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Study of the Characteristics of Neutron Radiation

Abstract

According to the time mode of operation, neutron sources can be divided into two groups: continuous sources and pulsed sources. Historically, the first were continuous-action sources based on the use of the (α, n) reaction on Be nuclei. In these sources, beryllium is irradiated with alpha particles of radioactive elements such as radium, polonium and plutonium. Ease of use and stable yields over short measurement periods have led to the widespread use of these sources, despite their relatively low neutron yield. The development of accelerator technology and nuclear reactors has led to a significant increase in neutron fluxes, making it possible to significantly expand the ranges of neutron yields and energies and control the energy composition of the radiation. Pulsed radiation sources have been developed to address many economic and scientific challenges, particularly in nuclear physics and nuclear energy. Pulsed radiation sources produce short, repetitive pulses of radiation, such as photons or neutrons, and allow the study of the properties of matter using the propagation of particles at a specific energy. For example, in the case of neutrons. This helps to separate them by speed in a special tube and provides precisely defined energies for experiments. Pulsed neutron sources can consist of a powerful accelerator that directs high-energy protons at a heavy target (such as mercury or tungsten), causing a spallation reaction and releasing neutrons, which includes accelerators, pulsed reactors and boosters. Scientific research involves the analysis of the properties of materials, the study of nuclear reactions.
Keywords: *neutron, measurement, pulse, analog, method, quantity*

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Neytron şüalanmasının xüsusiyyətlərinin öyrənilməsi

Xülasə

Zaman iş rejiminə görə neytron mənbələrini iki qrupa bölmək olar: davamlı mənbələr və impuls mənbələri. Tarixən davamlı mənbələr Be nüvələrində (α, n) reaksiyasının istifadəsinə əsaslanan davamlı təsirli mənbələr idi ki, bu mənbələrdə berilium, radium, polonium və plutonium kimi radioaktiv elementlərin alfa hissəcikləri ilə şüalanır. İstifadə asanlığı və qısa ölçmə dövrlərində sabit məhsuldarlıq, nisbətən aşağı neytron məhsuldarlığına baxmayaraq, bu mənbələrdən geniş istifadəyə səbəb olmuşdur.

Sürətləndirici texnologiyanın və nüvə reaktorlarının inkişafı neytron axınının əhəmiyyətli dərəcədə artmasına səbəb oldu ki, bu da neytron məhsuldarlığının və enerjilərinin diapazonlarını əhəmiyyətli dərəcədə genişləndirməyə və radiasiyanın enerji tərkibinə nəzarət etməyə imkan verdi. İmpulslu radiasiya mənbələri bir çox iqtisadi və elmi problemləri həll etmək üçün işlənib hazırlanmışdır, xüsusən də nüvə fizikası və nüvə enerjisi.

İmpulslu radiasiya mənbələri fotonlar və ya neytronlar kimi radiasiya, qısa və təkrarlanan impulslar istehsal edirlər və hissəciklərin müəyyən bir enerjidə yayılmasından istifadə edərək maddənin xüsusiyyətlərini öyrənməyə imkan verir. Məsələn, neytronlar halında. Bu, onları xüsusi bir boruda sürətə görə ayırmağa kömək edir və təcrübələr üçün dəqiq müəyyən edilmiş enerjilər verir.

İmpulslu Neytron Mənbələri yüksək enerjili protonları ağır bir hədəfə (məsələn, civə və ya volfram) yönəldən, spallasiya reaksiyasına səbəb olan və neytronlar buraxan güclü sürətləndiricidən ibarət ola bilər ki, bura sürətləndiricilər, impulslu reaktorlar və gücləndiricilər daxildir. Elmi tədqiqat materialların xüsusiyyətlərinin təhlili, nüvə reaksiyalarının öyrənilməsidir.

Açar sözlər: *neytron, ölçmə, impuls, analoq, metod, miqdar*

Introduction

Most pulsed accelerators currently in operation generate radiation in a periodic mode, where short-duration radiation pulses are repeated at a certain frequency, creating a regular sequence. The main characteristics of neutron sources include the neutron yield from the source, their energy distribution (spectrum), generation time and angular distribution. The neutron field created by a neutron source is characterized by neutron fluence, flux density, spectrum and temporal and spatial distributions of neutrons (Donahue & Nelson, 1988).

Studies of the characteristics of neutron sources and the neutron fields they create provide information on the physical processes occurring during neutron generation within the source itself and on the impact of neutrons from the source on the environment (International Commission on Radiological Protection, 2009; Bednarz, 2008).

Research

Measurement Features with Pulsed Neutron Sources

If the detector load is high, as is the case with high neutron fluxes, and the resolving time of the electronic equipment used is insufficient, then pulses from individual neutrons cannot be detected due to overlap. So-called analog measurement methods are becoming more promising. Analogue registration methods, in which the time distribution of neutrons entering the detector is converted into an electrical analogue (current) at the detector output, make it possible to obtain information about the shape of the neutron pulse N(t) (Chu, 2000).

The simplest analog recording of the neutron pulses being studied is accomplished by oscillography recording the shape of the current pulse generated at the detector's output. The setup for such measurements can be represented as follows (Figure. 1.2.1).

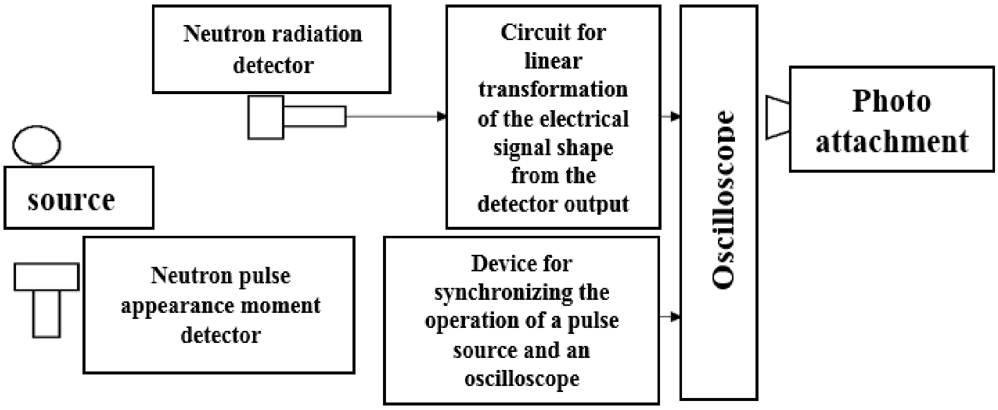

Figure 1.2.1. Neutron pulse measurement scheme.

The synchronization method depends on the neutron pulse duration and must ensure that the signal is recorded on the oscilloscope screen with an acceptable timing error. Neutron generation in most sources is accompanied by neutron γ- or x-ray radiation. When studying one type of radiation (γ or neutron), the other type of radiation must be considered background. Requirements for background suppression when operating in current recording mode are also specific. Undesirable radiation (example: γ x-ray radiation) can be protected with special shields (National Council on Radiation Protection and Measurements, 1995). In some cases, it is possible to separate γ- and neutron pulses by time of flight, with subsequent recording of only neutrons or only γ-quanta. The most effective method is to use detectors that are insensitive to one type of radiation. For example, activation neutron detectors eliminate the detection of γ-quanta, solid-state tracking detectors allow fission fragments to be detected even under very high γ- and neutron backgrounds, etc. The following sections discuss experimental methods for recording the parameters of single neutron pulses (Tiegel, 2011).

1.3. Measuring the time dependence of the flux density neutrons (analog method)

The detector has a time resolution τ, and its pulse load of individual particles n(t) is so high that the condition.

$$n(t)\,\tau \gg 1.$$

Then, pulses from individual particles cannot be detected due to overlap. However, if the current characteristic of the detector is such that it is not overloaded by the overlap of these n pulses, then the detector becomes a converter of the time distribution n(t) of the detected particles into an electrical analog—current. Such a detector will provide information on the time dependence of the neutron flux density, i.e., on the shape of the neutron pulse N(t). Recording the current signal from the detector output is usually accomplished using oscilloscope or similar methods (Zabihinpoor, 2011).

Let us establish a relationship between the neutron output of a pulsed source and the quantities measured in the analog recording mode. Let a neutron source with energy E generate a pulse N(t). Then, a neutron detector with a spectral sensitivity to (E) and located at a distance l from the source will record

$$N(t)\,k\,(E)\,/\,4\pi l^2 \qquad (1.3.1)$$

neutrons. If each neutron induces an electric current α K1 at the detector output, then when registering a neutron pulse, the current magnitude will be $I(t) = K_I[N(t)\,k\,(E)/4\,\pi l^2]$. This current on the load R, located at the detector output, creates a voltage pulse $U(t) = N(t)\,k\,(E) \times K_1R/4\pi l^2$. On the screen of an oscilloscope with a sensitivity of K_2 (mm/V), we obtain a deviation $\alpha\,(t)$ =

$$[N(t)/\,4\pi l^2\,]\,k\,(E)K_IK_2R. \qquad (1.3.2)$$

Thus, by measuring the beam deflection on the oscilloscope screen α(t) and knowing the characteristics of the recording channel, we obtain the value of the neutron flux at any moment in time

$$N(t) = \alpha\ (t)\ 4\pi l^2\ /\kappa(E)\ K_1K_2R. \qquad (1.3.3)$$

We obtain the total output by integrating (1.3.3) over the pulse time:

$$N = \int N(t)\ dt. \qquad (1.3.4)$$

If the detection system is linear, then the pulse area obtained by such integration can be used to estimate the number of neutrons that produced it, and consequently, the neutron yield from the source (Withers, & Elkind, 1970; Withers, Mason, Reid, Dubravsky, Barkley, Brown, & Smathers, 1974).

These relationships are suitable for determining the neutron yield (from the analog form of the recorded signal) in the case of monoenergetic (or close to monoenergetic) neutrons at $\Delta E \ll E$. In these cases, the actual neutron energy distribution can be assigned a certain effective value $\overline{k(E)}$, close to *k(E)*. This is true for facilities generating DD or DT neutron pulses. In the case of pulsed reactors, neutrons from the entire energy spectrum (e.g., fission neutrons) are emitted at each instant of the pulse. In this case, determining the spectral sensitivity requires knowing the neutron spectrum *S(E)* of the source and

$$\overline{k(E)} = \int k(E)\ S\ (E)dE\ /\ \int S\ (E)dE.$$

In the general case, for pulsed radiation with an arbitrary energy spectrum

$$\alpha\ (t) = \mathrm{K_1K_2{,}R}\int_0^t g\ (t-\tau)d\,\tau\ \int_E\ N\ (\tau, E)k(E)dE,$$

where (t-τ) is the impulse response of the recording channel.

I kind, respectively, at при $\boldsymbol{\mu} = \sum_t \approx \sum_S\ (\sum_t) -$ is the total macroscopic cross section for hydrogen, $\sum_S\ -$ is the scattering cross section on hydrogen).

For measurements using the analog method, the use of a system consisting of a semiconductor detector and a layer of an isotope fissile under the action of neutrons (or isotopes that undergo reactions with the formation of charged particles, for example: ^{6}Li (n, α), ^{10}B (n, α). is of great interest. Registration is carried out by a system that combines a semiconductor detector with a layer of fissile material located nearby (or adjacent to it). The neutron flux causes nuclear fission, the fragments enter the semiconductor detector and are registered. Due to the high carrier density due to the fragments formed, a current I is generated at the detector output, which is proportional to the neutron flux density *N(t)* causing fission in the sample and the fission cross-sectionσ_f (*E*), and depends on the geometry of the experiment:

$$I\ (t) = KN(t)\ \sigma_f\ (E)\ \ n_n, \qquad (1.3.5)$$

where $n_n$is the number of nuclei of the isotope used in the sample; K is a coefficient taking into account the specific experimental conditions. For a semiconductor detector

$$K = \Omega\ \bar{E}_f e\ /\ E, \qquad (1.3.6)$$

Here Ω- is the solid angle to the detector; $\overline{Ef}$ is the average energy of a fission fragment recorded by the detector; E -is the average carrier pair formation energy in a semiconductor detector; and e -is the electron charge (Withers, Flow, Huchton, Hussey, Jardine, Mason, Raulston, & Smathers, 1977). Relation (1.3.5) allows one to determine the neutron flux density *N(t)*. (For more details on determining the pulse shape, see Chapters 6 and 7.)

Conclusion

Measurement of the Total Neutron Yield (Flux). Individual Particle Counting Method. Individual particle counting was used in the early stages of pulsed source research. Specifically, it was used to study the operation of a spark-driven DD-neutrons generator. In the generator, the ion current was generated as a series of individual pulses of decreasing amplitude, each lasting approximately 10 µs. The duration of the entire series was 200 µs. Neutrons were generated during the ion current pulses. Neutrons were recorded by an FEU-24 scintillation detector with a plastic scintillator (70 mm in diameter and 70 mm in height). The detector signals were oscilloscope, so the pulse sequence from individual neutrons was visible.

Thus, individual particle counting is primarily an indicator method for a limited class of pulsed neutron sources (low yield and long pulse durations: greater than 10 µs) (Ladygin, Konovalov, Orlova, Ruchkin, Lagov, & Surma, 2006).

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