BIM 243: Radiation Detectors for Biomedical Application

Instructor: Prof. Simon Cherry

Description:

This course will cover radiation detectors and sensors that operate in the optical, x-ray and gamma-ray regions of the electromagnetic spectrum and particle detectors suitable for detecting electrons. These detectors are widely used in a range of important biomedical applications, including medical imaging, optical microscopy, electron microscopy, spectroscopy, optical sensing, autoradiography, radiation measurement and radiation protection. Devices covered in the course include charge-coupled device (CCD) cameras, photodiodes, photomultiplier tubes, ionization chambers, proportional counters, scintillation detectors and digital imaging plates. The basic physics underlying radiation detection and measurement will be introduced and for each technology, physical principles of operation, design principles and biomedical applications will be discussed. At the end of this course, students will have a firm foundation in the fundamentals of radiation detection, the technology that is available for radiation measurement and the applications of this technology in the biomedical arena.

Units: 4

Lecture
Class meets twice per week, for two hours each time
Offered alternate years only – in Winter or Spring

Grading

Letter grade based on:

- Homework
- Mid-Term
- Final
- Project

Syllabus:

Overview of use of radiation detectors and sensors in biomedical applications

Types of Radiation

- Particulate (electron, proton, alpha particles, heavy ions)
- Electromagnetic (optical, x-rays, gamma rays)

Sources of Radiation

- Units and definitions
- Source of electrons
- Sources of electromagnetic Radiation

Radiation Interactions

- Interaction of electrons
- Interaction of gamma Rays / X-rays
- Interaction of light
- Radiation exposure and dose

Counting Statistics and Error Prediction
- Statistical models
- Applications of statistical models
- Error propagation

General Properties of Radiation Detectors
- Simplified detector model
- Modes of detector operation
- Pulse height spectra
- Counting curves and plateaus
- Gain and amplification
- Energy resolution
- Detection efficiency
- Dead time

Film and Phosphors
- Basic principles
- Historic use
- Limitations

Ionization Chambers
- Basic principles
- Application in the measurement of radioactivity

Proportional Counters
- Basic principles
- Detection of electrons and x-rays
- Application in autoradiography

Geiger-Mueller Counters
- Basic principles
- Radiation detection with G-M counters
- Application in radiation protection

Photomultiplier Tubes
- Basic principles of PMTs
- Detection of light
- Application in confocal microscopy

Photodiodes and Avalanche Photodiodes
- Basic principles of silicon detectors
- Detection of light
- Application in spectroscopy

Scintillation Detector Principles
- Fluorescence, phosphorescence and scintillation
- Scintillators fundamentals
- X-ray and gamma-ray detection
- Radiation spectroscopy with scintillators
- Application in medical imaging

Semiconductor Detectors for X-rays and Gamma rays
- Germanium detectors
- Cadmium Zinc Telluride
- Amorphous silicon and selenium
- Applications in spectroscopy and medical imaging

Semiconductor Detectors for Light
- CCD Cameras – principles of operation
- Optical and electron microscopy

Imaging Plates
- Principles of operation
- Applications in autoradiography and medical imaging

Thermoluminescent Dosimeters
- Thermoluminescence fundamentals
- Application in radiation dosimetry

Electronics for Radiation Detection
- Pulse processing and shaping
- Linear and logic pulse functions
- Multichannel pulse analysis

Background and Detector Shielding
- Background for light detection
- Background for x-ray and gamma-ray detection
- Shielding

Radiation protection and Health Physics

Uses and relative strengths and weakness of different detectors and sensors in biomedical applications

Textbook:

Radiation Detection and Measurement
Author: Glenn Knoll
Edition: 4th
Publisher: Wiley & Sons