

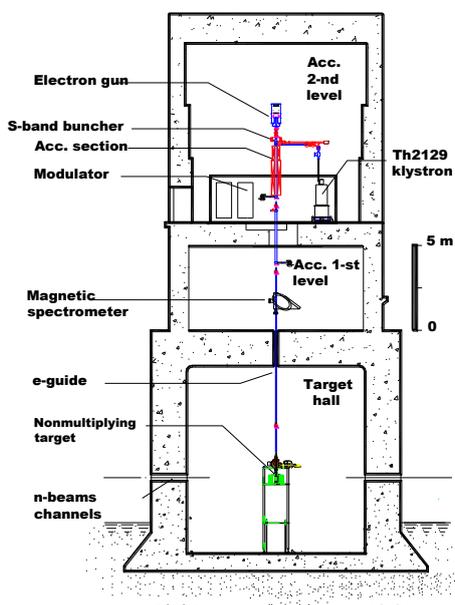
Non-destructive analysis of element and isotope composition by neutron spectroscopy methods

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Neutron spectroscopy is part of neutron physics studying energy dependence of effective cross sections of different neutron-nuclei interactions and formed nuclei excited state characteristics. In low energy range the neutron reaction cross sections have resonance peaks at specific energies. The neutron resonance is sharp increase ($10\text{-}10^4$ times) of capture and scattering of neutrons near resonance energy. Each resonance corresponds to each excited state of compound nucleus. Resonance parameters are connected with the properties of compound nucleus. Now, resonance parameters are known for practically all nuclei and don't coincide for any pair of isotopes. Neutron resonances are characteristic for every isotope and they constitute a useful "fingerprint" for the identification of elements into the sample.

Neutron resonance capture analysis (NRCA) is based on use of the pulsed neutron source and time-of-flight method (TOF) for neutron spectroscopy. Energies and intensities of resonances peaks are used to identify isotopes and to determine their concentrations. NRCA has the advantages in comparison with more conventional techniques. It is non-destructive, that is important for analysis of cultural heritage objects and archaeological artefacts. The residual activity of investigated sample is practically absent. It allows one to analyze relatively large objects including radioactive one. The method is sensitive to the isotopic composition of sample. In Frank Laboratory of Neutron Physics the NRCA method is used for the analysis of geological samples, cosmic objects, new composite materials.



IREN first stage general layout



General view of the detector.

The investigations are carried out at the Intense REsonance Neutron source (IREN) of FLNP. The main part of the IREN facility is a linear electron accelerator. The bunched electron beam generates bremsstrahlung in the tungsten target and it produces the neutron pulses via (γ, n) -reaction in the same target. NRCA is performed by measurement of radiative capture as well as by the measurement of neutron spectrum transmitted through the sample. The liquid scintillator detector of gamma-quanta is used in both cases. Detector is installed at 60 m flight path. Detector contains 6 sections forming together the cylinder with the channel along the neutron beam direction. The investigated sample is placed into this channel. Diameter of the channel is 300 mm, external diameter of the detector is 730

mm, length 600 mm. Total volume of liquid scintillator is 250 liters. There are photomultipliers in both ends of each section. Electronics is able to work at different multiplicities of gamma-quanta. The mode of 2 or 3 multiple coincidence is optimum, which essentially reduces a background of the detector without appreciable reduction of detector efficiency for (n, γ) -reactions. The detector registers the moment of the appearance of gammas, connected with the time of capture of a neutron. Detected events and neutron energies are correlated by measuring the time elapsed between the generation of the neutron burst and the detection of the neutron. For transmission measurements a neutron converter is placed into detector.

We are ready to accept 2-4 students for Summer-Practice. Obligatory: general physics, course on nuclear physics.

Before Practicals, students are instructed for radiation safety and get acquainted with Instruction on experimental work in the fields of ionizing radiation at JINR (Instruction РБ-П1Р).

CONTENTS

of Special Course during practicals

Lecture 1

Neutron properties. Interaction of neutrons with matter. Structure of neutron reaction cross sections.

Lecture 2

Neutron sources and neutron detectors.

Lecture 3

Neutron spectroscopy. Measurement of neutron cross sections and resonance parameters.

Lecture 4

Determination of elemental and isotopic composition of samples with use of neutron spectroscopy methods.

Practical (25-30 hours)

Acquaintance with the IREN facility and the experimental setup.

Acquaintance with elements of detectors and data acquisition system. Observation and adjusting of the signals from the detector and electronics.

Performance of the experiment, statistics collection, control for measurements.

Data treatment.