# Concerning the use of supercompression of matter by reactive pressure to obtain neutron pulses

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Possible ways of generating intense neutron pulses for physical research are considered. The conditions for obtaining such pulses by the method proposed by Askar'yan *et al.*, viz., via a chain fission reaction that develops when an intense laser beam acts on the medium, are analyzed.

The development of high-intensity neutron pulsed sources for research in nuclear physics and solid-state physics, using time-of flight methods for monochromatization of the neutrom beams, have attracted great interest in recent years. Various means of generating neutron pulses are used: with the aid of beams of charged particles and accelerator targets, using a chain fission reaction in pulsed fast reactors with one-shot[1] and periodic[2] operation, or nuclear explosions.[3] The development of high-intensity laser beams has suggested the use of the interaction of these beams with matter for the generation of neutron pulses. Two such suggestions are noted here.

Brugger[4] considered a pulsed neutron source for physical research on the basis of direct excitation of a thermonuclear reaction by laser radiation (see, e. g., [5]). Estimates have shown that approximately $3.6\times10^{19}$ neutrons are released from a pellet of deuterium and tritium weighing $\sim10^{-2}$ g at a laser flash energy $\sim10^4$ kJ released within $\sim10^{-9}$ sec. If the flash repetition frequency is 0.1 Hz, then the average neutron intensity is $\sim3.6\times10^{18}$ neut/sec at an average heat release ~10 MW in the system and at an average laser pwer 1 MW.

Much lower laser beams are needed, in accordance with the authors' estimates, to obtain neutron pulses via a chain reaction in a microcritical mass of fissioning matter, obtained by compressing the matter in a laser beam (see Askay'yan *et al.* [6]). According to the estimates in[6], critical masses $\sim10^{-2}$ g can be obtained at a laser beam energy $\sim10^2$ kJ released in $10^{-9}$ sec. Assuming a "burnup" of ~1%, the authors of[6] talk of emission of $\sim10^{17}$ neutrons per pulse. At a repetition frequency ~0.1 Hz, such a pulsed source would have an average intensity $\sim10^{16}$ neut/sec and a heat release ~1 MW. The average laser power would then be of the order of 10 kW.

It should be noted, however, that the feasibility of obtaining the critical mass of fissionable matter, demonstrated in[6] still does not mean that it is possible to obtain neutron pulses of sufficient intensity with a small amplitude scatter of the pulses. Under the conditions considered in[6] the time of development of the chain reaction is small (less than $10^{-9}$ sec), and to obtain intense neutron pulses the nuclear density must greatly increase the critical value, and accordingly the multiplication coefficient should be much larger than unity. At the same time, the intensity of the "extraneous" neutron source must be high.

Indeed, the rms scatter of the neutron pulse amplitudes $I$ generated in a fission chain reaction is

$$\sigma(I)/I = \sqrt{\frac{\nu\Delta^2}{2S\tau}},$$

where $\nu$ is the average number of secondary neutron per fission, $\Delta^2$ is the variance of the multiplication coefficient for a single fission act, $S$ is the intensity of the exciting neutrons, $\tau$ is the average lifetime of the neutrons in the multiplication system see[7]). Assuming as an estimate $\Delta^2\sim1$ and $\tau\sim2\times10^{-11}$ sec,[6] we find that a pulse-amplitude scatter ~10% corresponds to $S\sim10^{13}$ neut/sec.

The total number of fissions per pulse is estimated from the relation

$$I = W_m T_{1/2},$$

where $W_m$ is the number of fissions per second in the maximum of the pulse, and $T_{1/2}$ is its half-width. Analogously[3]

$$W_m \sim \frac{2.5S}{\nu\sqrt{\gamma_1\tau_0}}\, e^{\int\limits_{\Delta k>0}\frac{\Delta k(t)}{\tau(t)}dt}, \qquad T_{1/2}\sim 2.35\sqrt{\tau_0/\gamma_2}\,.$$

Here $\tau_0$ is the neutron lifetime at the critical density $n_0$, while $\gamma_1$ and $\gamma_2=dk/dt$ are the rates of change of the multiplication coefficient on going through the critical point. To estimate the number of fissions, we approximate the time dependence of the excess multiplication coefficient $\Delta k$ and of the nuclear density $n$ by parabolas:

$$\Delta k(t) = \Delta k_0\left(1-\frac{4t^2}{\theta_0^2}\right),\quad n(t)=n_0\left\{1+\left(\frac{n_m}{n_0}-1\right)\left(1-\frac{4t^2}{\theta_0^2}\right)\right\}.$$

Here $\Delta k_0$ is the maximum value of the excess multiplication coefficient, $n_0$ and $n_m$ are the critical and maximal values of the nuclear density, and $\theta_0$ is the supercriticality time. Then

$$I\sim\frac{1.5S\theta_0}{\nu\Delta k_0}\, e^{\frac{\Delta k_0\theta_0}{\tau_0}\left(\frac{8}{15}\frac{n_m}{n_0}+\frac{2}{15}\right)}$$

If the maximum nuclear density is double the critical value, $\Delta k_0\sim0.6$ ($k\propto n^{2/3}$), then to obtain $\sim10^{17}$ fissions per pulse[6] at $\theta_0=0.5\times10^{-9}$ sec the priming density required is $S/\nu\sim2\times10^{18}$ fissions/sec. Such an intensity is possible only when extraneous neutron-pulse sources of extremely high intensity are used. For example, using for the excitation proton bunches of energy ~600 MeV from the bunching storage ring of the meson factory of the USSR Academy of Sciences (bunch lifetime $\sim2.5\times10^{-8}$ sec, peak current ~5 A, project of[8]), then the intensity of the fissions produced by the exciting radiation in the fissioning-matter sample weighting ~0.01 g is $\sim10^{18}$ $\text{sec}^{-1}$ provided the bunch is focused to a diameter ~1 mm. It is also possible to use as the priming radiation high-power electron beams from pulsed one-shot accelerators, and finally neutrons from the D–T reaction, if the ablative coating of the samples (see[6]) contains a mixture of deuterium with tritium.

In conclusion, I consider it my pleasant duty to thank E.S. Matusevich for calling my attention to[6].

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[1] H. C. Paxton, Nucleonics 13, 48 (1955).

[2] I. I. Bondarenko and Yu. Ya. Stavisskii, Atom. Energ. 7, 417 (1959).

[3] V. S. Diven, Ann. Rev. of Nucl. Sc. 20, (1970).

[4] R. Brugger, Nucl. Technology 15, 14 (1972).

[5] M. Lubin and A. Fraas, Sc. Amer. 224, 21 (1971).

[6] G. A. Askar'yan, V. A. Namiot, and M. S. Rabinovich, ZhETF Pis. Red. 17, 597 (1973) [JETP Lett. 17, 424 (1973)].

[7] G. E. Blokhin, D.I. Blokhintsev, *et al.*, Pulsed Fast Neutron Reactor, Conf. on Physics of Fast and Intermediate Reactors, Vienna, 1962.

[8] G. I. Batskikh, A. A. Vasil'ev, *et al.*, Proc. 3rd All-Union Conf. on Accelerators, Moscow, Vol. 1, 249 (1973) (in Russian).