PD233: Design of Biomedical Devices and Systems

Lecture-9 Medical Diagnostic Imaging Ultrasound and Thermography

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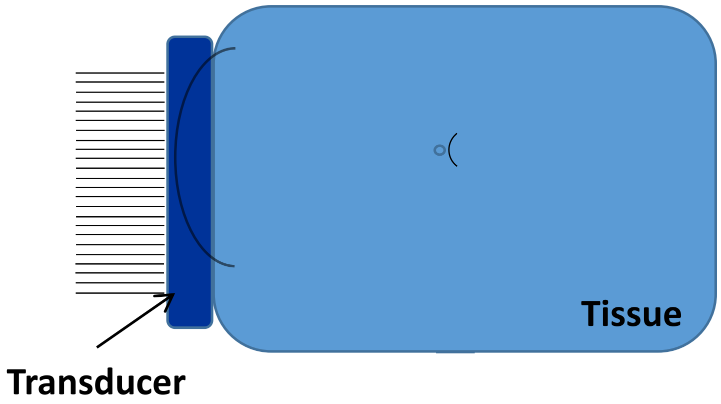
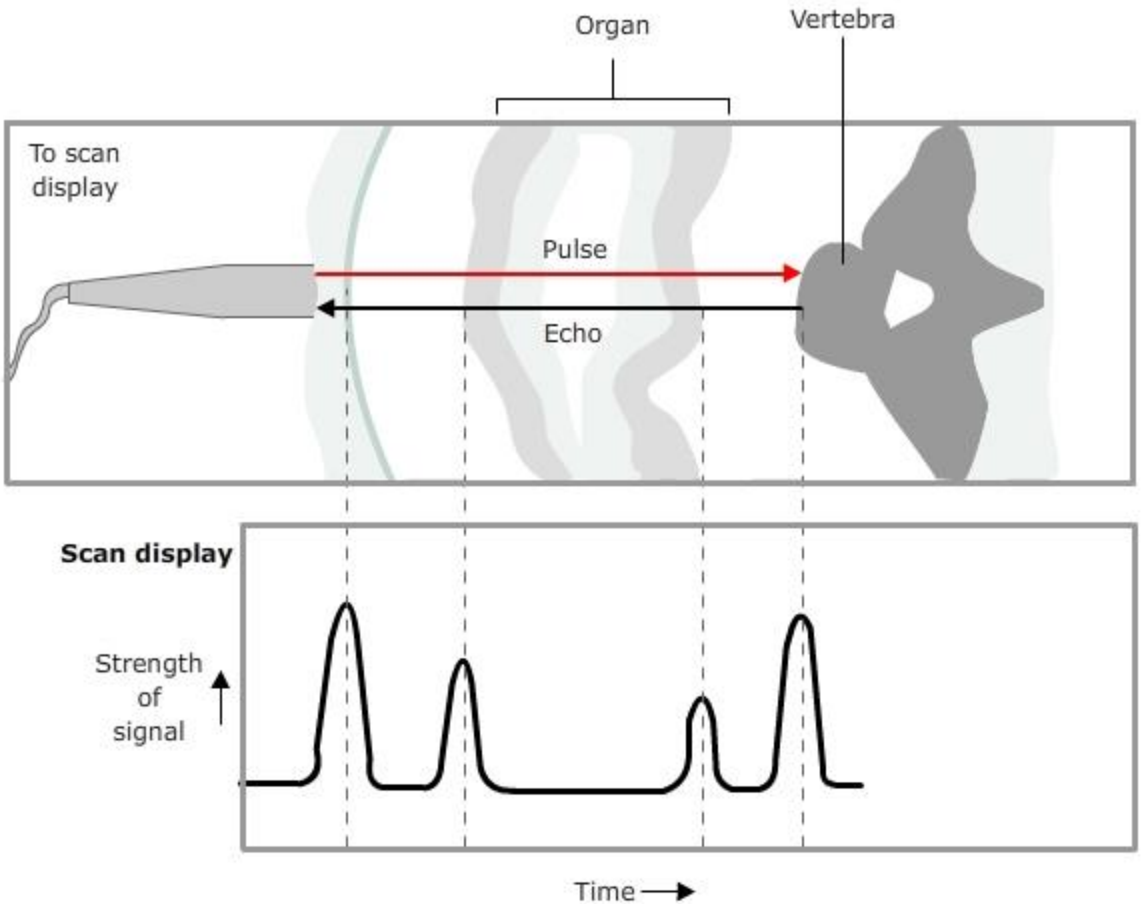
Course Website: http://cpdm.iisc.ac.in/utsaah/courses/

Ultrasound Physics

- Acoustic wave with frequency > 20kHz
- Part of ultrasound waves are reflected by interfaces and scatters
  - Basis for Ultrasonic Imaging



A-Mode Ultrasound



Distance of interface = Time of flight * Speed of Sound / 2

Applications: Measurement of thicknesses of cornea

Image credit: http://www.rcemlearning.co.uk

B-mode ultrasound

(Brightness mode)

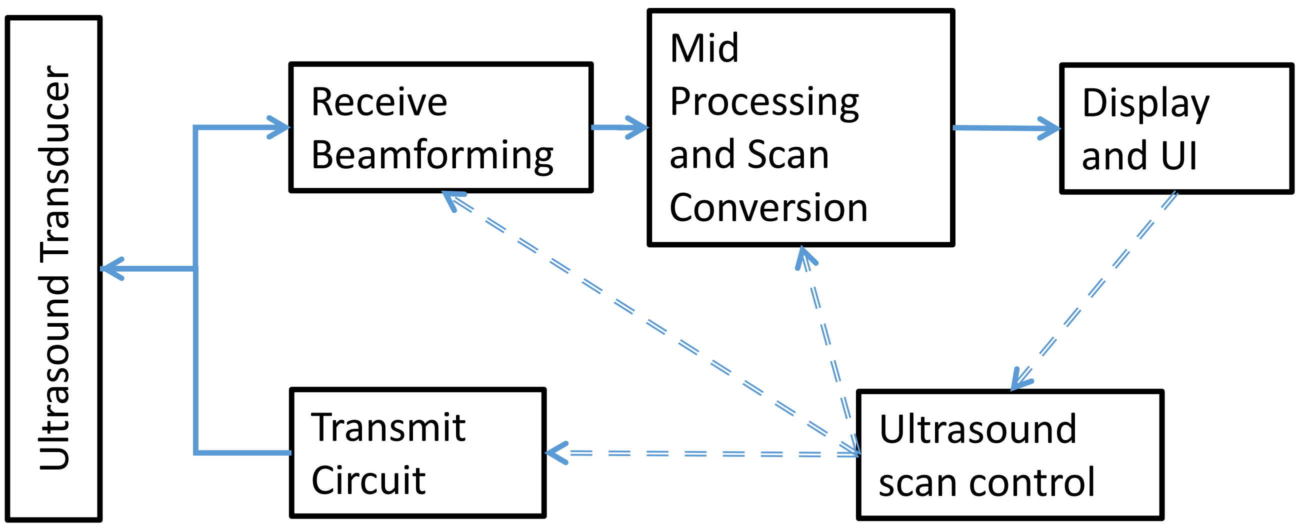
Mechanical Scanning

Electronic Scanning

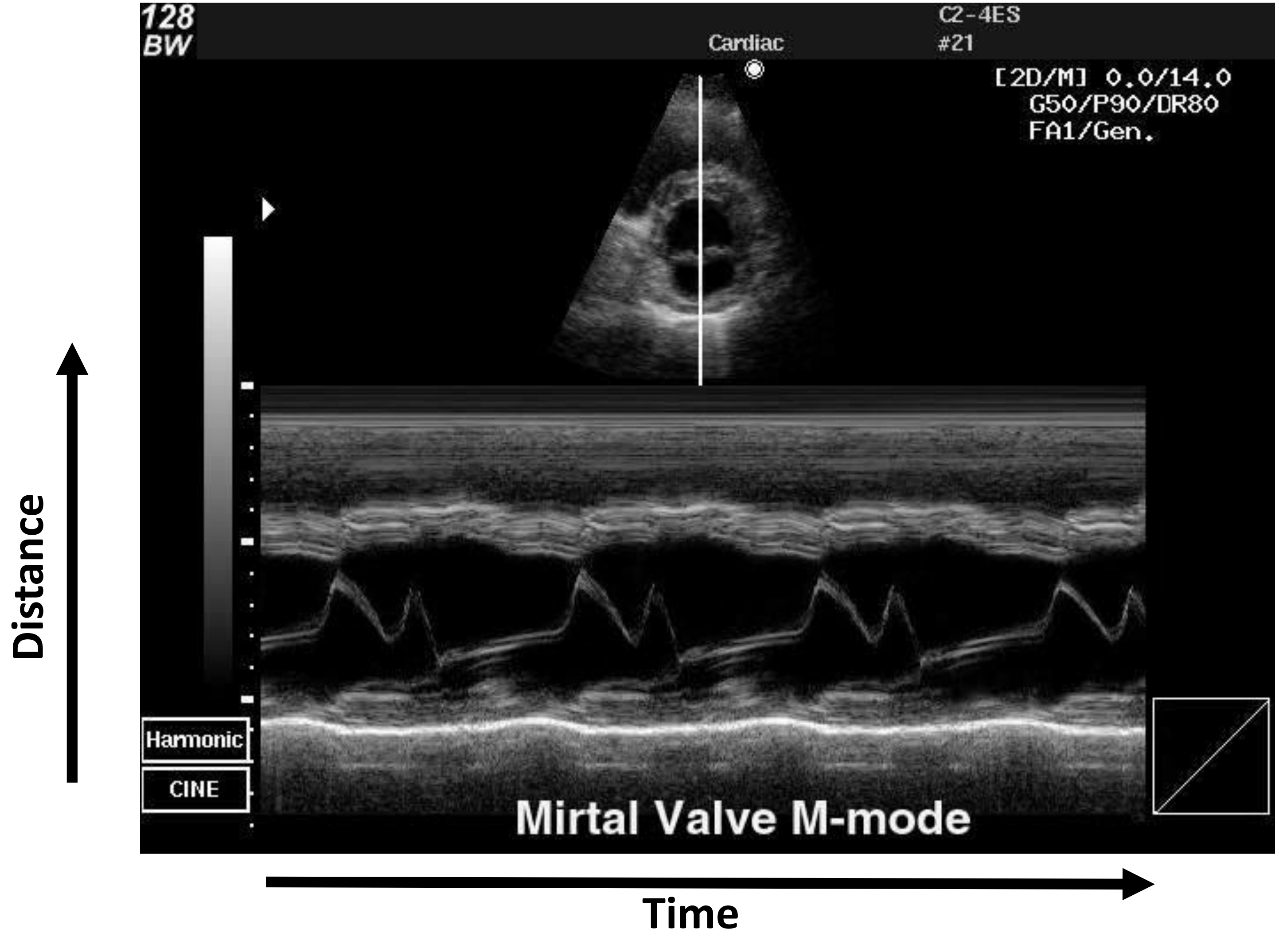

CRL
CRL
GA


9.1

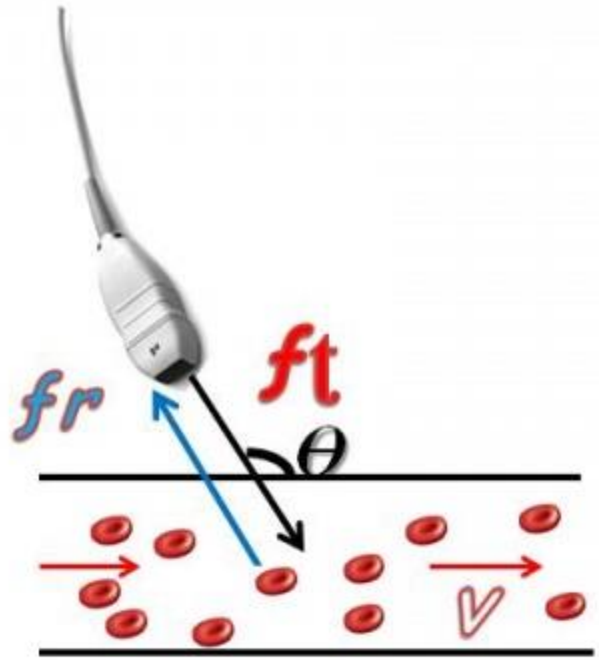
Imaging Ultrasound System Signal-chain



M –Mode Ultrasound



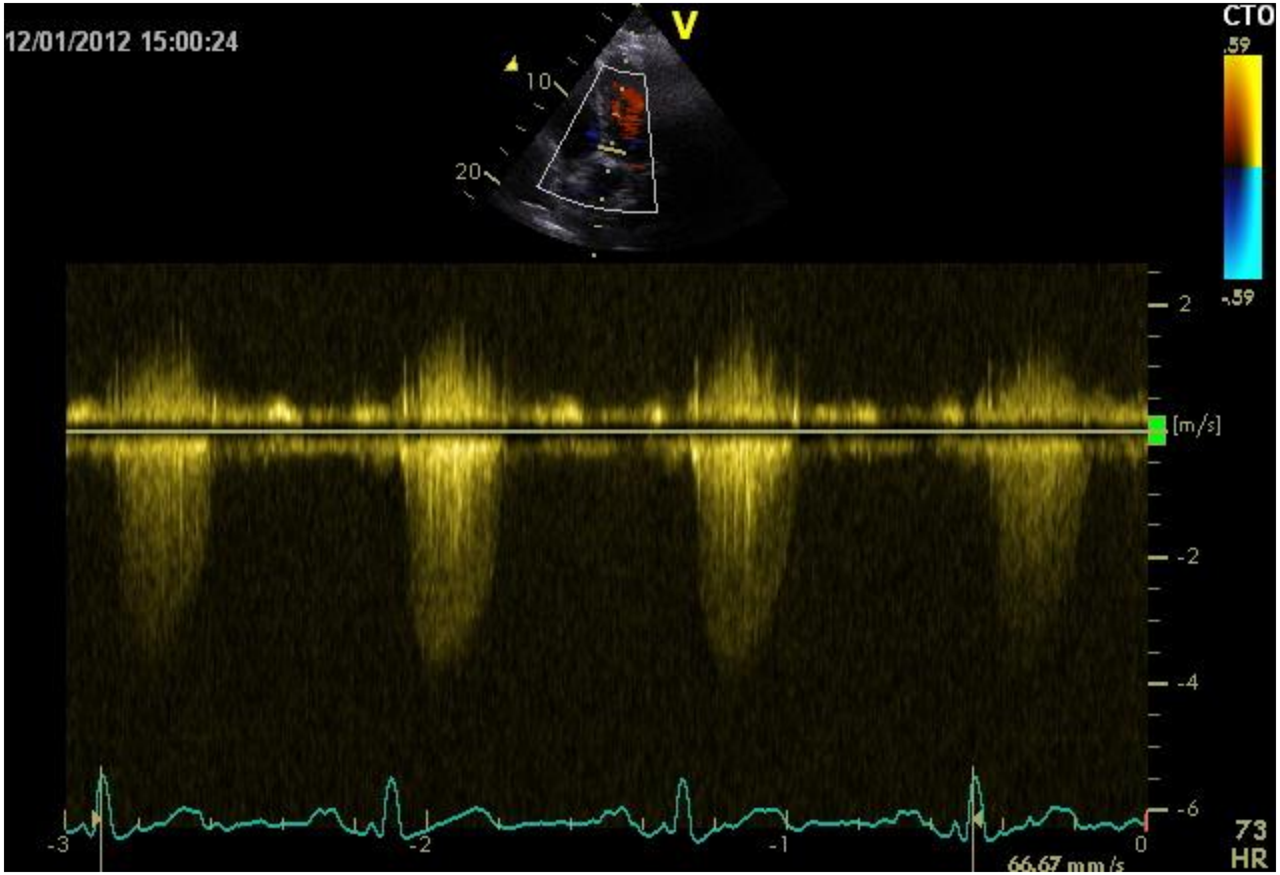
CW Doppler



$$\Delta f = f_t - f_r = \frac{2f_t \bullet v \bullet \cos\theta}{c}$$

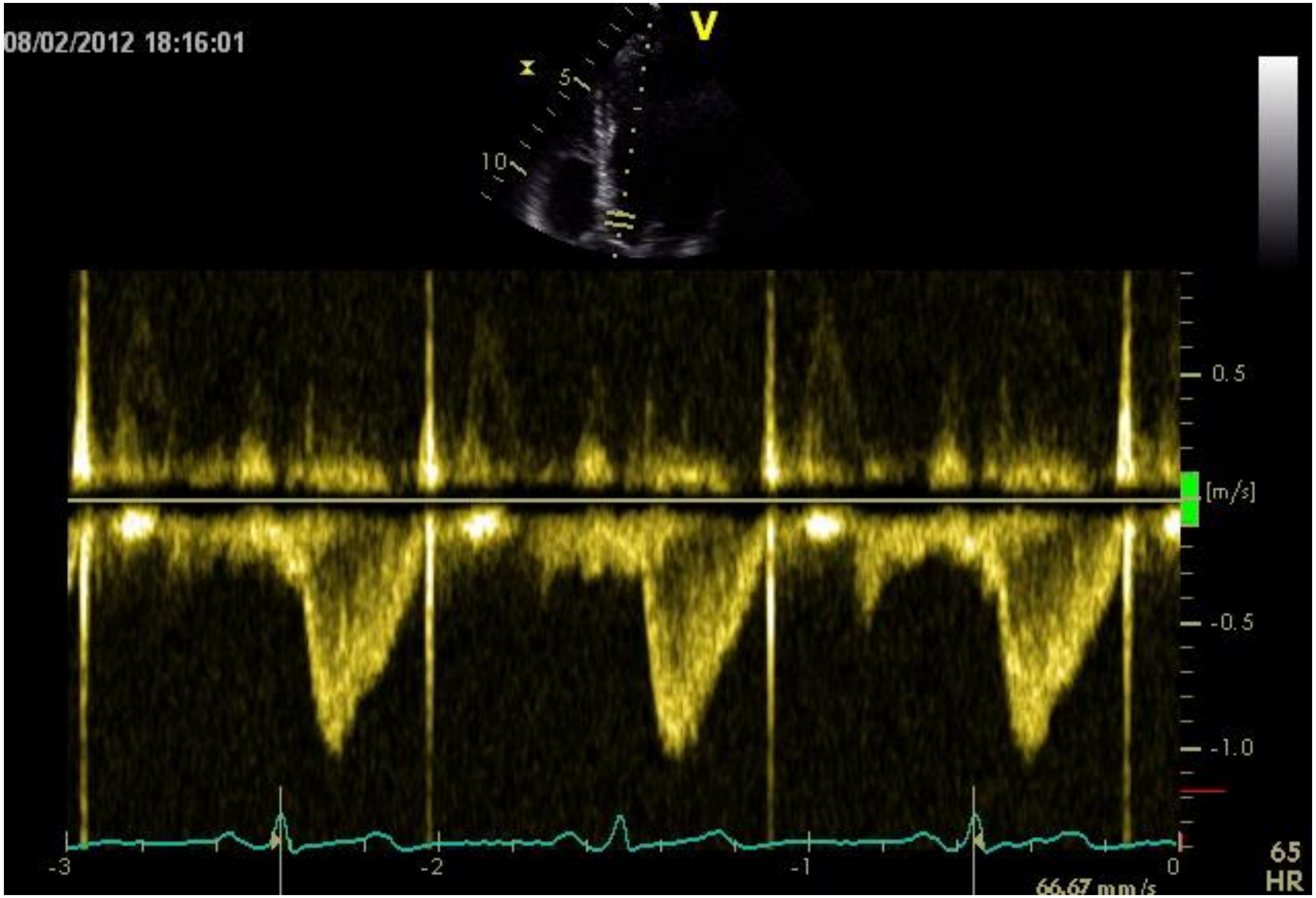
Image source: http://www.wikiecho.org

CW Doppler



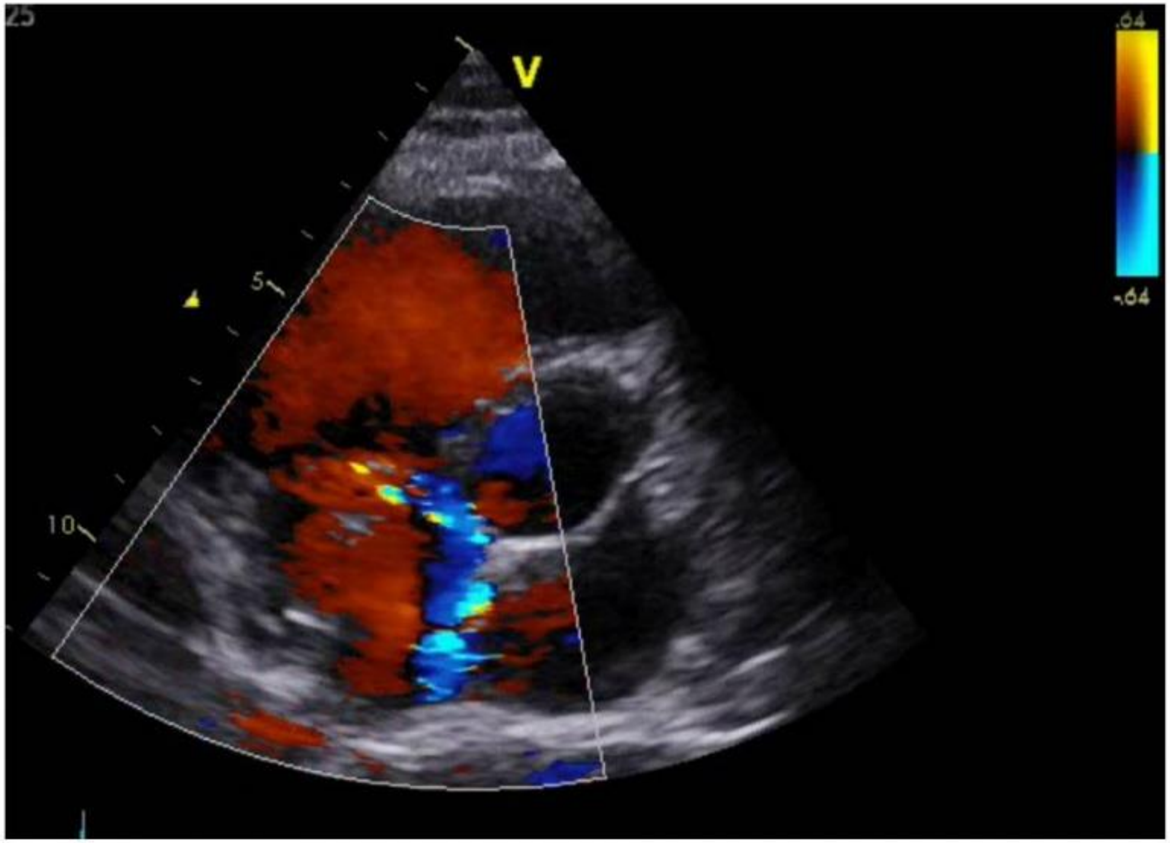
CW excitation and receive (half of transducer for each)
B-mode not available when doing CW Doppler
No depth information

PW Doppler



Doppler analysis in small window (range gated)
B-Mode available in Duplex mode

Color Doppler




Surface
Th33/Qual low
B108°/V85°
Mix24/76
V-SRI 6
3D Static
3D

Wireless probes

Siemens

Clarius

Wuhan Tianyi Electronic Co., Ltd.

Back to single element probe...

http://wiki.echopen.org/images/8/8c/Neasham2.jpg

Biological effects

Thermal Effects

-Tissue heating due to adsorption of Ultrasound

Thermal index (T.I.)

$= W_p/W_{deg}$

W_p= relevant (attenuated) acoustic power at depth of imaging

W_{deg}=estimated power for 1°C temperature rise.

Mechanical effects

- Due to cavitation – formation, oscillation and collapse of bubble due to high intensity pressure wave

-Mechanical index (M.I.)

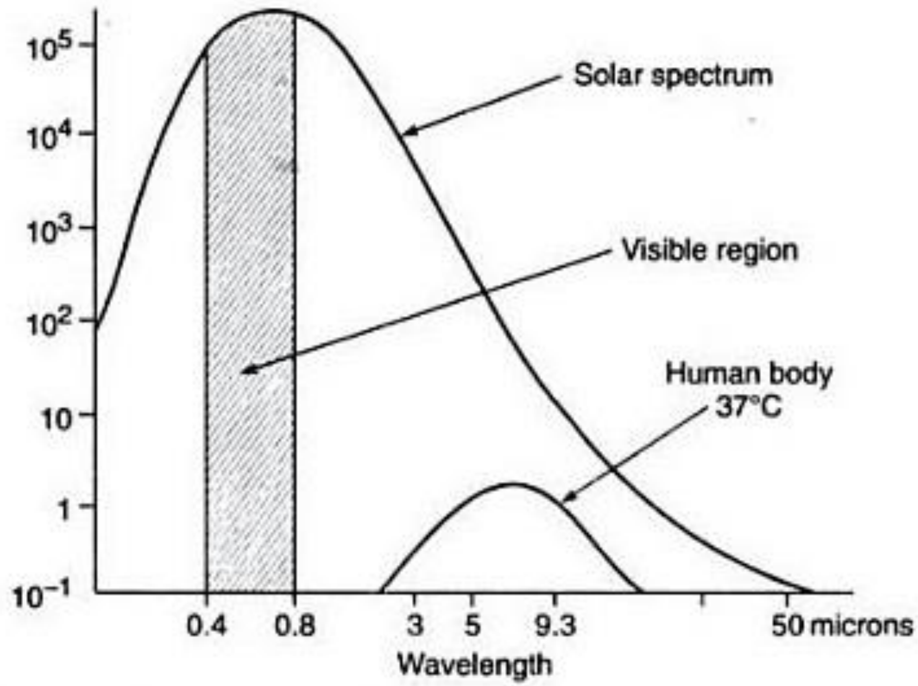
=peak rarefaction pressure/sqrt(centre frequency)

Pressure in MPa and frequency in MHz

What is Thermography?

- Imaging of temperature (differences) over the surface of skin
- Provides indication of metabolic processes
- Unlike radiography dose not provide anatomical information, just information about metabolic changes and circulation changes
- Human body absorbs all the infrared radiation and emits back depending on its own temperature

Physics of Thermography



Spectral distribution of infrared emission from human skin. The emission peaks at around 9 microns regardless of pigmentation

All object with Temperature > 0K emit radiation ➔ Black-Body radiation

$$W = \sigma\epsilon T^4$$

W= radiant flux density W/cm^2

ϵ = Emissivity factor

σ = Stefan –Boltzman constant

= 5.67 x 10^{-12} W/cm^2-K^4

T =absolute temperature

$$\lambda_{max} = \frac{2897\ (\mu m)}{T\ (K)}$$

Image source: Khandpur, pp671

Physics of Thermal Imaging

- Emissivity

The ratio of energy radiated per unit area by an object to energy emitted per unit area by a black body at the same temperature

$$\epsilon = \frac{W_o}{W_b}$$

Spectral radiant emissivity

$$\epsilon_\lambda = \frac{W_{o\lambda}}{W_{b\lambda}}$$

- Reflection

Ratio of reflected power to incident power

$$\rho_\lambda + \alpha_\lambda = 1$$

Since $\alpha_\lambda = \epsilon_\lambda$, $\epsilon_\lambda = 1 - \rho_\lambda$

- *Transmittance and Absorption* of infrared to be considered when semi transparent body is present between radiating object and detector

Thermal imaging systems

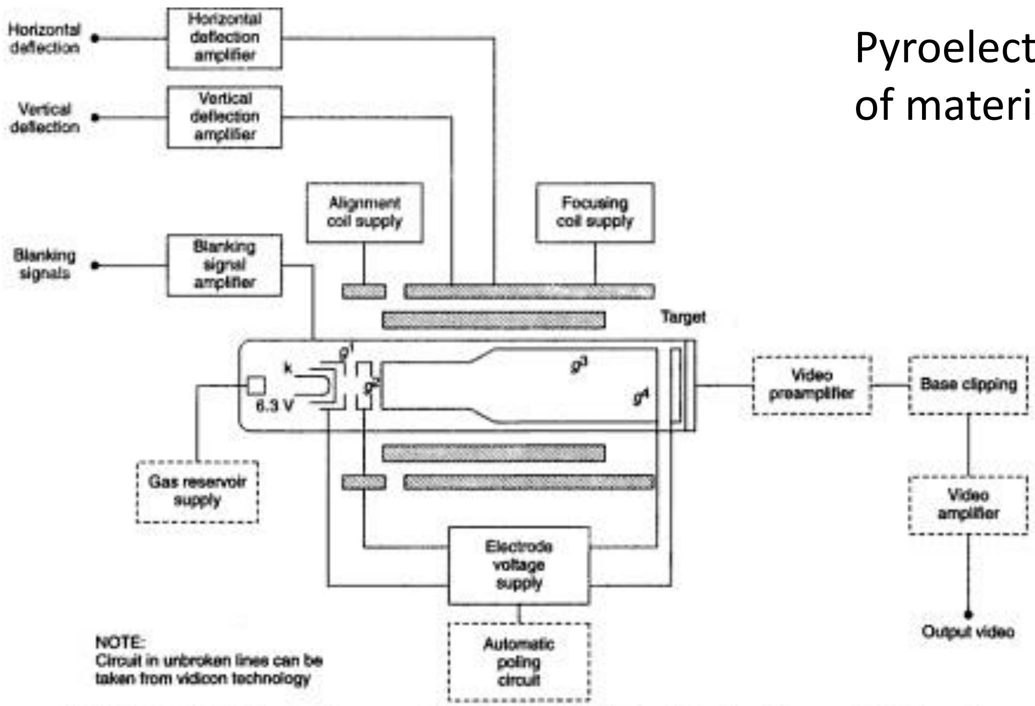
- Thermal Detector
  - depend on temperature change in detectors (e.g thermocouple and bolometer
  - Broad spectral response
  - Slow response
- Photodetector – like solar cells for Infrared

InSb (indium antimonide) sensitive in 2-6μm which has only 2.4% of energy emitted by human body

Clinically we are looking or temperature resolution of 0.5°C

Pyroelectric Vidicon Camera

Pyroelectric Vidicon Camera is modified cathode ray tube similar to old days video cameras to used record Infrared



➤ **Fig.** 24.8 ***Block diagram of camera electronics used with Pyricon (Courtesy: Thomson CSF, France)***

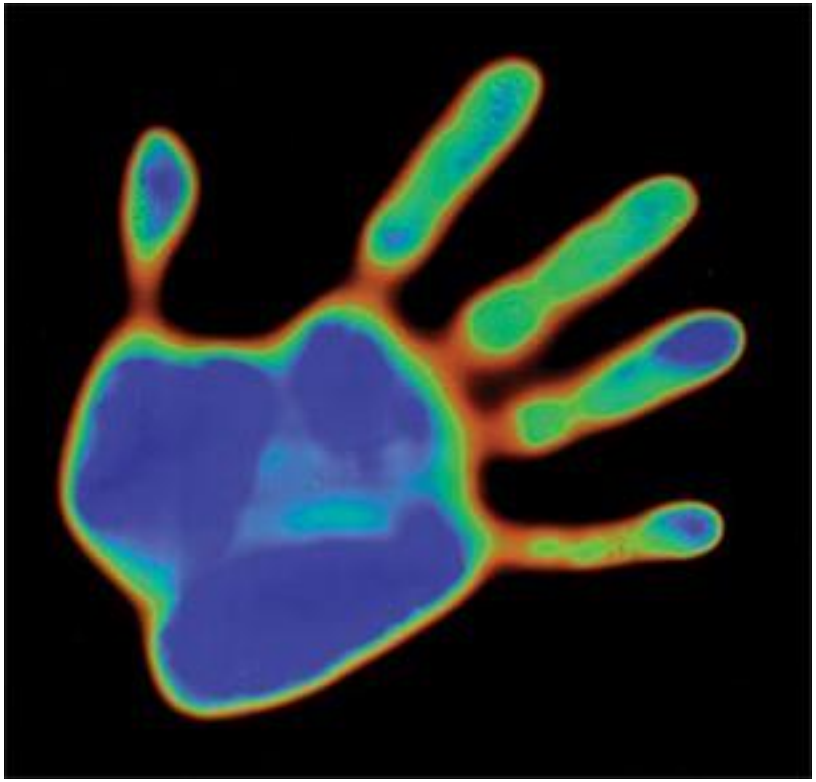
Pyroelectric effect change in polarization of material due to temperature change

Sensitive to changing temperature not absolute temperature

Hence the incoming radiation should be chopped or camera panned

Liquid Crystal Thermography

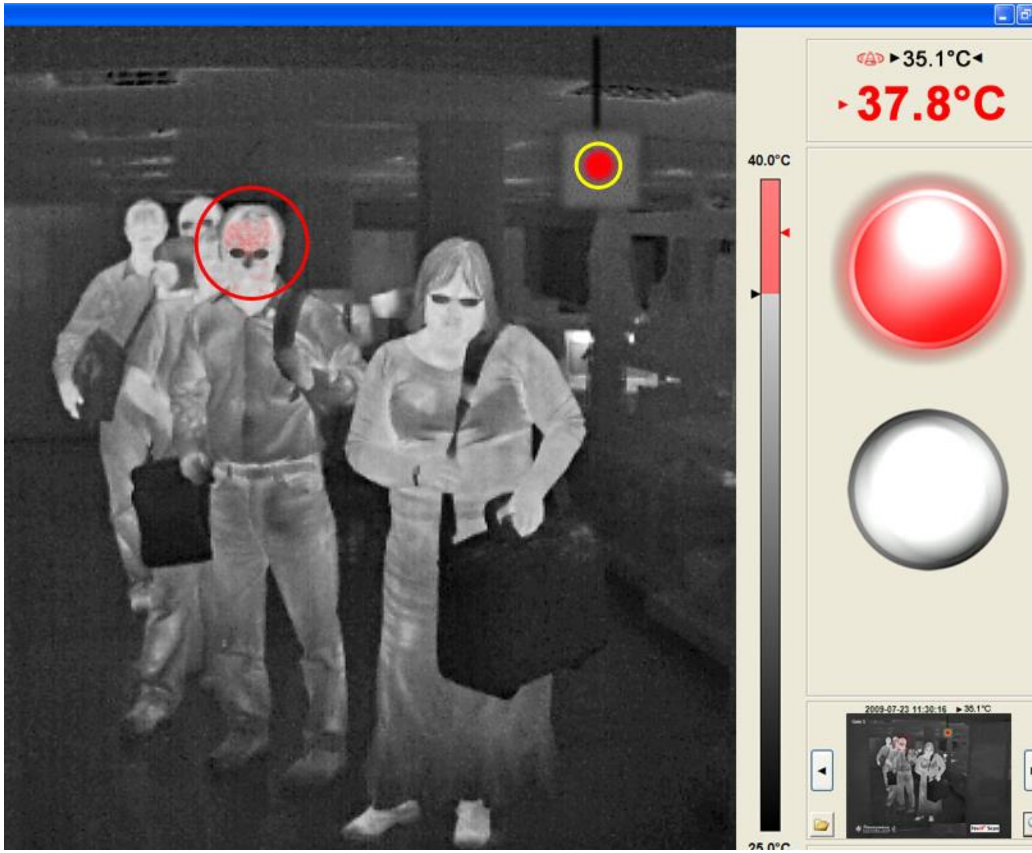
Liquid Crystals show changes in color due to change in temperature. This technology has wide ranging applications but also has been applied to medical diagnostics.



LC are applied to skin surface in conforming manner and imaged using regular camera or eye to reveal temperature changes. Compared to thermal imaging camera is more sensitive.

Digital IR cameras

- Ebola/H1N1 Screening at airports - uses IR cameras
- Though CMOS sensors are not optimum for 10um infrared they are highly sensitive to pick up temperature rise in range 0.5C
- Used together with calibrated blackbody source



Diagnostic Radiology

Thermography, Mammography, and Clinical Examination in Breast Cancer Screening LEGACY

Review of 16,000 Studies[1]

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Gary S. Shaber, M.D., , Gordon F. Schwartz, M.D., , Arthur Patchefsky, M.D., , Herman I. Libshitz, M.D.[2], , Jack Edeiken, M.D., , Rudolph Nerlinger, B.S., , Robert F. Curley, B.S., , and John D. Wallace, A.B.[3],

DOI: http://dx.doi.org/10.1148/122.1.123

Abstract Cited by PDF

Breast cancer screening detected 139 biopsy-proved malignancies in 16,000 self-selected women (8.7/1,000). In these, xeroradiography detected 78% (109), clinical examination 55% (76), and thermography 39% (54). In all 16,000 women, the thermogram was interpreted as positive in 17.9% (2,864). The greatest effectiveness of mammography *vs.* clinical examination was seen in detection of early breast cancers (small lesions with negative axillary lymph nodes). In this group, thermography was less effective than it was in patients with larger lesions and lymph node metastases.

Keywords: Index terms (Breast, special procedures 0[0].120) ; Breast neoplasms, diagnosis ; Mammography ; Thermography ; Xeroradiography

Assignment 3

Q1: Calculate TP,FP, TN,FN.

What is sensitivity and specificity of thermography for breast cancer screening?

Q2: Critically compare the results of Q1 recent claim of Indian med-tech startup Niramai which claims 98% Sensitivity and 68% Specificity.

https://waset.org/publications/10008935/thermalytix-an-advanced-artificial-intelligence-based-solution-for-non-contact-breast-screening

What design/technological innovation could be responsible for possible improvement?