University of Zagreb
Faculty of Electrical Engineering and Computing

Biomedical Instrumentation - Clinical Laboratory Instrumentation

prof.dr.sc. Ratko Magjarević

Clinical Laboratory

- Analysis of patien specimens
- Provide information to
  - Aid diagnosis
  - Evaluate therapy
- Sections:
  - Chemical lab
  - Hematology
  - Microbiology
  - Blood bank

Clinical Laboratory

- Chemical laboratory
  - Chemical analysis of body fluids:
    - Blood
    - Urine
    - Cerebrospinal fluid (CSF)
    - Other fluids
  - Microbiology
  - Blood bank

Clinical Laboratory

- Hematology
  - Determination of
    - Number
    - Characteristics of formed parts of the blood like
      - Red blood cells
      - White blood cells
      - Platelets
    - Test of function of physiological systems in the blood
      - Clotting studies

Clinical Laboratory

- Microbiology laboratory
  - Study of body tissue and fluids
    - Search for pathological microorganisms
    - Susceptobility tests
      - Sensitivity of microorganisms to antibiotics
      - Characteristics of formed parts of the blood like
- Blood bank
  - Classification of blood product
      - ABO grouping

Clinical Laboratory Instrumentation

Owerview of instrumentation

- Spectrophotometry
- Automated Chemical Analysers
- Chromatography
- Electrophoresis
- Hematology

Spectrophotometry

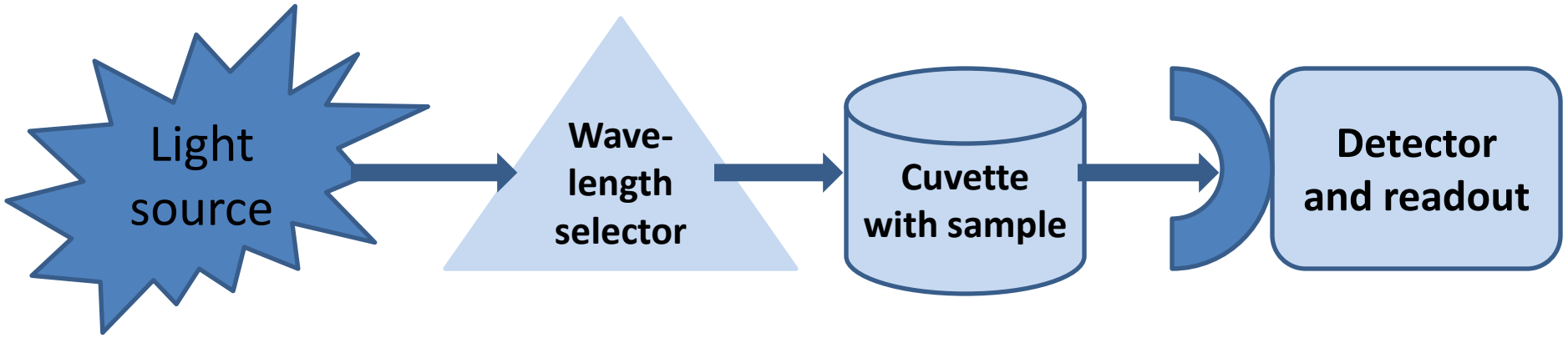
Characteristics of spectrophotometers:

- Accuracy
- Precision
- Sutability for automatic instrumentation

Theory of operation

- Substances of clinical interest selectively absorc or emit electromagnetic energy at different wavelengths
  - Ultraviolet light (200 to 400 nm)
  - Visible light (400 to 700 nm)
  - Near infrared (700 to 800 nm)

Spectrophotometer block diagram



- Light source supplies radiant energy
- Wavelength selector filters selected wavelengths
- Cuvette holds the sample in the path of radiant eneggy
- Detector produces electrical signal proportional to the energy received and readout displays the received energy as a function of eg. concentration of the substance

Light (power) sources

Hydrogen or deuterium discharge lamps (UV)

Tungsten filament lamps (visible)

- Continous spectrum
- Much of the specrum emitted in the IR
- Regulated power supply – emitted output energy varies with 4th power of filament voltage!

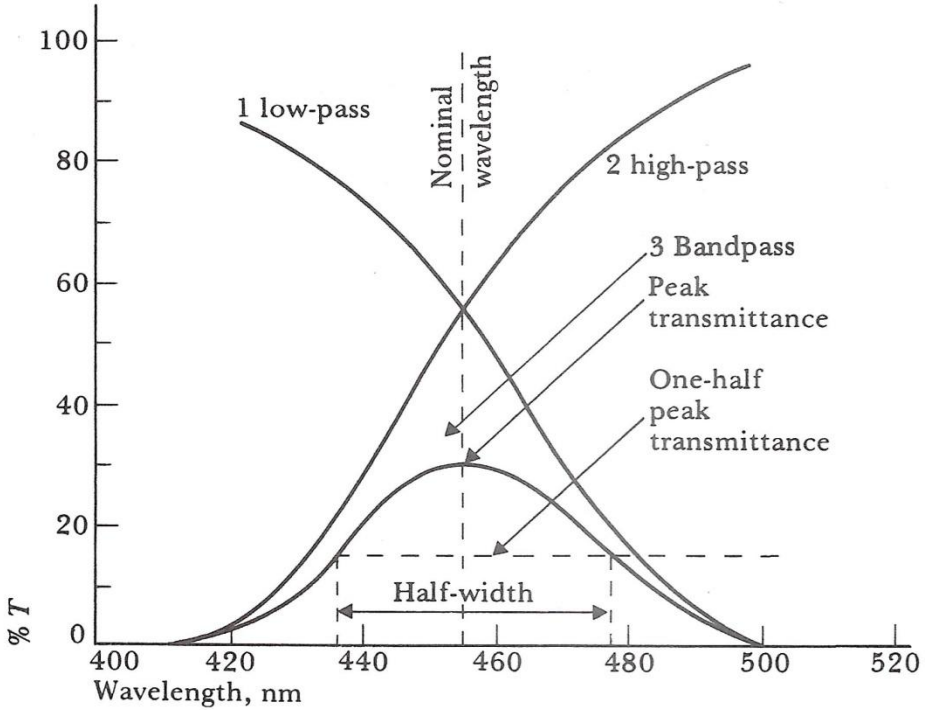
$$E \approx u_F^4$$

- Considerations how to design constant power spectrum for measurements

Wavelength selectors

Filters

- Glass filters
  - Absorb power
  - High pass and low pass filters
  - Combination of two- band pass filter
    - Note that transparence T is decreasing with reducing the bandwith



Wavelength selectors

- Filters
  - Interference filters
    - Principle of operation:
      - Spacing reflecting surfaces (mirrors) at a short distance
      - Light is reflecting back and forth
      - Distance selected in such a way that
        - » the wavelength of interest is in phase and reinforced (selected)
        - » Light out of interest is out of phase and canceled
      - Higher harmoncs have to be removed by optical filters

Wavelength selectors

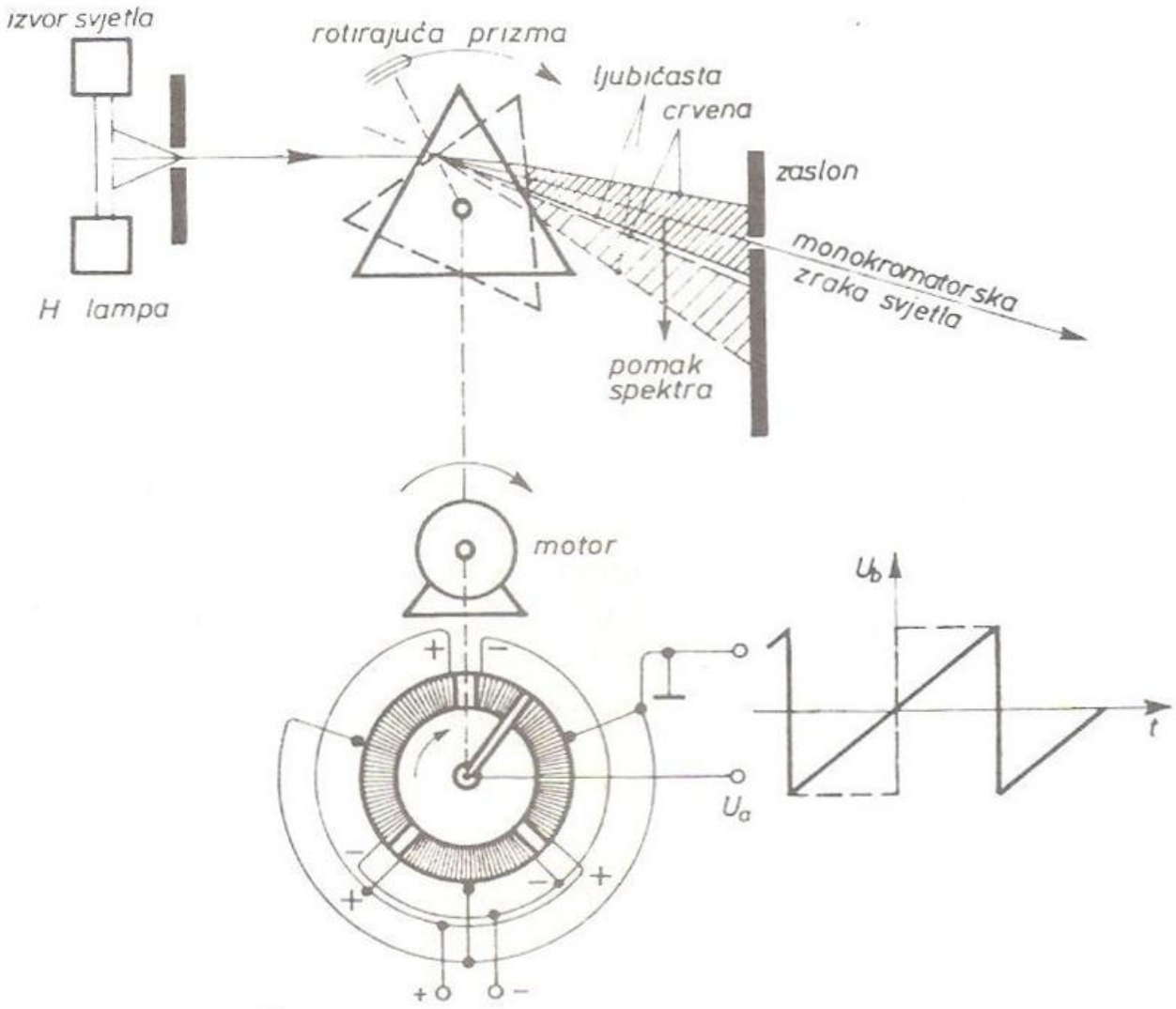
Monocromators

devices utilizing

- Prisms
- Diffraction gratings

- Provide narrow wavelengths
- Adjustable nominal wavelengths
- Principle of operation:
  - Disperse inpul light spatially as a function of wavelength
  - Only the band of interest is allowed to pass a slit

Wavelength selectors



Cuvette

Holder of the analysed substance

Optical characteristics do not influence measurement

Sample

Sample absorbs light selectively

Described by Beer's Law

$$P = P_0 10^{-aLC}$$

P_0 – radiant power arriving at the cuvette

P - radiant power leaving the cuvette

a – absorptivity of the sample

L – length of the light path through the sample

C – concentration of the absorbing substance

Sample

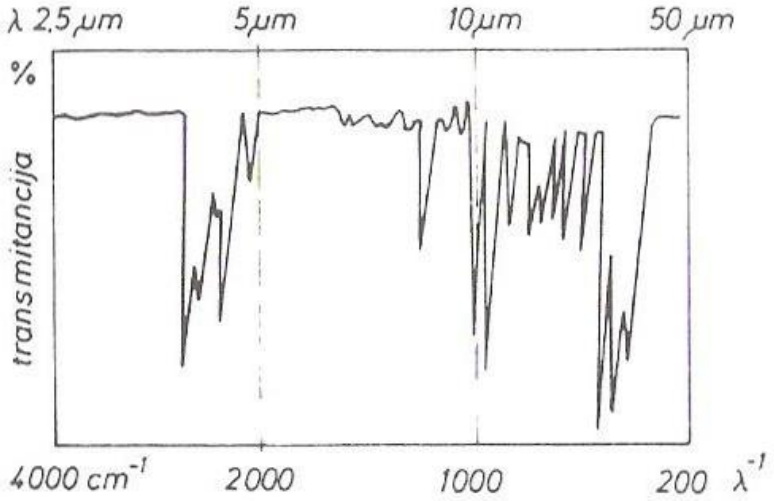
Results:

Transmittance

$$\%T = 100\,P / P_0 = (100)10^{-aLC}$$

Absorbance

$$A = aLC$$



– Plotted against wavelength

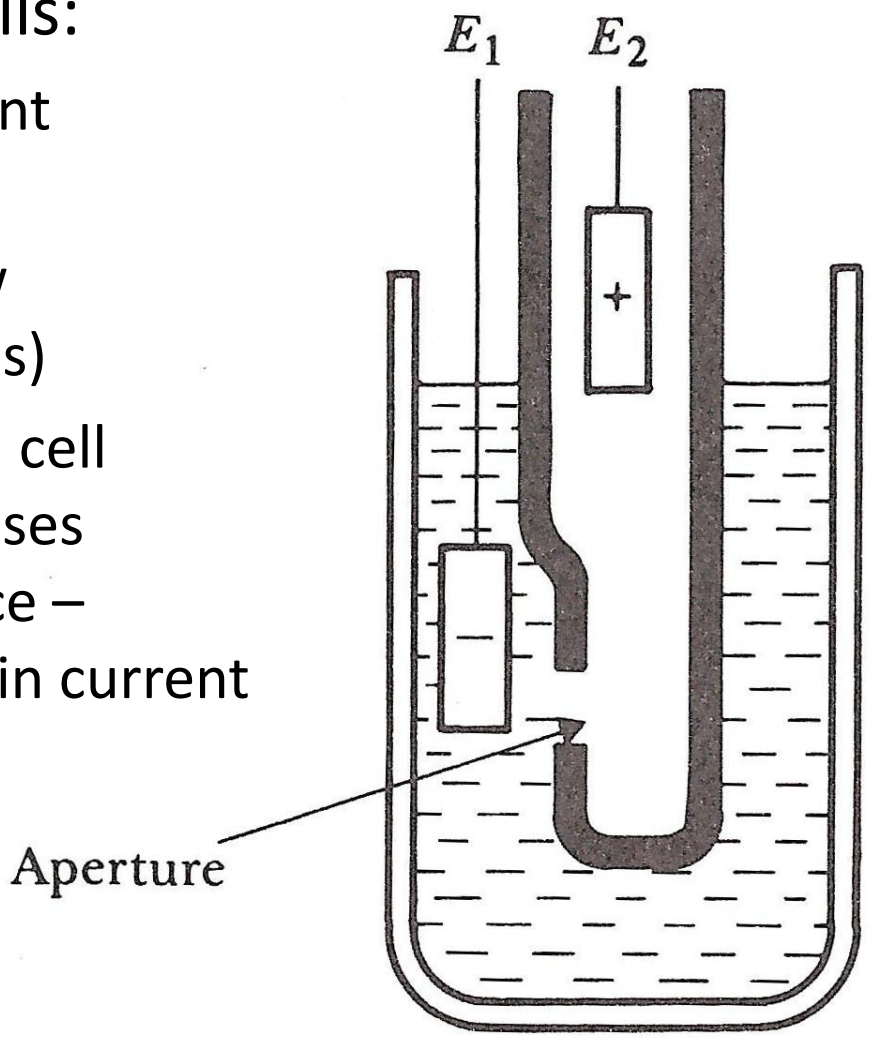
Hematology Lab

- Determination of
  - Number of elements in microliter (µl)
  - Characteristics of formed parts of the blood like
    - Red blood cells – male: 4.6 to 6.2 x 10^6 / µl
      - female: 4.2 to 5.4 x 10^6 / µl
    - White blood cells: 4.500 to 11.000 / µl
    - Platelets

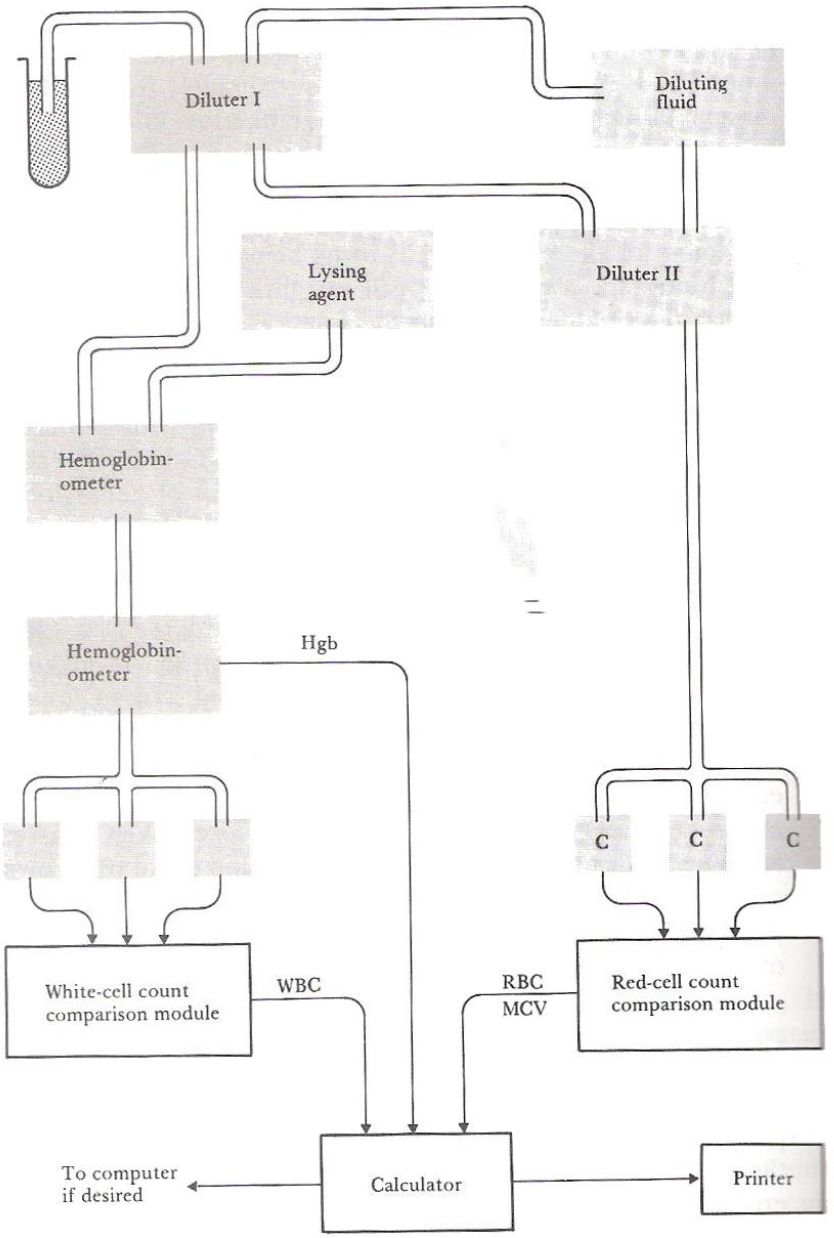
Hematology Lab

– Counter of blood cells:

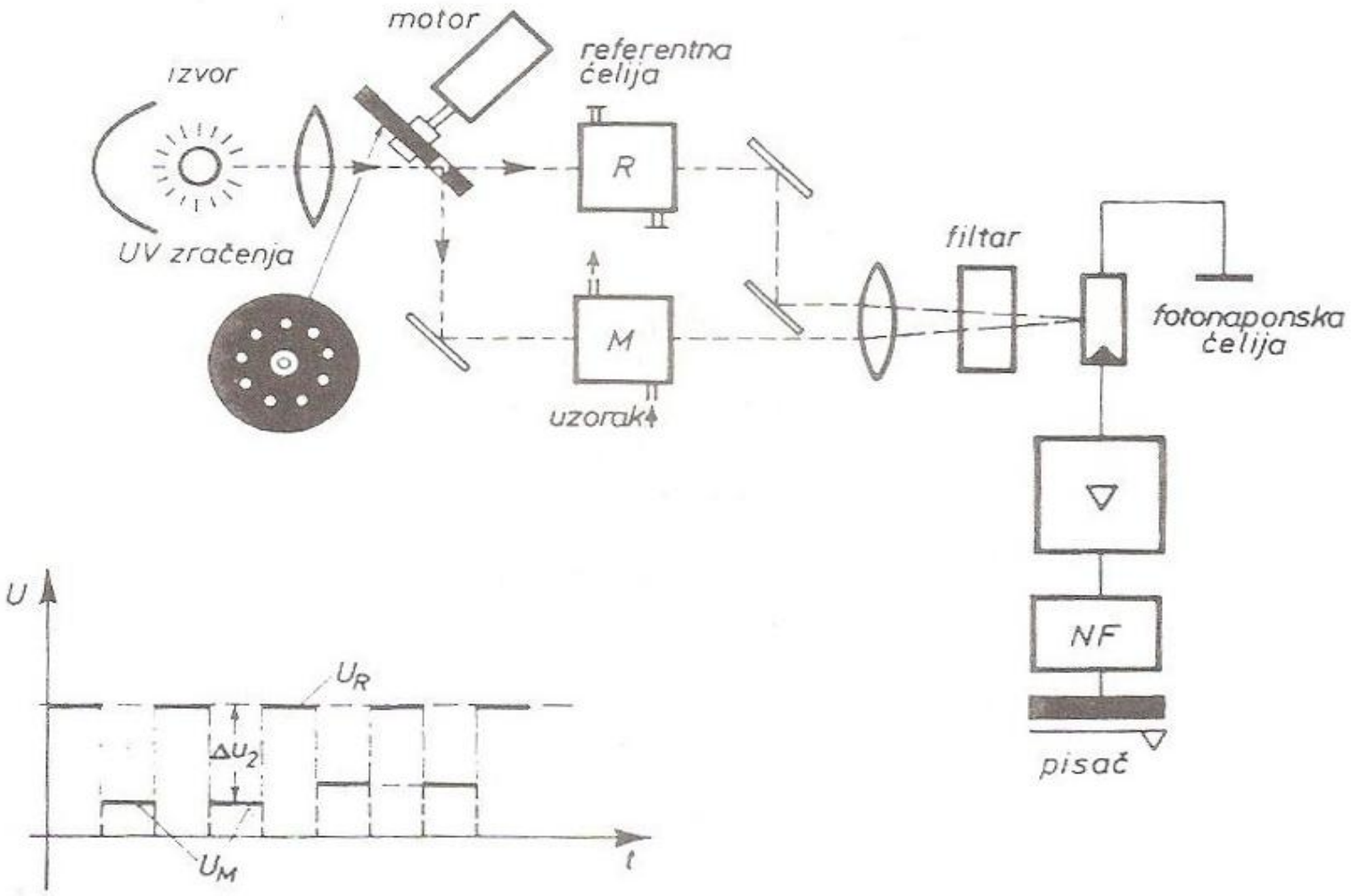
- 2 Electrodes – current measurement
- Pump for liquid flow (including blood cells)
- Passing of the blood cell through the gap causes change of impedance – measured as chane in current



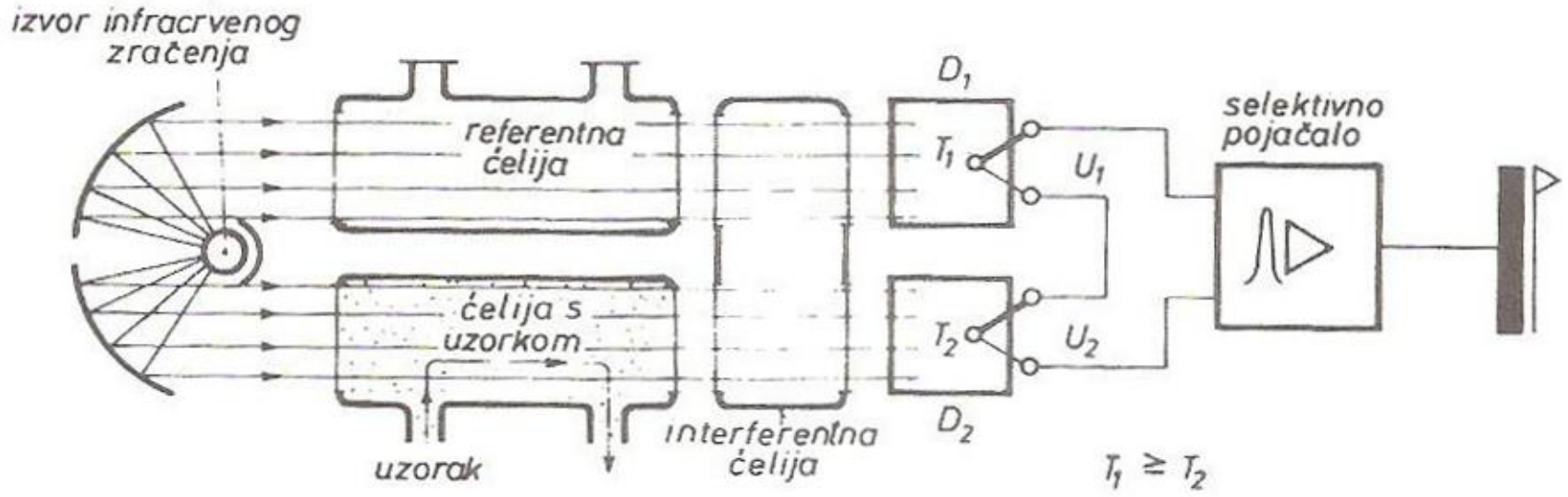
Block diagram for blood characteristics measurement



Block diagram of UV spectral analyser

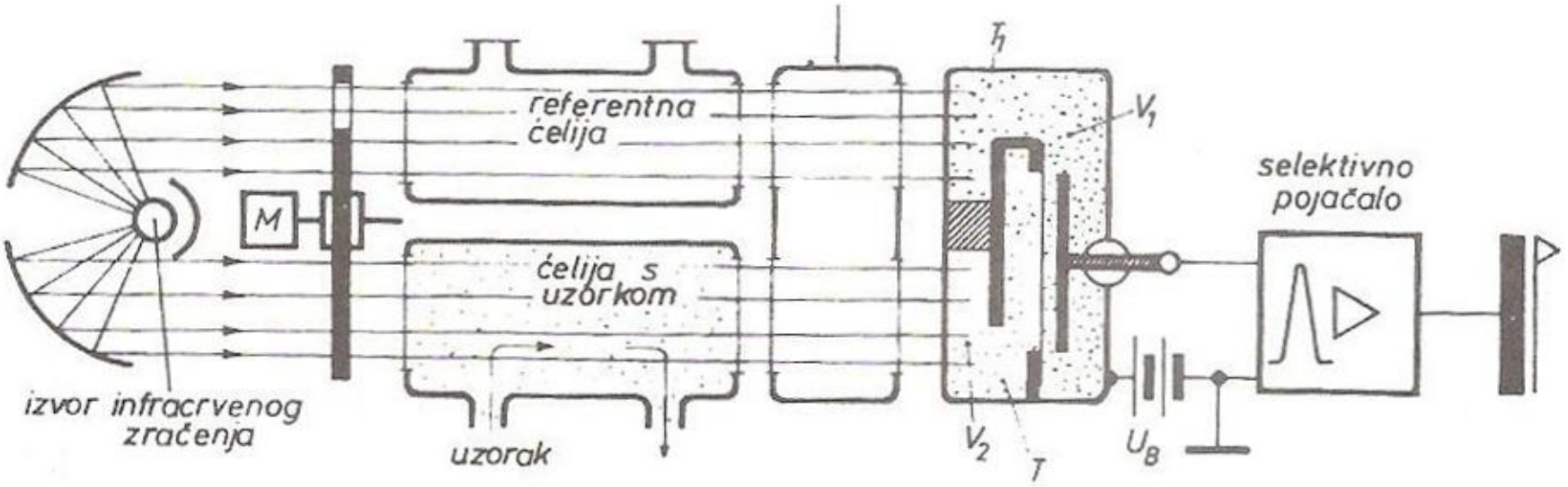


Block diagram of IR apsorption analyser



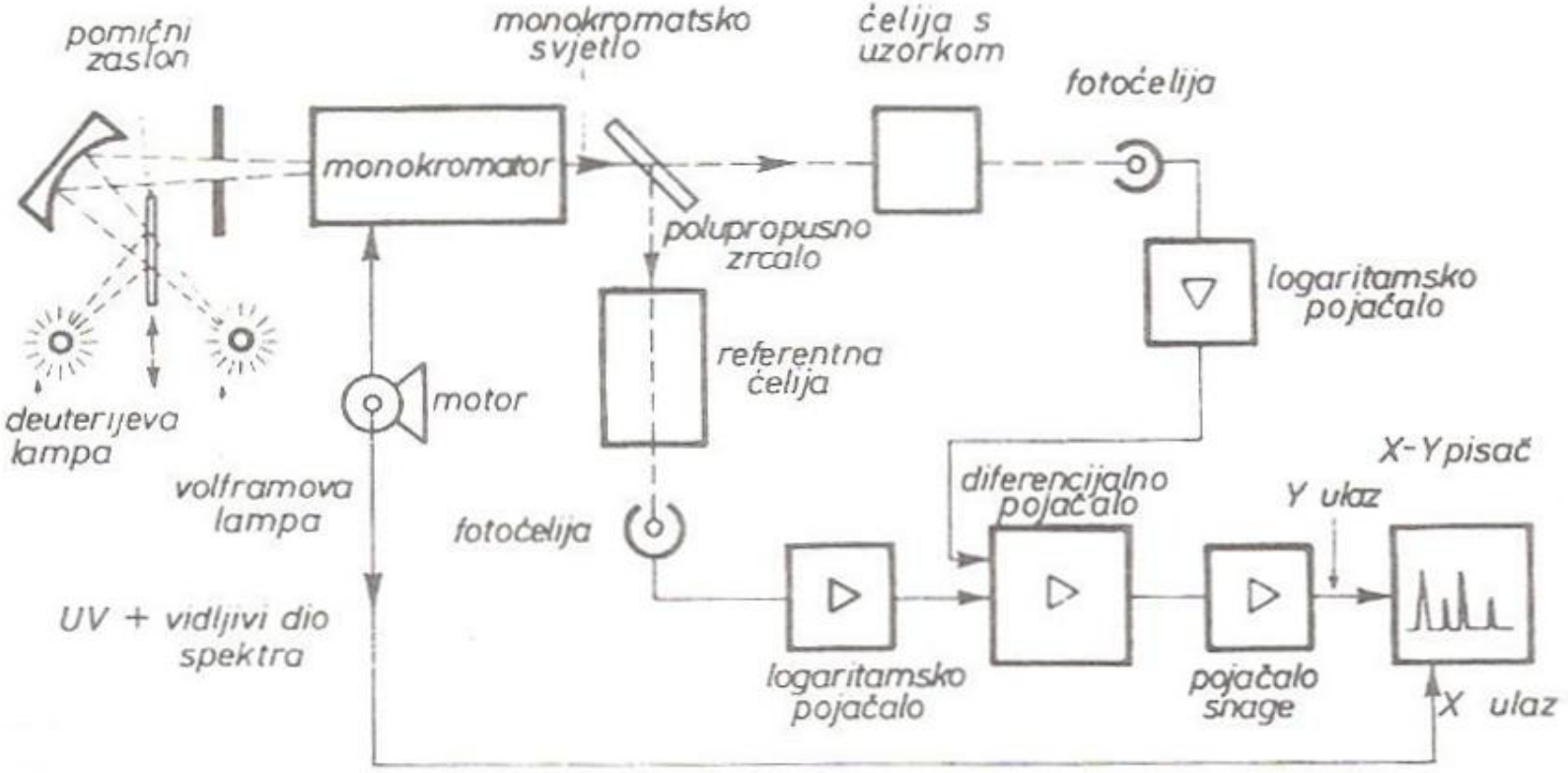
- With termocouples

Block diagram of IR apsorption analyser

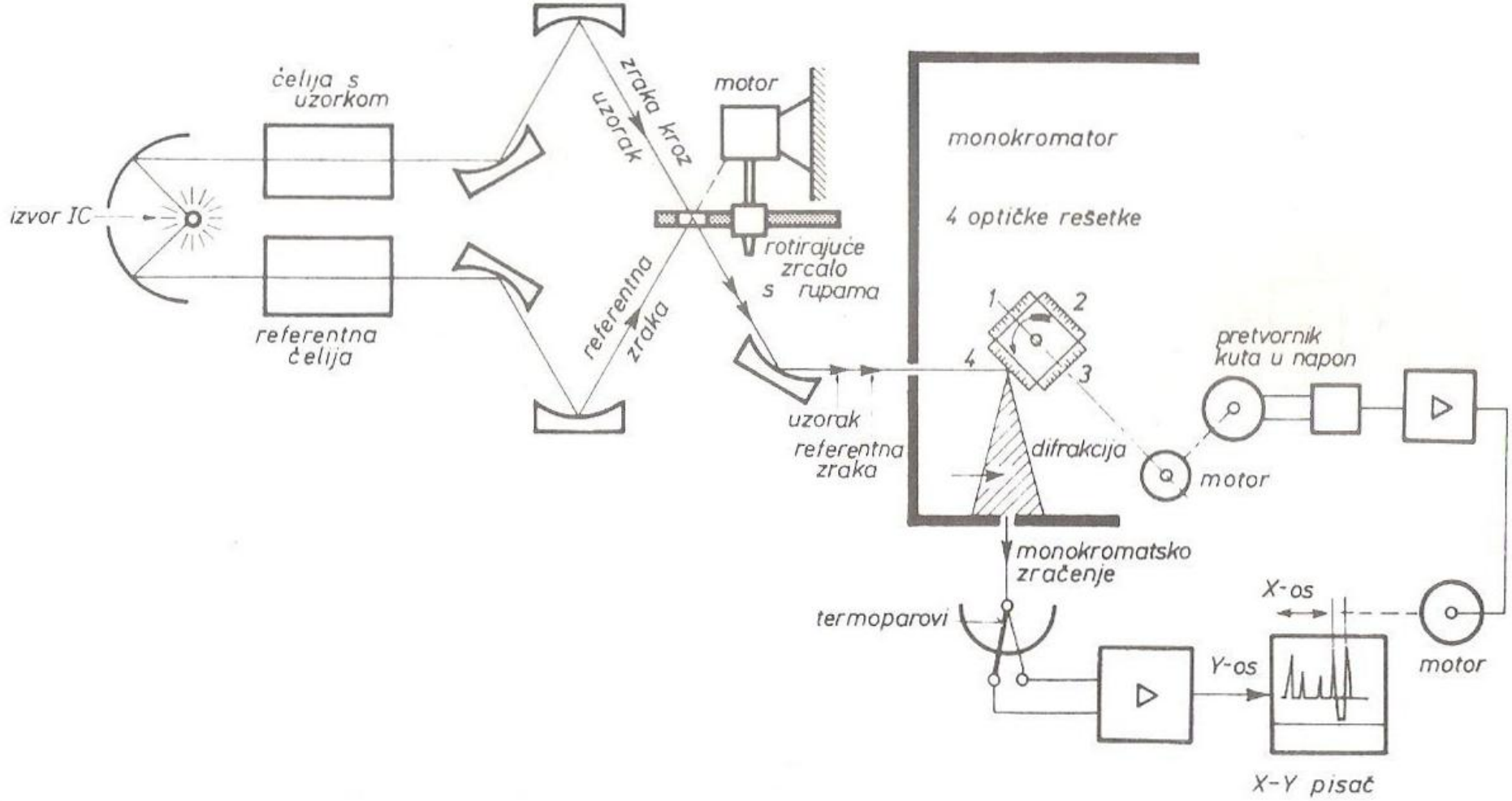


- With capacitive detector

Block diagram of UV/visible light spectrophotometer



Blockdiagram of IR spectrophotometer



Literature

- Webster, J., “Medical Instrumentation”
- Brown, BH., Smallwood, RH., et al., “Medical Physics and Biomedical Engineering, IoP Press, Bristol, 1999