUV300C | ODD-SXU-044 | 331 | See Responsivity Graph | 1-190 |
| SXUV5 | ODD-SXU-008 | 5 | See Responsivity Graph | 1-90 |

Engineered with durability and performance in mind, the SXUV detectors are designed to withstand rigorous use in laboratory and industrial environments, ensuring long-term reliability. Whether you are working on cutting-edge semiconductor fabrication, advanced materials research, or critical quality assurance, the SXUV family of detectors is your go-to solution for achieving superior performance and accuracy in extreme UV detection.

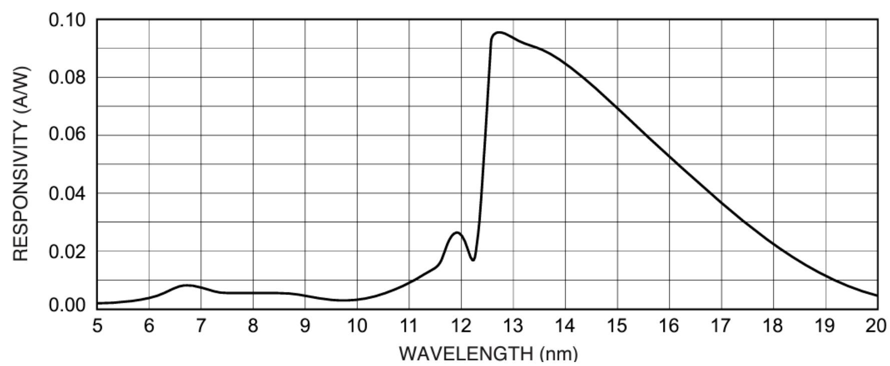
## Tailored Solutions

| Model Number | Part Number | Active Area Size (mm²) | Typical Responsivity (A/W) | Detection Range (nm) |
|---|---|---|---|---|
| **Multi Element and Array** | | | | |
| SXUVPS4 | ODD-SUXU-013 | 5 | See Responsivity Graph | 1-190 |
| SXUVPS4C | ODD-SUXU-023 | 5 | See Responsivity Graph | 1-190 |
| **Detectors with Integrated Thin Film** | | | | |
| SXUV100TF135 | ODD-SUXU-003 | 100 | 0.09 @ 13.5nm | 12 - 18 |

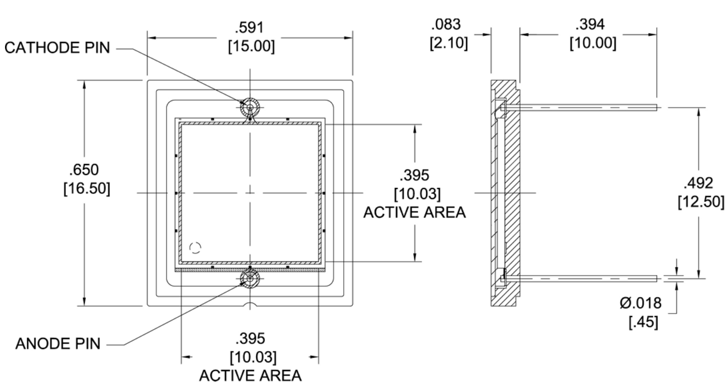
**Typical Responsivity (SXUV Series)**



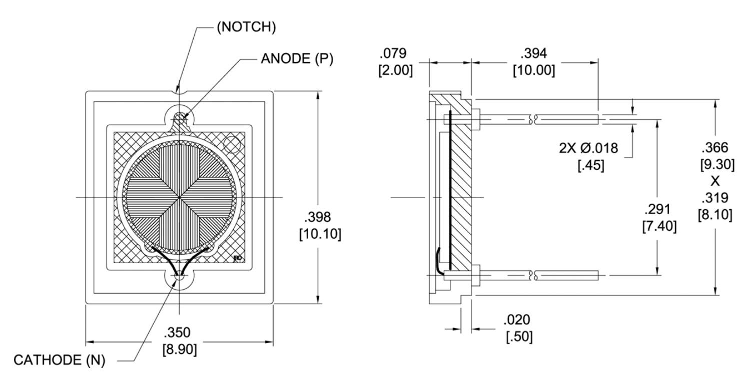

**Typical Responsivity (SXUV100TF135)**




## Typical Packaging



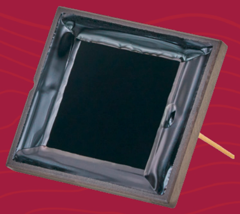

SXUV100



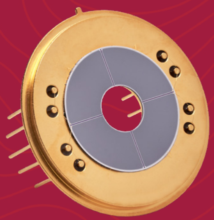

SXUV20HS1

# AXUV Series

## Electron, Photon & X-Ray Detectors



AXUV100TF030



AXUVPS7

## KEY FEATURES

- Large Detection Areas
- Vacuum Compatible
- High Speed Configurations
- Broad Wavelength Response
- Customizable

## APPLICATIONS

- Electron Detection
- High Energy Photon Detection
- Synchotron X-Ray Detection
- Back-Scatter Electron Detection
- Advanced Diagnostics

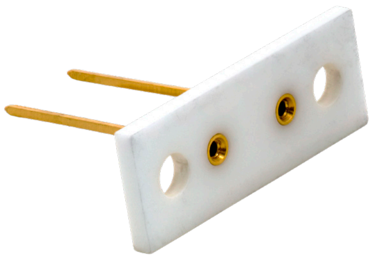
The AXUV Series excels in applications such as synchrotron and beamline instrumentation, where high-intensity photon beam monitoring is critical. They are also ideally suited for particle accelerators, providing precise measurements for high-energy physics experiments. In the semiconductor manufacturing sector, these photodiodes ensure precision and stability in photolithography and process control tasks. Additionally, their high energy detection capabilities make them a preferred choice for radiation monitoring in both medical diagnostics and industrial safety applications.

With versatile configurations, the AXUV Series offers both standard and custom options, including multi-element or array designs that adapt seamlessly to diverse operational requirements. These detectors are engineered for durability and performance, withstanding rigorous use in both laboratory and industrial settings.

Whether you are conducting cutting-edge experiments in physics and materials science, advancing diagnostic capabilities in medical imaging, or ensuring quality control in industrial processes, the AXUV Series provides the reliability and accuracy essential to your success.

## Product Lineup

| Model Number | Part Number | Active Area Size ($mm^2$) | Typical Responsivity (A/W) | Detection Range (nm) |
|---|---|---|---|---|
| AXUV100G | ODD-AXU-010 | 100 | See Responsivity Graphs | 0.0124 to 190 |
| AXUV20A | ODD-AXU-026 | 23 | See Responsivity Graphs | 0.0124 to 190 |
| AXUV20HS1 | ODD-AXU-036 | 20 | See Responsivity Graphs | 0.0124 to 190 |
| AXUV300C | ODD-AXU-082 | 331 | See Responsivity Graphs | 0.0124 to 190 |
| AXUV576C | ODD-AXU-048 | 576.5 | See Responsivity Graphs | 0.0124 to 190 |
| AXUV63HS1 | ODD-AXU-049 | 63 | See Responsivity Graphs | 0.0124 to 190 |
| AXUV63HS1-CH | ODD-AXU-051 | 63 | See Responsivity Graphs | 0.0124 to 190 |

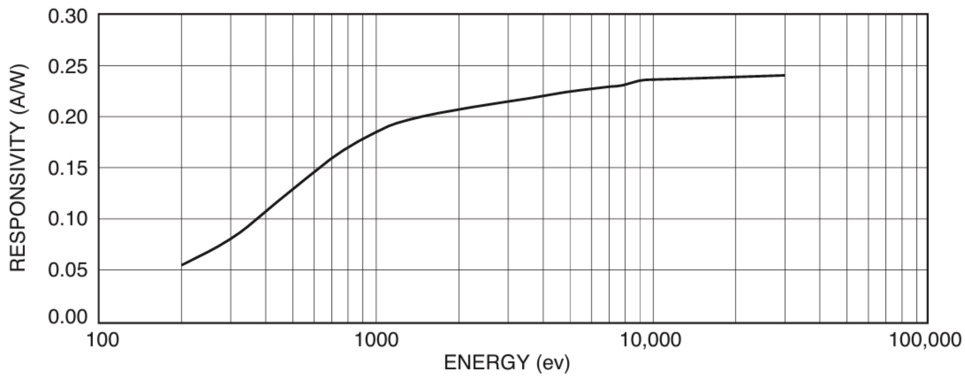


Sockets available for easy replacement and integration!

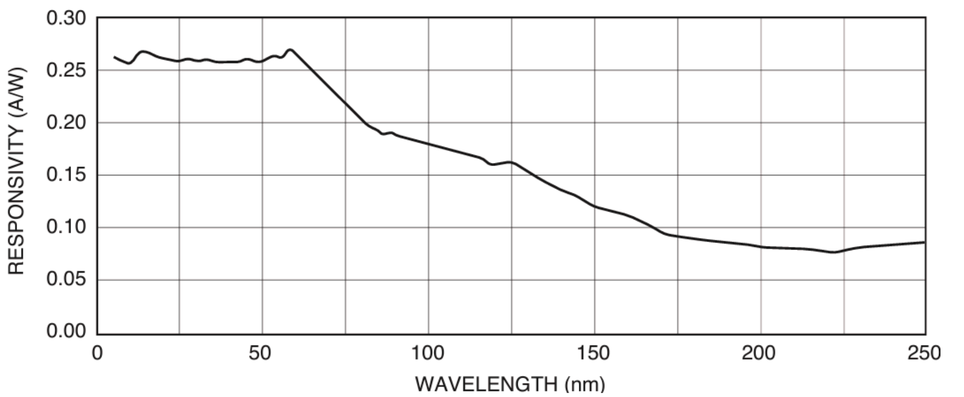
## Tailored Solutions

| Model Number | Part Number | Active Area Size (mm²) | Typical Responsivity (A/W) | Detection Range (nm) |
|---|---|---|---|---|
| **Multi-element and Array Detectors** | | | | |
| AXUV16ELG | ODD-AXU-023 | 36.5 | See Responsivity Graphs | 0.0124 to 190 |
| AXUV20ELG | ODD-AXU-033 | 3 | See Responsivity Graphs | 0.0124 to 190 |
| **Back Scatter Detectors** | | | | |
| AXUVPS7 | ODD-AXU-096 | 5 | See Responsivity Graphs | 0.0124 to 190 |
| **Detectors with Integrated Thin Films** | | | | |
| AXUV100TF030 | ODD-AXU-019 | 100 | See Responsivity Graphs | 1 - 12 |
| AXUV100TF400 | ODD-AXU-002 | 100 | See Responsivity Graphs | 18 - 80 |

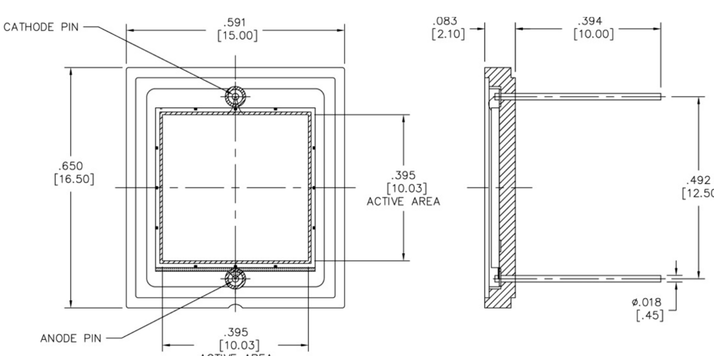
**Typical Electron Response**



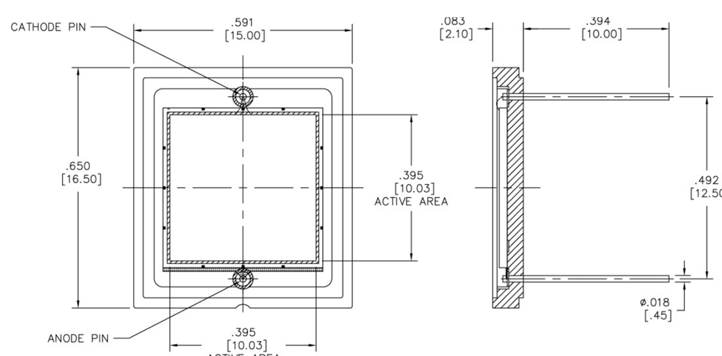

**Typical EUV-UV Response**




## Typical Packaging



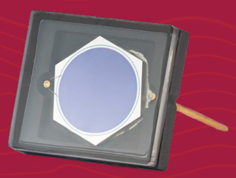

AXUV100TF030




AXUV100G

# UVG Series

## UV Enhanced Photodetectors



UVG-20S

Space Qualified Solutions

## KEY FEATURES

- Large Detection Areas
- 100% Internal QE
- Highly Stable UV Response
- Vacuum Compatible
- Ideal for 190-400nm

## APPLICATIONS

- UV-A, UV-B, UV-C Detection
- Laser Monitoring
- Photolithography
- UV Radiation Dosimetry
- Fluorescence Spectroscopy

Ideal for applications where reliability and accuracy are critical, the UVG Series excels in tasks such as laser power monitoring, UV light measurement, and quality assurance systems. Whether utilized in industrial processes, scientific research, or environmental monitoring, these detectors provide consistent results with minimal performance degradation over time.

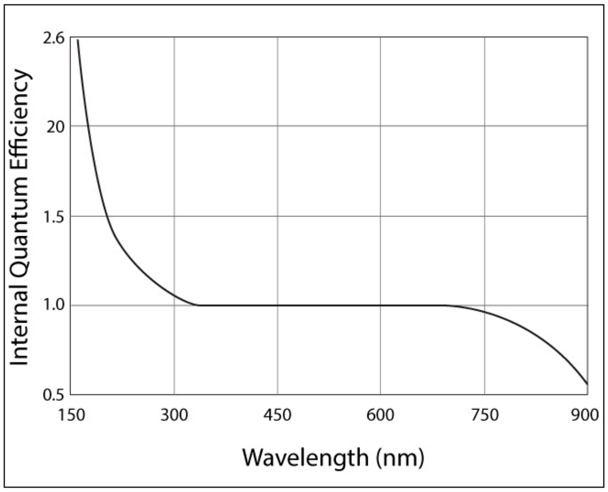
In semiconductor manufacturing, they ensure accurate laser monitoring in photolithography systems. In environmental monitoring, the detectors enable precise measurement of UV radiation levels for ozone studies and solar performance assessments. Medical fields benefit from their ability to monitor UV exposure in sterilization systems, while industrial applications rely on their stable output for UV curing and material testing processes.

With a design philosophy centered on durability and adaptability, the UVG Series offers a range of configurations to suit diverse operational needs. Customers can select from standard models or explore custom configurations tailored to specific requirements, ensuring optimal integration into existing systems.

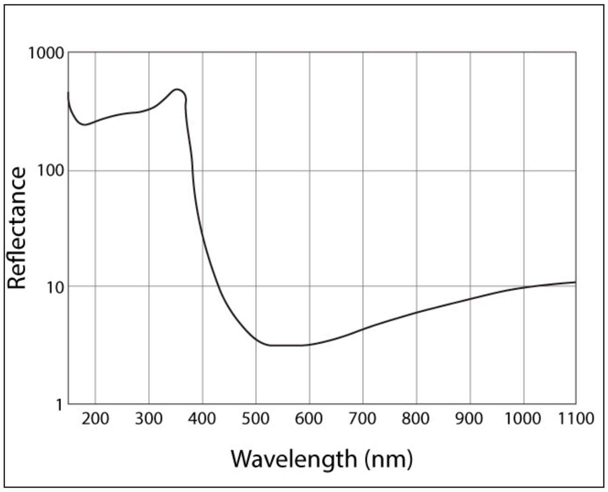
## Product Lineup

| Model Number | Part Number | Active Area Size (mm²) | Typical Responsivity (A/W) | Detection Range (nm) |
|---|---|---|---|---|
| UVG100 | ODD-UVG-002 | 100 | See Responsivity Graphs | 190 - 400 |
| UVG12 | ODD-UVG-014 | 12 | See Responsivity Graphs | 190 - 400 |
| UVG20C | ODD-UVG-004 | 19 | See Responsivity Graphs | 190 - 400 |
| UVG20S | ODD-UVG-013 | 24 | See Responsivity Graphs | 190 - 400 |
| UVG5S | ODD-UVG-007 | 5 | See Responsivity Graphs | 190 - 400 |

### Internal Quantum Efficiency

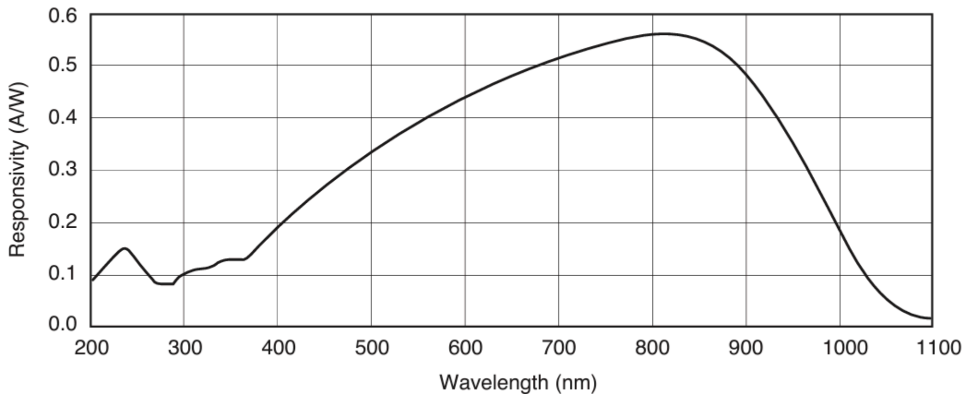



### Typical Reflectance

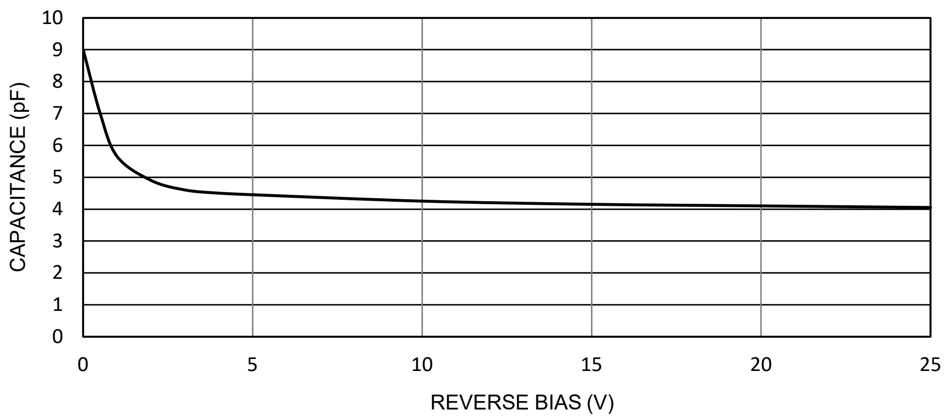


## Performance Specifications

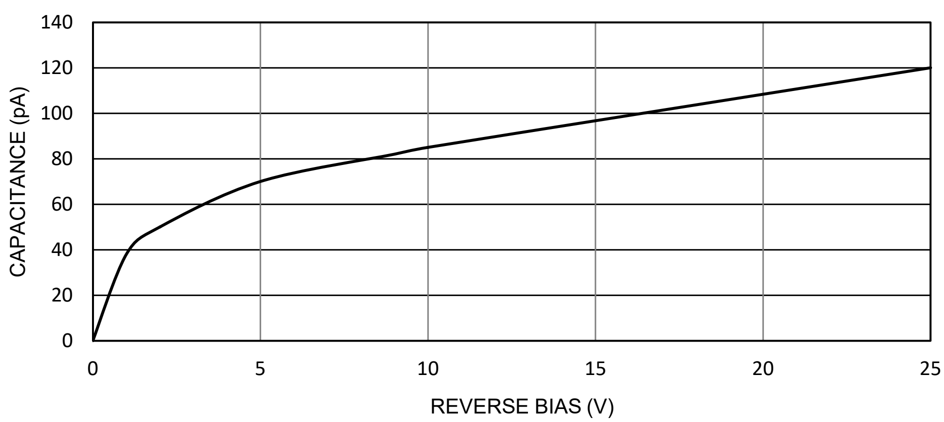
**Typical Photon Responsivity**



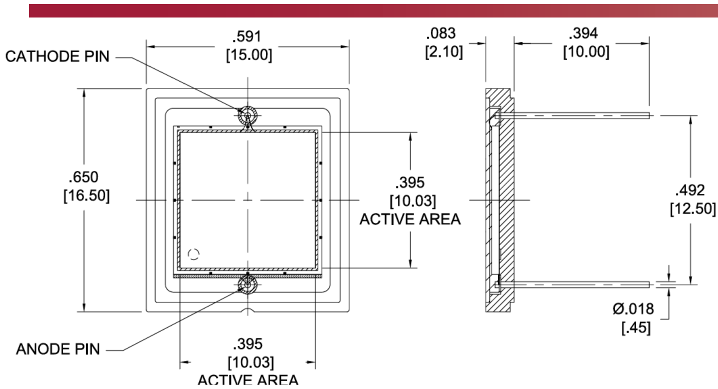

**Typical Capacitance vs. Bias (Per mm² of Active Area)**



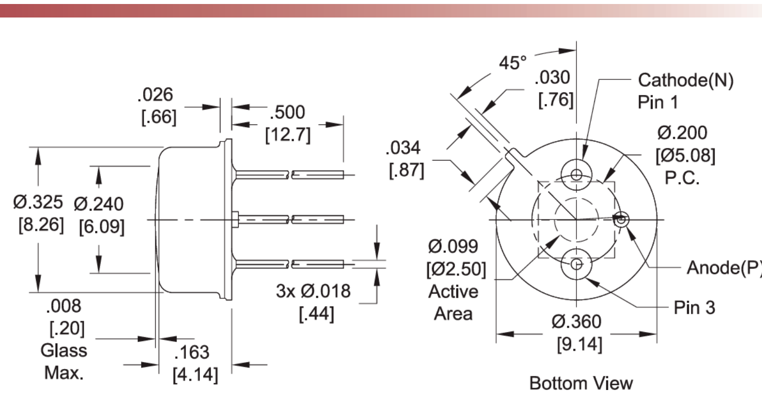

**Typical Dark Current vs. Bias (Per mm² of Active Area)**




## Sample Packaging



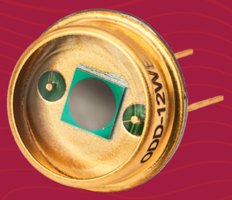

UVG100




UVG5S

# Standard Photodiodes

## Red and Blue Enhanced




ODD-12WB


ODD-1WB

## KEY FEATURES

- Large Detection Areas
- 100% Internal QE
- Highly Stable UV Response
- Vacuum Compatible
- Ideal for 190-400nm

## APPLICATIONS

- UV-A, UV-B, UV-C Detection
- Laser Monitoring
- Photolithography
- UV Radiation Dosimetry
- Fluorescence Spectroscopy

Opto Diode's Red and Blue Enhanced silicon photodiode detectors are designed to deliver exceptional performance across the visible spectrum, from 400nm to 1000nm. With low dark current and low capacitance, these photodiodes provide reliable and accurate light detection for applications that demand high sensitivity and precision.

Ideal for industries including medical diagnostics, scientific research, environmental monitoring, and industrial automation, these devices excel in tasks requiring consistent responsivity and stable output. Their red and blue wavelength enhancement ensures optimized detection in specific wavelength ranges, making them invaluable for applications such as color sensing, fluorescence detection, and light intensity measurements in imaging systems.

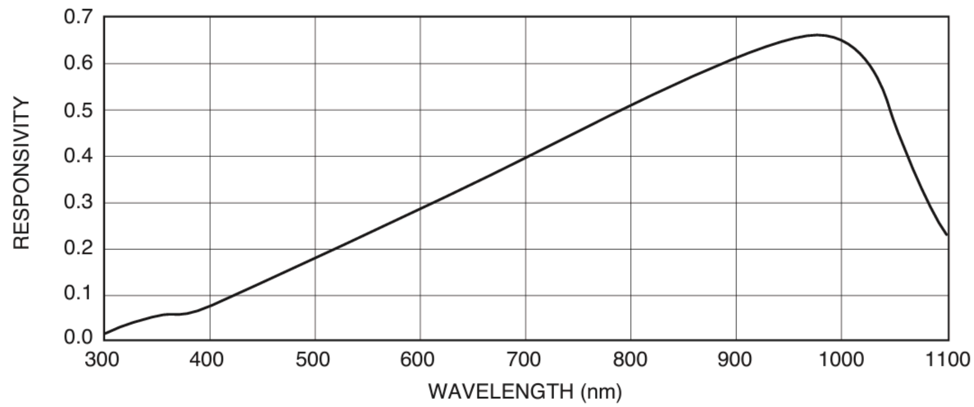
Available in both standard and customizable configurations, Opto Diode's photodiodes can be tailored to meet your specific requirements.

## Product Lineup

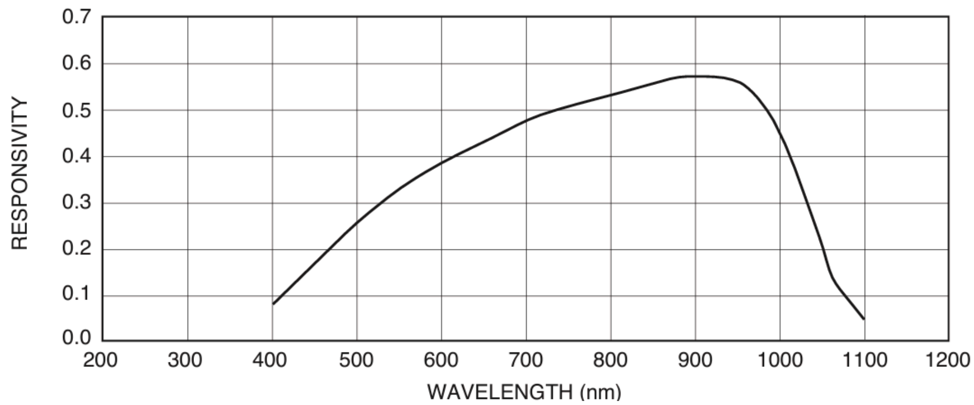
| Model Number | Part Number | Active Area Size (mm²) | Description | Typical Responsivity (A/W) |
|---|---|---|---|---|
| ODD-1 | ODD-632-001 | 1 | Red Enhanced Photodiode in TO-18 Pkg | 0.40 @ 632nm |
| ODD-12W | ODD-632-004 | 12 | Red Enhanced Photodiode in TO-8 Hermetic Pkg | 0.35 @ 632nm |
| ODD-12WB | ODD-450-004 | 12 | Blue Enhanced Photodiode in TO-8 Hermetic Pkg | 0.28 @ 450nm |
| ODD-15W | ODD-632-005 | 15.8 | Red Enhanced Photodiode in TO-5 Hermetic Pkg | 0.35 @ 632nm |
| ODD-15WB | ODD-450-005 | 15.8 | Blue Enhanced Photodiode in TO-5 Hermetic Pkg | 0.28 @ 450nm |
| ODD-1B | ODD-450-001 | 1 | Blue Enhanced Photodiode in TO-18 Pkg | 0.28 @ 450nm |
| ODD-1W | ODD-632-008 | 1 | Red Enhanced Photodiode in TO-18 Pkg | 0.40 @ 632nm |
| ODD-1WB | ODD-450-007 | 1 | Blue Enhanced Photodiode in TO-18 Pkg | 0.28 @ 450nm |
| ODD-42W | ODD-632-006 | 42 | Red Enhanced Photodiode in TO-8 Hermetic Pkg | 0.35 @ 632nm |
| ODD-42WB | ODD-450-006 | 42 | Blue Enhanced Photodiode in TO-8 Hermetic Pkg | 0.28 @ 450nm |
| ODD-5W | ODD-632-002 | 5 | Red Enhanced Photodiode in TO-5 Hermetic Pkg | 0.35 @ 632nm |
| ODD-5WB | ODD-450-002 | 5 | Blue Enhanced Photodiode in TO-5 Hermetic Pkg | 0.28 @ 450nm |
| ODD-5WBISOL | ODD-450-003 | 5 | Blue Enhanced Photodiode in TO-5 Hermetic Pkg | 0.28 @ 450nm |
| ODD-5WISOL | ODD-632-003 | 5 | Red Enhanced Photodiode in TO-5 Hermetic Pkg | 0.35 @ 632nm |

## Performance Specifications

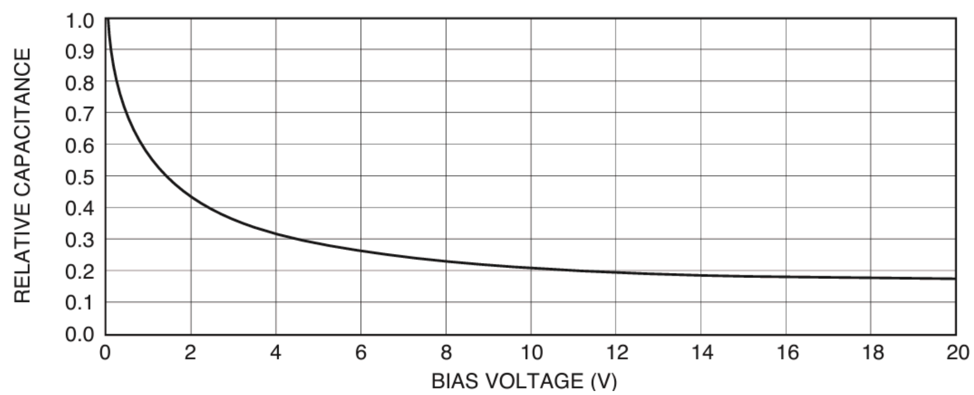
**Typical Red Enhanced Photodiode Responsivity**



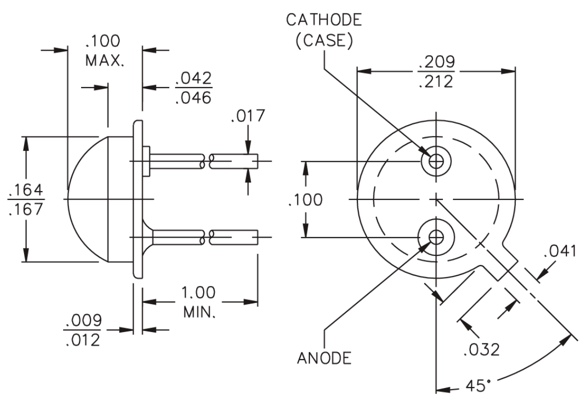

**Typical Blue Enhanced Photodiode Responsivity**



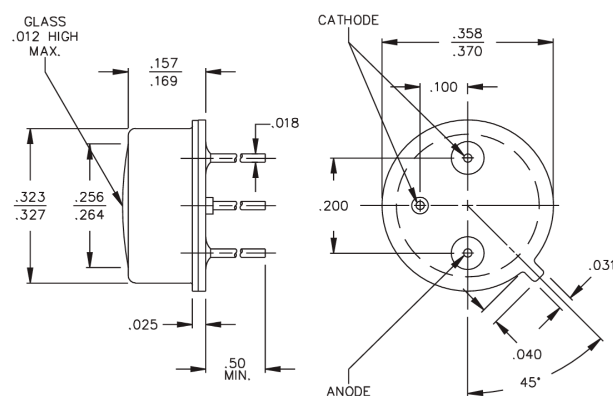

**Capacitance vs. Reverse Bias (Per mm² of Active Area)**




## Sample Packaging

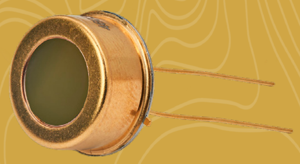



ODD-1




ODD-15W

# PbS Infrared Detectors



AP-58E

AP-68

## KEY FEATURES

- High Sensitivity (2um - 4um)
- High Signal to Noise Ratio
- High Durability Ensuring Long Field Operation
- Customizable Configurations

## APPLICATIONS

- Gas Analysis
- Emission Monitoring
- Spectroscopy
- Process Control Systems
- Thermal Imaging

The A Series single channel infrared detectors integrates PbS technology with proven manufacturing processes to provide the highest sensitivity detectors across the spectral range from two to four microns. In addition, the product line minimizes maintenance costs and provides dependable operation with industry leading quality, durability, and reliability.

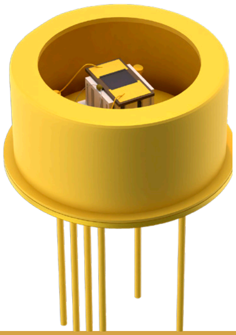
Many of today's demanding applications, including industrial, environmental, and medical uses, require a high level of performance to address evolving challenges. The A Series IR Detectors deliver superior sensitivity, meeting the need to detect trace elements, gases, fire, flame, and emissions with accuracy and consistency. This makes them ideal for tasks ranging from process control to safety monitoring in high-stakes environments.

Available in a variety of standard configurations, customers can choose from an assortment of options including element size, cooling alternatives, and package size to suit numerous system and application requirements. Cooled units provide additional sensitivity for very low-level signal detection and enhanced stability in environments where temperatures are in constant flux. These features allow users to tailor their solutions to specific operational needs, ensuring optimal performance in any scenario.

## AP Series - Uncooled PbS IR Detectors

| Model Number | Part Number | Sensing Element Size (mm) | D* (cm $HZ^{1/2}$ $W^{-1}$) | Resistance (MΩ) | Window Type |
|---|---|---|---|---|---|
| AP-15G | 40725 | 1mm x 1mm | 1x$10^{11}$ Typ. | 0.5 - 2.0 | Glass Molded Lens |
| AP-25G | 40370 | 2mm x 2mm | 1x$10^{11}$ Typ. | 0.5 - 2.0 | Glass Molded Lens |
| AP-35 | 40363 | 3mm x 3mm | 1x$10^{11}$ Typ. | 0.5 - 2.0 | Glass Molded Lens |
| AP-20505 | 40009 | 2mm x 2mm | 7x$10^{10}$ Min. | 0.5 - 2.0 | Glass Molded Lens |
| AP-58E | 40736 | 5mm x 5mm | 7x$10^{10}$ Min. | 0.5 - 2.0 | Flat Silicon |
| AP-68 | 40368 | 6mm x 6mm | 7x$10^{10}$ Min. | 0.5 - 2.0 | Flat Silicon |

- D* measurements @ ʎp, 650 Hz, 1 Hz
- Specifications apply at voltage (VBias) of 50V/mm with a 1MΩ resistor in series. Except for 40009 uses a 0.5MΩ. ʎp @ 500K.



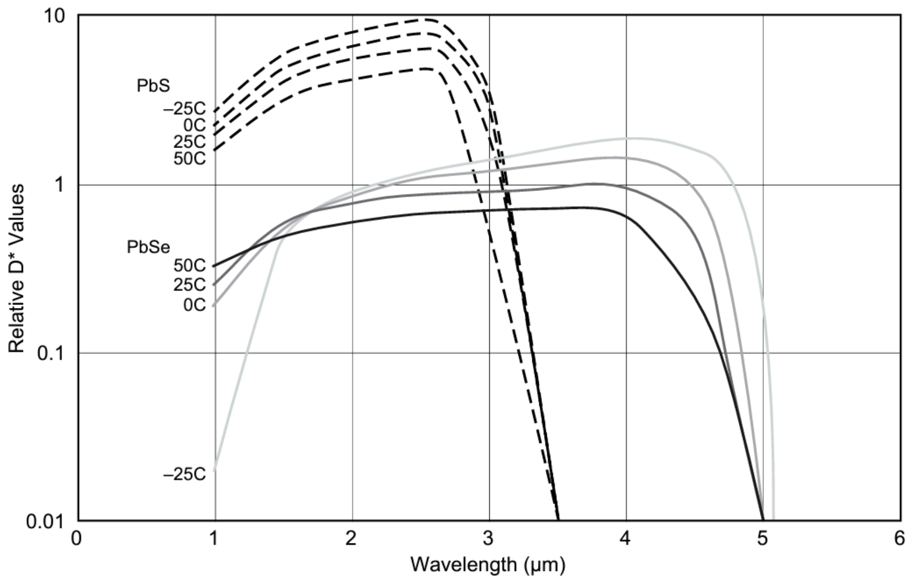
## AT1 & AT2 Series - Cooled PbS IR Detectors

| Model Number | Part Number | Sensing Element Size (mm²) | D* (cm HZ$^{1/2}$ W$^{-1}$) | Resistance (MΩ) | Window Type | Number of Cooling Stages |
|---|---|---|---|---|---|---|
| AT1-27TE | 40373 | 4 | 1.5x10$^{11}$ Typ. | 1.5-10.0 | Flat Sapphire | 1 |
| AT1-37T | 40147 | 9 | 1.5x10$^{11}$ Typ. | 1.5-10.0 | Flat Sapphire | 1 |
| AT2-28TE | 40028 | 4 | 2.5x10$^{11}$ Typ. | 2.5-15.0 | Flat Sapphire | 2 |
| AT2-37T | 40193 | 9 | 2.5x10$^{10}$ Min. | 2.5-15.0 | Flat Sapphire | 2 |
| AT2S-38T | 40029 | 9 | 3x10$^{10}$ Min. | 3.0-20.0 | Flat Sapphire | 2 |

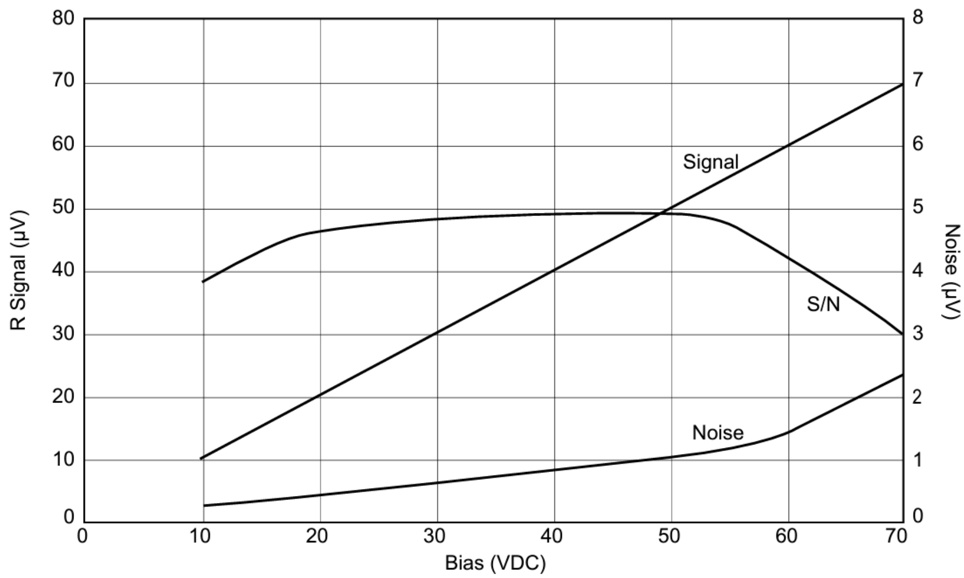
- D* measurements @ ʎp, 650 Hz, 1 Hz

## Response Spectrum and SNR

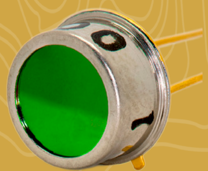
**Detector Spectral Response**



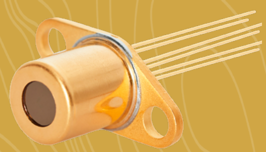

**Signal to Noise Ratio vs. Bias Voltage**



# PbSe Infrared Detectors



BPX-35F



BXT2-17TF

## KEY FEATURES

- High Sensitivity (1um - 5um)
- High Signal to Noise Ratio
- High Durability Ensuring Long Field Operation
- Customizable Configurations

## APPLICATIONS

- Gas Analysis
- Emission Monitoring
- Spectroscopy
- Process Control Systems
- Thermal Imaging

The BX Series PbSe Infrared Detectors deliver exceptional performance for material analysis across the 1 to 5-micron spectrum. With a combination of high sensitivity, fast response times, and proven reliability, these detectors are designed to meet the rigorous demands of applications such as gas analysis, emissions monitoring, and industrial process control. Their precision and speed make them indispensable tools for detecting trace elements, analyzing gases, and monitoring pollutants with accuracy and consistency, ensuring compliance with regulatory standards and optimizing industrial processes.

Uncooled options in the BXP Series provide cost-effective performance, while the BXT1 Series single-stage TEC detectors enhance temperature stability and sensitivity. For the most challenging environments, the BXT2 Series two-stage TEC detectors deliver superior temperature stability and the highest levels of sensitivity, ensuring reliable operation even under harsh conditions.

Designed to maximize dynamic range, the BX Series supports real-time measurements with fast response times and low maintenance requirements. The rugged construction and long operational life of these detectors reduce downtime and maintenance costs, making them an ideal choice for high-stakes environments.

## BXP Series - Uncooled PbSe IR Detectors

| Model Number | Part Number | Sensing Element Size (mm) | D* (cm $HZ^{1/2}$ $W^{-1}$) | Resistance (MΩ) | Window Type |
|---|---|---|---|---|---|
| BXP-15E | 40785 | 1mm x 1mm | $2x10^{10}$ Typ. | 0.7 - 1.5 | Falt Saphire |
| BXP-25M | 42413 | 2mm x 2mm | $2x10^{10}$ Typ. | 0.1 - 2.5 | AR Silicon |
| BXP-35E | 40055 | 3mm x 3mm | $1.5x10^{10}$ Typ. | 0.5 - 1.75 | Falt Saphire |
| BXP-35F | 40333 | 3mm x 3mm | $1.5x10^{10}$ Typ. | 0.5 - 1.0 | 2.4um Longpass Ge Filter |

- D* measurements @ ʎp, 1000 Hz, 1 Hz
- Specifications apply at voltage (VBias) of 25V/mm for cooled and 35V/mm for uncooled detectors with either a 1MΩ or 0.5MΩ load resistor in series.

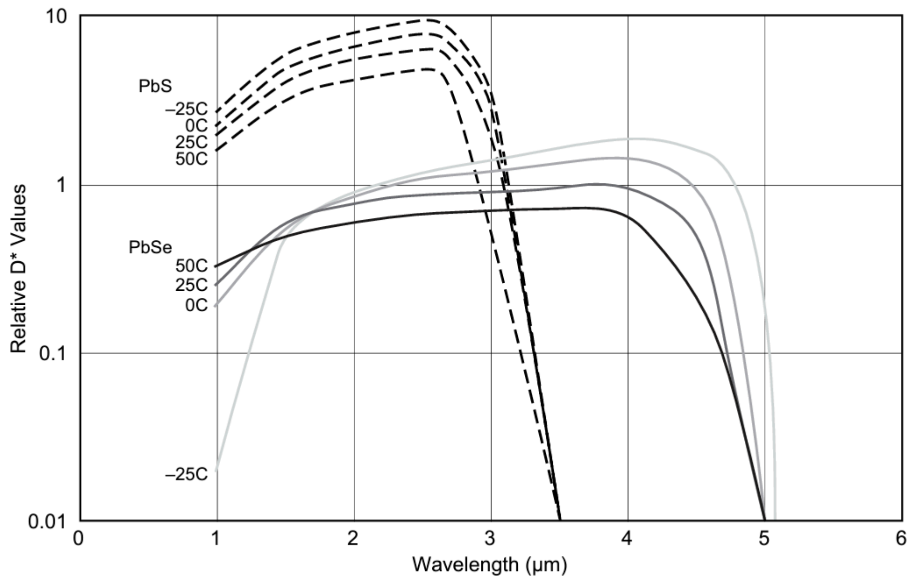
Single- and two-stage cooling options enable precise measurements, even in environments with varying temperatures.

# BXT1 & BXT2 Series - Cooled PbSe IR Detectors

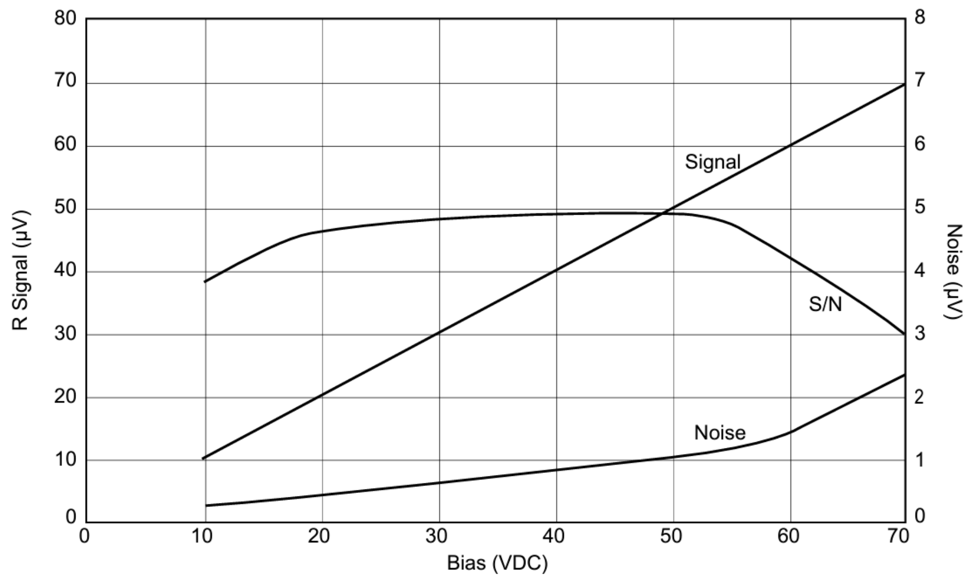
| Model Number | Part Number | Sensing Element Size (mm²) | D* (cm $HZ^{1/2}$ $W^{-1}$) | Resistance (MΩ) | Window Type | Number of Cooling Stages |
|---|---|---|---|---|---|---|
| BXT1-28TE | 40373 | 2mm x 2mm | $2.8x10^{10}$ Typ. | 0.5 - 10.0 | Flat Sapphire | 1 |
| BXT1-37T | 40147 | 3mm x 3mm | $2.8x10^{10}$ Typ. | 0.5 - 10.0 | Flat Sapphire | 1 |
| BXT2-17T | 40174 | 1mm x 1mm | $1.6x10^{10}$ Min. | 1.0 - 15.0 | Flat Sapphire | 2 |
| BXT2-17TF | 40065 | 1mm x 1mm | $2.4x10^{10}$ Min. | 1.5 - 7.0 | Flat Sapphire | 2 |
| BXT2-27 | 40587 | 2mm x 2mm | $1.8x10^{10}$ Min. | 1.0 - 4.5 | 2.7um Longpass Si Filter | 2 |
| BXT2-37T | 40071 | 3mm x 3mm | $1.6x10^{10}$ Min. | 1.0 - 15.0 | Flat Sapphire | 2 |
| BXT2S-28T | 40186 | 2mm x 2mm | $3.5x10^{10}$ Typ. | 1.0 - 15.0 | Flat Sapphire | 2 |
| BXT2S-38T | 40203 | 3mm x 3mm | $3.5x10^{10}$ Typ. | 1.0 - 15.0 | Flat Sapphire | 2 |
| BXT2S-68TE | 40076 | 6mm x 6mm | $1.5x10^{10}$ Min. | 1.0 - 15.0 | Flat Sapphire | 2 |

- D* measurements @ ʎp, 650 Hz, 1 Hz

**Detector Spectral Response**

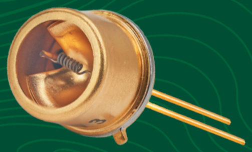



**Signal to Noise Ratio vs. Bias Voltage**



# IR-Emitters

## NIR to IR Emitters



SHA727-5M0

SA10510-8M2

## KEY FEATURES

- Calcium Fluouride window options
- Choose from Steady State or Pulsable
- High Emissivity
- Configurable Options

## APPLICATIONS

- Environmental Monitoring
- Spectroscopy
- Process Monitoring
- Gas Analysis

The IR Emitter Series by Opto Diode offers a versatile range of high-performance infrared emitters, meeting the demands of industrial and medical applications such as gas analysis, environmental monitoring, spectroscopy, and process control.

The **SA Series** emitters provide steady-state blackbody radiation with sapphire or calcium fluoride windows, delivering consistent performance in TO5 and TO8 packages. For higher output, the **SHA Series** emitters offer windowless TO5 packaging and blackbody-like spectral distribution, ideal for applications requiring stability and high power. For pulsable sources of blackbody radiation, the **SVF Series** excels with emissivity up to 0.88, while the **SPF Series** offers fast, dynamic performance for high-speed applications. The PIREPLUS emitters take innovation further with high-speed IR emission and integrated drive electronics, streamlining complex setups.

Designed for adaptability, these emitters suit a broad range of industries, from medical diagnostics to industrial safety, enabling gas detection, advanced spectroscopy, and process monitoring. Engineered for durability and seamless integration, the IR Emitter Series exemplifies Opto Diode's commitment to quality and innovation. Whether for steady-state or pulsable needs, this series delivers unmatched performance for today's most critical applications.

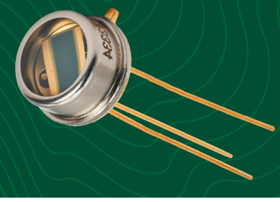
## Steady State IR Emitters

| Model Number | Part Number | Window Type | Typical Resistance |
|---|---|---|---|
| **Steady State: SA Series** | | | |
| SA1037-5M2 | 40089 | Sapphire | 0.80 ohms |
| SA1037-5M3 | 40090 | Calcium Fluoride | 0.80 ohms |
| SA10510-8M2 | 40092 | Sapphire | 1.60 ohms |
| SA10510-8M3 | 40093 | Calcium Fluoride | 1.60 ohms |
| SA727-5M2 | 40095 | Sapphire | 1.00 ohms |
| SA727-5M3 | 40096 | Calcium Fluoride | 1.00 ohms |
| SA727-8M2 | 40198 | Sapphire | 1.30 ohms |
| **Steady-State SHA High Power Series** | | | |
| SHA1037-5M0 | 40099 | Windowless | 0.80 ohms |
| SHA727-5M0 | 40100 | Windowless | 1.00 ohms |

# Pulsable IR Emitters

| Model Number | Part Number | Window Type | Typical Resistance |
|---|---|---|---|
| **Pulsable SVF Series** | | | |
| SVF230-5M2 | 40103 | Sapphire | 0.80 ohms |
| SVF230-5M3 | 40104 | Calcium Fluoride | 0.80 ohms |
| SVF350-5M2 | 40106 | Sapphire | 1.60 ohms |
| SVF350-5M3 | 40107 | Calcium Fluoride | 1.60 ohms |
| SVF350-8M3 | 40172 | Calcium Fluoride | 1.00 ohms |
| SVF360-8M2 | 40432 | Sapphire | 1.00 ohms |
| SVF360-8M3 | 40110 | Calcium Fluoride | 1.30 ohms |
| **Pulsable High Speed** | | | |
| SPF220-5M2 | 40101 | Sapphire | 2.46 ohms |
| SPF220-5M2H | 40800 | Sapphire | 2.46 ohms |
| Pire Plus | 40801 | Sapphire | --- |

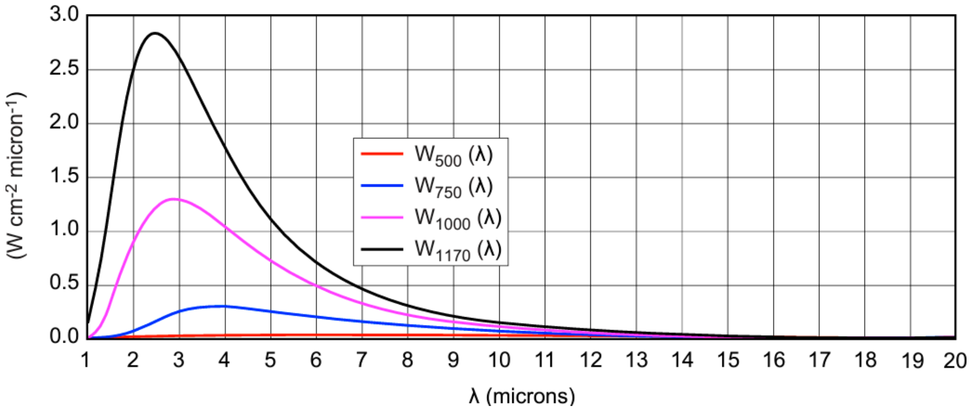
Pair with our IR-Detectors!



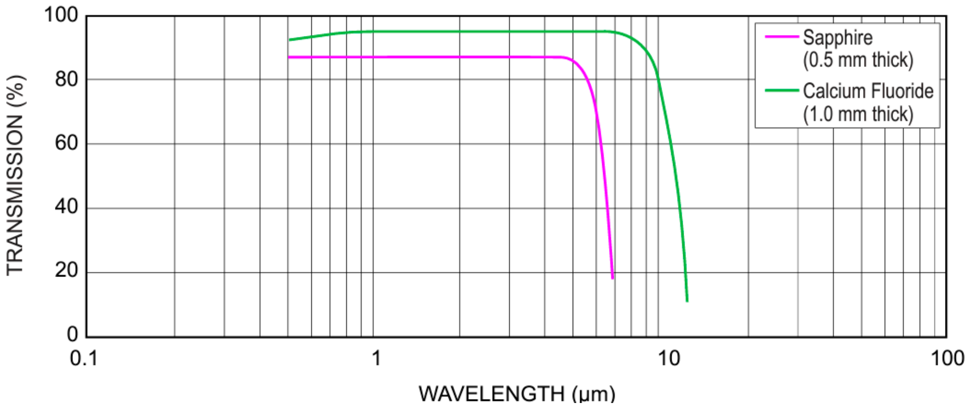
* Customization available for specific wavelengths.

# Emission Specifications

**Black Body Radiant Emittance**



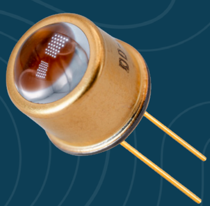

**Window Spectral Transmission Options**



# LEDs

## Visble and Near-Infrared

OD-110W



OD-110L

## KEY FEATURES

- Variety of Packaging Available
- Visible to Near Infrared (NIR)
- Cusomizable
- High Power Output
- Hi-Rel Qualified

## APPLICATIONS

- Industrial Systems
- Night Vision
- Surveillance
- Stealth Illumination
- Optical Encoders

Our high-performance light-emitting diodes are engineered to meet the demands of the most rigorous applications. Designed with rugged, hermetically sealed packaging, these LEDs excel in environments requiring extreme durability and precision, withstanding temperatures from -65°C to +150°C. Their versatility and reliability make them indispensable for markets such as medical, automotive, aerospace, imaging, scientific research, and military operations.

The standard product line includes high-output visible LEDs in red and blue with narrow beam angles, ideal for radiometric measurements and tight spectral bandwidth requirements. For near-infrared needs, Opto Diode offers high-power near-IR LEDs producing up to 250mW DC from single chips or up to 1000mW DC from arrays, tailored for surveillance, night vision, and advanced imaging systems. Available in wide, medium, or narrow light patterns, these near-IR LEDs provide superior linear power output and are available in high-speed grades for dynamic applications.

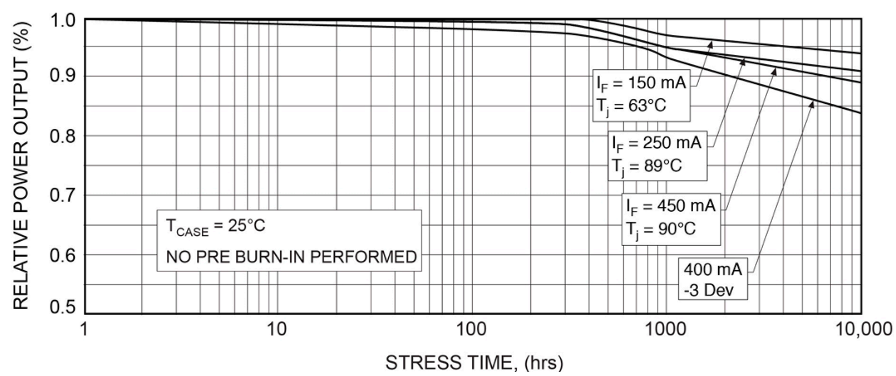
## Standard Product Line

| Model Number | Part Number | Typ. Power Output (mW) | Peak Emission Walvelength (λP) | Typ. Forward Voltage (V) | Package Type |
|---|---|---|---|---|---|
| OD-800F | OD-810-005 | 3.0 | 810nm @ 50mA | 1.45V @ 100mA | TO-46 |
| OD-800L | OD-810-003 | 3.0 | 810nm @ 50mA | 1.45V @ 100mA | TO-46 |
| OD-800W | OD-810-002 | 3.0 | 810nm @ 50mA | 1.45V @ 100mA | TO-46 |
| OD-850F | OD-850-004 | 30 | 850nm @ 20mA | 1.60V @ 100mA | TO-46 |
| OD-850FHT | OD-850-010 | 22 | 810nm @ 50mA | 1.60V @ 100mA | TO-46 |
| OD-850L | OD-850-003 | 35 | 810nm @ 50mA | 1.60V @ 100mA | TO-46 |
| OD-850LHT | OD-850-009 | 25.5 | 810nm @ 50mA | 1.60V @ 100mA | TO-46 |
| OD-850W | OD-850-002 | 40 | 810nm @ 50mA | 1.60V @ 100mA | TO-46 |
| OD-850WHT | OD-850-008 | 27.5 | 810nm @ 50mA | 1.60V @ 100mA | TO-46 |
| OD-685C | OD-2438 | 2.0 | 685nm @ 20mA | 1.80V @ 20mA | SMD |
| D-469L | OD-469-001 | 170 | 470nm @ 350mA | 3.2V @ 350mA | TO-39 |
| OD-624L | OD-624-001 | 170 | 635nm @ 350mA | 2.3V @ 350mA | TO-39 |

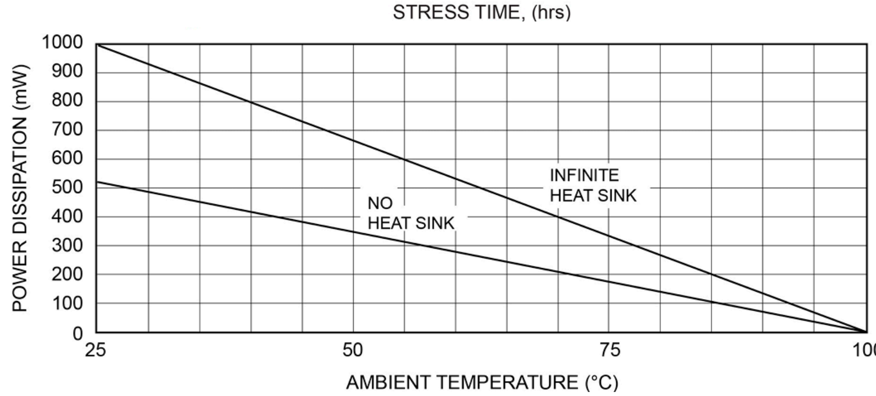
## High Power NIR LEDs

| Model Number | Part Number | Typ. Power Output (mW) | Peak Emission Walvelength (λP) | Typ. Forward Voltage (V) | Number of LED Die | Package Type |
|---|---|---|---|---|---|---|
| OD-110L | OD-850-006 | 110 | 850nm @ 50mA | 1.7V @ 500mA | 1 | TO-39 |
| OD-110W | OD-850-005 | 140 | 850nm @ 50mA | 1.7V @ 500mA | 1 | TO-39 |
| OD-110LISOLHT | OD-850-015 | 100 | 880nm @ 50mA | 1.75V @ 500mA | 1 | TO-39 |
| OD-110WISOLHT | OD-850-014 | 120 | 880nm @ 50mA | 1.75V @ 500mA | 1 | TO-39 |
| OD-250 | OD-850-007 | 250 | 850nm @ 50mA | 1.7V @ 500mA | 1 | TO-39 |
| OD-663 | OD-880-015 | 170 | 880nm @ 50mA | 4.5V @ 300mA | 3 | TO-66 |
| OD-663-850 | OD-850-011 | 425 | 850nm @ 50mA | 4.8V @ 300mA | 3 | TO-66 |
| OD-666 | OD-880-016 | 330 | 880nm @ 50mA | 9.0V @ 300mA | 6 | TO-66 |
| OD-669 | OD-880-017 | 500 | 880nm @ 50mA | 13.5 @ 300mA | 9 | TO-66 |
| OD-669-850 | OD-850-013 | 1250 | 850nm @ 50mA | 13.5 @ 300mA | 9 | TO-66 |

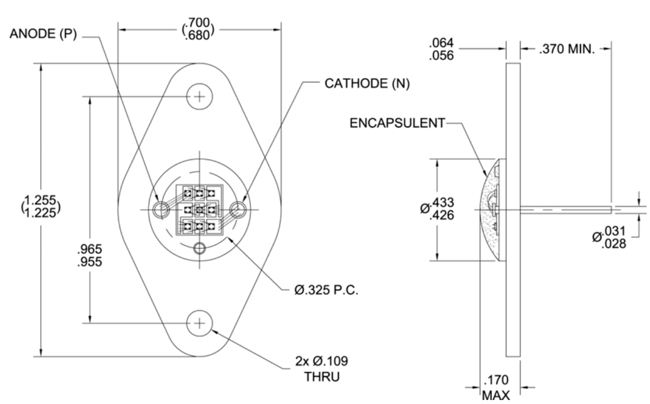
**Typical Degradation Curve**



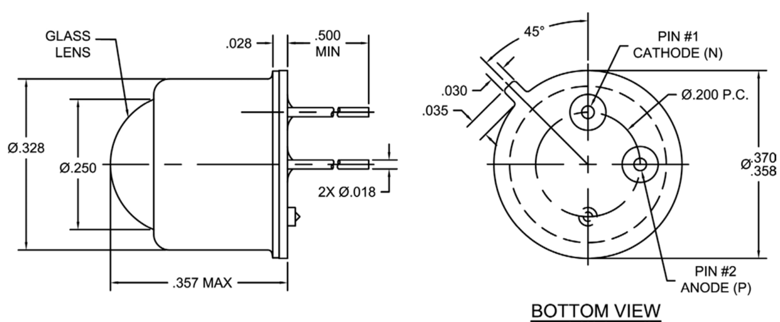

**Maximum Rated Thermal Derating Curve**




## Typical Packaging




OD-669-850




OD-110LISOLHT

# APDs

## Near-Infared to Infrared

ODD-APD-003

## KEY FEATURES

- High Gain
- High responsivity
- Low dark current
- Low capacitance

## APPLICATIONS

- Automotive LiDAR
- Industrial safety scanners
- Time-of-Flight (ToF)
- Autonomous Systems

Avalanche photodiodes (APDs) amplify faint optical signals internally, enabling the detection of weak reflections from distant or low-reflectivity objects. Operating under high reverse bias, the ODD-APD-002 provides gain up to ~100× while maintaining low noise and excellent linearity. With a 500 µm active area and responsivity of ~0.55 A/W at 905 nm, it ensures strong signal conversion and rapid response, even in bright ambient light. The device's low capacitance (~1.2 pF) supports sub-nanosecond rise times, critical for accurate time-of-flight ranging.

**Driving Precision in Next-Generation LiDAR and Autonomous Systems**

LiDAR (Light Detection and Ranging) technology is transforming automotive, industrial, and mapping applications by providing high-resolution distance and imaging data. As systems push for greater range and reliability under challenging environmental conditions, detector performance becomes critical. Opto Diode's ODD-APD-002 Silicon Avalanche Photodiode, optimized for 905 nm, delivers the sensitivity, speed, and stability required for advanced LiDAR and time-of-flight (ToF) systems. With decades of photonics expertise, Opto Diode offers a dependable solution for designers seeking enhanced accuracy, range, and detection confidence.

## Standard Product Line

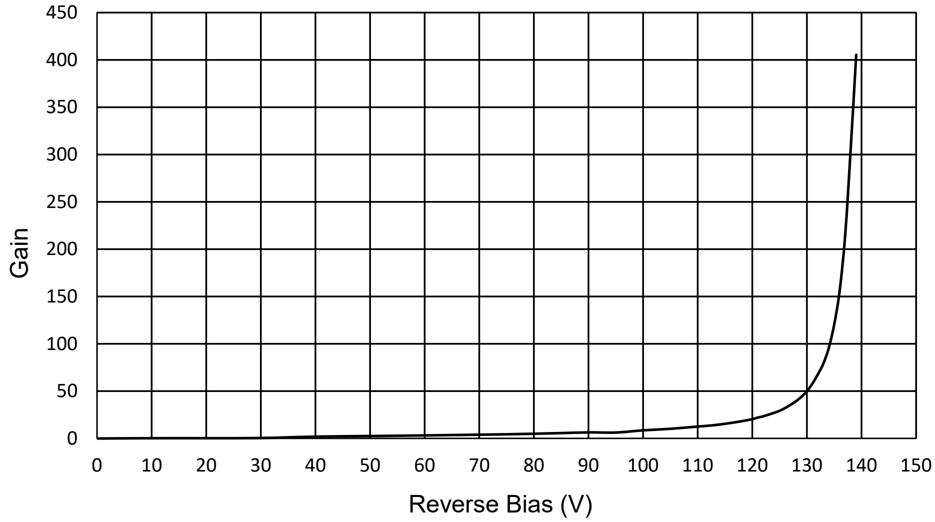
| Model Number | Active Area ($mm^2$) | $V_{op}$ (V) (Gain = M) | Responsivity (A/W) | Dark Current (nA) | Rise Time (ns) | Reverse Breakdown (V) |
|---|---|---|---|---|---|---|
| ODD-APD-001 | 0.03 | 93V @ $\lambda_p$, M= 10 | 1550nm, M = 1 | 8.0 @ M=30 | 0.3 @ $\lambda_p$, $R_L$ = 50Ω | 50 |
| ODD-APD-002 | 0.20 | 95V @ $\lambda_p$, M = 100 | 905nm, M = 1 | 0.4 @ M=100 | 0.5 @ $\lambda_p$, $R_L$ = 50Ω | 220 |
| ODD-APD-003 | 0.20 | 332V @ $\lambda_p$, M = 100 | 1064nm, M = 1 | 5.0 @ M=100 | 2.0 @ $\lambda_p$, $R_L$ = 50Ω | 460 |


## Why use APDs?

- Higher responsivity than PIN diodes and lead based detectors
- Internal gain for weak signals
- Better SNR at low light levels
- Ideal for LiDAR, ToF, and long-distance sensing

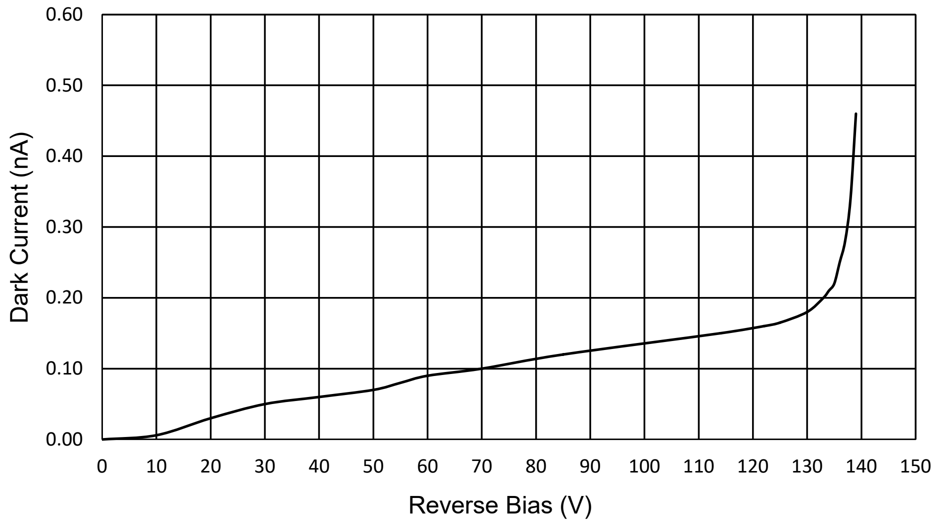
**Typical Gain vs. Reverse Bias**

(ODD-APD-002)

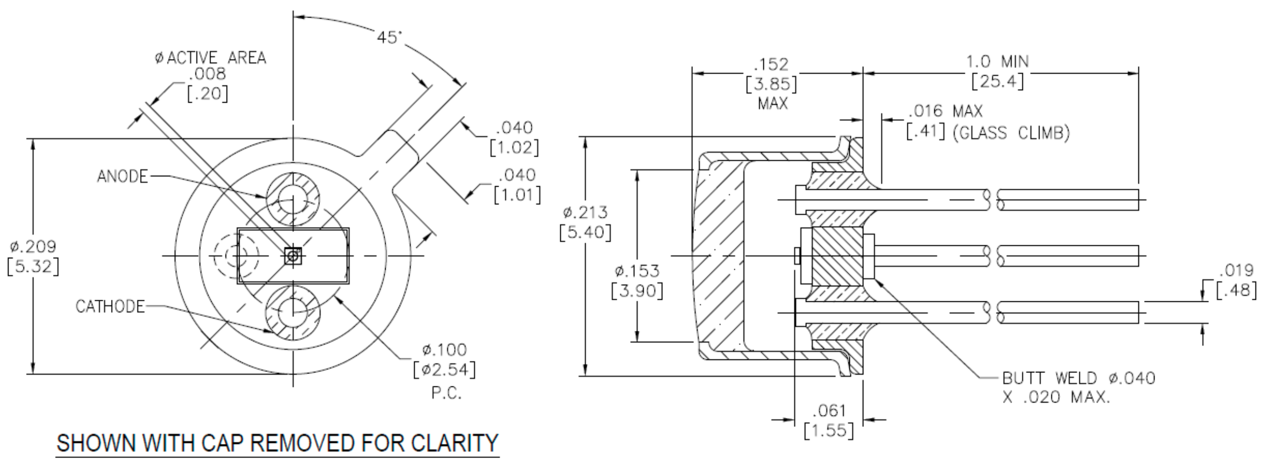



**Typical Dark Current vs. Reverse Bias**

(ODD-APD-002)




## Typical Packaging




ODD-APD-001

# Silicon Photodiode Fundamentals

Photodiodes are versatile semiconductor devices that exhibit a broad-spectrum response to a diverse range of radiation sources. These sources include not only high-energy particles, electrons, and X-Rays, but also photons in the UV, visible, and infrared spectrums. Incident radiation is converted into a photogenerated current which can be measured directly as current or voltage by an external circuit. Despite their simple operating principles, photodiode's exceptional sensitivity, robustness, and adaptaability makes them incredibly versatile across numerous industries. They find extensive applications in diverse sectors such as industrial manufacturing, medical technology, aerospace engineering, the semiconductor industry, and many more.

Typical applications include:

- Medical Instruments
- EUV Metrology & Inspection
- Laser Light Monitoring
- Optical Encoders
- UV Light Monitoring
- Barcode Readers
- Spectroscopy
- Surface Characterization
- Optical Power Meters

## Principle of Operation

When illuminated by a radiation source, silicon photodiodes convert the incident energy into an electrical signal. Current-conducting carriers are generated and quickly accelerated to the diode terminals where they are collected by an external circuit. The generated photocurrent is typically converted to a voltage via a transimpedance or integrating amplifier whose output porportional to the photogenerated current.

At the heart of a standard photodiode lies a silicon PN junction, where P and N denote p-type and n-type materials respectively. An n-type material is characterized by an abundance of electrons, while a p-type material is defined by a scarcity of electrons, also known as "holes". The surplus or deficit of electrons is regulated by diffusing impurities such as boron for p-type or phosphorus for n-type, into the starting silicon wafer. Upon joining these two types of semiconductors at the junction, holes from the p-side diffuse into the n-side and electrons from the n-side diffuse into the p-side, thereby forming a depletion region. As a result, an electric field emerges which propels charges away from the depletion region and into the bulk materials.

Silicon is categorized as a semiconductor due to its relatively small energy band gap of 1.12eV at ambient temperature. This energy gap represents the difference between the lowest energy level in the conduction band and the highest energy level in the valence band, which are created by interatomic interactions among adjacent silicon atoms. At absolute zero (0 Kelvin), electrons vacate the conduction band, migrating to the lowest energy state within the valence band. However, as temperatures increase, particularly at room temperature, thermal kinetic energy excites electrons into vacant energy states in the conduction band. External forces such as high-energy particles , X-Rays, and photons with energies exceeding the 1.12eV band gap can also ionize additional electrons into the conduction band.

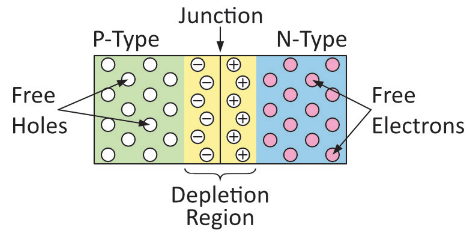



**Figure 1:** PN Junction Structure

When incident radiation penetrates the device, incoming particles or photons disrupt loosely bound electrons near the top of the valence band, exciting them into the conduction band. This process leaves behind a gap in the valence band, a phenomenon referred to as electron-hole pair generation. Electrons thus excited into the conduction band are free to move within the silicon crystal lattice. Electron-hole pairs generated within the depletion region are accelerated towards the diode terminals by the internal electric field, contributing directly to the photogenerated signal. In contrast, pairs generated outside this region undergo diffusion until they either reach the depletion region, recombine, or potentially contribute to the photocurrent through random motion.

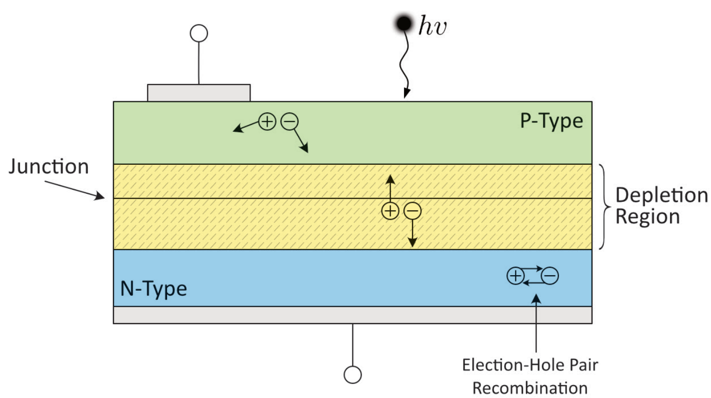



**Figure 2:** Electron-hole pairs generated within the depletion region are quickly swept away to the diode terminals. Those generated outside of the depletion region either diffuse through the material at random or are recombined.

The generation of electron-hole pairs, particularly within or near the depletion region, constitutes the primary source of current-conducting carriers in a photodiode. In the absence of external bias, maximizing the photocurrent necessitates ensuring that a significant portion of incident radiation reaches the depletion region. Two primary factors influencing this are the wavelength-dependent penetration depth and the exponential decay of absorption with increasing depth. Notably, shorter wavelengths (e.g., UV) exhibit higher absorption coefficients and thus are absorbed near the surface, while longer wavelengths can penetrate deeper into the device. Wavelengths with energies below the band gap are not absorbed at all and are effectively transparent to the silicon material.

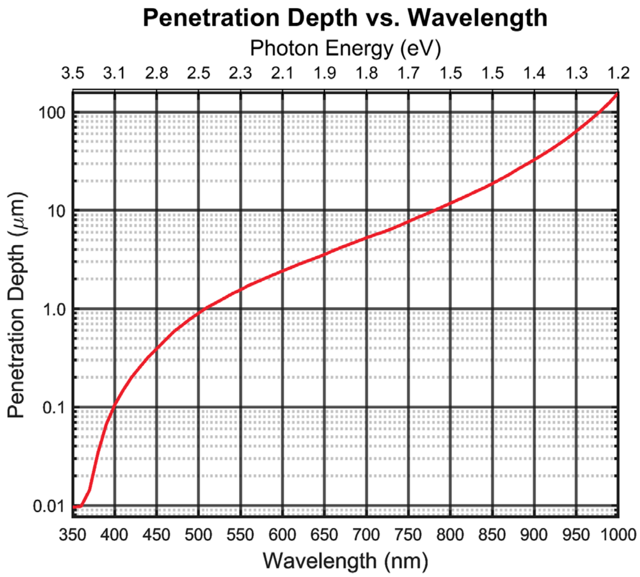



**Figure 3:** Wavelength-dependent penetration depth in silicon, illustrating the strong absorption of high-energy (short wavelength) radiation near the surface and deeper penetration of lower-energy radiation.

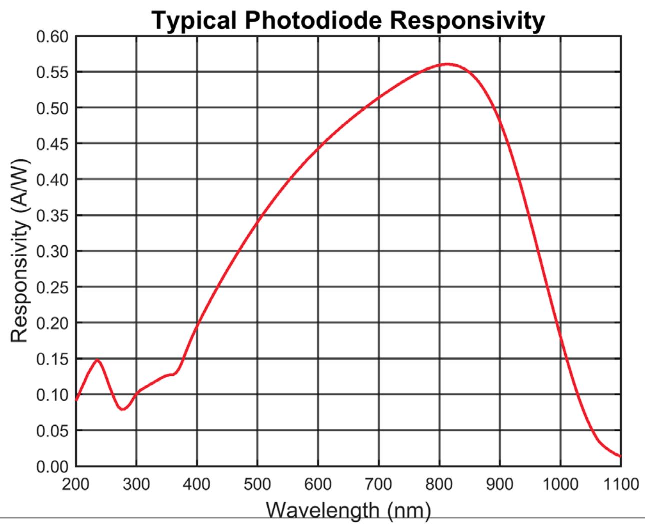



**Figure 4:** Typical responsivity as a function of wavelength.

Due to their wavelength-dependent nature, photodiodes will produce different output currents when exposed to varying wavelengths of light. For example, a 400 nm laser will generate a different response than an 800 nm laser. This conversion efficiency, the ratio of incident light energy to electrical current, is known as responsivity. Responsivity is a key metric for photodiodes, measured in amps per watt of incident light. A higher responsivity translates to a greater ability to convert light into a stronger electrical signal, often referred to as quantum efficiency.

## Photodiode Structure

General-purpose photodiodes typically employ a planar PN junction configuration, as depicted in Figure 5. The device foundation is a bulk semiconductor substrate, either P-type (doped with electron acceptors) or N-type (doped with electron donors). Upon this substrate, a thin layer of oppositely doped material is epitaxially grown or diffused, creating the PN junction that defines the photodiode's active area.

To maximize the efficiency of photon absorption, the top surface of the photodiode is often treated with an antireflective (AR) coating. This coating typically consists of a dielectric material with a carefully chosen thickness and refractive index to minimize light reflection and maximize transmission into the active region. The thickness of the AR coating is often tuned to achieve optimal performance for specific wavelengths of interest. Additionally, metallic contacts are deposited on both the top and bottom surfaces to facilitate electrical connections and enable efficient extraction of the photogenerated current.

Beyond the boundaries of the active area, a layer of silicon dioxide (SiO2) is grown or deposited to passivate the device. This SiO2 layer serves several crucial functions: it acts as a diffusion barrier to prevent impurities from entering the active region, provides electrical isolation to minimize leakage currents, and protects the underlying semiconductor from environmental contaminants like moisture and dust. This passivation layer is instrumental in ensuring the long-term stability and reliability of the photodiode.

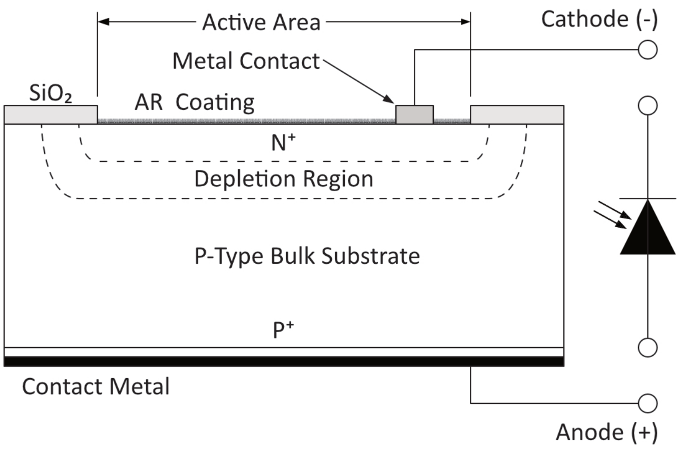



**Figure 5:** General Purpose Photodiode Structure.

While the planar PN junction structure is the foundation for many photodiodes, specialized designs have been developed to optimize performance for specific wavelength ranges or applications.

**Blue-Enhanced Photodiodes**: These photodiodes are engineered to exhibit increased sensitivity in the blue and green spectral regions. This is typically achieved by modifying the doping profile or utilizing materials with wider bandgaps. Blue-enhanced photodiodes find applications in flame detection, and medical diagnostics, where sensitivity to shorter wavelengths is crucial. Additionally, they can be used in color sensing applications to accurately measure the blue component of light.

**Red-Enhanced Photodiodes**: Conversely, red-enhanced photodiodes are tailored to maximize sensitivity in the red and near-infrared (NIR) regions. This is often achieved by adjusting the thickness of the active region or incorporating specific materials that enhance absorption at longer wavelengths. These photodiodes are widely used in telecommunications, encoders, missile proximity sensors, munitions guidance, remote sensing, and pulse oximetry, where the detection of red and NIR light is essential for data transmission or physiological measurements. They are also well-suited for applications requiring low dark current and high responsivity in the red and NIR spectral regions.

Another widely employed photodiode structure is the PIN photodiode. This variant incorporates an intrinsic (undoped) layer sandwiched between the P and N regions. The presence of this intrinsic layer widens the depletion region, increasing the volume available for light absorption and carrier generation. This translates to higher quantum efficiency and reduced capacitance. PIN photodiodes are particularly well-suited for high-speed optical communication systems, where their low capacitance and fast response times are essential for handling high-frequency signals.

# Electrical Characteristics

The equivalent circuit of a photodiode can be modeled as a current source (Iph) representing the photogenerated current, in parallel with an ideal diode to account for the rectifying behavior of the PN junction. This parallel combination is then placed in parallel with a shunt resistance (Rsh) to account for leakage currents, and the entire network is connected in series with a series resistance (Rs), representing the bulk resistance of the semiconductor material and contacts. Additionally, a junction capacitance (Cj) is included in parallel with the current source to model the capacitive effects associated with the depletion region.

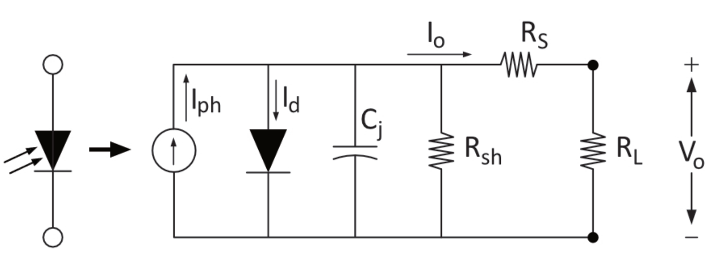



**Figure 6:** Photodiode Equivalent Circuit

## Shunt Resistance

The shunt resistance (Rsh) of a photodiode, is quantified as the slope of the current-voltage (I-V) characteristic curve at zero bias (V = 0). In an ideal photodiode, Rsh would be infinite, implying zero leakage current in the absence of illumination. However, practical photodiodes exhibit finite shunt resistances typically ranging from tens to thousands of megaohms. Leakage current typically arises from thermally generated electron-hole pairs, crystal defects, impurities, and trap states that facilitate the generation of electron-hole pairs, even in the absence of sufficient thermal energy.

Shunt resistance is determined by applying a small bias voltage (e.g., ±10 mV) and measuring the resultant current. Using Ohm's law, this current-voltage relationship yields the shunt resistance value. A higher shunt resistance signifies lower leakage current, which is particularly advantageous in low-light conditions where even small currents can obscure the desired signal. Maximizing the shunt resistance is therefore a key objective in optimizing photodiode performance.

## Junction Capacitance

Junction capacitance arises from the depletion region which behaves like a dielectric material sandwiched between two conductive plates (the P and N regions), forming a parallel plate capacitor. The width of the depletion region is influenced by the doping concentrations in the P and N regions, as well as any applied reverse bias voltage. When a reverse bias is applied, the electric field across the junction increases, widening the depletion region. This increase in the distance between the "plates" of the capacitor leads to a decrease in the junction capacitance.

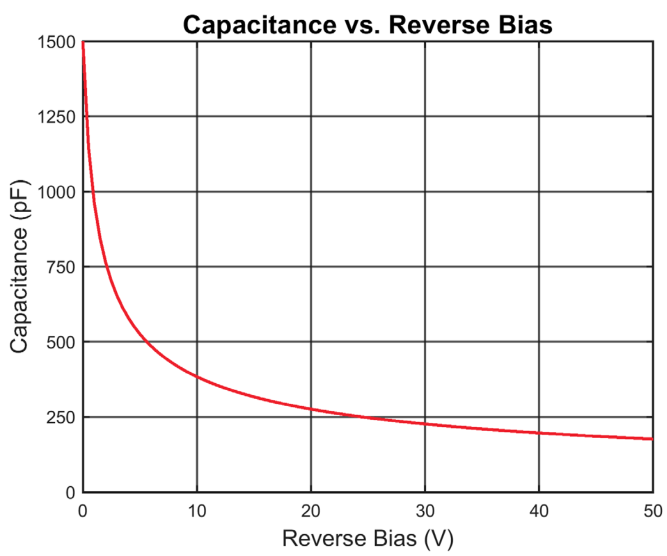



**Figure 7:** Capacitance drop as a result of an applied reverse bias for a device having an initial capacitance of 1200pF when unbiased.

In general, junction capacitance, including reverse bias effects, can be calculated using the following formula:

$$C_J = \frac{\epsilon_s A}{W_d} = \sqrt{\frac{q\epsilon_s N_{eff}}{2(V_{bi} - V_A)}}$$

$$W_d = A\frac{\sqrt{2\epsilon_s(V_{bi} - V_A)}}{qN_{eff}}$$

$$\begin{aligned}\epsilon_s &= \text{Permittivity of Silicon } (K_S\epsilon_s)\\ \epsilon_0 &= 8.854\text{x}10^{-14}\\ q &= \text{electron charge } (1.602x10^{-19})\\ V_A &= \text{Applied bias}\\ V_{bi} &= \text{Built-in potential}\\ N_{Eff} &= \text{Effective doping of the lightly doped side}\end{aligned}$$

**Equation 1:** Junction capacitance calculation given device parameters and an applied bias.

If initial conditions are known, a simplified formula may be used for quick estimations:

$$C_D = \frac{C_{D0}}{\sqrt{1 + V_R/V_{bi}}}$$

$$\begin{aligned}C_{D0} &= \text{Capacitance without bias}\\ V_R &= \text{Reverse Bias}\\ V_{bi} &= \text{Built in Potential}\end{aligned}$$

**Equation 2:** Simplied junction capacitance calculation for an applied reverse bias given the zero bias condition.

## Series Resistance

Series resistance (Rs) in a photodiode encapsulates the combined resistance of the semiconductor material itself, the metal contacts, and any interfacial layers. It manifests as a voltage drop proportional to the photocurrent flowing through the device, as described by Ohm's law (V = I * Rs). This voltage drop not only reduces the overall output current but can also lead to non-linear behavior at higher currents due to self-heating effects. Consequently, minimizing Rs is crucial for achieving optimal photodiode performance, particularly in high-speed applications where even small delays due to RC time constants can be detrimental.

While an ideal photodiode would have zero series resistance, typical values range from a few ohms to several hundred ohms. The series resistance can be approximated by the following equation:

$$R_S = \frac{\rho\,(W_S - W_d)}{A} + R_C$$

$$\begin{aligned}\rho &= \text{Bulk material resistivity}\\ W_S &= \text{Subtrate thickness}\\ W_d &= \text{Depletion region width}\\ R_C &= \text{Contact Resistance}\\ A &= \text{Area of PN junction}\end{aligned}$$

**Equation 3:** Series resistance calculation given device parameters.

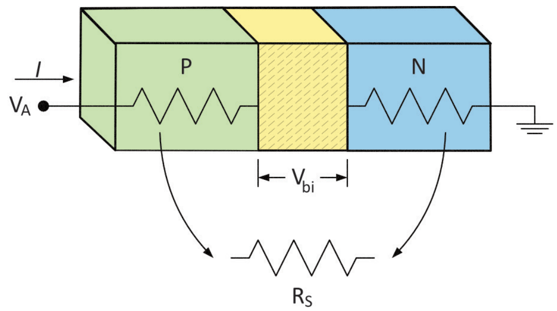



**Figure 8:** PN Junction diode representation of series resistance between contacts.

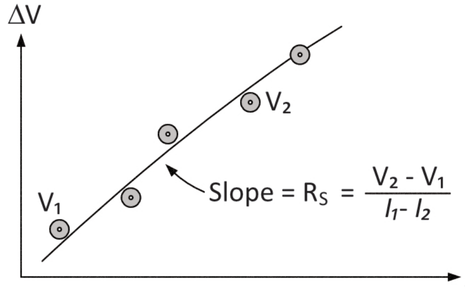



**Figure 10:** Series resistance can be directly measured as the slope between two or more voltage readings for small forward biased currents.

## Frequency Response and Rise Time

Frequency response, often characterized by the rise time or cut-off frequency, plays a critical role in the design and selection of photodiodes. This parameter quantifies the device's ability to reproduce rapid light intensity variations via rapid transport of photogenerated carriers to an external circuit. Rise time is defined as the time taken for the output signal to transition from 10% to 90% of its final value. In photodiodes, this parameter is governed by the following three time constants.

$$\begin{aligned}T_{RC} &= 2.2RC = 2.2(R_S + R_{Load})(C_J)\\ T_{Drift} &= \text{Carrier drift time constant}\\ T_{Diffusion} &= \text{Carrier diffusion time constant}\end{aligned}$$

$$T_r = \sqrt{(T_{RC})^2 + (T_{Drift})^2 + (T_{Diffusion})^2}$$

**Equation 4:** Rise time calculation. Where $C_J$ is the junction capacitance, Rs is the series resistance and RLoad is the load resistance. Their combined net effect can be summarized by this equation. The load is assumned to be 50 Ohms.

Minimizing the RC time constant is crucial for high-frequency performance in photodiodes. As discussed earlier, junction capacitance (Cj) is a key contributor to the time constant. Fortunately, we have several strategies to reduce Cj. Reducing the active area size and applying a reverse bias not only shrinks Cj directly, but also sets up a strong electric field across the depletion region. This stronger field enhances carrier drift velocity, effectively reducing the drift-diffusion time constant. Applications requiring very fast response times typically employ small active areas and significant reverse biases exceeding 100V or more. Additionally, using higher resistivity silicon allows for a wider depletion region at a given bias voltage, further lowering Cj.

If the rise time ($T_r$) is known, cut-off frequency (fc) is defined to be:

$$fc = \frac{0.35}{T_r}$$

**Equation 5: Cut-off frequency calculation.**

## Optical Characteristics

### Responsivity

Responsivity, measured in Amperes per Watt (A/W), quantifies a photodiode's ability to convert incident radiation of a given wavelength to a photogenerated current signal. This conversion efficiency is directly dependent on the wavelength of the incident light. Standard silicon PN junction photodiodes, without optimization, typically exhibit a spectral response limited to wavelengths between 320nm and 1100nm. This limitation is due to the silicon's inherent bandgap.

$$R_\lambda = \frac{I_p}{P_{opt}}$$

$$I_p = \text{Generated Photocurrent}$$
$$P_{opt} = \text{Incident Optical Power}$$

**Equation 6:** Responsivity calculation given a known incident optical power and measured photogenerated current.

### Quantum Efficiency

While responsivity focuses on the ratio of electrical output (current or voltage) to the total light power input, Quantum Efficiency (QE) looks at the efficiency at the individual particle level. It describes the probability of an incident particle or photon being converted into an electron that contributes to the photocurrent and its units are given as a percentage (%) and is always less than unity. QE is a crucial parameter for applications demanding high sensitivity and efficient light detection, especially at specific wavelengths such as scientific instruments for spectroscopy or low-light imaging applications.

$$QE = \left(\frac{I_p}{q}\right) \cdot \left(\frac{P_{opt}}{hv}\right)^{-1}$$

$$= \frac{I_p}{P_{opt}} \cdot \frac{hv}{q} \quad , \quad R_\lambda = \frac{I_p}{P_{opt}} \quad , \quad hv = \frac{hc}{\lambda}$$

$$= R_\lambda \cdot \frac{hc}{q\lambda}$$

$$QE = R_\lambda \cdot \frac{1240}{\lambda}$$

**Equation 7:** Quantum efficiency calculation and relationship to responsivity.

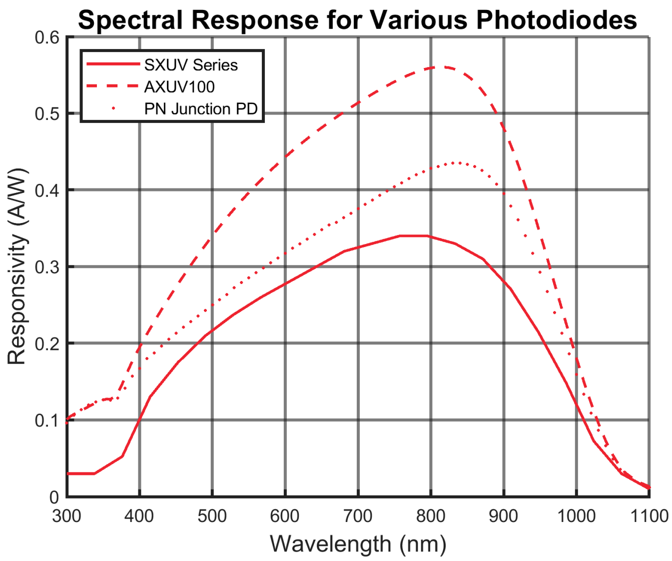



**Figure 9:** The above graph illustrates the spectral response for various photodiode technologies. Notice how the responsivity at a given wavelength is different, particularly 450nm to 1000nm.

### Noise Equivalent Power (NEP)

Noise Equivalent Power (NEP) quantifies the sensitivity of a photodetector, representing the minimum incident light power required to produce a signal-to-noise ratio of unity. This parameter is influenced by factors such as the detector's dark current, bandwidth, and the inherent noise characteristics of the photodetector material. A lower NEP indicates a more sensitive detector, capable of detecting weaker light signals.

$$NEP = \frac{I_n}{R_\lambda} \ (\mathrm{W/Hz^{1/2}})$$

**Equation 8:** Noise Equivalent Power (NEP) calculation given total noise and responsivity for a particular wavelength.

### Non-Linearity

Nonlinearity refers to the deviation from a perfectly linear relationship between the incident light power and the resulting photocurrent. Ideally, we would expect the photocurrent to increase proportionally with increasing light power. However, real-world photodiodes exhibit some degree of nonlinearity, meaning the photocurrent doesn't rise exactly in proportion to the light intensity.

The degree of nonlinearity in a photodiode depends on several factors, including: material properties, device design, operating conditions, but most importantly recombination, and series resistance. At higher light intensities, recombination, the process where photogenerated electron-hole pairs recombine within the device before contributing to the photocurrent, doesn't rise proportional to the incident light power. Additionally, all photodiodes have some inherent series resistance. This resistance causes a voltage drop across the device that increases with rising photocurrent. This voltage drop effectively reduces the driving force for current flow, leading to a further deviation from linearity at high light levels.

### Non-Uniformity

While ideal photodiodes exhibit a perfectly uniform response across their active area, real-world devices can exhibit variations in responsivity. These variations, often caused by slight differences in material properties, surface conditions, or processing variations, can lead to different electrical outputs for the same incident light at various locations on the photodiode. Non-uniformity is most typically experienced in applications requiring small source spot sizes such as small diameter lasers where a smaller spot size interacts with a more localized area of the photodiode, potentially highlighting any variations in responsivity across its active region.

## IV Characteristics

The IV curve of a diode exhibits distinct characteristics under forward and reverse bias conditions. In forward bias, when the positive terminal of the voltage source is connected to the p-type side and the negative terminal to the n-type side, the diode conducts current. The IV curve shows a steep exponential rise in current as the forward voltage increases beyond threshold voltage. Conversely, under reverse bias conditions, positive voltage applied to the n-type terminal and negative voltage to the p-type terminal, the IV curve remains relatively flat (GL=0 curve in figure XX) with a small leakage current.

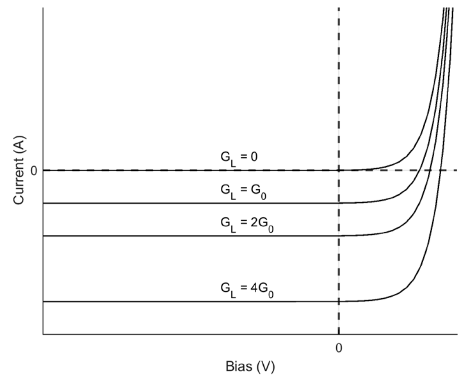



**Figure 10:** Typical I-V curve for a photodiode without illumination, and increasing multiples of incident photon densities on the active area. (GL=0 signifies that there are no processes other than drift, diffusion, and thermal recombination-generation taking place inside the diode.)

$$I = I_0(e^{qV_A/kT} - 1)$$

$$I_0 = \text{Saturation Current}$$
$$V_A = \text{Reverse Bias}$$

**Equation 9:** Dark current (Leakage current) for a reverse biased device is reverse bias and temperature dependent.

When the diode is illuminated or irradiated by a radiation source GL = G0), the IV curve is shifted proportional to the photogenerated current. Increasing the incident power on the photodiode active area will further shift the IV curve.

$$I = I_0(e^{qV_A/kT} - 1) - I_p$$

$$I_p = \text{Photogenerated Current}$$

**Equation 10:** The reverse bias current from equation 9 is shifted by the magnitude of the photogenerated current.

To determine the photodiode's performance under illumination, two key parameters are measured: short-circuit current (Isc) and open-circuit voltage (Voc). Isc is obtained by shorting the device terminals and illuminating the active area, allowing direct measurement with an ammeter. Voc, on the other hand, is measured with an open circuit at the anode terminal. Figure 12 demonstrates that Voc also shifts with increasing light levels. However, Voc is highly sensitive to temperature fluctuations, resulting in non-linear shifts that make it unsuitable for precise illumination measurements.

In contrast, the reverse bias condition exhibits a much more linear response to illumination, and temperature effects are more predictable.

## Noise / Dark Current

Unwanted noise can interfere with the desired photogenerated signal. In silicon Photodiodes, this noise originates from various sources and can limit the sensitivity and performance of the device. There are two fundamental sources of noise that contribute to the overall electrical signal:

**Shot Noise**: This arises from the inherent statistical nature of the photocurrent generation process and dark current moving through the detector material. Light is quantized into packets of energy called photons. When these photons interact with the silicon material, they can create electron-hole pairs. However, the arrival of these photons is not perfectly uniform, even for a constant light source. This statistical fluctuation in the number of generated carriers translates into a random fluctuation in the photocurrent, known as shot noise.

$$I_{sn} = \sqrt{2q(I_p + I_D)\Delta f}$$

$$I_p = \text{Photogenerated Current}$$
$$I_D = \text{Dark Current}$$
$$\Delta f = \text{Operating Frequency Bandwidth}$$
$$q = 1.6\text{x}10^{19}\text{C}$$

**Equation 11:** Shot noise calculation.

**Thermal Noise**: This originates from the thermal agitation of electrons within the silicon material itself. Even in the absence of light, these thermally excited electrons contribute to a small, random current flowing through the photodiode. Thermal noise is often further categorized into two sub-types:

- **Johnson Noise**: This refers to the thermal noise arising from the inherent resistance of the silicon material and the electrical contacts within the photodiode.

$$I_{jn} = \sqrt{\frac{4k_B T \Delta f}{R_{sh}}}$$

$$K_B = \text{Boltzman Constant}(1.38)\text{x}10^{-23}(\text{J/K})$$
$$T = \text{Temperature } (^\circ\text{K})$$
$$R_{sh} = \text{Shunt Resistance (Ohm)}$$
$$\Delta f = \text{Operating Frequency Bandwidth (Hz)}$$

- **1/f Noise (Flicker Noise)**: This type of noise exhibits a specific frequency dependence, increasing in intensity as the frequency decreases (hence the 1/f notation). The exact mechanisms behind 1/f noise are complex and not fully understood, but it is often attributed to surface imperfections or carrier trapping within the device.

## Total Noise

Combining the two major noise sources leads to the following equation:

$$I_{Total} = \sqrt{(I_{sn})^2 + (I_{jn})^2}$$

**Equation 12:** Total photodiode current noise as a result of shot and johnson noise.

## Breakdown Voltage / Dark Current

Applying a reverse bias has various performance benefits such as decreased capacitance and increased response time. However, exceeding the maximum reverse bias will cause the photodiode to enter what is referred to as breakdown. During breakdown, the large electric field across the junction causes carriers to gain enough kinetic energy to generate electron-hole pairs via the avalanche/impact ionization process, resulting in a large reverse current that flows through the device. This process is reversible and does not cause damage to the device, but it can, however, lead to excessive heating and possible damage to other components within the circuit, and should therefore should be avoided.

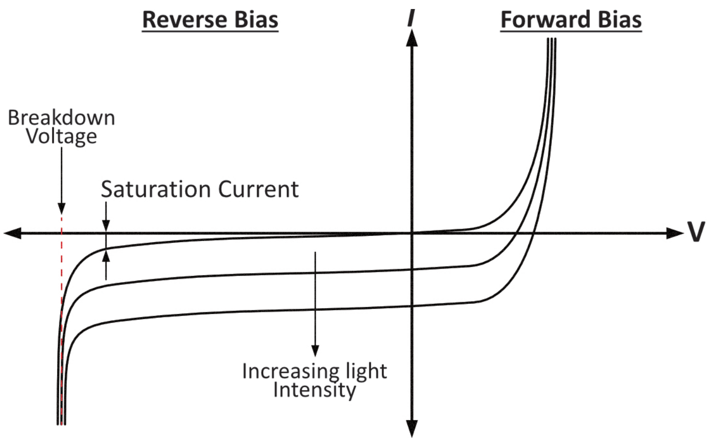



**Figure 11:** Full IV characteristic graph, including break down and saturation. Note that saturation current is not consistent and increases in magnitude with increasing reverse bias.

It's important to note that the saturation current exhibits a slight slope and increases in magnitude with increasing reverse bias. This phenomenon arises from the widening of the depletion region as the reverse bias increases. This wider depletion region allows longer wavelengths of light to contribute to the photogenerated current. Additionally, the higher electric field across the junction effectively drifts the photogenerated carriers towards the device terminals. Concurrently, dark current also increases with increasing reverse bias, further contributing to the overall current flow.

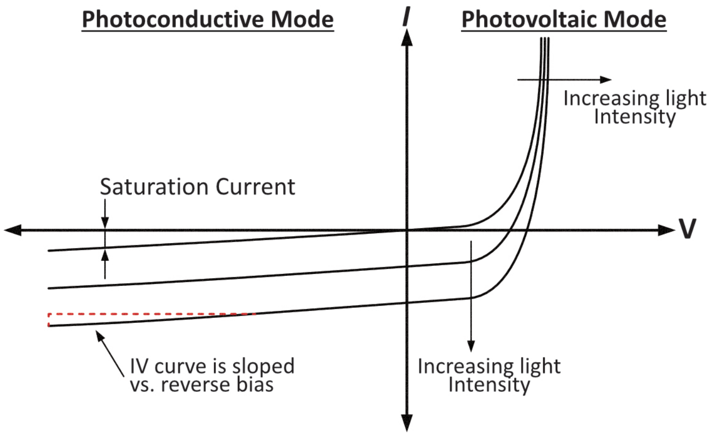



**Figure 12:** Increasing the applied reverse bias on the device has several effects which result in an apparent slope on the IV curve.

## Temperature Effects

### Shunt Resistance / Dark Current

The dark current in a photodiode increases with increasing temperature due to the enhanced thermal generation of electron-hole pairs within the depletion region. As temperature rises, the thermal energy available to the atoms in the semiconductor material increases. This increased energy allows more electrons to jump from the valence band to the conduction band, creating more free charge carriers. These thermally generated carriers contribute to the dark current, even in the absence of light.

Shunt resistance is inversely proportional to dark current. The increased leakage current results in an increase in conductivity across the diode junction and hence and drop in shunt resistance. As a general rule, dark current doubles approximately every 10°C and shunt resistance halves every 6°C.

### Responsivity

As temperature increases, the bandgap of silicon decreases, resulting in a small increase in responsivity for the longer wavelengths between 900nm and 1100nm.

## Biasing

Device biasing is a powerful tool that can significantly alter the electrical behavior of devices. Understanding the appropriate conditions for applying bias and its subsequent effects is essential for optimizing device performance and ensuring reliable operation.

### Photovoltaic Mode

Photovoltaic mode, operating without an external bias, is the preferred mode for photodiodes in low-frequency applications, and for applications involving extremely low light levels. This mode offers not only a simple operational configuration but also exhibits reduced temperature dependence in photocurrent responsivity, and reduced dark current, making it highly suitable for applications requiring high stability and accuracy.

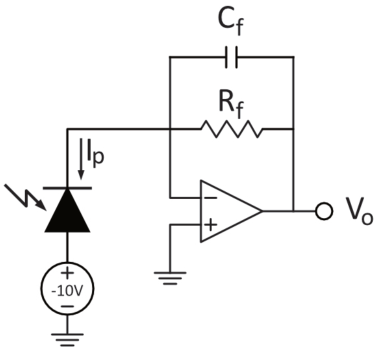



**Figure 13:** Photovoltaic mode circuit for low light detection.

$$f_{op}[Hz] = \frac{1}{2\pi R_F C_F}$$

**Equation 13:** Depending on the photodiode properties, the photovoltaic configuration can typically be used up to approximately 300KHz.

### Photoconductive Mode

The photoconductive mode in a photodiode is preferred when speed and sensitivity are paramount, even at the cost of increased dark current. This mode, characterized by reverse biasing the diode, allows for faster response times due to the widened depletion region, reducing capacitance.

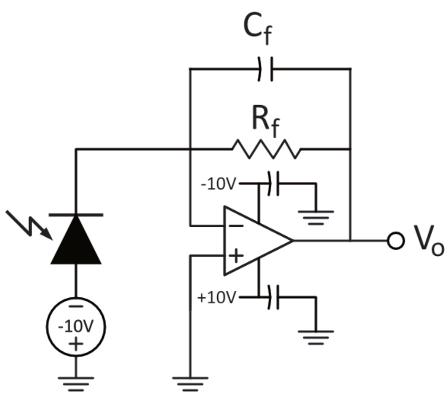


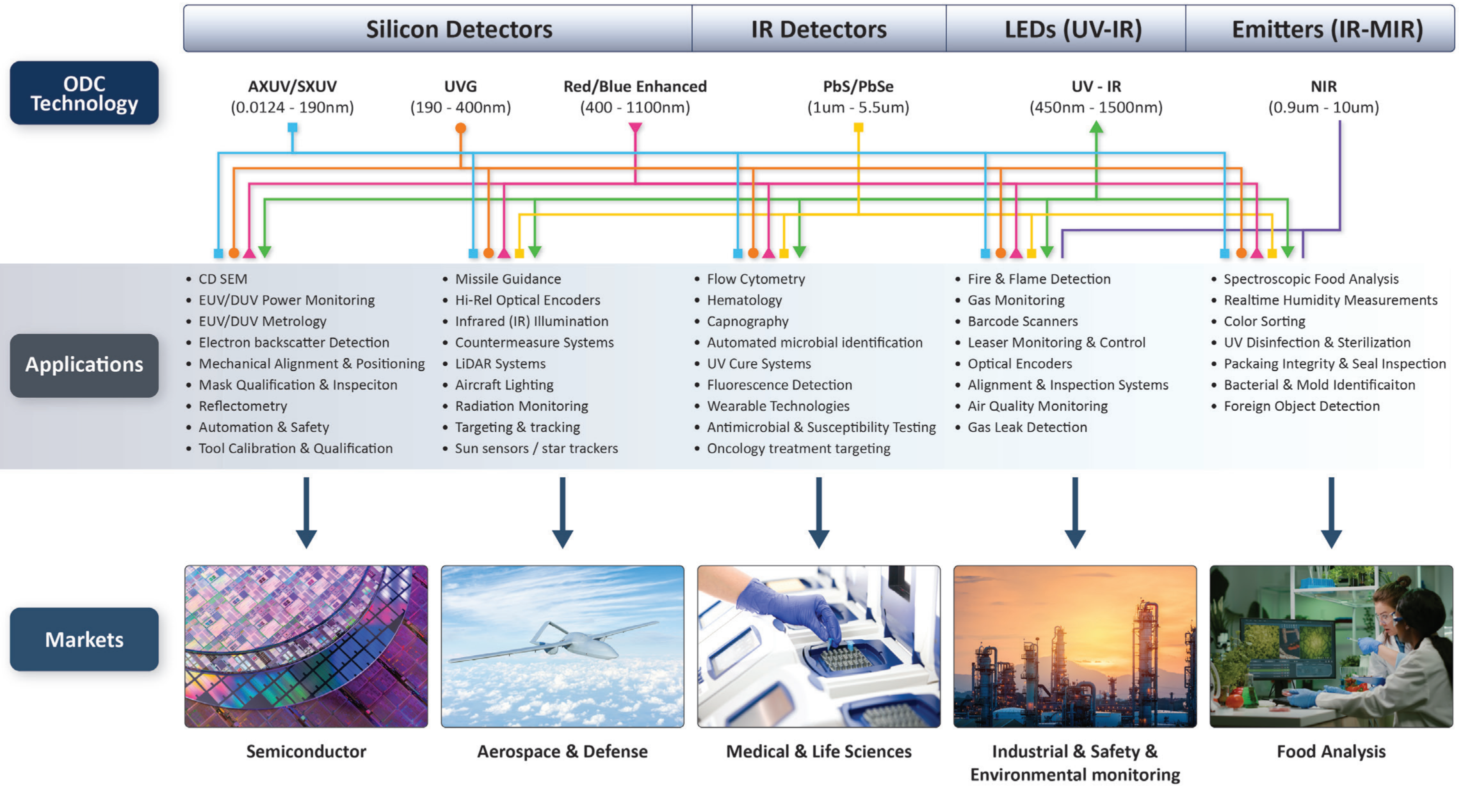

**Figure 14:** Photoconductive mode circuit with a reverse bias on the photodiode.

$$V_O = R_F * I_P$$

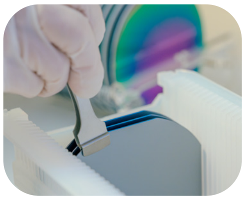
$$I_P = \text{Photogenerated Current}$$

**Equation 14:** Transimpedance Amplifier (TIA) output

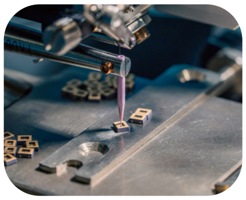
# Opto Diode Technology Mapping




# Our Capabilities



- 4 and 6 inch wafer processing in class 1000 (ISO 3) cleanroom
- Full front-end flow: thin film deposition, photoresist coat, photolithography, dry and wet etch, implantation, and metal evaporation
- Back-end steps: wafer sawing plus wafer level electrical characterization



- LED and photodiode die attach with precision pick place
- Gold and aluminum wire bonding plus cap welding for hermetic seals
- Class 10000 (ISO 4) production lines with electrical verification

- Dark current, shunt resistance, capacitance, IV curves, forward and reverse bias, breakdown voltage
- Responsivity, response time, power output, peak emission, thermal resistance, and custom measurements on request

- Custom-built test fixtures and automation designed around OEM part specs to maximize yield, measurement accuracy, and throughput
- Support for non-standard geometries, pinouts, and test parameters with full data reporting for qualification, traceability, and compliance

# Handling Precautions for AXUV, SXUV, and UVG Detectors

AXUV, SXUV and UVG photodiodes are high sensitivity detectors designed for EUV and DUV applications. Their shallow junctions, thin-film coatings and exposed active areas make them more delicate than standard silicon photodiodes. Proper handling is critical to maintain performance, stability and calibration integrity. The guidelines below outline best practices for protection, cleaning, soldering and mechanical handling during assembly.

## Protection

Always keep the protective cover in place on windowless devices until the photodiode is installed into its next level of integration. This prevents dust, oils and airborne contaminants from settling onto the active area. Even small particles can alter EUV response or introduce nonuniformity. For storage longer than a few days place the device in a clean antistatic container with an inert to minimize moisture exposure. Avoid placing any mechanical load on the top of the package.

## Cleaning

EUV windowless photodiodes require strict contamination control. Do not breathe, cough or touch the active region while handling the part. Oils and moisture from skin can degrade responsivity, especially at short wavelengths. If contamination occurs the surface may be cleaned using a lint free clean room swab moistened with electronic grade acetone or alcohol. Avoid rubbing in circles because this increases the risk of scratching. Instead use slow linear passes across the surface with minimal force.

Since EUV photodiodes have extremely shallow junction depths aggressive cleaning can damage the device. Only a light and controlled swabbing motion should be used. Filtered detectors with carbon or silicon passivation can be cleaned the same way. Devices that use metal or multilayer EUV filters may have different surface sensitivities. Contact the factory before attempting to clean these parts to avoid damaging the coating stack.

## Bond Wire Damage

Bond wires are extremely fragile and must never be contacted during handling or assembly. Any impact, bending or downward force can detach the wire or push it into the die, resulting in an open or short circuit. If a wire has been displaced upward it may be possible to gently reposition it using a fine tip needle under a microscope, but this should only be done by experienced personnel. If the wire is broken the device cannot be repaired and the warranty is void. When mounting the photodiode avoid touching the top surface of the package and use side gripping tweezers or vacuum pickup tools whenever possible.

## Soldering

Photodiodes may only be soldered per the temperature and time specifications provided in the individual datasheet. Exceeding the recommended solder profile may damage the die attach, deform the package or degrade performance. Most devices can be soldered directly to the package pins as long as the stated limits are followed. Hand soldering is generally preferred for prototypes while reflow processes must be reviewed case by case.

Flux will contaminate the photodiode surface so the protective window should remain in place during soldering and any post solder cleaning steps. After soldering remove all flux residue from the package using D.I. water, alcohol or acetone as appropriate. Ensure that no solvent or residue enters the cavity of windowless parts. Allow the device to dry completely before electrical testing.

## Electrostatic Discharge

While the devices are not typically classified as highly ESD sensitive, they should still be handled using standard ESD precautions. Use grounded wrist straps, antistatic mats and properly grounded soldering equipment. Avoid handling the device in low humidity environments without ESD protection.

## Storage and Environmental Considerations

Store all photodiodes in controlled environments away from vibration, moisture and direct light. Extended exposure to bright UV sources, high humidity or corrosive atmospheres can degrade coatings or metal contacts. For long term storage antistatic boxes, clean polyethylene bags and desiccants are recommended. Do not store devices in foam packaging since certain foams outgas and produce chemical residues that can affect response.

OPTO DIODE
An ITW Company

To learn more about our products or explore a custom solution tailored to your application, connect with our team today. We'll help you identify the right technology and support your project from concept to completion.

(805) 465-8700
sales@optodiode.com

1260 Calle Suerte
Camarillo, CA 93012

**WWW.OptoDiode.com**