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# INFRARED DETECTOR

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**Abstract**

Infrared radiations are radiations below (infra) visible spectrum. This emergent dual use technology field is fast emerging amongst the most ubiquitous ones. It spans from low-end automatic supermarket door openers to high-end space based detectors used to detect nuclear tests, missiles and intra galactic radiations. At the heart of this technology is the IR detector. Objective of this report is to review infrared (IR) detectors. Evolution of IR technology has been largely synonymous to advances in IR detectors. Various types of detectors, formats and materials interlaced with their applications have been studied.

## 1. INTRODUCTION

Infrared (IR) detectors have been called the eyes of the digital battlefield. Military applications for IR systems such as target acquisition, search and track, missile seeker guidance, there is a great potential for IR systems in the commercial market. IR systems enhance automobile and aircraft safety, medical diagnosis, and manufacturing quality and control. Industry is looking to expand into the commercial market because the military market is decreasing and concurrently becoming more specialized. [1]

## 2. IR FUNDAMENTALS

IR radiations are electromagnetic (EM) waves where wavelengths are larger than those of red light. IR radiation occurs between 0.75µm to 1000µm. The division shown below (Table1) is based on Hudson. 1µm is sensitivity limit of popular Si detectors. Similarly, wavelength 3 µm is sensitivity of PbS and InGaAs detectors. 6 µm is sensitivity limit of InSb, PbSe, PtSi detectors and MCT detectors are optimised for 3-5 µm atmospheric window; and finally wavelength 15 µm is a long wavelength sensitivity limit of HgCdTe detectors optimised for 8-14 µm atmospheric window.

**Table 1:** Division of IR region

| Region (abbreviation) | Wavelength range (µm) |
|---|---|
| Near infrared (NIR) | 0.78–1 |
| Short wavelength IR (SWIR) | 1–3 |
| Medium wavelength IR (MWIR) | 3–6 |
| Long wavelength IR (LWIR) | 6–15 |
| Very long wavelength IR (VLWIR) | 15–30 |
| Far infrared (FIR) | 30–100 |
| Submillimetre (SubMM) | 100–1000 |

## 3. CHOICE OF IR BAND

In the spectral range of.0.78 - 3.0 µm, IR detectors are used for applications as diverse as fiber optic communications, agricultural sorting, environmental monitoring, and chemical analysis. The LWIR (8-15 µm) corresponds to a peak for thermal emission at ambient temperature and better transmission through mist and smoke. These ranges also have high transmission through the atmosphere. This spectral region is thus optimal for such applications as thermal imaging, non-contact temperature sensing, security sensing, and environmental monitoring. Photoconductive MCT detectors provide best performance at these wavelengths.

The advantage of MWIR band is smaller diameter of the optics required to obtain a certain resolution and that some detectors may operate at higher temperatures (thermoelectric cooling) than it is usual in the LWIR band where cryogenic cooling is required (about 77 K). MWIR and LWIR spectral bands differ substantially with respect to background flux, scene characteristics, temperature contrast, and atmospheric transmission under diverse weather conditions[2]. The far infrared (FIR) range generally refers to the electromagnetic band from 30-1000µm and is the source of much of the astrophysics information.

## 4. IR DETECTOR FUNDAMENTALS

Infrared detectors are transducers of radiant energy. Since infrared radiations do not rely on visible light, they offer possibility of seeing in the dark or through obscured conditions, by detecting the infrared energy emitted by objects. The detected energy is translated into imagery showing the energy differences between objects. Hot objects such as people stand out from the typically cooler backgrounds (Fig.1) regardless of the available visible light.

**Fig. 1** Person's IR image in night

There are two fundamental IR detectors, photon and thermal detectors. Classification of detectors is placed in Fig. 2 below. Thermal detectors respond to temperature changes generated from incident IR radiation through changes in physical and electrical properties. Photon detectors generate free electrical carriers through interaction of photons and bound electrons. Four main types of photodetectors are intrinsic (PV, PC) extrinsic, photoemissive and newer QWIP' s. Thermal detectors can be classified as thermometers, thermocouples, thermopiles, bolometers and newer microbolometers and microcantilevers.

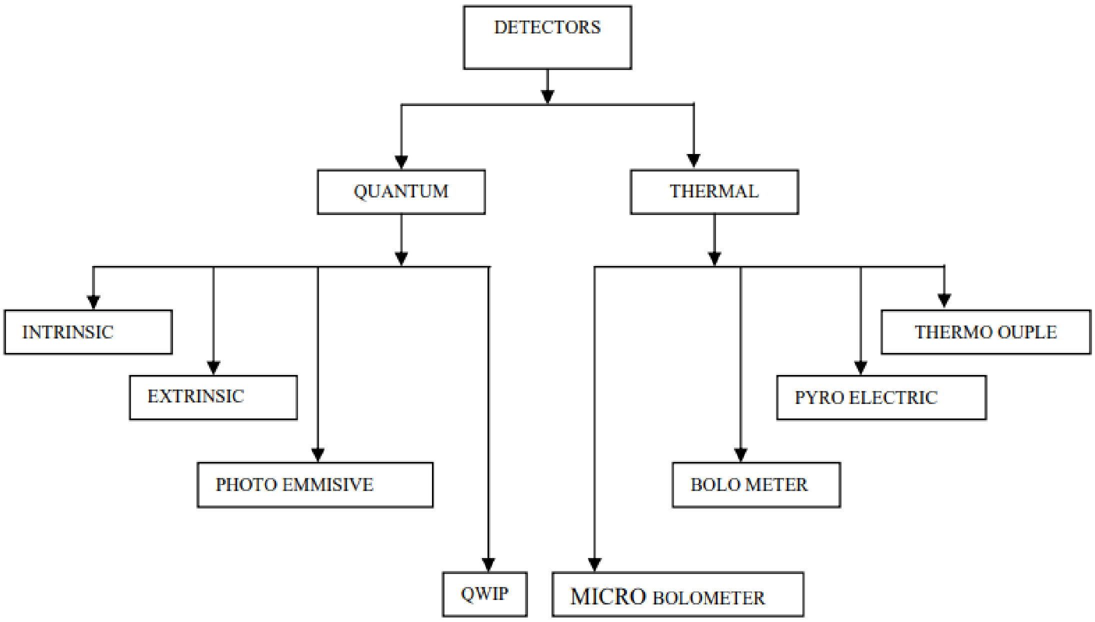


**Fig. 2** Classification of detectors

## 5. MATERIALS IN IR DETECTOR FORMATS

Differences in materials and their compositions have profound effect on behaviour of material as an IR detector. Various materials are used for detection. Silicon, gallium arsenide, MCT and lead salts are amongst most used [3]. Materials typically used are shown below in Table 2.

**Table 2:** Materials used in IR detectors

| Photon Detectors | | Energy Detectors | |
|---|---|---|---|
| Intrinsic, PV | - MCT | Bolometers | - Vanadium Oxide ($V_2O_5$) |
| | - Si, Ge | | - Poly-SiGe |
| | - InGaAs | | - Poly-Si |
| | - InSb, InAsSb | | - Amorph Si |
| Intrinsic, PC | - MCT | Thermopiles | - Bi/Sb |
| | - PbS, PbSe | Pyroelectric | - Lithium Tantalite (LiTa) |
| Extrinsic | - SiX | | - Lead Zirconium Titanite (PbZT) |
| Photo-emissive | - PtSi | Ferro-electric | - Barium Strontium Titanite (BST) |
| QWIP | - GaAs/AlGaAs | Micro cantilever | - Bimetals |

### 5.1 Silicon and Germanium detectors

Silicon and Germanium detectors have inherent advantages of manufacturing due to compatibility with semiconductor production techniques. The use in IR detector stems from variations possible due to doping. In case of silicon doping with gold gives it an energy band gap of 0.02 eV and cut off wavelength of 5μm. These figures get altered to 0.05 eV and ~20μm with phosphorus doping. Similarly the quantum efficiency, electric field and thickness can be varied from 20% to40%, 100 to 500V/cm and 1 to 3 respectively. Doping silicon with boron, arsenic, or gallium, for example, introduces different energy levels into the host-material bandgap.

### 5.2 MCT detectors

MCT detectors have been the most important semiconductor for mid and long-wavelength (3- 30 μm) infrared photodetectors. No single known material surpasses MCT in fundamental performance and flexibility. MCT ($Hg_{1-x}Cd_xTe$) is a combination of mercury telluride and cadmium telluride. Relative concentrations of two molecules i.e. x and 1-x are deliberately adjusted in growth process to obtain desired mixture. This helps to adjust cut off wavelength (maximum wavelength of response). Hence, MCT exhibits extreme flexibility. It can be tailored for optimized detection at any region of the IR spectrum. Both PC and PV types are available.

Limitations of MCT are compositional nonuniformity, difficulty to grow on silicon and fragility. For high-performance applications such as thermal imaging and radiometry, photoconductive, MCT provides better sensitivity, faster response, and lower bias voltage [4]. Three-stage or even four- stage cooling is used for maximum performance.

## 5.3 Indium antimonide

Indium antimonide detectors are most commonly used III-V material, which provide high- performance detector in the wavelength region from 2 to 5 µm. Unfortunately, InSb detectors have to be cooled to liquid-nitrogen temperature. Indium antimonide (InSb) is a detector material that was very common in single-detector, mechanically scanned units. It is a highly versatile detector, which can be used for PC, PV, cooled and uncooled formats thereby justifying the economics of using it. The material typically offers higher sensitivity as a result of its very high quantum efficiency (80%-90%). However, high quantum efficiency is not the most important factor. With InSb, the detectors swamp in a few microseconds, but then the rest of the photons must be dumped. As a result, for most applications there is little benefit to the added quantum efficiency. Another drawback is that InSb infrared FPAs have been found to drift in their nonuniformity characteristics over time and from cool down to cool down, thus requiring periodic corrections in the field. As a result, the system becomes more complex by requiring thermoelectric coolers, and additional electronics in the camera.

## 5.4 Ternary compounds

Ternary compounds made from III-V elements such as indium gallium arsenide (InGaAs) are already available. They operate in the near-IR region at 1 to 1.8 µm or higher, and no cryogenic cooling is required. Very good performance using thermoelectric cooling can be achieved below 1.8 µm. Linear arrays made from InGaAs elements is commercially available.

# 6. FUTURE TRENDS

Third generation of IR systems are essentially the future trends in this industry that has enjoyed the patronage of US Department of Defence (DoD). However, it can be said that in future, the performance of detector formats with cooled or uncooled FPA technologies will be further enhanced by development of new detection methodologies and signal processing techniques [4]. Moreover, the concept of military and commercial dual-use technology in IR detector formats will lead to lower cost, small size, reduced weight and increased user friendly application-oriented development.

## 7. CONCLUSION

The IR industry is in transition. After years of existence as an esoteric technology reserved for military, academia and narrow niche markets, IR technology is on the brink of emerging as a dramatic new mainstream tool for countless applications, including security, firefighting, surveillance, and industrial imaging. Two-waveband FPAs improve the detection of targets with various surface temperatures and enable real-time thermal discrimination. Operation at longer wavelengths enables detection of cold targets at long ranges. Large-format (256 x 256 pixels and larger) FPAs provide large search areas concurrently accurate tracking. Improved operability and yield reduce production costs and schedules.

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