Thermography and its widening applications

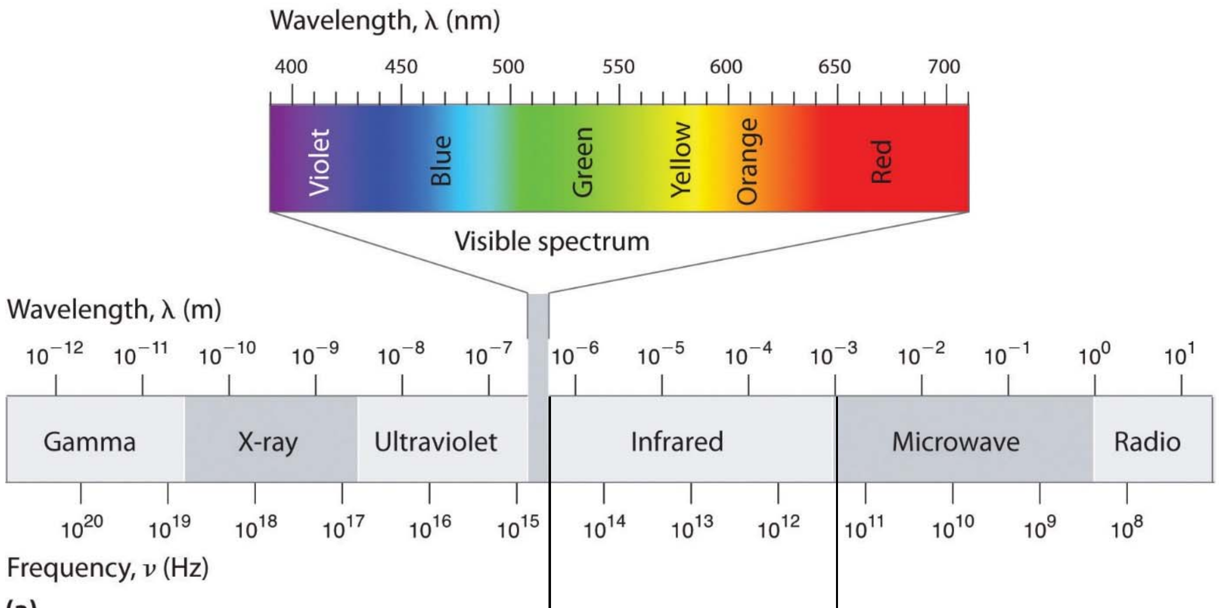
Sir Joseph Swan Centre for Energy Research
Newcastle University

Dr. Mohammad Royapoor

Newcastle University

Sir Joseph Swan Centre for energy research

Scintific principles: Electromagnetic spectrum



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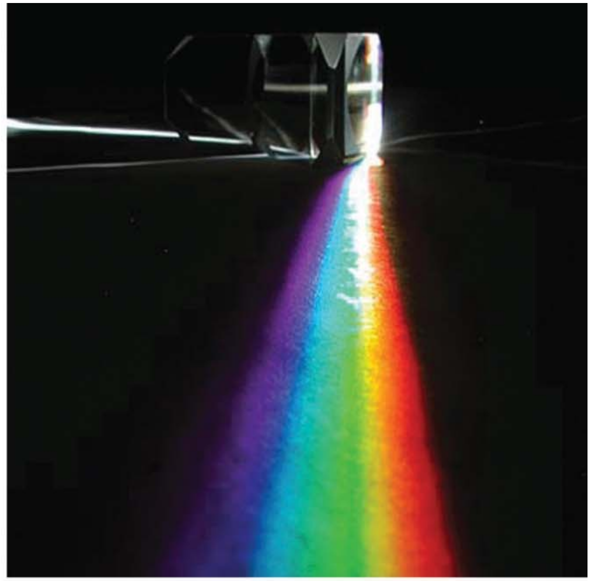


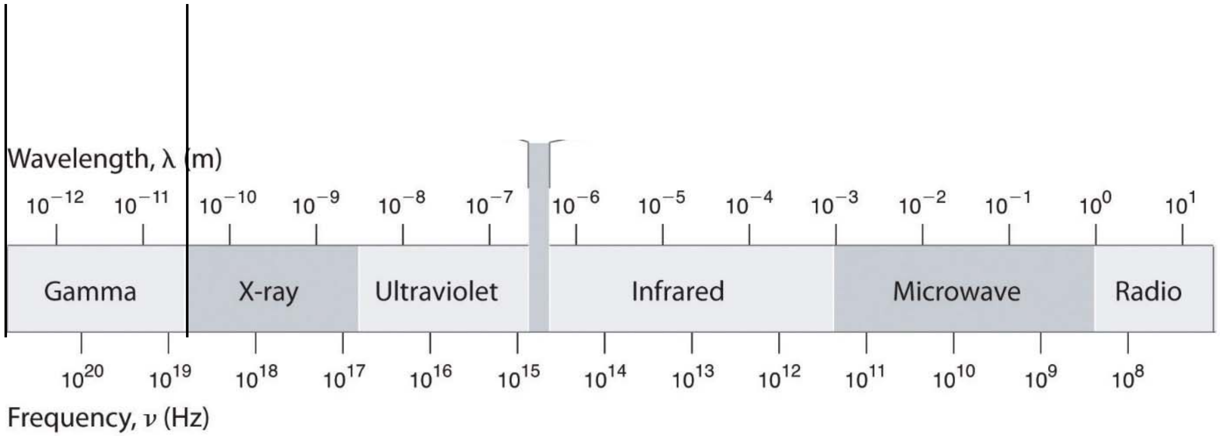
(b)

Gamma Rays

National Nuclear Security Administration / Nevada Site Office

Gamma rays (Ionising radiation)

- Need nuclear fusion to arise
  - i.e. radioactive decay of atomic nuclei (from high to low energy state)
- highly penetrating, high energy (hence used to treat cancer)
- consists of high-energy photons, can ionise other atoms and biologically hazardous

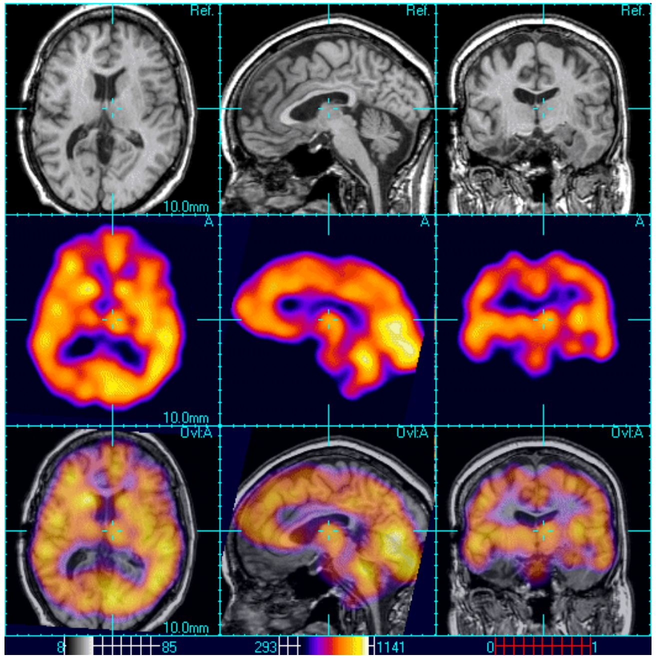


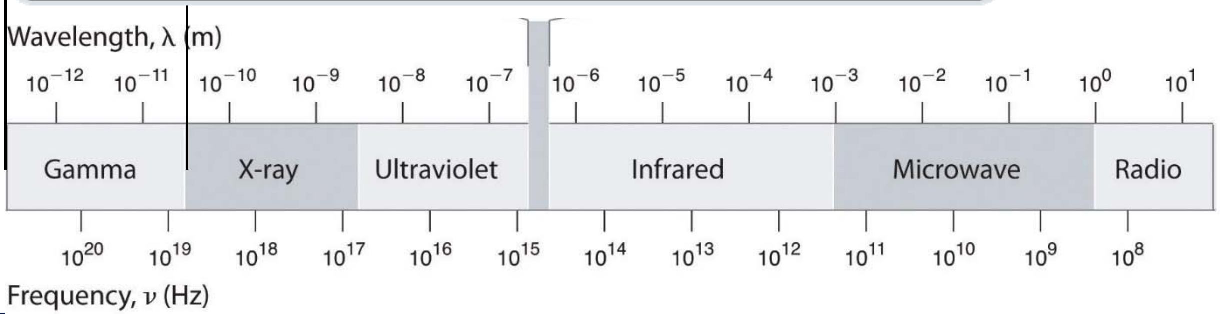
(a)

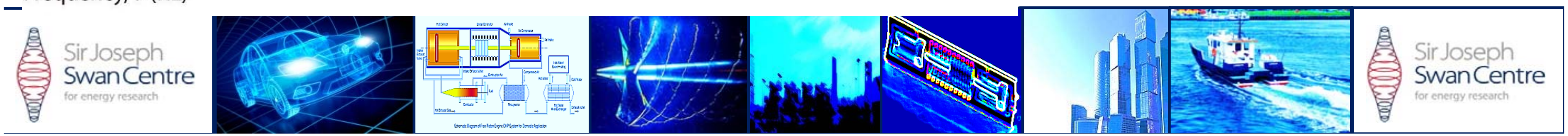
Gamma Rays

Gamma rays (Ionising radiation)

- Used in US for border scanning of vehicles
- diagnostic nuclear medicine
- Cancer treatment
- Some process, mining and refinement industries







X- Rays

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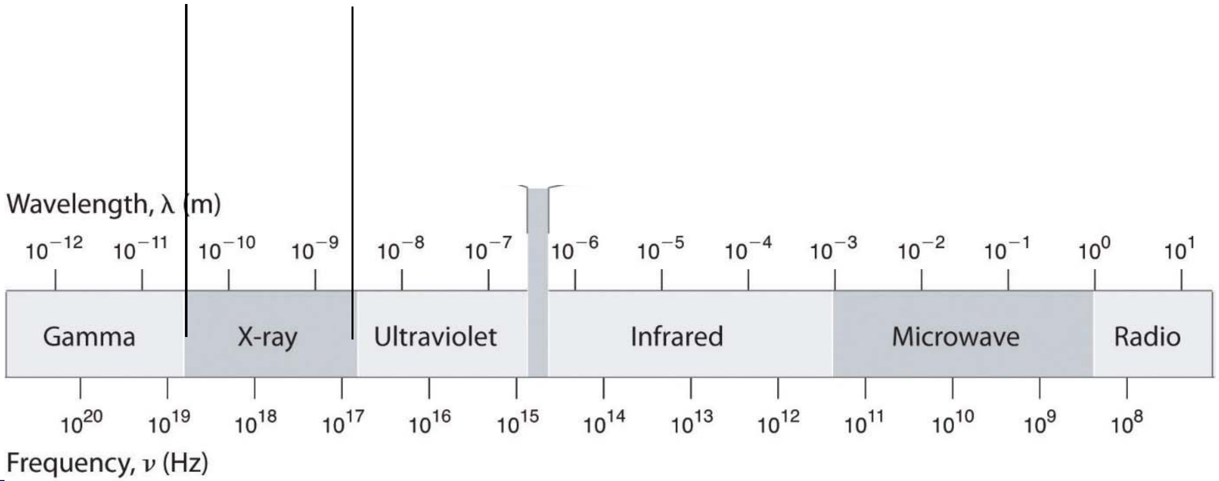
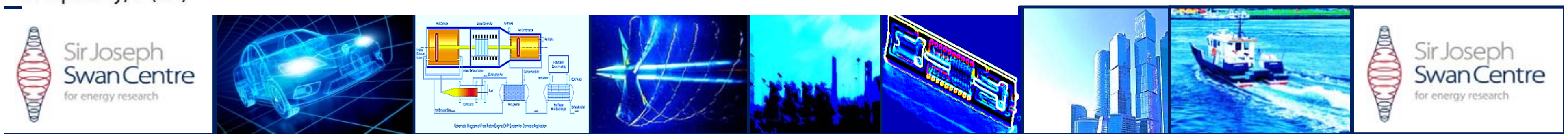
X-rays (Ionising radiation)

- Another high energy radiation type harmful to biological tissues (it can ionise atoms)
- Generated by X-ray or vacuum tubes
- Broadly used in
    - Medicine
    - crystallography and microscopy
    - Astronomical observations



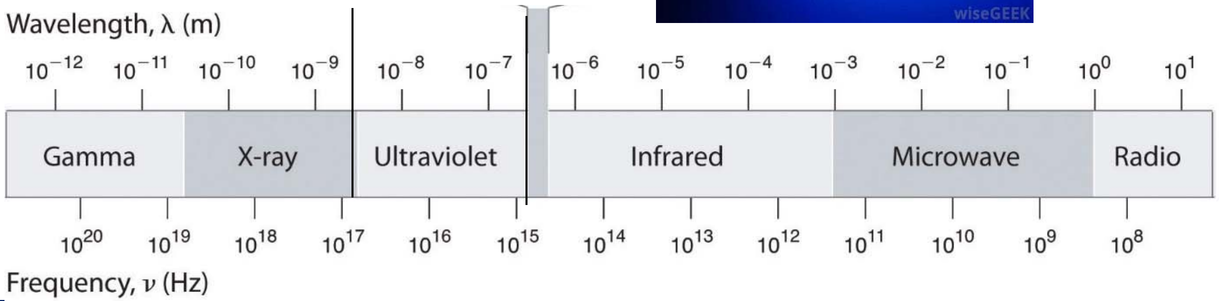


Solar UV

Ultraviolet (Extreme and near)

- 8×10^{14} to 3×10^{16} Hz
- Wavelength 10 - 400 nm
- Helps to produce Vitamin D

- Applications:
  - Barcode readers/forensics
  - Optical sensing instrumentations/imaging
  - Disinfections
  - Solid state lighting



Subdivided into :

UV-A (320–400 nm)

UV-B (290–320 nm)

UV-C (220–290 nm) All absorbed by Ozone

Near UV Visible to birds, insects and fish

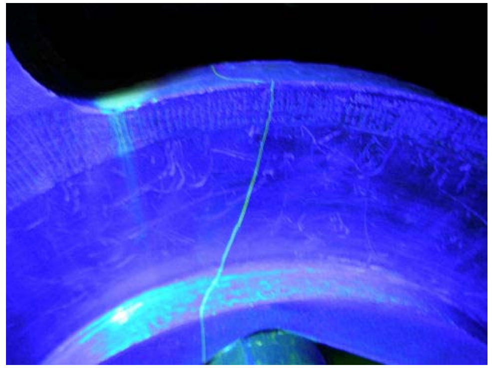
Middle UV

Far UV

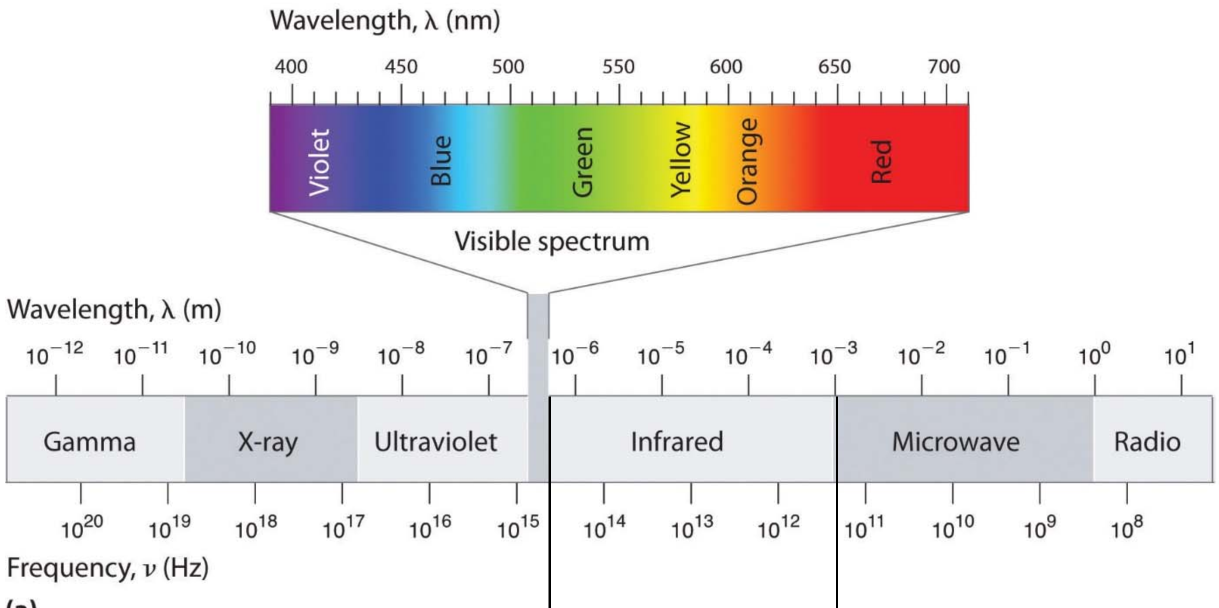
H Lyman-α

Vacuum UV

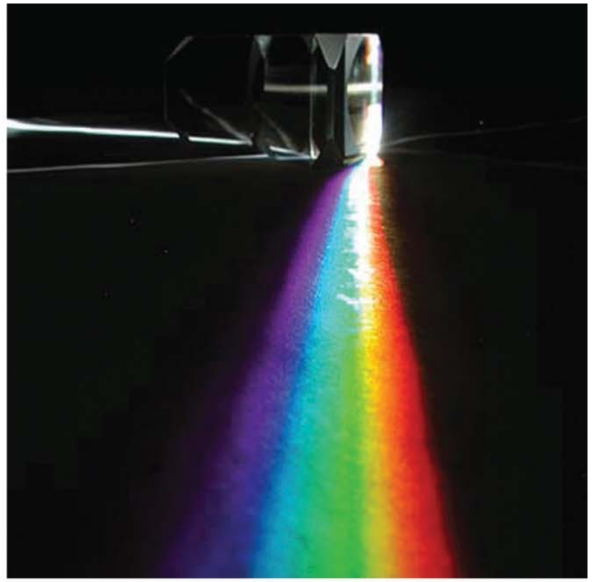
Extreme UV (10-121 nm) (entirely ionising)



Visible and Infrared



(a)



(b)

Micro & Radio Waves

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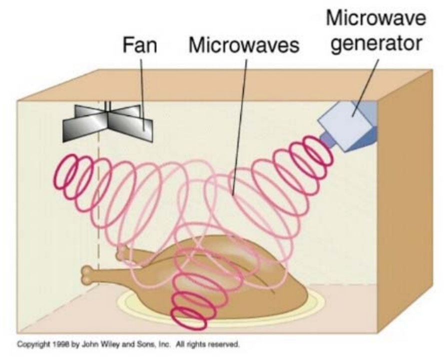
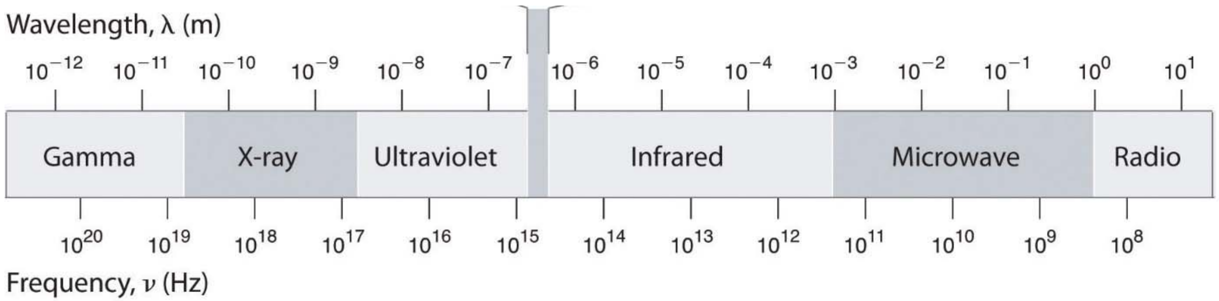
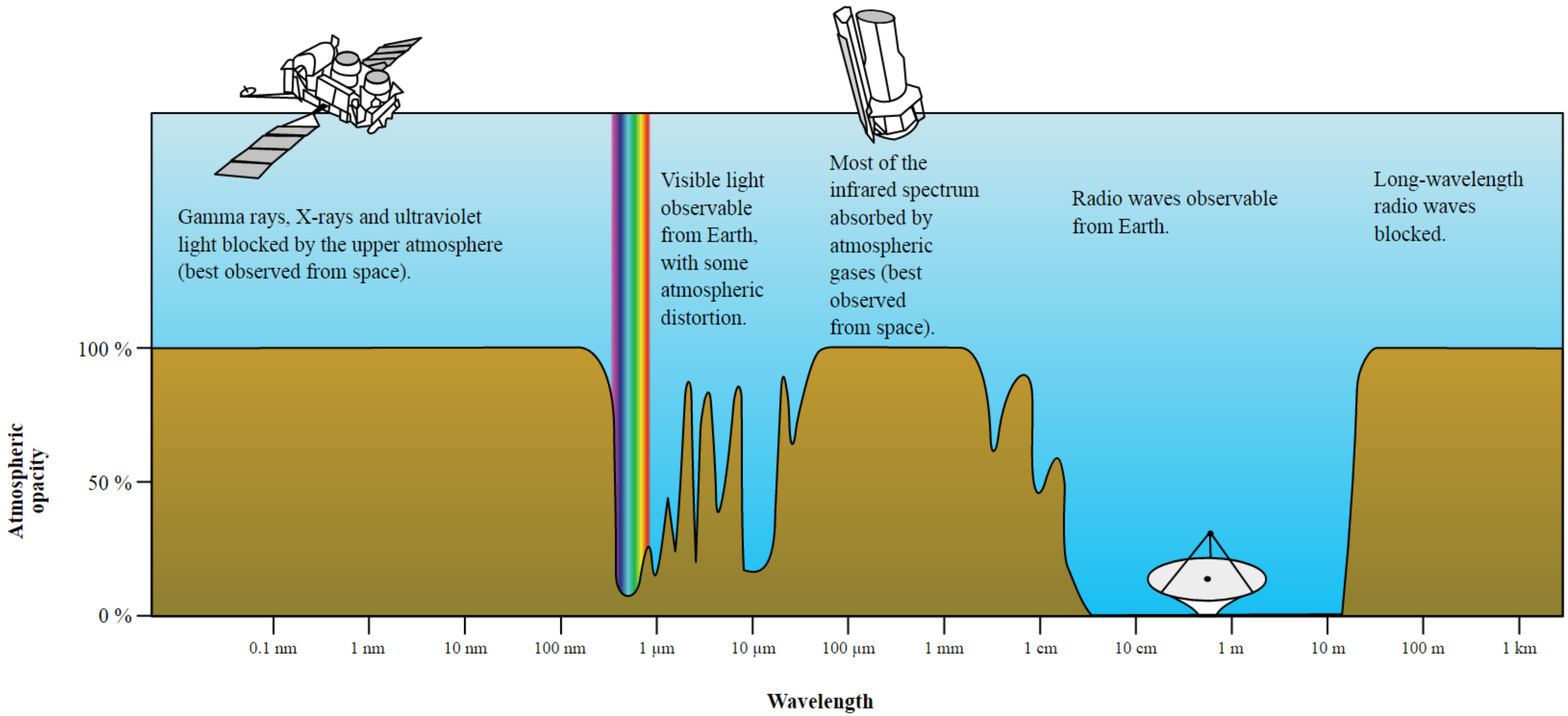
Microwaves: 300 MHz (100 cm) and 300 GHz (0.1 cm)
Navigation/radar/communication/heating



Radio waves 300 GHz (1 mm) to as low as 3 kHz (100 km),
Radio/TV communication



Atmospheric transmittance



Infrared thermography

Pros:

- No contact
- Non intrusive
- Quick
- Maintains a distance
- Shows the exact location of faults
- Convincing photographic evidence
- Product improvement

Cons

- Requires temperature deference
- Requires experience
- Sensitivity and resolution suffers with distance and angle of view
- Limited in range (-60°C-300°C with ±1°C accuracy

IR Governing principles

Captured by Stefan Boltzmann law:

Energy radiated by a black body ≈ 4th power of temperature (kelvin)

$$E = \sigma T^4$$

σ (sigma) =Boltzmann Constant or

σ =1.3806488 × 10^{-23} m^2 kg s^{-2} K^{-1}

The elastic (Delta) and angle (Phi) of deflection:

$$\delta_B = \frac{qL^4}{8EI}$$

$$\phi_B = \frac{qL^3}{6EI}$$

$$P = \frac{C_p \mu_c A \rho V^3}{2}$$

Where P *is power in Watts (Joules / sec)*

C_p *is the Coefficient of performance*

μ_c *Conversion efficiency*

A *is the swept area* (m^2)

ρ *is the density of air*

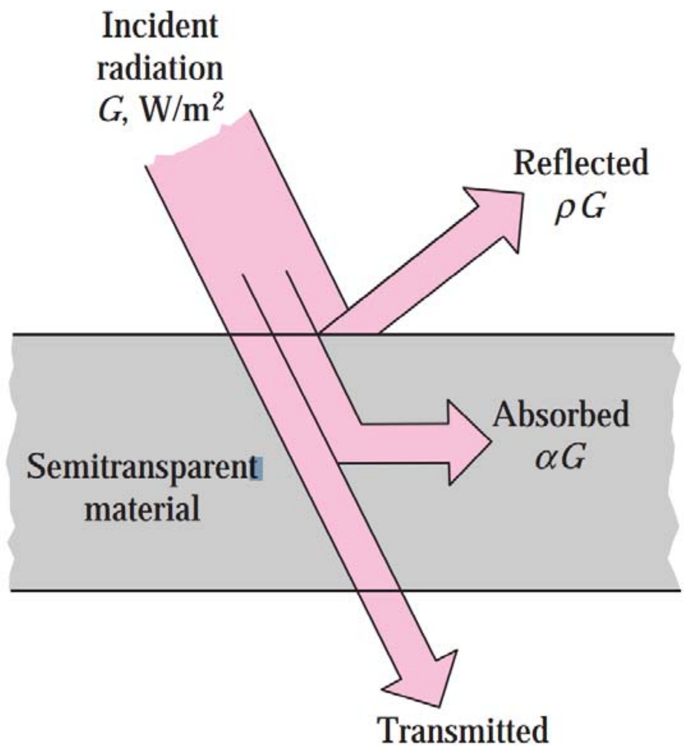
V *is the wind speed (m / sec)*

Emissivity principle

- Infrared (thermal) energy, when incident upon matter, be it solid, liquid or gas, will exhibit the properties of absorption, reflection, and transmission such that

Absorptivity (α)+ reflectivity (ρ)+ transmissivity (t) = 1

At constant material temperature:
Emitted Energy = Absorbed Energy



Emissivity principle

- If not for emissivity, thermographers wouldn't need training…
- Most solid objects exhibit very low transmissivity - the majority of incident energy is either absorbed or reflected.
- There are few materials that transmit energy efficiently in the infrared region (7 and 14µm).
- Germanium is one of the few good transmitters of infrared energy.

Emissivity (ε)

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- Emissivity (Ranging from 0.1 to 0.95)

  The most important parameter; a measure of how much radiation is emitted from the object, expressed as a ratio of comparison with the perfect blackbody

- Highly polished mirror — $\varepsilon < 0.1$
- Oil based paint (regardless of colour) — $\varepsilon > 0.9$
- Human skin — $\varepsilon \approx 0.97\text{-}0.98$
- Metals — <u>Low ε increasing with temperature</u>
- Non-metals — <u>Generally high ε decreasing with temperature</u>

- The emissivity of the majority of building material is between 0.85 to 0.95 (0.9 is a good starting point for general applications)

Error sources

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- First major correction   Emissivity
- Second major correction   Reflected temperature/thermal background

If emissivity is relatively high → background corrections are less important.
If the background temperature is very different → the affect will be more significant.

- Atm. Temperature:
  The surrounding air temperature
- Object distance
- Humidity

- Colour has no noticeable effect (effects reflectivity)

Ideal conditions

- Thickly clouded sky
- Low air velocities / little wind
- No rainfall/wet surfaces
- Preferably a perpendicular viewing angle
- Best with lower levels of humidity (avoid mist)
- High emissivity surfaces

i.e. A cloudy day in Nevada

Measurement of reflected temperature

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Lambert radiator, i.e. in all directions.

A piece of crumpled aluminium foil is a suitable substitute for a Lambert radiator for this purpose. The foil has high reflectance and optimum diffusion

To measure Tr

1. Place the Lambert radiator near the measuring object or ideally on the surface of the measuring object.
2. Then measure the temperature at the radiator with emissivity set to one.
3. Input this value as the RTC
4. Measure the object temperature

Determining emissivity

1. Method 1: using a contact thermometer
2. Method 2: Using a thermal camera and emissivity adhesive tape

Cold bridging – differences in ε

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Reflectivity of glass

Cold sky affect

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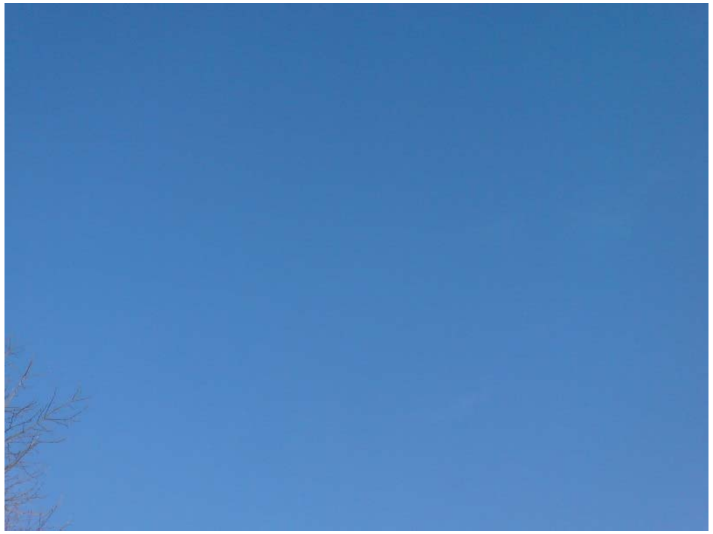
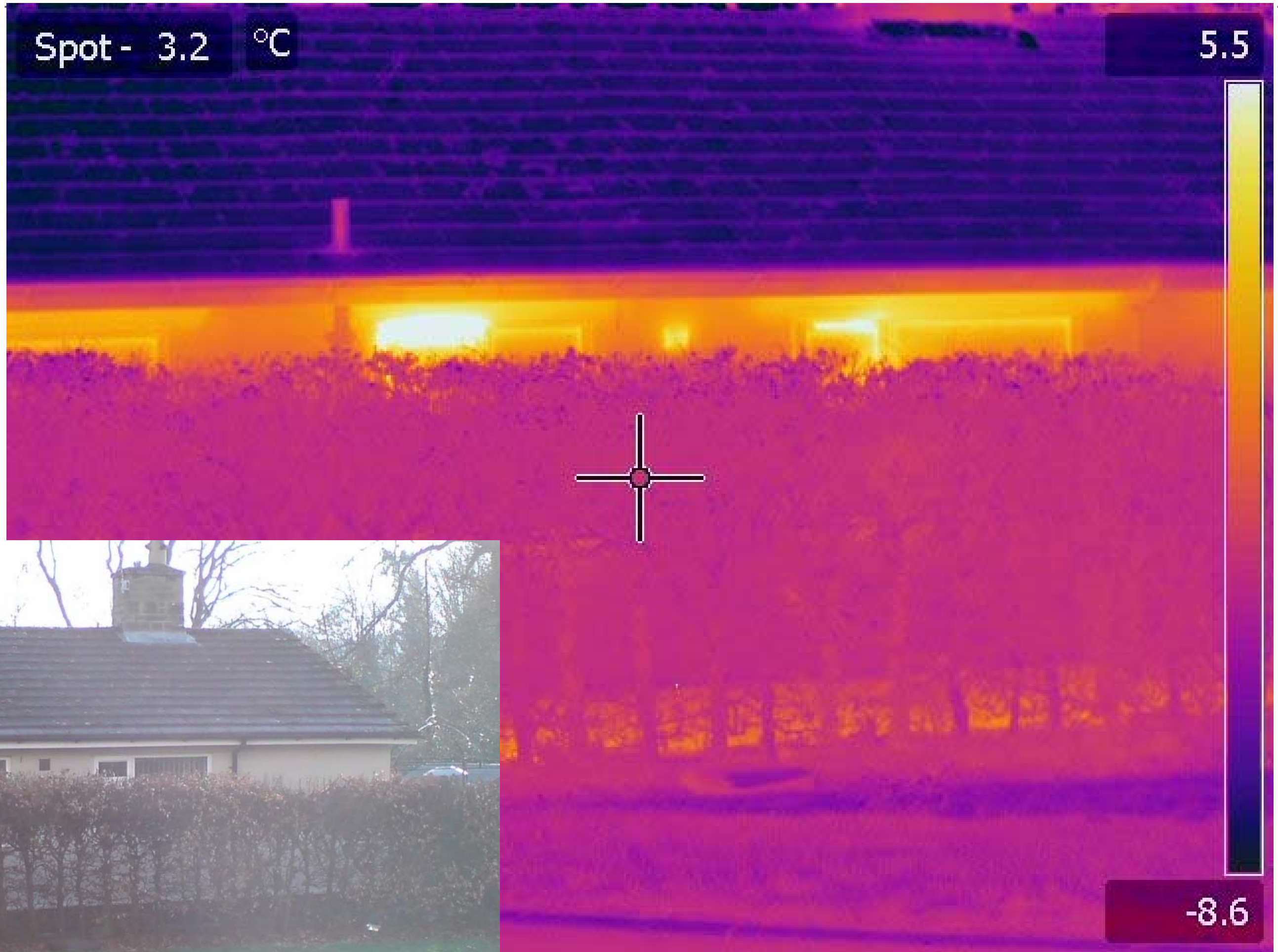
- Cold sky radiation (~ -50 °C to -60 °C)
- Hot solar radiation (~ 5500 °C)



Cold sky affect



Solar loading and windows

Solar loading and windows

Fabric surface properties windows

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Fabric surface properties windows

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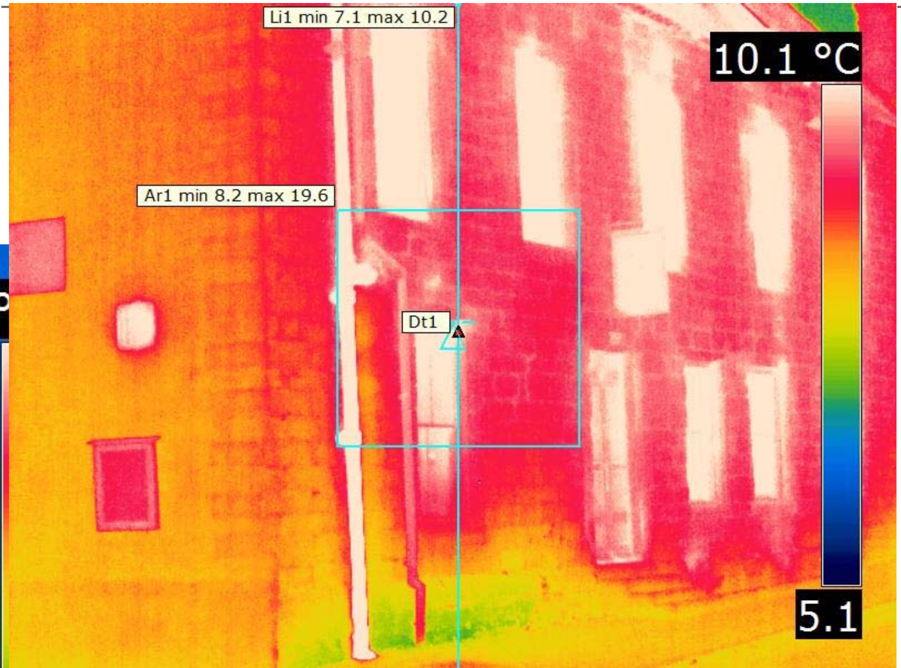

Fabric thermal bridges

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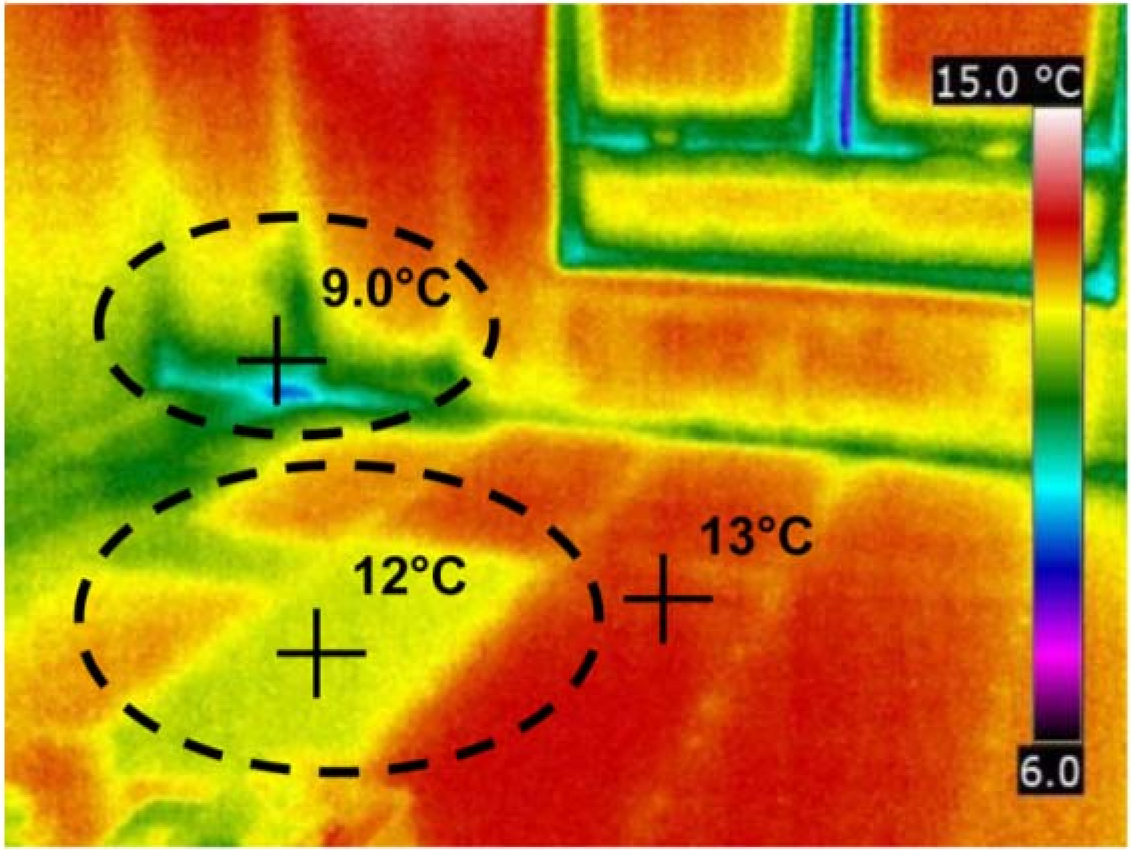
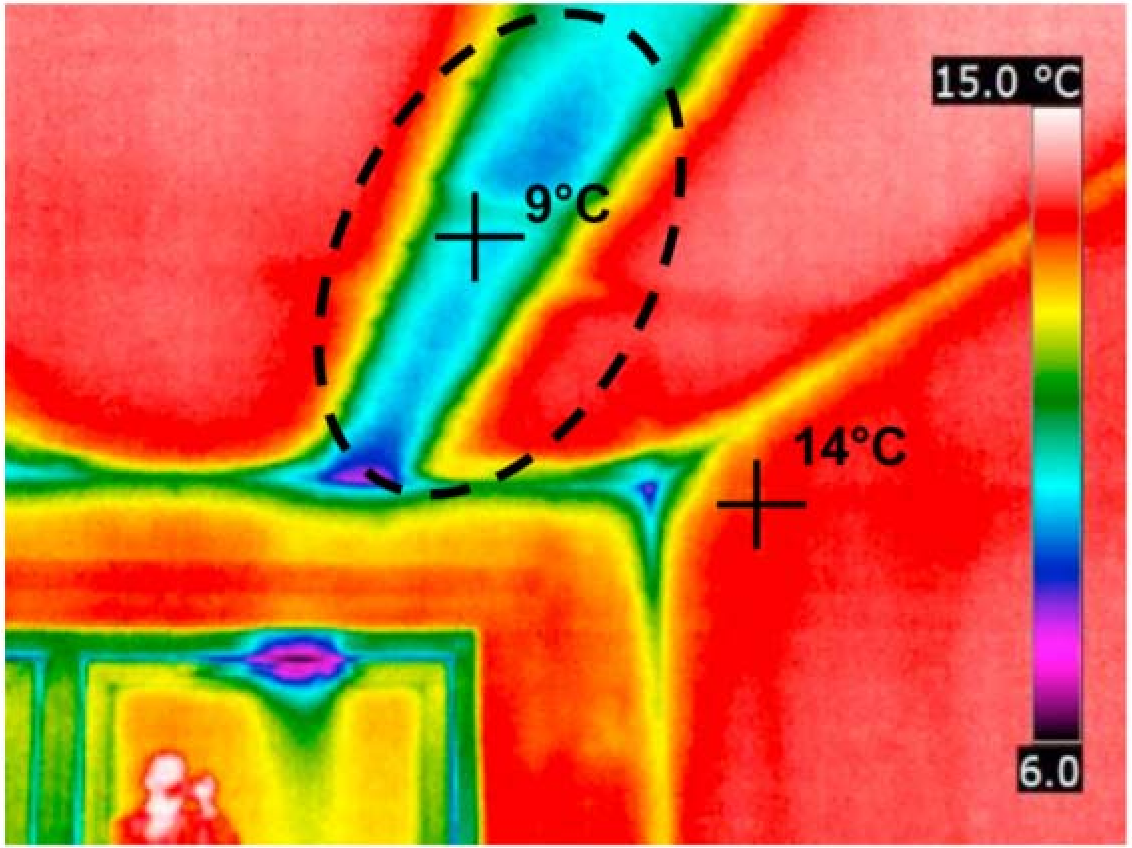
Internal fabric heat loss



Julio Bros-Williamsona,b,∗, Celine Garnier a,b, John I Currie (, Edinburgh Napier University)

Duct-induced cold bridges



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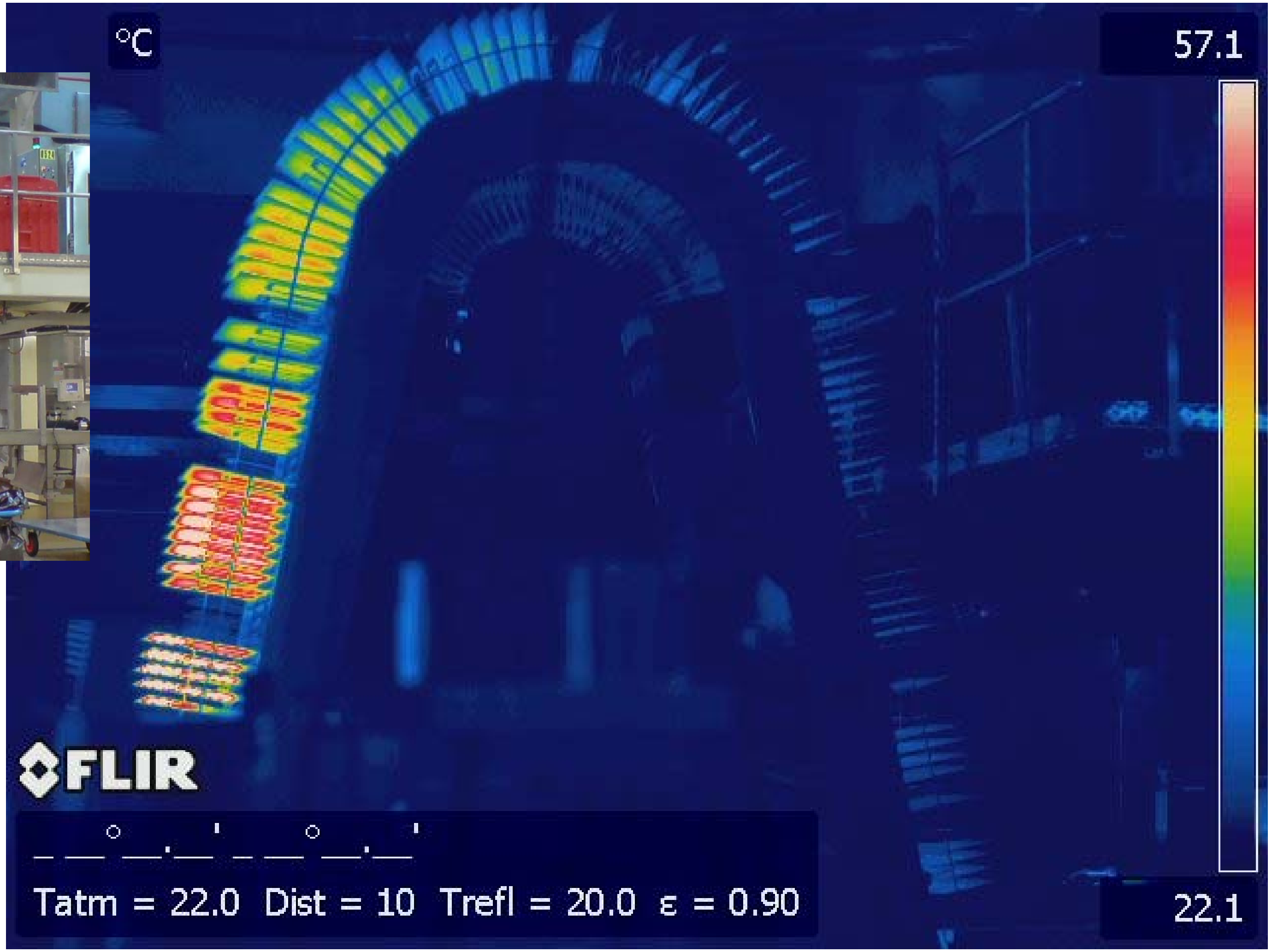
Product improvement



Moisture ingress

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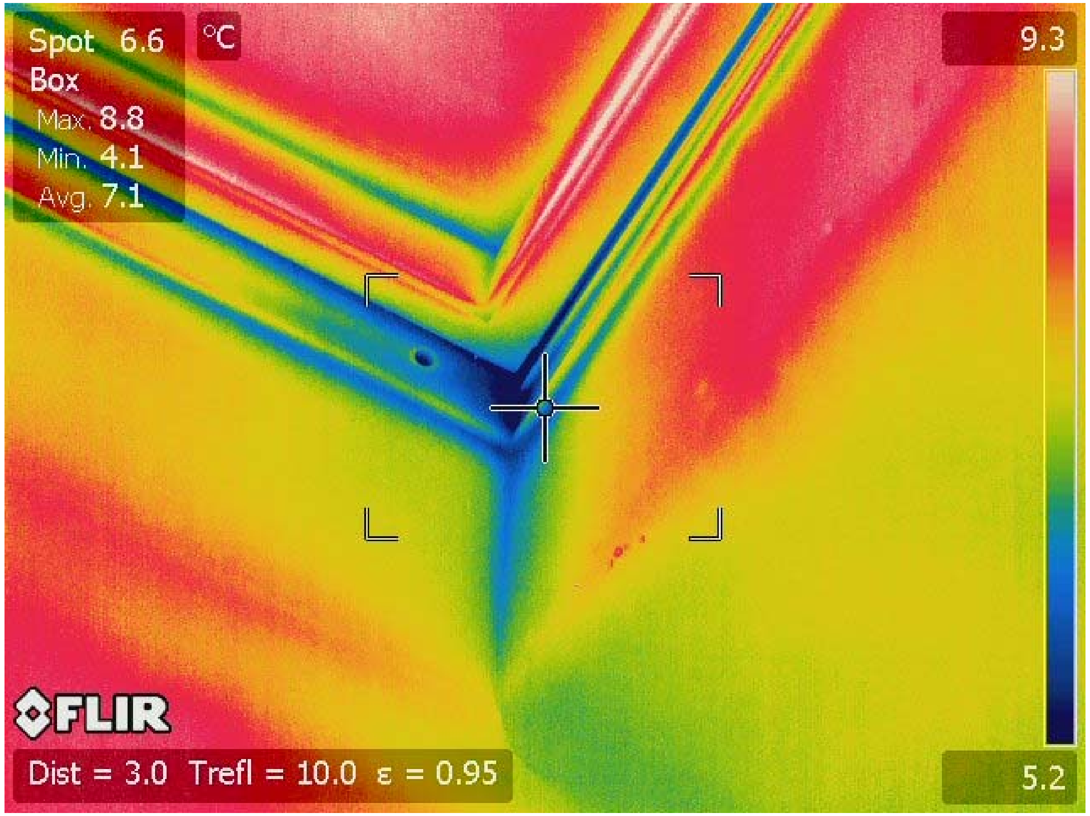
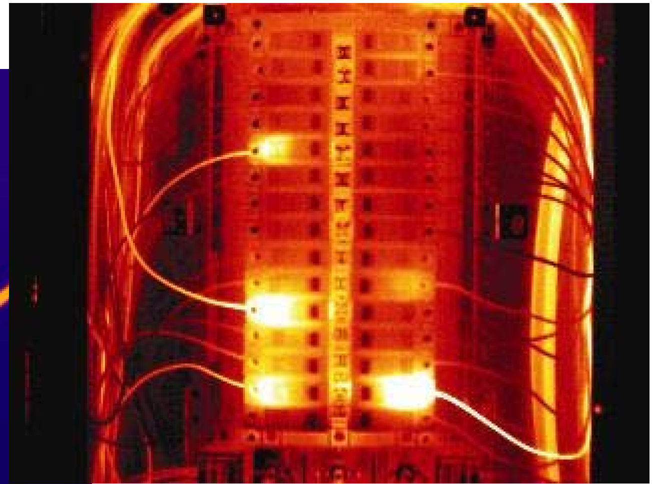
Elevated evaporative cooling effect rising from surface moisture content



Electrical faults



- Cables and connections
- Transformers
- Switch Gear
- Fuse boxes
- Insulation

Livestock Thermography

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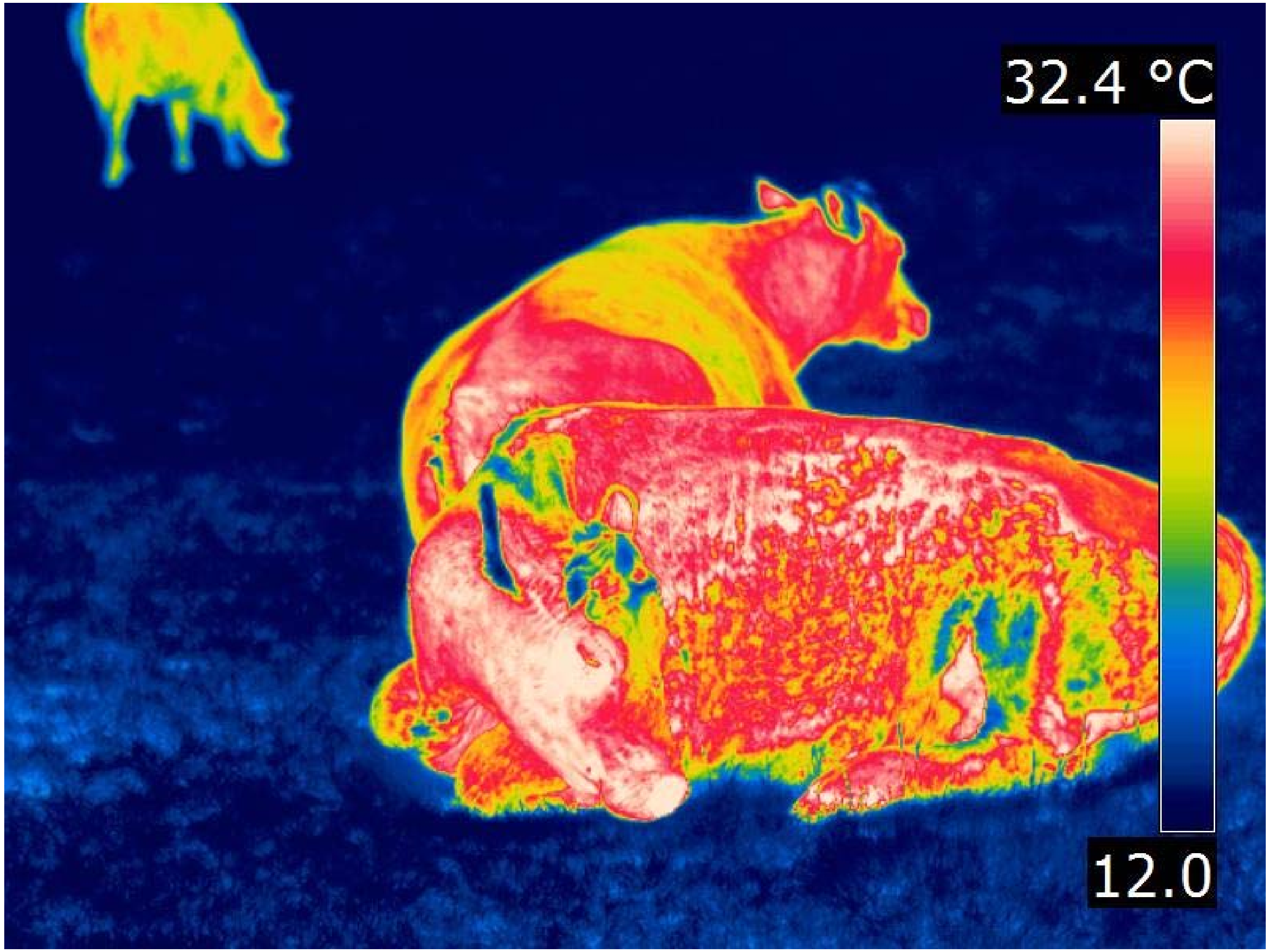
- Muscle injury
- Post-calving injuries
- Joint degradation
- Elevated temperatures
- Inflammations
- Infectious diseases



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IR and natural world

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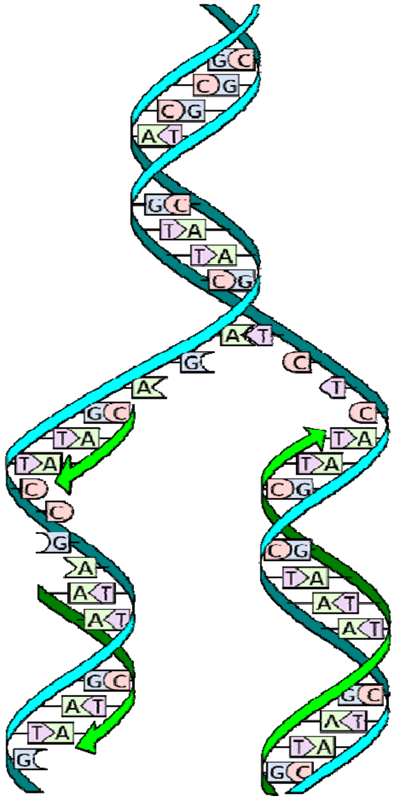
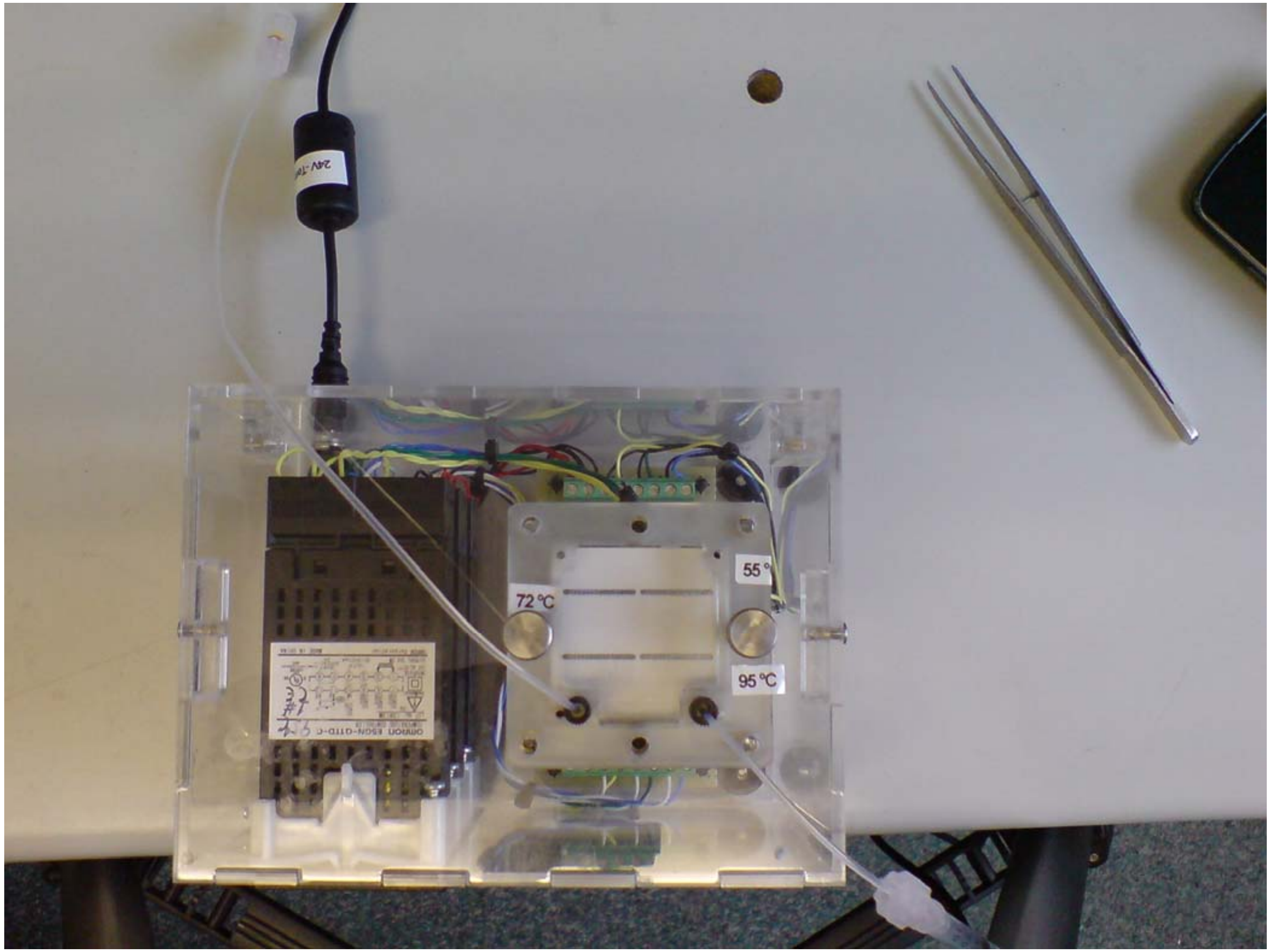
- Non-intrusive and stress-free way of examining
- Animal behaviour
- Thermoregulation
- Control of reproductive processes
- Disease diagnosis

DNA replication





DNA replication

- Copper

E= 0.04 → T= 117°C
E= 0.05 → T= 97.8°C
E= 0.06 → T= 88°C

- Aluminium

E= 0.05 → T= 104°C
E= 0.06 → T= 94.6°C
E= 0.07 → T= 84.4°C

Thanks

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