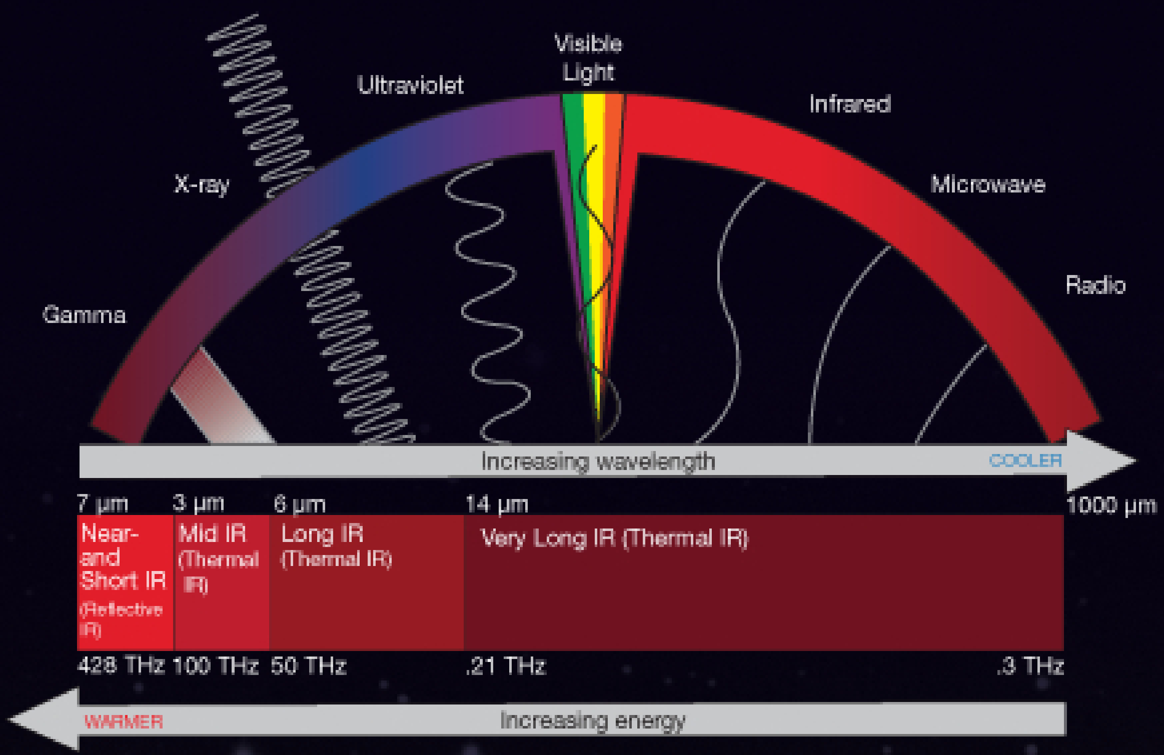
Infrared Radiation

Seeing an invisible world

In 1800, Sir Frederick William Herschel, a German-born astronomer, passed sunlight through a prism and held a thermometer just beyond the red end of the spectrum. He found the temperature reading to be higher than when the thermometer was placed in the visible spectrum, concluding there must be an invisible form of light.

Infrared radiation (IR) has a wavelength that lies between 0.7 and 1000 micrometers, which equates to a frequency range between approximately 0.3 and 430 THz. These wavelengths are longer (and lower frequency) than that of visible light, but shorter (and higher frequency) than that of microwaves. Infrared waves are given off by all objects at a temperature above absolute zero, they produce heat in all objects they strike. The Sun emits radiation in the infrared as well as the gamma ray, x-ray, ultraviolet, visible, microwave, and radio wave regions of the spectrum.

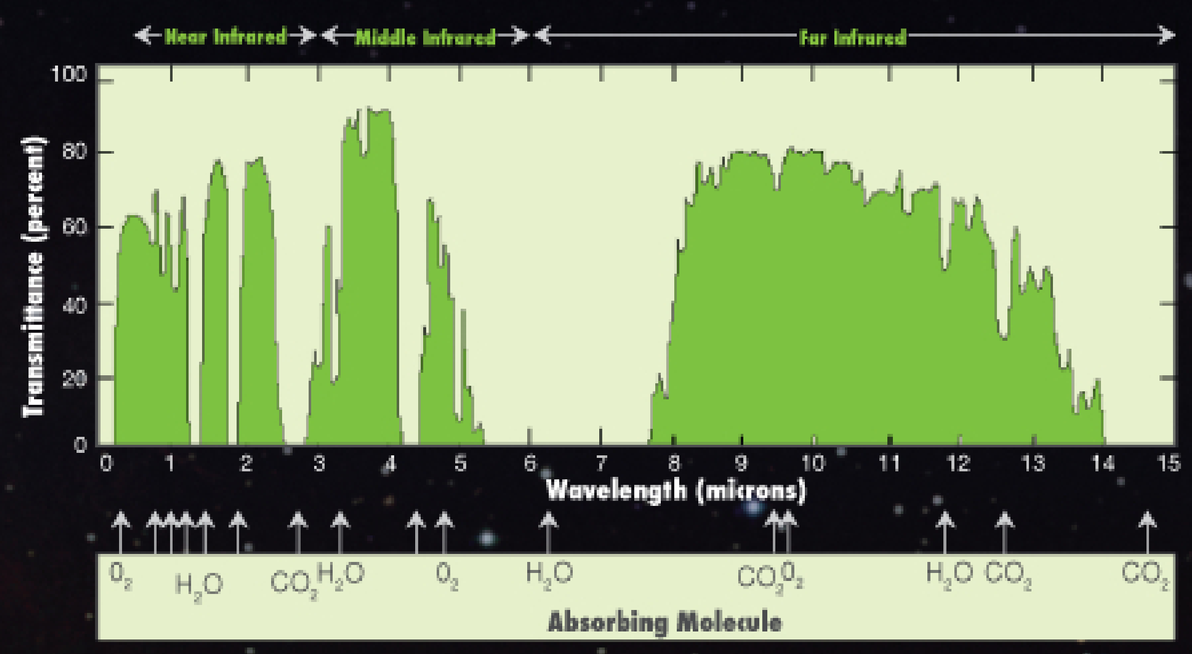


OBJECT TO BE IMAGED

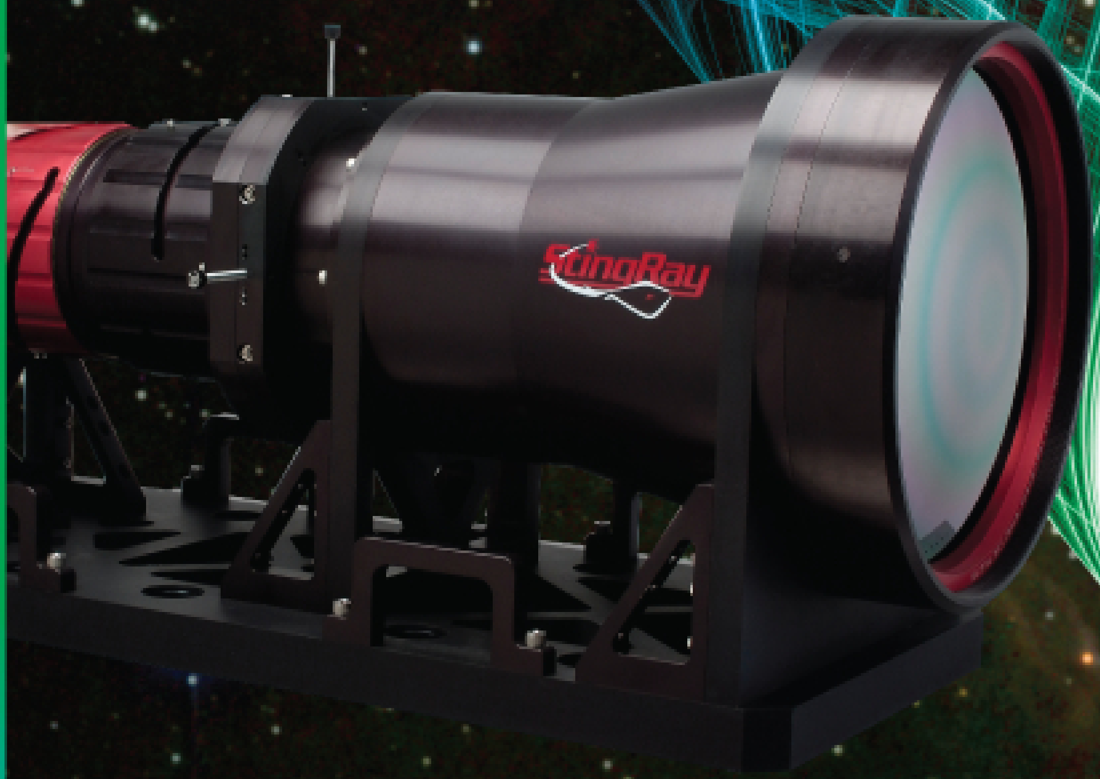
ABSORPTION AND EMISSION OF IR

are critical parameters when developing infrared systems. A **blackbody** is a theoretical object that absorbs all radiant energy that strikes it. Blackbodies have maximum spectral emittance possible for a body at a specified temperature, either over a particular spectral region or integrated over all wavelengths. They are a convenient baseline for radiometric calculations, since any thermal source at a specified temperature is constrained to emit less radiation than a blackbody source at the same temperature.

Electromagnetic Spectral Transmission



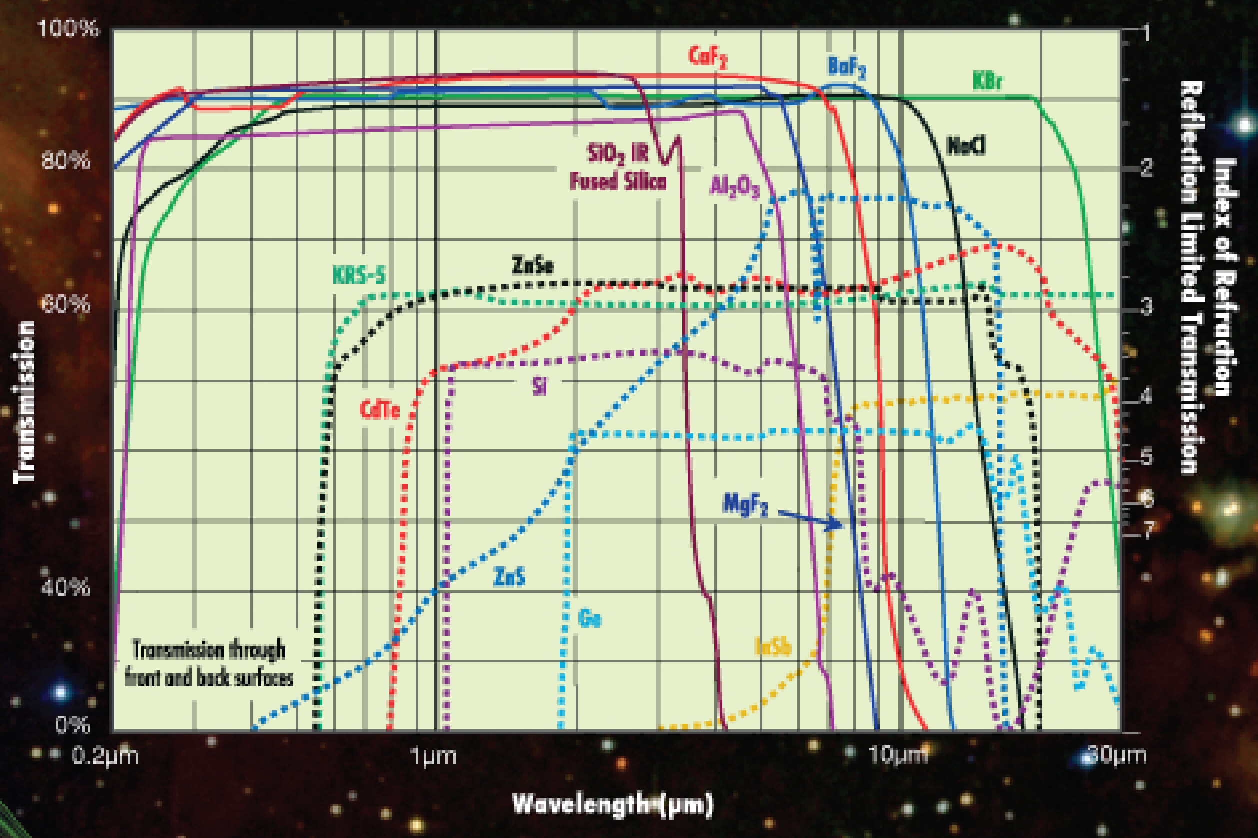
The bands of IR wavelengths that the atmosphere transmits are called the **atmospheric windows**. These windows vary greatly with local conditions such as water content and land temperature. A large gap in the absorption spectrum of water vapor, the main greenhouse gas, is most important in the dynamics of the windows. System technologies optimize operations in these windows.



OPTICAL MATERIALS

used in IR systems must transmit and focus the radiation onto tiny detector elements. Many of the best IR transmitters, e.g., silicon or germanium, do not transmit visible light, although zinc selenide does. These materials have high refractive indices and have mechanical and optical properties that are strongly temperature dependent. This complicates optical system design and the application of optical coatings.

Transmission of Common Optical Materials



INFRARED DETECTOR MATERIALS

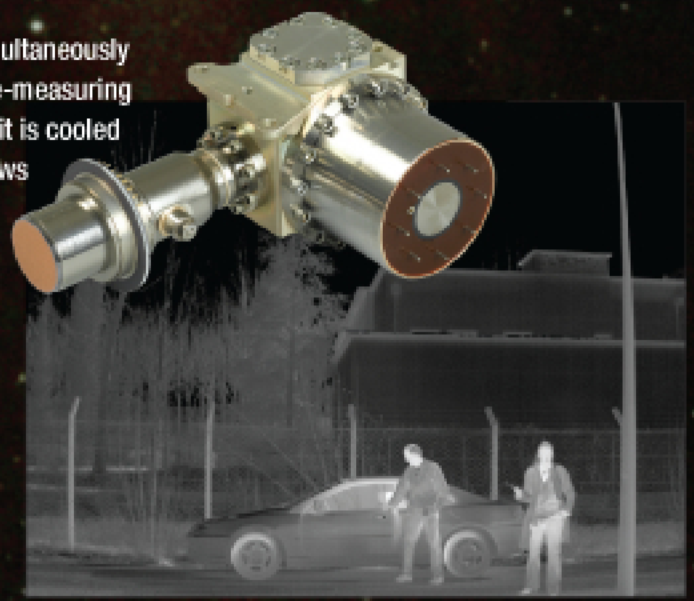
are transducers that sample the incident radiation and produce an electrical signal. Two main types are thermal and quantum (or photonic). Thermal detectors do not require cooling, but have slower response time and lower detection capability. Quantum detectors are faster and offer better detection, but need to be cooled for accurate measurement.

Types of Infrared Detectors and Their Characteristics

Type			Detector	Spectral response (µm)	Operating temperature (K)	D^*(cm · Hz$^{1/2}$/W)
Thermal type	Thermocouple · Thermopile			Depends on window material	300	$D^*(\lambda,10,1) = 6 \times 10^8$
	Microbolometer		VOx, a-Si		300	$D^*(\lambda,10,1) = 1 \times 10^8$
	Pneumatic cell		Golay cell, condenser-microphone		300	$D^*(\lambda,10,1) = 1 \times 10^9$
	Pyroelectric detector		PZT, TGS, $LiTaO^3$		300	$D^*(\lambda,10,1) = 2 \times 10^9$
Quantum type	Intrinsic type	Photoconductive type	PbS	1 to 3.6	300	$D^*(500,600,1) = 1 \times 10^8$
			PbSe	1.5 to 5.8	300	$D^*(500,600,1) = 1 \times 10^8$
			InSb	2 to 6	213	$D^*(500,1200,1) = 2 \times 10^9$
			HgCdTe	2 to 16	77	$D^*(500,1000,1) = 2 \times 10^{10}$
		Photovoltaic type	Ge	0.8 to 1.8	300	$D^*(\lambda p) = 1 \times 10^{11}$
			InGaAs	0.7 to 1.7	300	$D^*(\lambda p) = 5 \times 10^{12}$
			Ex. InGaAs	1.2 to 2.55	253	$D^*(\lambda p) = 2 \times 10^{11}$
			InAs	1 to 3.1	77	$D^*(500,1200,1) = 1 \times 10^{10}$
			InSb	1 to 5.5	77	$D^*(500,1200,1) = 2 \times 10^{10}$
			HgCdTe	2 to 16	77	$D^*(500,1000,1) = 1 \times 10^{10}$
	Extrinsic type		Ge : Au	1 to 10	77	$D^*(500,900,1) = 1 \times 10^{11}$
			Ge : Hg	2 to 14	4.2	$D^*(500,900,1) = 8 \times 10^9$
			Ge : Cu	2 to 30	4.2	$D^*(500,900,1) = 5 \times 10^9$
			Ge : Zn	2 to 40	4.2	$D^*(500,900,1) = 5 \times 10^9$
			Si : Ga	1 to 17	4.2	$D^*(500,900,1) = 5 \times 10^9$
			Si : As	1 to 23	4.2	$D^*(500,900,1) = 5 \times 10^9$

Uncooled infrared detectors are small, light and of low cost. Like the cooled detector, they have up to one million elements.

The most advanced **cooled infrared detector** operates simultaneously in middle- and long-wave IR bands, and has an active range-measuring mode in the short-wave band. Made from HgCdTe material, it is cooled to −196°C by a Stirling type cryocooler. This technology allows imaging at very long ranges, particularly useful in military applications such as night vision.

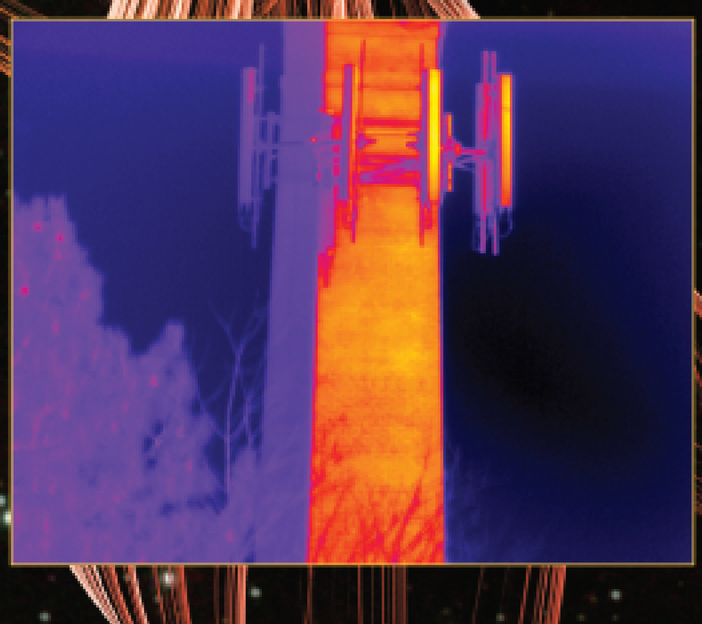


APPLICATIONS

Infrared imaging is used extensively for military and civilian purposes. Military applications include target acquisition, surveillance, night vision, homing and tracking. Non-military uses include thermal efficiency analysis, remote temperature sensing, short-ranged wireless communication, spectroscopy, and weather forecasting. Infrared astronomy uses sensor-equipped telescopes to penetrate dusty regions of space (such as molecular clouds), detect cool objects such as planets, and to view objects from the early days of the universe.

Fighting a fire using an infrared camera makes the job more efficient and effective. This enables firefighters to concentrate water use in hottest areas, locate people, and find remaining hot spots after the fire is knocked down.

IMAGED OBJECT



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