Measured spectrum of DT neutrons from a plasma focus

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Measurements of the energy spectrum of the DT neutrons from a plasma focus are reported. The measurements were made by a time-of-flight method with an energy resolution $(\Delta E/E) \approx 0.4\%$. The kinetics of the neutron emission from the focus was taken into account in finding the neutron spectrum. The ion temperature calculated under the assumption that these neutrons are of thermonuclear origin lies in the range 3–5 keV.

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The number of published papers reporting time-of-flight studies of the energy spectrum of the DD neutrons produced in a dense plasma focus is now fairly large.[1-9]

Surskiĭ and Zysin[10] have proposed a method for measuring the spectrum of DT neutrons, with a correction for the production time of these neutrons. The method proposed in Ref. 10 applies to cases in which the neutron production time in the plasma can lead to a serious distortion of the neutron spectrum detected by the time-of-flight method, and the flight distance cannot be increased because of limitations imposed by the detection statistics. In such cases, Surskiĭ and Zysin propose finding the temporal distribution of neutrons $[u(t)]$ which corresponds to the neutron energy spectrum by working from the experimental temporal distribution and using a mathematical reconstruction method which allows for the measured neutron production time.

In this letter we are reporting measurements of the spectrum of neutrons produced in the DT reaction in the plasma focus in a discharge chamber of the type developed by the Filippovs.[11]

The experimental arrangement is shown in Fig. 1. The discharge chamber (1) is surrounded by polyethylene shielding (2) with a thickness of 40 cm. This shielding serves as a first collimator. A second collimator (3), made of lead and placed 280 cm from

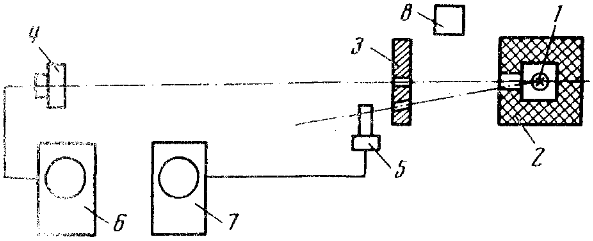

FIG. 1. The experimental arrangement. 1–Discharge chamber; 2–polyethylene shielding; 3–collimator; 4,5–detectors; 6,7–oscilloscopes; 8–activation detector.

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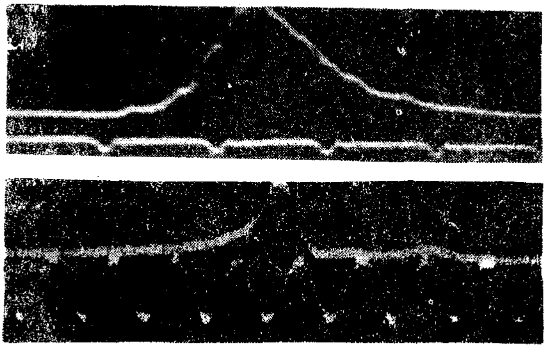

FIG. 2. Time distributions of the DT neutrons. a–At a distance of 268.5 m (the time marker is 10 MHz); b–at 8.5 m (the time marker is 20 MHz).

the source, does the final shaping of narrow emission beams from the plasma focus. A detector (4) consisting of a plastic scintillator, a conical acrylic plastic lightguide, and a fast high-current photomultiplier is placed at a distance of 268.5 m, in the direction of the axis of the discharge chamber. The scintillator, which is 36 cm in diameter and 12.5 cm thick, is made of polystyrene with 2% *p*-terphenyl and 0.02% POPOP. The sensitivity of this detector for 14-MeV neutrons is $\sim 2 \times 10^{-8}$ A cm^2 s/neutron, and its time resolution is no worse than $\tau_{0.5} \cong 9$ ns. A fast detector (5) with a time resolution $\tau_{0.5} = 2$ ns, placed 8.5 m from the plasma focus, measures the temporal distribution of the DT neutrons in order to allow for the operating time of the source. At such a short distance, the temporal distribution of DT neutrons is essentially equivalent to the emission kinetics of DT neutrons, i.e., the time dependence of the emission of these neutrons from the focus. The output signals from detectors 4 and 5 are fed along RK-75-9-13 coaxial cables of identical length (388 m) to oscilloscopes 6 and 7. The integrated yield of neutrons for the focus is monitored with an activation detector 8.

In a series of experiments we determined the scattered-neutron background level and found it to be less than 5% at the detector positions. Because of the relatively short flight distance between the focus and detector 5, we observed an effect of the trailing edge of the x-ray and γ emission pulse accompanying the discharge on the shape of the pulse showing the emission kinetics of the DT neutrons. This effect was minimized by placing the detector in lead shielding, and it was taken into account in the analysis of the experimental results.

Figure 2 shows some typical oscilloscope traces of the pulsed time distributions $F(t)$ and $g(t)$ measured at distances of 268.5 m (a) and 8.5 m (b), respectively.

The measured time distributions are related to the time distribution $u(t)$, undistorted by the operating time of the source, by the equation

$$F(t) = \int_0^t u(\tau)\, g(t-\tau)\, d\tau. \qquad (1)$$

The reconstruction problem was solved on a computer to find $u(t)$. Figure 3 shows the spectrum of DT neutrons obtained from the time distribution $u(t)$ for one of the

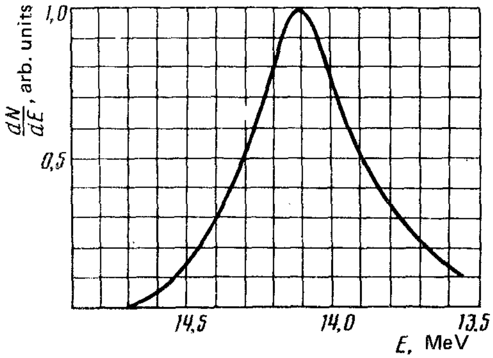

FIG. 3. Energy spectrum of the DT neutrons from the plasma focus (the capacitor bank stores an energy of 60 kJ; the pressure of the deuterium-tritium mixture is 21 Torr; the integrated yield of DT neutrons is 1.6×10^{11}; and the length of the neutron pulse is 20 ns).

discharges, with the parameters also specified in Fig. 3. The spectral peak corresponds to a neutron energy of 14 MeV, and the energy resolution is $\Delta E/E \approx 0.4\%$.

If the DT neutrons are of thermonuclear origin, then the half-width of the spectrum, $\Delta E_{0.5}$ (in MeV), is related to the ion temperature θ (also in MeV) of the DT plasma by[10]

$$\theta = \left(\frac{\Delta E_{0.5}}{5.6}\right)^2. \tag{2}$$

The nature of the neutron production in a plasma focus remains problematical. If we assume that the neutrons are of thermonuclear origin, we can evaluate the ion temperature from (2). To reduce the error in the temperature determination, we should calculate it from only the first half-width of the spectrum, which is less subject to distortion by scattered neutrons. The ion temperature determined in this manner is not constant from discharge to discharge; it varies over the range 3-5 keV.

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