2D Medical Image Acquisition summary

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2D Medical Image Acquisition

- **Introduction**
- Radiography
  - Conventional Radiography (X-Ray)
  - Fluoroscopy
- Ultrasonography
- Nuclear Scan
  - Scintigraphy
- Elastography
- Photoacoustic Imaging
  - Photoacoustic Microscopy (PAM)

Introduction

The basic concept of a medical imaging system is shown in Figure 1.1. The basic elements are a sensor that directs energy to the human body causing the production of signals depending on the density and atomic number of tissues. These signals are recorded by a detectors and with mathematical algorithms give us the medical image [KAS15].

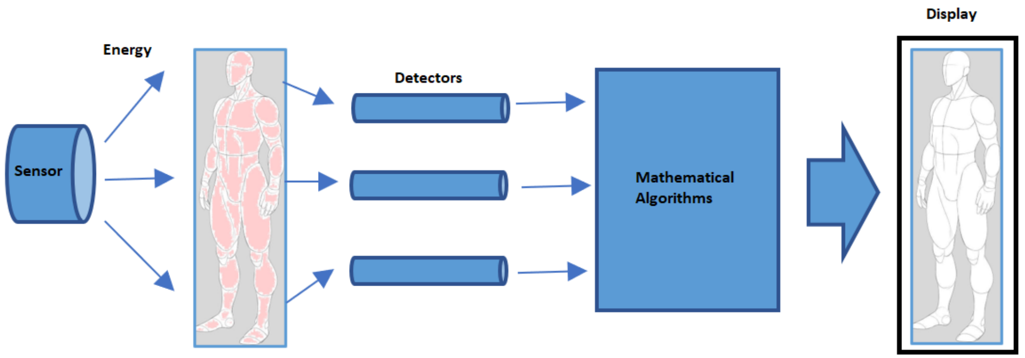

Figure 1.1: Medical Imaging System.

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Radiography

- Radiography is a commonly used technique to diagnose structural damages or abnormally of human body. During the radiographic scan an x-ray beam passes through the body. A portion of the x-rays are absorbed or scattered by the internal structure and the remaining x-ray pattern is transmitted to the detector. The recorded image of the body may occur on film or through electronic means [FDA].

Conventional Radiography

Conventional Radiography uses x-rays to create two-dimensional (2D) images. Radiographs generally use x-rays. The x-rays are created by x-rays generators, which generate x-rays from x-ray tubes. X-rays result from the conversion of the kinetic energy into electromagnetic radiation. This phenomenon occurs when electrons accelerated under a potential difference because of collisional and radiative interactions [SEI04].

Conventional Radiography

The following image presents the structural components of an x-ray generator and an x-ray tube [SEI04].

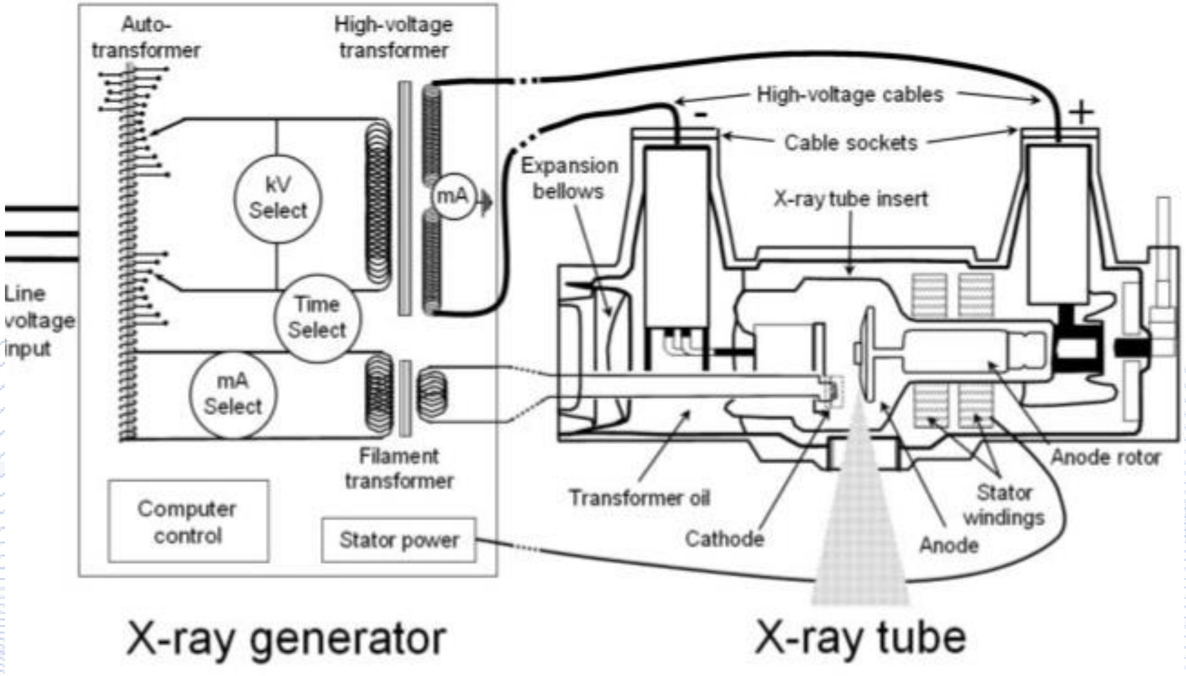

Figure 1.2: X-ray generator and x-ray schematic diagram [SEI04].

Conventional Radiography

X-rays interact with matter following the Beer's law:

$$I = I_o e^{-\mu t}$$

where I_o is the number of x-rays entering in the object, I is the number of x-rays exiting an object, t is the thickness and μ is an intrinsic property of the material. It's a physical value and called linear x-ray attenuation coefficient. This relationship is frequently termed exponential attenuation [BRY09].

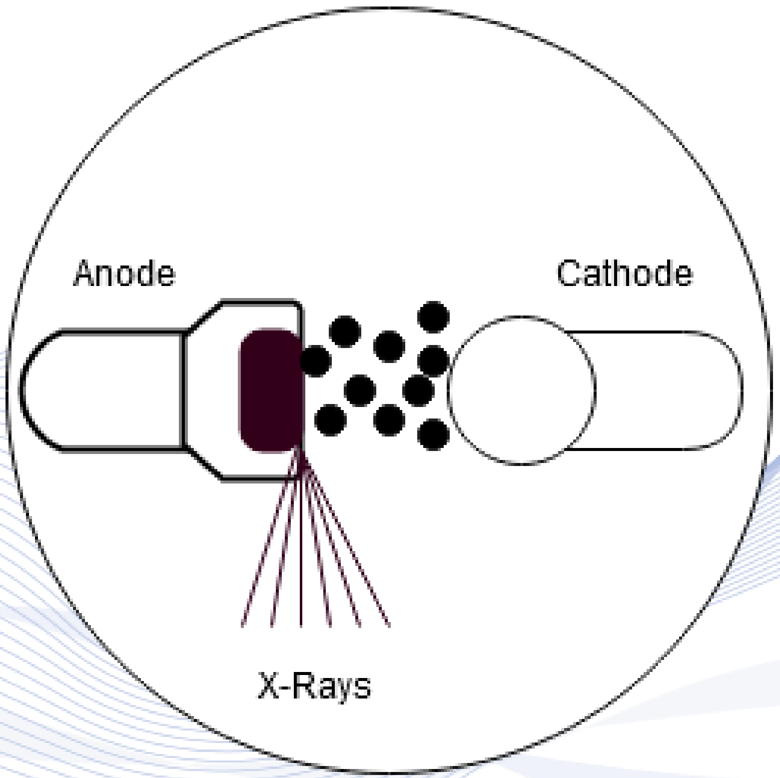

Figure 1.3: Inside the x-ray tube.

Fluoroscopy

Fluoroscopy is a medical imaging technique which produces real-time images of internal the body. It works in the same way like radiography, but generates x-rays, at a lower dose rate to provide moving projection radiographs of lower quality. Fluoroscopy it is used to view the movement of tissue or to guide a medical intervention. Based on these capabilities some applications are angiography or joint replacement [PHY].

Fluoroscopy

Fluoroscopy is useful for digestive system examination using a substance like barium sulfate or gastrografin which is introduced into the digestive system. This technique is supported on double contrast by using positive and negative contrast [PHY].

Fluoroscopy

In modern Fluoroscopy systems, the fluorescent screen is connected to a device which amplifies and transforms the glowing light into a video signal. The produced is presented on a monitor and provides the appropriate data to complete the examination/treatment process [GIN14].

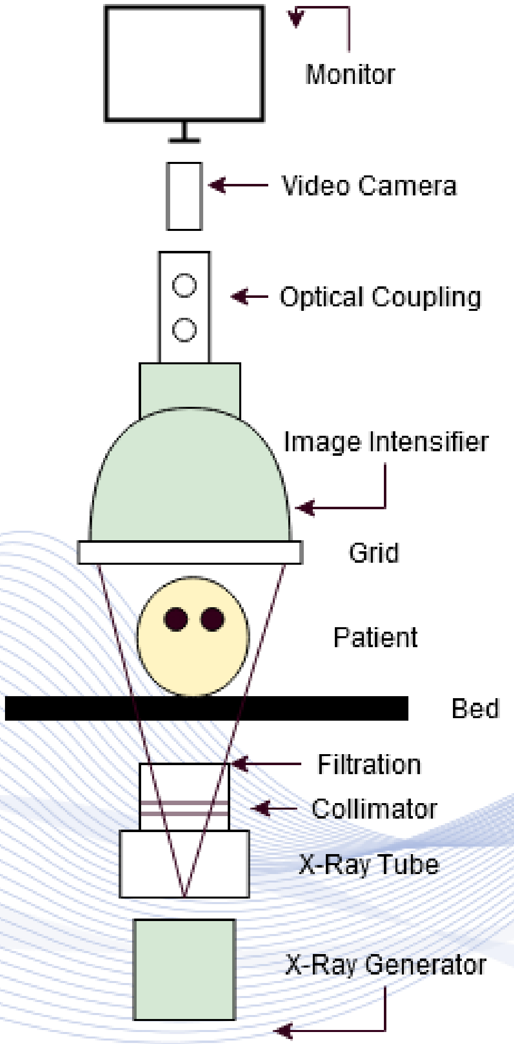

Figure 1.5: Diagram of a fluoroscopic system.

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Ultrasonography

The Ultrasound (US) imaging technique uses high-frequency sound waves that are above the range of human hearing. The emitted frequencies are higher than 20 kHz. Medical ultrasound imaging is performed at higher frequencies than kHz, typically in the MHz range.

Ultrasonography

Ultrasound is different from other conventional imaging methods because of the following two ways.

- **First**, ultrasound waves are non-ionizing pressure waves in compare with the electromagnetic radiation.

- **Second**, the ultrasound uses the reflection mode to record signals and not the transmission mode which is used for x-ray and Computed Tomography imaging.

Ultrasonography

The image is created by longitudinal mechanical waves which interact with the tissues of the body after a pulse echo is first sent. The applied energy is reflected to the source by tissue inhomogeneities. The information contained in the signals concerns the source and the medium in which they were disseminated. In order to produce an image, decoding of the signals is required. This is done by separating the detected signals from the source and the medium (tissue) [BRY09].

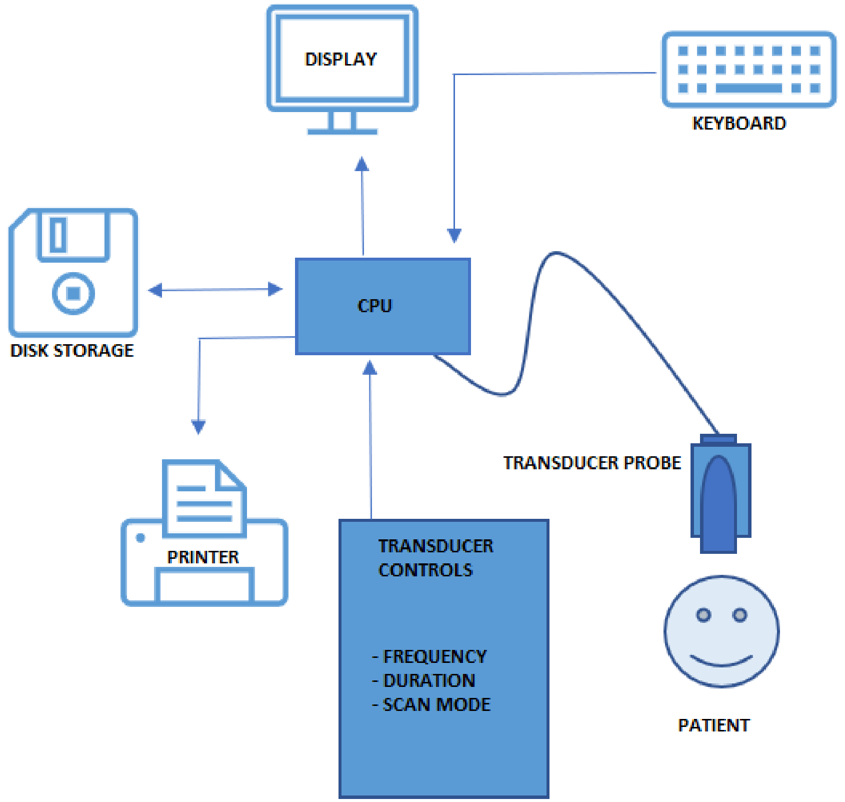

Figure 1.8: Diagram of an ultrasound machine

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Ultrasonography

A piezoelectric crystal-based transducer plays the role of the source to form an ultrasound beam like a detector to which is used to receive the returned signal from the tissue. A piezoelectric crystal is formed in a plastic case and is used along with a damping material layer and acoustic insulation layer inside the plastic casing. The electromagnetic tuning coil controls the voltage pulse to produce ultrasound waves [DHA11].

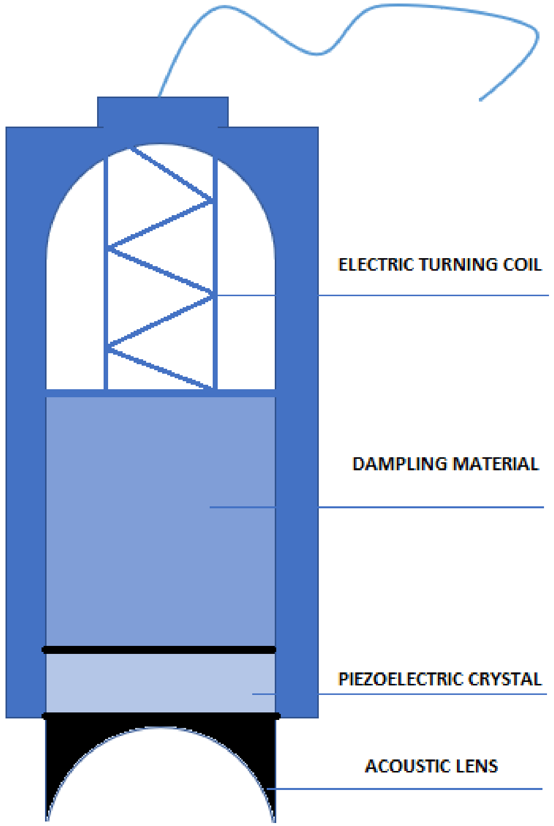


Figure 1.9: A schematic diagram of an ultrasound single-crystal transducer.

Ultrasonography

Figure 1.10 shows the far-field effect of the ultrasound beam which is diverging with an angle. This angle is formed from the following equation [DHA11]:

$$\theta = \arcsin\left(\frac{0.61\lambda}{r}\right)$$

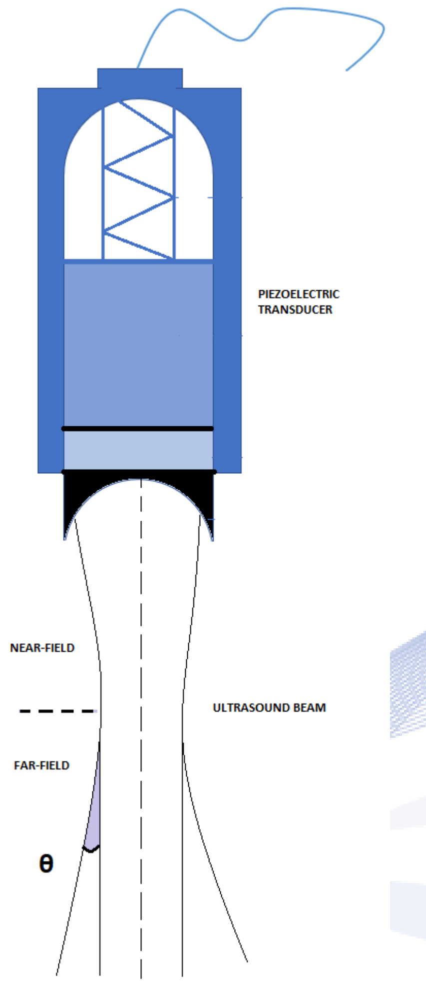


Figure 1.10: Ultrasound beam from a piezoelectric transducer.

Ultrasonography

- **Doppler Mode**

In Figure 1.11, Doppler shift is measured by comparing the incident ultrasound frequencies with the reflected ultrasound frequency from the blood [BRY09].

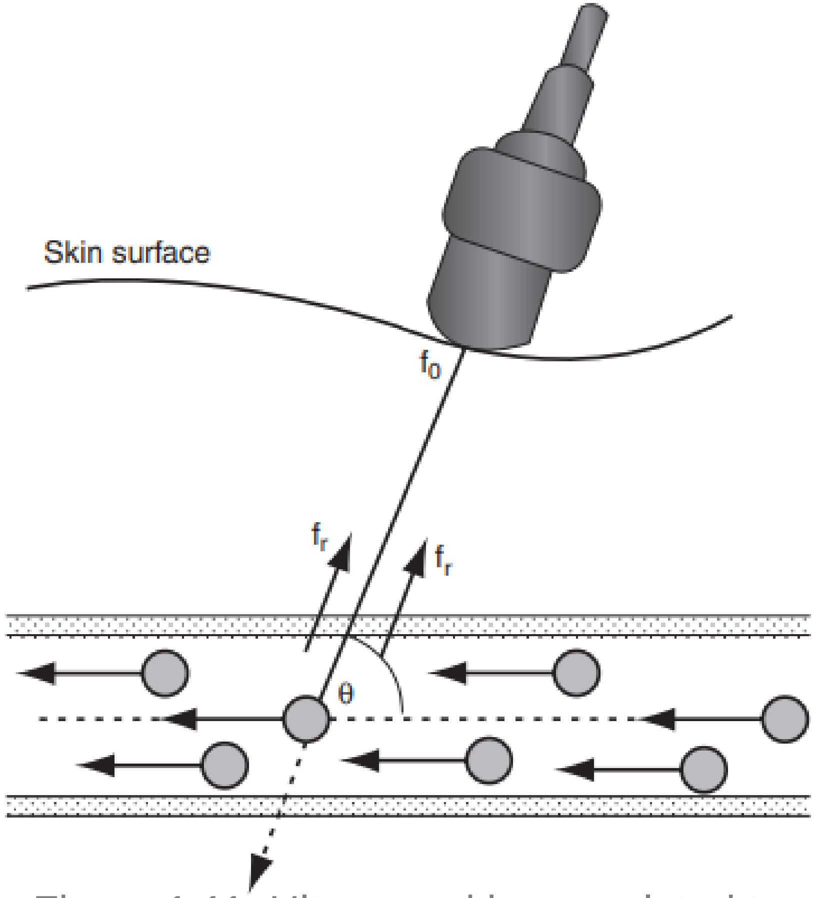
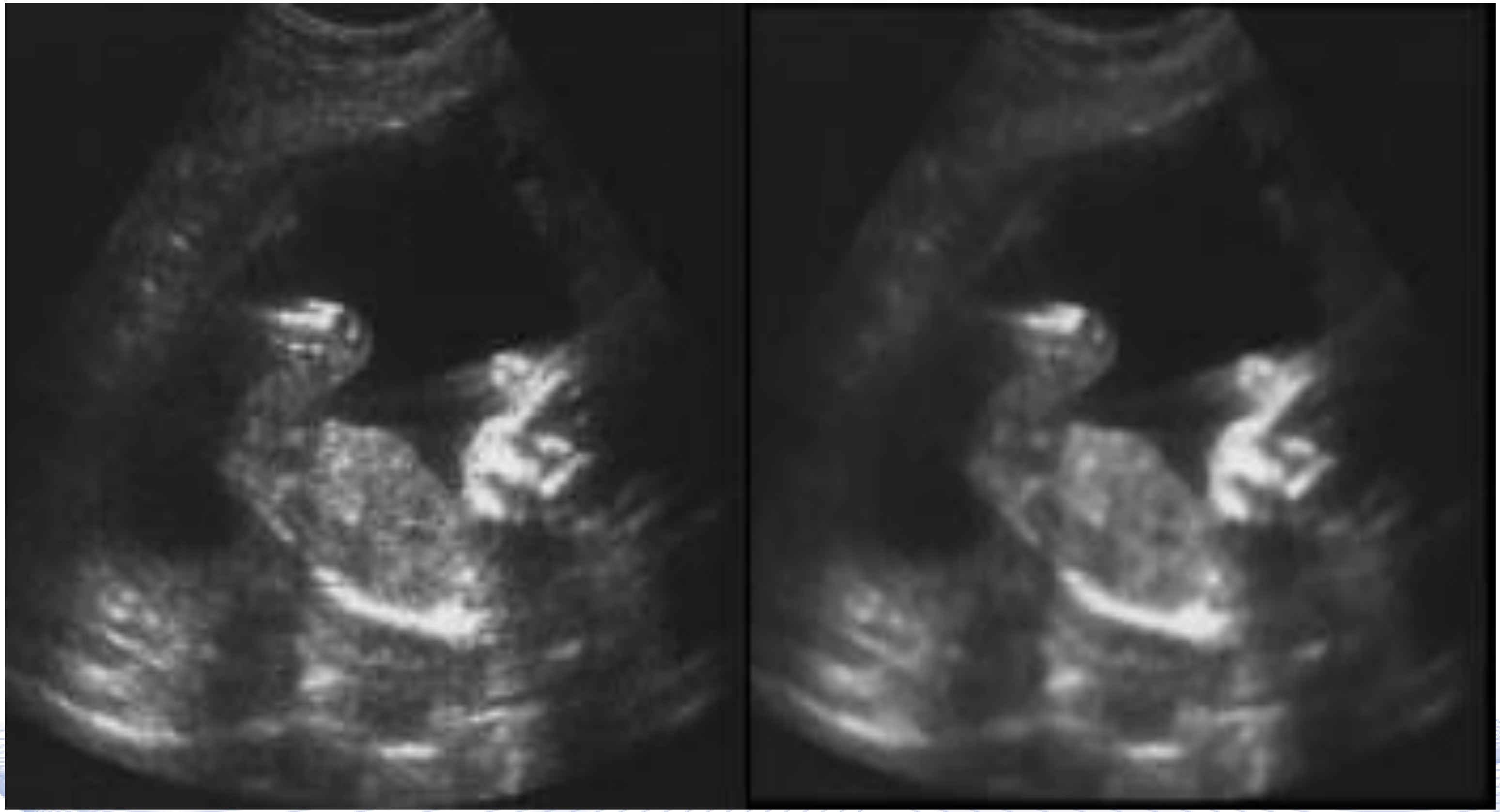


Figure 1.11: Ultrasound beam related to blood flow and Doppler flow measurement [BRY09].

Ultrasonography



a) Ultrasound image; b) noise filtering [PIT2000].

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Nuclear Scan

Nuclear medicine imaging is a diagnostic technique that uses small amounts of radioactive material for internal body images generation.

Initially, small amounts of radioactive isotopes are injected. These isotopes are bound by the organs and tissues of the human body.

As soon as the tissue absorbs the radioactive isotope, it starts emitting radiation which is received by special detectors. These transmissions that get through the scanner reach a computer and are converted into an image [ΚΑΣ15].

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Scintigraphy

The use of limited number of radio-actives combined with rectilinear scanners stopped after the invention of the gamma camera. The gamma camera offered a better resolution image thus increasing diagnostic capacity [CAR12].

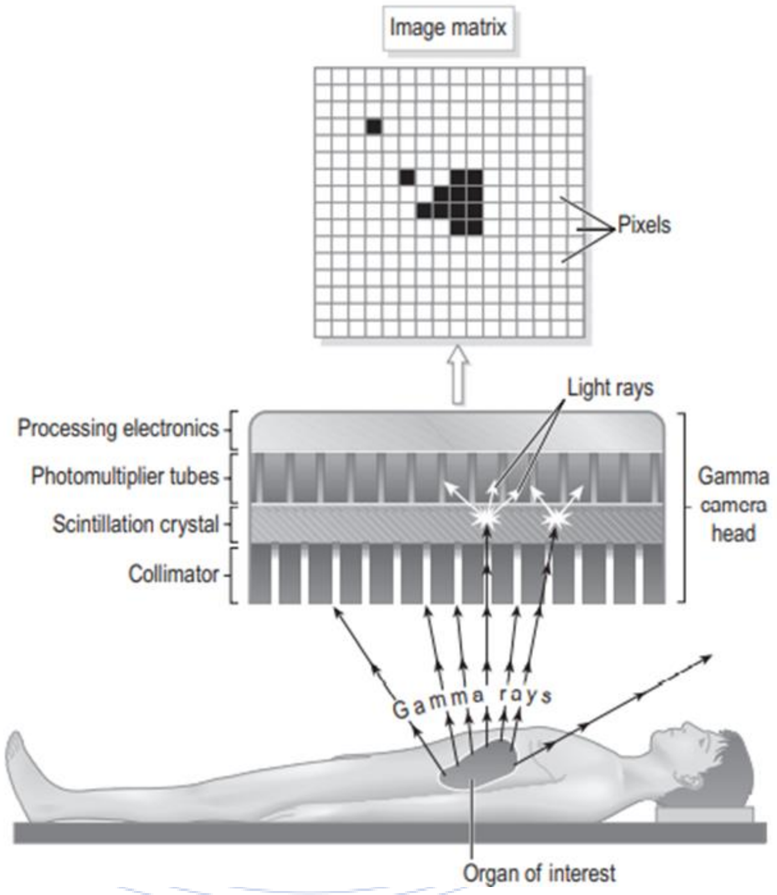

Figure 1.12: Schematic diagram of a gamma camera [CAR12].

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Elastography

The change in tissue elasticity is the main stimulus for elastography. These contractions can result from injuries or other processes in the body. The main use of elastography is to examine the elasticity of the medium, the ability to resist any deformation due to force exerted or to return to the initial state after removal of the force [SIG17].

Elastography

There are two types of wave propagation

1. **Longitudinal waves**

2. **Shear waves**

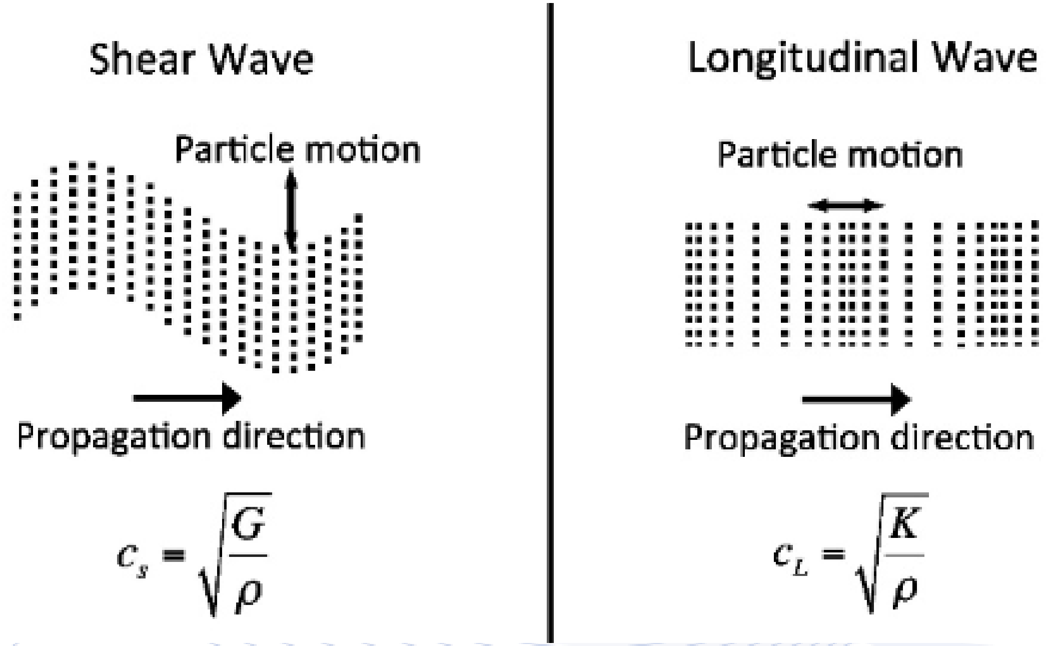

Figure 1.14: Ultrasound elastography methods [SIG17].

Elastography

B. Shear wave Imaging

After shear interaction, the tissue will return to the original shape, while the adjacent layers undergo shear, and there will be further shifting of the shear wave, which propagates as a transverse shear wave [TAL17].

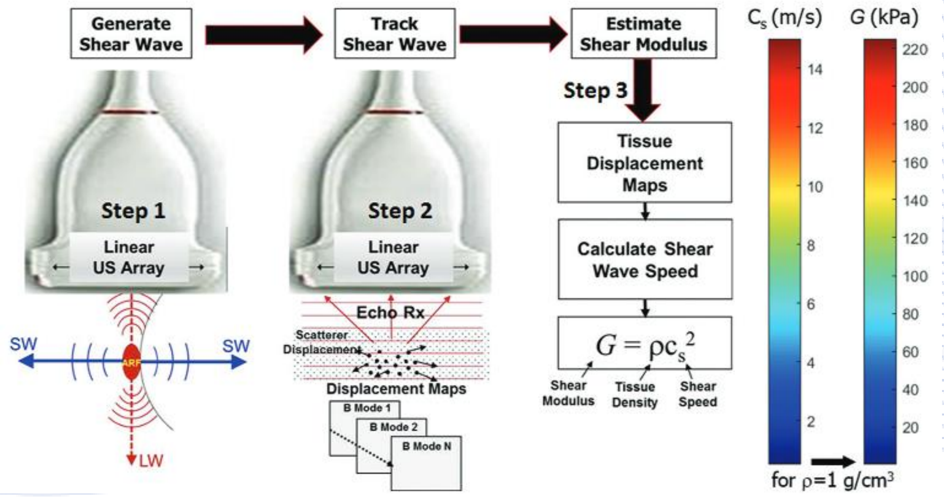

Figure 1.15: Physics of Shear Wave Imaging [TAL17].

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Photoacoustic Imaging

Photoacoustic Tomography (PAT) is one of the fastest growing technologies for medical imaging. The features of a PAT system combine optical excitation and acoustical detection, leading to the following three features [LWY18].

- **First**, PAT relies on optical absorption, hence it can provide high-contrast spectral properties of biological tissues, including the physiological functions and the molecular compositions.

Photoacoustic Imaging

- **Second**, PAT detects the local acoustic pressure induced by pulsed-laser excitation. Thus, provides large penetration depth, as acoustic pressure waves has two to three orders of magnitude less attenuation than light in tissues.

- **Third**, PAT system is scalable and combines different light delivery and acoustics detection methods, thus it can perform multi-scale imaging with flexible spatial resolution and penetration depth.

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Photoacoustic Microscopy

The main features of a Photoacoustic microscopy system are optical stimulation and acoustic detection. The PAM signals are generated by optical absorption of the target. If the optical excitation is satisfied by the stress and thermal confinements, the generated initial acoustic pressure amplitude can be expressed as [LWY18]:

Photoacoustic Microscopy

In PAM, the implementations of focused optical excitation and acoustic detection are similar to confocal microscopy. The confocal configuration is maximized by the detection sensitivity. In Figure 1.16 is illustrated the typical setups of OR-PAM and AR-PAM [LWY18].

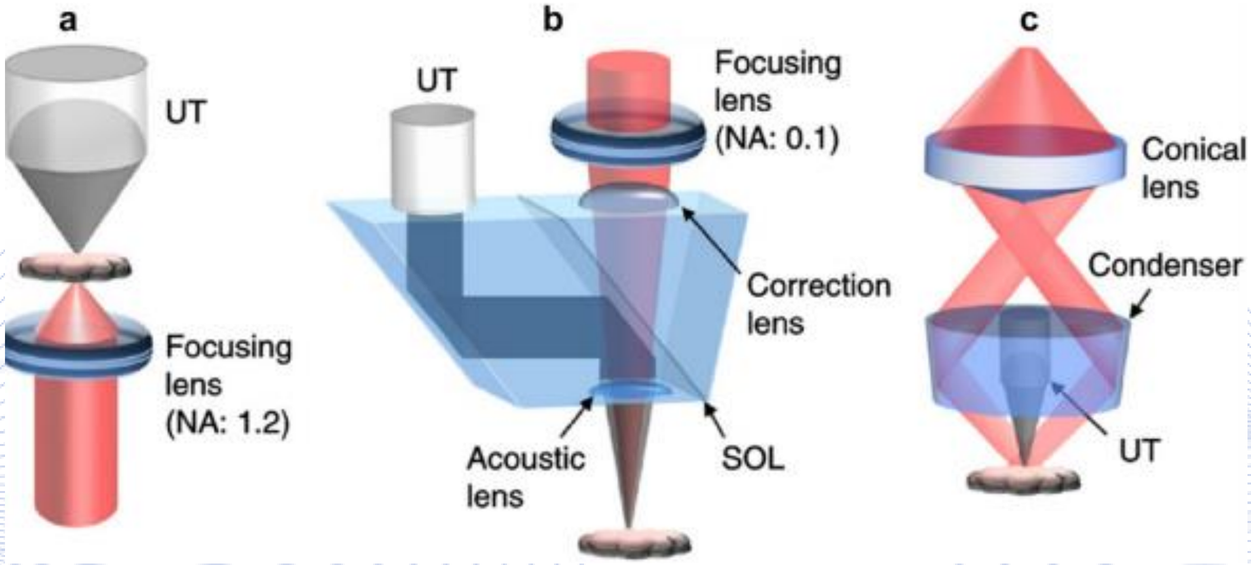

Figure 1.16: The schematic diagrams of PAM systems [LWY18].

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Q & A

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