- HW 5 AVAILABLE
- HW 3, 4 AVAILABLE THIS WEEK (GRADED)
- HW 5 AVAILABLE BY END MONDAY
- MIDTERM NEXT WEEK, REVIEW SHEET BY FRIDAY
- ADVANCED LECTURE, STARTING NEXT WEEK, TIME TBD.

X-RAY COMPUTED TOMOGRAPHY (CT):

- PRODUCE CROSS-SECTIONAL IMAGES, NOT PROJECTIONS!
- FROM GREEK τομος (SLICE) AND γραφειν (TO WRITE)
- USING A THIN x-ray BEAM, A SET OF LINES IS SCANNED COVERING THE ENTIRE FOV
- PROCESS REPEATED AT DIFFERENT ANGLES

HISTORY:

- WILHELM RÖNTGEN, 1895 DISCOVERS x-rays, 1ST NOBEL PRIZE IN PHYSICS IN 1901
- RECONSTRUCTION FROM PROJECTIONS: JOHANN RADON IN 1917

BEFORE COMPUTED TOMOGRAPHY (CT):

① LINEAR OR MOTION TOMOGRAPHY: SOURCE AND DETECTOR MOVE AT CONSTANT SPEEDS IN OPPOSITE DIRECTIONS.

② AXIAL TRANSVERSE TOMOGRAPHY: PATIENT AND FILM ROTATE IN SAME DIRECTION, FILM PLACED HORIZONTALLY AND SLIGHTLY BELOW FOCAL PLANE.

- FIRST CT SCANNER (THE EMI SCANNER) DEVELOPED BY GODFREY HOUNSFIELD IN 1972, BASED ON MATHEMATICAL & EXPERIMENTAL METHODS DEVELOPED BY A.M. CORMACK A DECADE EARLIER. (SHARED NOBEL PRIZE IN MEDICINE & PHYSIOLOGY IN 1979).
- ROBERT LEDLEY: 1ST WHOLE BODY CT SCANNER IN 1974
- SPIRAL CT: 1989
- MULTI-SLICE CT: 1998

MODERN CT SCANNERS:

- TYPICALLY 512 x 512 PIXELS
- IMAGE SHOWS THE CT NUMBER, EXPRESSED IN HOUNSFIELD UNITS (HU).

$$\text{CT NUMBER (IN HU)} \equiv \frac{\mu - \mu_{H_2O}}{\mu_{H_2O}} \cdot 1000$$

μ IS LINEAR ATTENUATION COEFFICIENT

WITH THESE UNITS, WE HAVE CT NUMBERS OF:

AIR $\approx$ -1000 HU
WATER = 1 HU
BONE $\approx$ 1000 HU

DYNAMIC RANGE IS LARGE. NEED TO WINDOW.

DETECTORS:

- DETECTORS TYPICALLY USE SCINTILLATING CRYSTALS (SODIUM IODIDE, CADMIUM TUNGSTATE, BISMUTH GERMANATE, ETC.) THAT PRODUCES LIGHT FROM X-rays (MAINLY VIA PHOTOELECTRIC EFFECT)
- LIGHT FROM SCINTILLATING CRYSTALS IS THEN CONVERTED TO ELECTRICITY USING:
  - SOLID STATE PHOTO DIODES ← Q.E. OVER 98% / VERY FAST
  - PHOTOMULTIPLIER TUBES
- SOME MODERN SCANNERS REPLACE SCINTILLATING CRYSTALS WITH GAS IONIZATION CHAMBERS. (FIG. 6.7 IN BOOK)
  (XENON)
  - HIGH PACKING DENSITY, HIGHLY DIRECTIONAL
  - SLOWER RESPONSE TIME (~700 μs)
  - LOWER Q.E. (~60%)

CT GENERATIONS:

TABLE 6.1 IN BOOK

SINGLE x-ray SOURCE

- **1G:** SINGLE BEAM, SINGLE DETECTOR. FIG. 6.3
  - FLEXIBLE ⇒ RESOLUTION + ANGLES!
  - SLOW, ALMOST NO SCATTER!
- **2G:** LIMITED FAN BEAM, MULTIPLE DETECTORS. FIG. 6.4
  - ↑ NOT FULL F.O.V.
  - FASTER
  - MORE SCATTER
- **3G:** FULL F.O.V. FAN BEAM, LARGER DETECTOR ARRAY.
  - SMALLER DETECTORS, (NOT AS EFFICIENT) HIGHER DOSE
  - COST
- **4G:** SINGLE ROTATING SOURCE, FULL RING OF DETECTORS
  - ↑ NO COLLIMATION ON DETECTORS
  - SCATTERING A MAJOR PROBLEM

5G: ELECTRON-BEAM CT

ELECTRON BEAM IS STEERED ELECTROMAGNETICALLY TO HIT ONE OF FOUR TUNGSTEN ANODE STRIPS THAT ENCIRCLE PATIENT.

- NO MOVING PARTS!
- VERY FAST! (50 ms / SLICE)
- STOP ACTION IMAGES OF BEATING HEART!
- EXPENSIVE

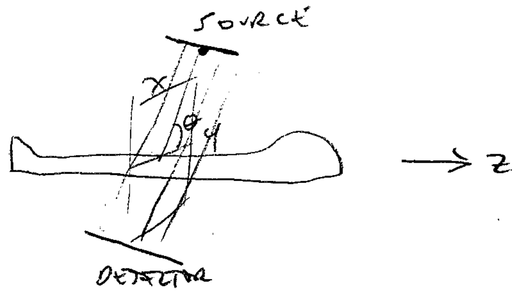
6G: HELICAL CT

7G: MULTI-SLICE CT

- THICK FAN BEAM
- 2D DETECTOR ARRAYS
- MORE EFFICIENT USE OF x-ray TUBE
- FAST.
- EXPENSIVE

DATA ACQUISITION:

- LET'S FIRST LOOK AT PARALLEL RAY GEOMETRIES (SIMPLER)



- SINOGRAM

- RADON TRANSFORM
  - TRANSFORMATION OF $f(x,y)$ INTO SINOGRAM $p(r,\theta)$
  - $p(r,\theta) = p(r, \theta + 2\pi)$ ⇐ PERIODIC w/ PERIOD 2π
  - $p(r,\theta) = p(-r, \theta \pm \pi)$ ⇐ SYMMETRIC IN θ w/ PERIOD π