

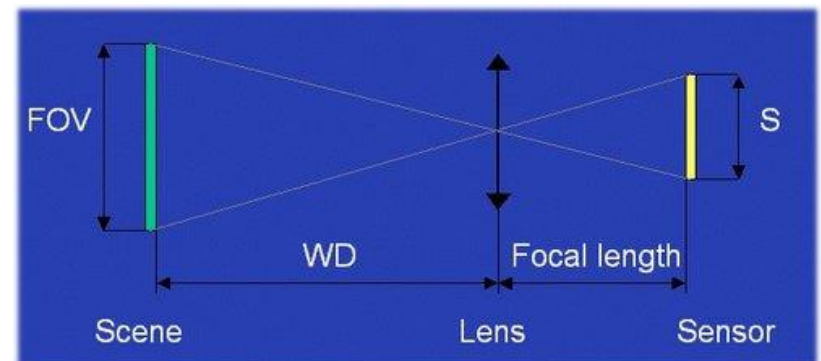
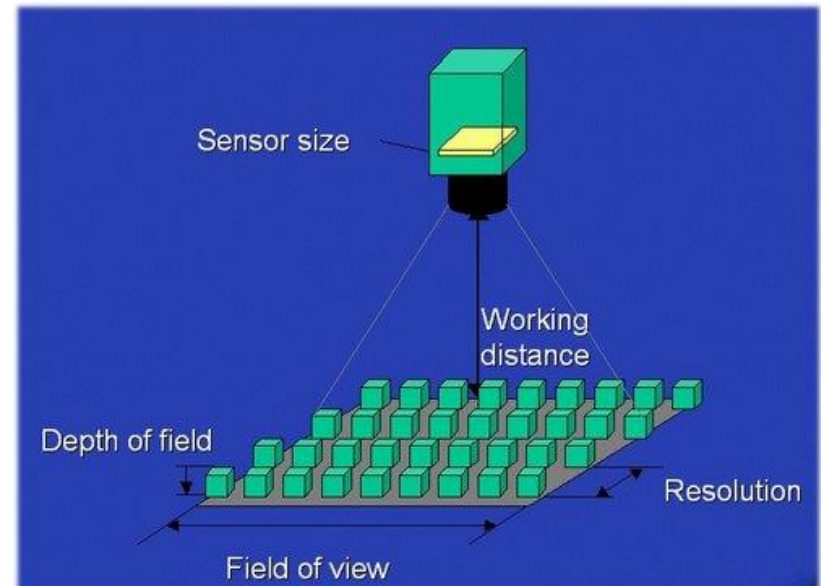
Camera Optical Parameters

Calculating Camera Sensor Resolution and Lens Focal Length

Problem:

How do I make sure that I have the correct lens, focal length, and sensor resolution (number of columns and rows of CCD pixels in the camera sensor?) I know the following about the real life situation:

- **Field of view (FOV)** - Area under inspection that the camera can acquire
- **Resolution** - Amount of object detail that the imaging system should reproduce
- **Working distance** - Distance from the front of the lens to the object under inspection



Camera Optical Parameters

Problem.

- a) For the camera specification provided, develop a pixel (**spatial**) resolution as a function of working distance. Ensure that you do this for both the horizontal and vertical planes.
- b) Determine the sensor dimensions in mm.
- c) Assuming a linear temperature response, calculate the minimum observable temperature difference.
- d) State the **temporal** resolution of the system.
- e) State the horizontal and vertical pixel angular field of view in mrad.
- f) Calculate the full field of view at a working distance of 0.5metres.

Thermal Imager

Sensor

Type: Uncooled Focal Plane Array

Array Size (Pixels): 320 x 240

Spectral Response: 8 – 14 μm

Dynamic Range: -40°C - 160°C

Sampling: 16 bit

Frame Rate: 30Hz

Optics

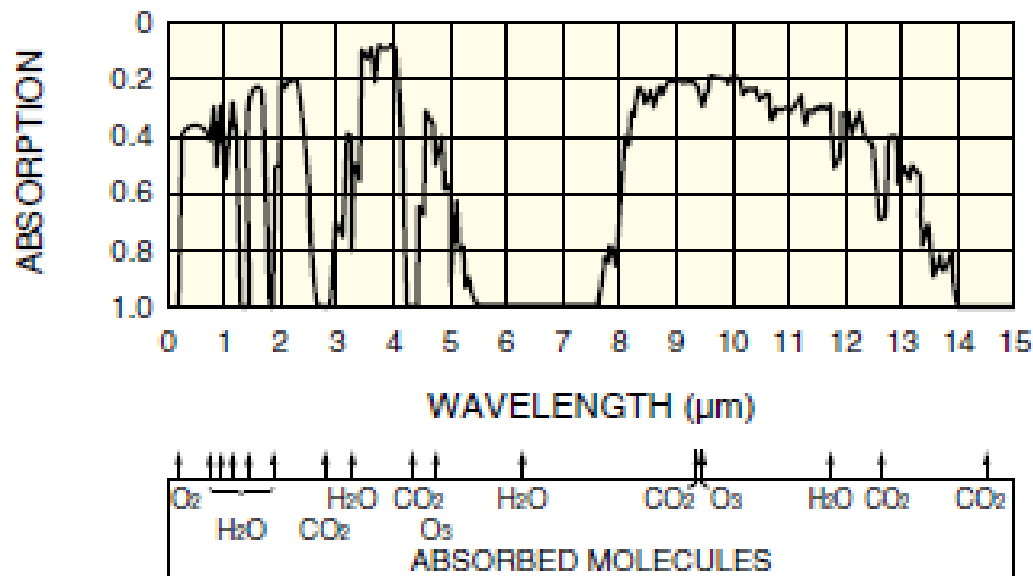
Lens: 19mm, F1.4

Field of View: 36° H, 27° V

Spectral Response

Infrared transmission media include a vacuum, the atmosphere, and optical fibres. In the atmosphere absorption by H_2O , CO_2 and other elements takes place at specific wavelengths. The bandwidths from 3 μm to 5 μm and from 8 μm to 12 μm , where the rate of absorption is lower are sometimes called “atmospheric windows” and are often used for remote sensing applications.

Atmospheric absorption on sea surface ²⁾



Spectral Response

Types of infrared detectors

Infrared detectors are classified into thermal types and quantum types.

- **Thermal detectors** - use the infrared energy as heat and their photo sensitivity is independent of wavelength. Thermal detectors do not require cooling, but have disadvantages that response time is slower and detection capability.
- **Quantum detectors** – offer higher detection performance and a faster response speed, although their photo sensitivity is dependent on wavelength. In general, quantum detectors must be cooled for accurate measurement, except for detectors used in the near infrared region.

The table and figure on the next 2 slides provide characteristics for typical infrared detector types.

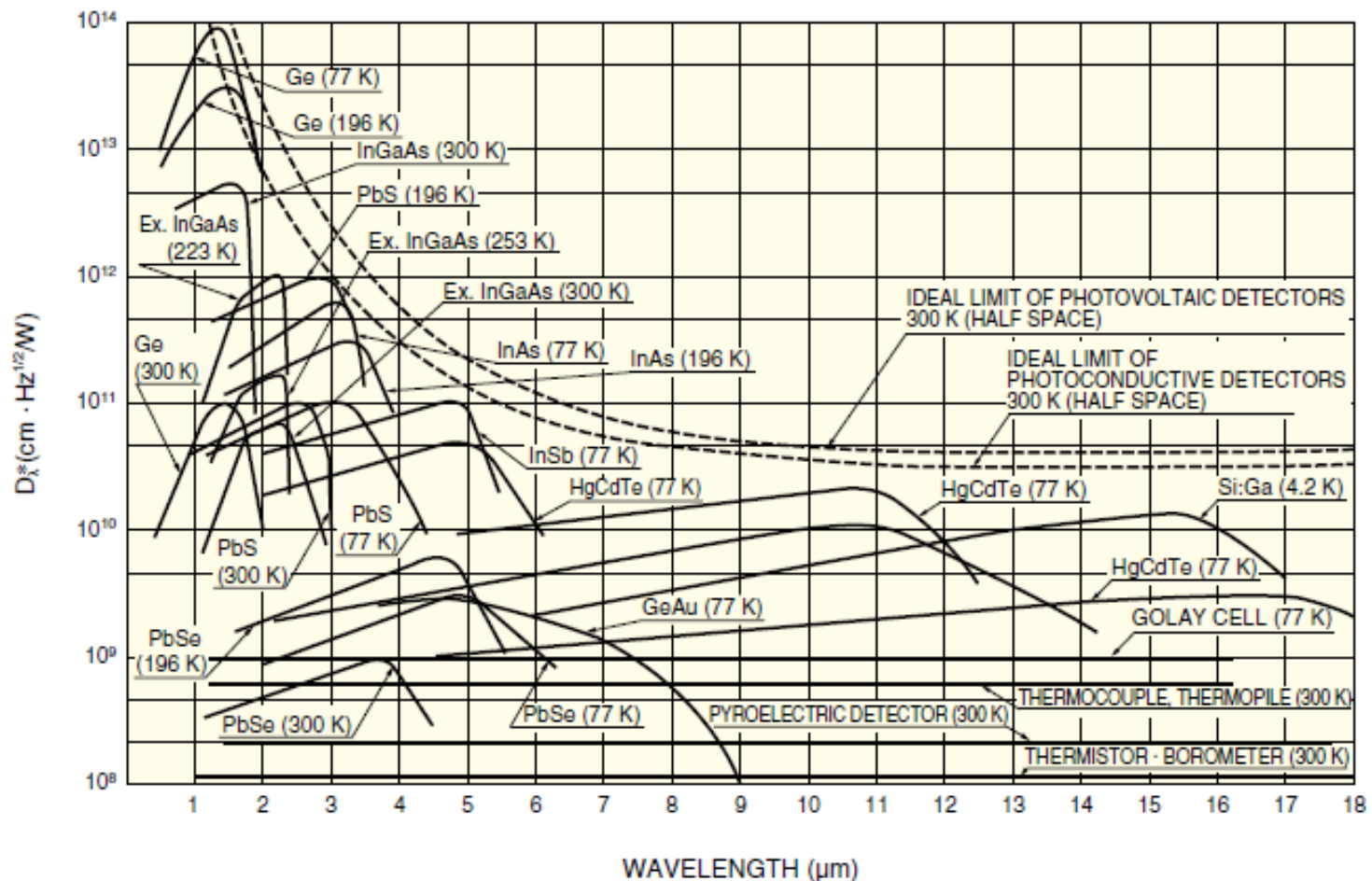
Spectral Response

Types of infrared detectors and their characteristics

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

Spectral Response

Spectral response characteristics of various infrared detectors



The specifications for an infra-red camera used as part of an inspection system are given below.

- Determine the necessary working distance to provide a 10mm spatial resolution.
- Assuming a linear temperature response, calculate the minimum observable temperature change.
- A typical surface temperature decay curve for a component under inspection is given in the following figure. The emissivity of the component surface is 0.93 and behaves like a grey body. Using Planck's equation and the emissivity relationship, along with relevant numerical techniques, determine the radiant intensity over the camera's bandwidth for the 3 points (A, B and C) highlighted. Sketch the camera's correlation curve representing component temperature in °C as a function of radiant intensity.
- Would the temperature variations given in the decay curve be observable by the specified camera? Explain your reasoning.
- During a spectroscopic thermal investigation of a process, it is observed that the maximum radiated energy intensity occurs at a wavelength of 750nm. Assuming that the distribution of the radiated energy is similar to that of a blackbody, determine:
 - the temperature of the process. State your answer in °C, and
 - the total radiated energy of the process per unit area.
- Comment on the net effects of the observed and derived values if the temperature of the process were to increase.

