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(54) **A neutron amplifier assembly**

(57) This invention relates to a neutron amplifier assembly comprising an array of fissile material which is subjected to a primary neutron flux.

According to the invention a thin layer (1) of fissile

material is located on the inner surface of a hollow support cylinder (2) of moderator material, the fissile material layer thickness and the inner diameter of said cylinder being chosen such that the array is close to criticality.

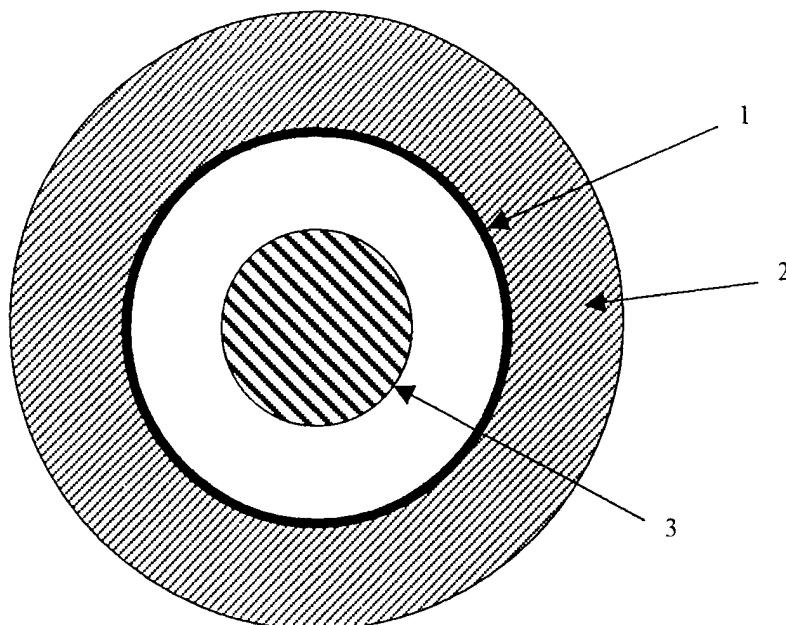


Fig. 1.

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Description

[0001] This invention refers to a neutron amplifier assembly comprising a slightly subcritical array of fissile material which is subjected to a primary neutron flux.

[0002] A neutron flux is used not only for research purposes but also for irradiating goods, for cancer treatment and even for controlling a nuclear power generator. For example, a high neutron intensity above 10^{17} s^{-1} would be useful for many purposes. Such a high flux is beyond the practical possibilities of modern accelerators, even in combination with a spallation target. It is therefore an object of the present invention to provide a neutron amplifier assembly which supplies an intense and readily controllable neutron flux.

[0003] This object is achieved according to the invention by the neutron amplifier assembly as defined in claim 1. For further improvements of this assembly reference is made to the secondary claims.

[0004] The invention will now be described in detail by means of some preferred embodiments and the enclosed drawings.

[0005] Figure 1 shows schematically in cross-section a first embodiment of the assembly according to the invention.

[0006] Figure 2 shows the relation between the mass and layer thickness of fissile material in the hollow cylindrical arrangement of given dimensions for $k_{\text{eff}} = 1$.

[0007] Figure 3 shows a variant which is conceived to produce a high flux of fast neutrons.

[0008] Figure 4 is an improved embodiment with two subcritical arrays in series.

[0009] According to a first embodiment shown in figure 1, the fissile material is $\text{Am}^{242\text{m}}$. This material constitutes a thin layer 1 on the inner surface of a hollow cylinder 2 of circular cross-section, made of a neutron moderator material such as graphite or beryllium. Along the axis of this cylinder a spallation target 3 is located which is intended to receive a proton beam from an accelerator (not shown) along the axial direction of the cylinder 2. As an example, the cylinder height and its inner diameter are both 1 m, the diameter of the target 3 being 30 cm.

[0010] The thickness of the layer 1 is in the micrometer range and will be specified later. This thickness depends upon the type of fissile material and its concentration in this layer. In any case it must be sufficiently small in order to allow fast neutrons to pass there-through without interaction, whereas thermal neutrons are trapped.

[0011] Neutrons starting from the target 3 may be either thermal or fast neutrons.

[0012] Thermal neutrons react immediately with the layer 1 and generate fast neutrons whereas fast neutrons pass there-through without interaction. In both cases fast neutrons penetrate into the graphite cylinder 2 and become thermalized. If these neutrons penetrate again into the layer 1 they cause more fissions. Those which escape from the cylinder at its outside constitute the output of the amplifier assembly.

[0013] It should be noted that the thickness of the fissile material layer on the inner surface of the graphite cylinder should be such that the arrangement does not become critical, but a criticality factor k_{eff} close to 1 should be achieved in order to enhance the neutron amplification gain.

[0014] The tables following here-after show, for a cylinder having an inner diameter ϕ equal to its height, the thickness of a layer of $\text{Am}^{242\text{m}}$ and U^{235} respectively required for various inner cylinder diameters ϕ necessary to make the system critical.

ϕ (cm)	critical thickness (cm)	critical mass (kg)
10	0.4	2.6
20	0.063	1.6
30	0.005	0.25
40	0.001	0.1
60	0.0004	0.08

Table 1. Layer thickness of $\text{Am}^{242\text{m}}$ metal and corresponding mass required for criticality for various cylinder diameters ϕ .

ϕ (cm)	critical thickness (cm)	critical mass (kg)
10	2	14
20	0.8	20
40	0.15	14
60	0.023	5

(continued)

ϕ (cm)	critical thickness (cm)	critical mass (kg)
100	0.007	4

Table 2. Layer thickness of U^{235} metal and corresponding mass required for criticality for various cylinder diameters ϕ .

[0015] These values are also represented in the plot of Figure 2 as small circles and crosses respectively. One can for example deduce there-from that criticality is obtained with an Am^{242m} layer thickness of 4 μm on the inner surface (diameter 60 cm) of a graphite cylinder (axial length 60 cm). The overall critical mass of fissile material is under these circumstances only 80 g which is considerably less than the (bare) critical mass of a solid sphere of the same material (4.7 kg).

[0016] Thus if a thickness below 4 μm is chosen then the arrangement will be subcritical. If for example the criticality factor k_{eff} is 0.95 then its neutron amplification factor will become 20.

[0017] A commercial cyclotron supplying a proton beam of 150 MeV produces in a lead spallation target about 1 neutron per proton. Due to the layer of fissile material this neutron produces on average M neutrons where $M \approx 1/(1 - k_{eff})$. For the case of $k_{eff} = 0.95$, M is approximately 20.

[0018] The invention is not restricted to the embodiment described above. One could employ other fissile materials, such as U^{235} (see table 2 and figure 2). It should further be noted that the invention is also applicable to materials others than pure fissile materials, in which the fissile material is present in the layer at a substantially reduced amount.

[0019] It is also possible to cover the inner layer 1 of fissile material with a layer of moderator material in order to reduce damages in the fissile material layer due to high energy neutrons.

[0020] The neutron source can instead of a spallation target consist of a neutron emitter such as Californium.

[0021] The cylinder 2 is not necessarily of circular cross-section as shown in the drawings. In fact, the cross-section might be square or present an inner corrugated shape like a star. In this latter case the overall diameter of the cylinder 2 can be reduced whilst maintaining the same surface area of fissile material.

[0022] The heat production in the arrangement is rather low: Taking the above cited example of a 150 MeV accelerator supplying a proton current of 2 mA (corresponding to 300 kW power output) and a neutron amplification factor of 20 due to the layer 1 of fissile material, the neutron intensity will become about $2.5 \cdot 10^{17} s^{-1}$. Since the neutron generation rate is approximately equal to the rate of fissioning, the maximum heat generation rate is about 8 MW. This heat can be easily extracted through coolant channels in the graphite cylinder.

[0023] In case that not a thermal neutron flux but a fast neutron flux is desired, the arrangement according to figure 1 should be completed, as shown in figure 3, by a further layer 4 of fissile material on the outer surface of the graphite cylinder 2 and optionally by a metal casing 5 around this layer, especially made of tungsten. This second layer 4 is again transparent to fast neutrons as it interacts only with neutrons which have been thermalized in the graphite cylinder. These neutrons cause fissions which result in fast neutrons. A part of these fast neutrons escapes through the casing whereas others return into the graphite cylinder and cause further fissions in one of the layers of fissile materials.

[0024] According to a further improvement of the present invention two or more layers of fissile material are located, preferably in a concentric axial configuration, between the spallation target and the inner diameter of the graphite cylinder. Such an example is sketched in figure 4. Here, one additional layer 6 of fissile material is added which is either self-supporting or deposited on a metal tube, for example made of tungsten (not shown).

[0025] As a further improvement, one or more moderator rods (not shown) can be inserted in a controlled manner into the free space inside the graphite cylinder. This insertion increases the criticality factor and allows a fine control of the neutron amplification factor and of the criticality factor, in order to take into account inhomogeneities of the thin layers and their burn-up.

Claims

1. A neutron amplifier assembly comprising an array of fissile material which is subjected to a primary neutron flux, characterized by a thin layer (1) of fissile material on the inner surface of a hollow support cylinder (2) of moderator material, the fissile material layer thickness and the inner diameter of said cylinder being chosen such that the array is close to criticality.
2. An assembly according to claim 1, characterized in that at least one further thin cylindrical layer (5) of fissile material is placed in said cylinder at a distance from the previous layer (1), its diameter and thickness being chosen such that the overall configuration constitutes again a nearly critical array.

3. An assembly according to claim 1, characterized in that the primary neutron flux is generated by a neutron emitter situated in the centre of the assembly.
4. An assembly according to claim 3, characterized in that the neutron emitter is constituted by a spallation target (3) intended to be bombarded by accelerated particles.
5. An assembly according to any one of the preceding claims, characterized in that the hollow cylinder (2) is made from graphite.
6. An assembly according to any one of the preceding claims, characterized in that the hollow cylinder (2) is surrounded by a layer (4) of fissile material.
7. An assembly according to any one of the preceding claims, characterized in that at least one moderator material rod is movably inserted into the free space in the hollow cylinder (2).

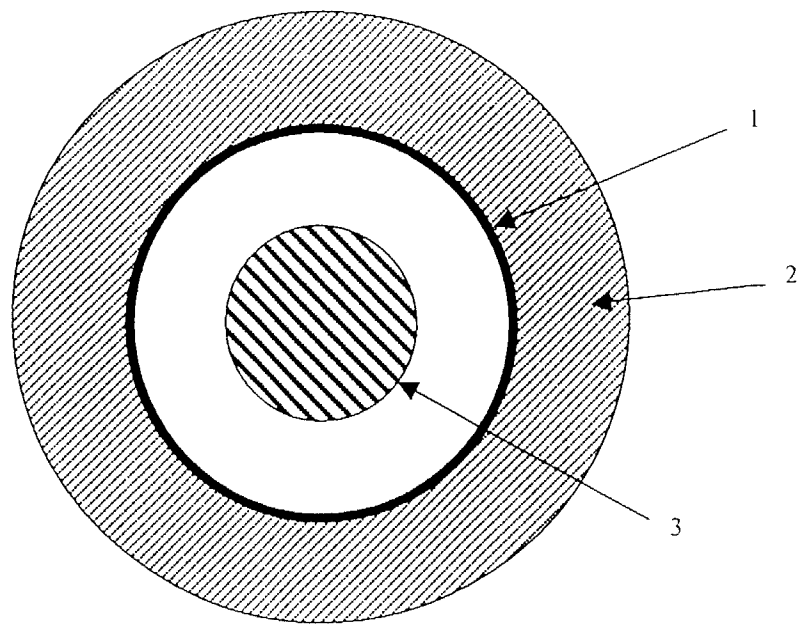


Fig. 1.

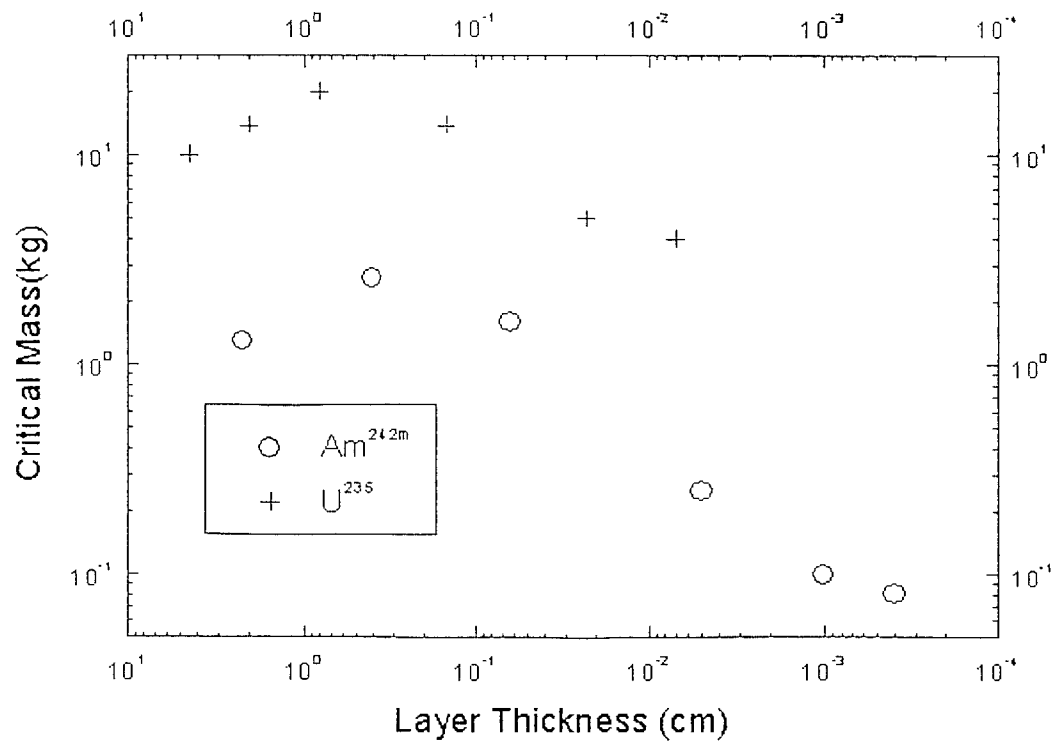


Fig. 2.

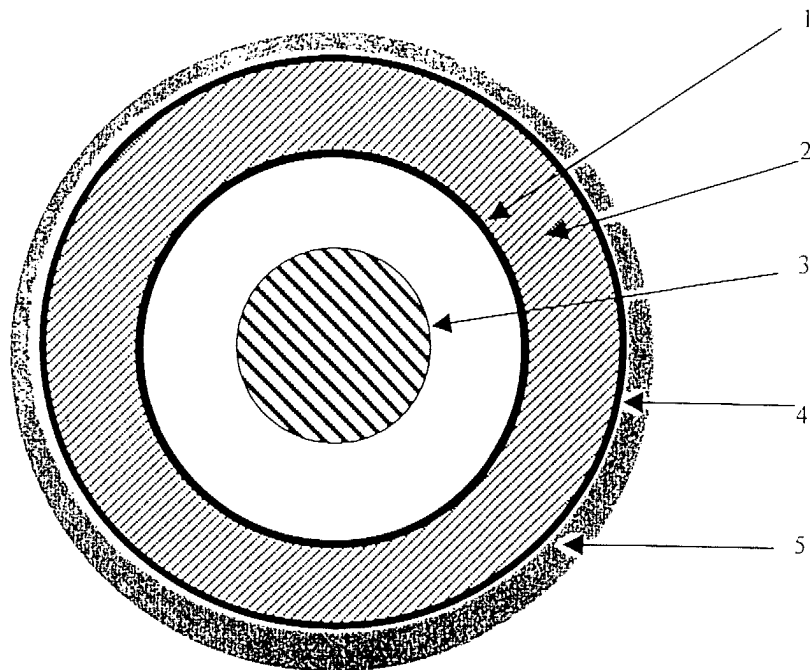


Fig. 3.

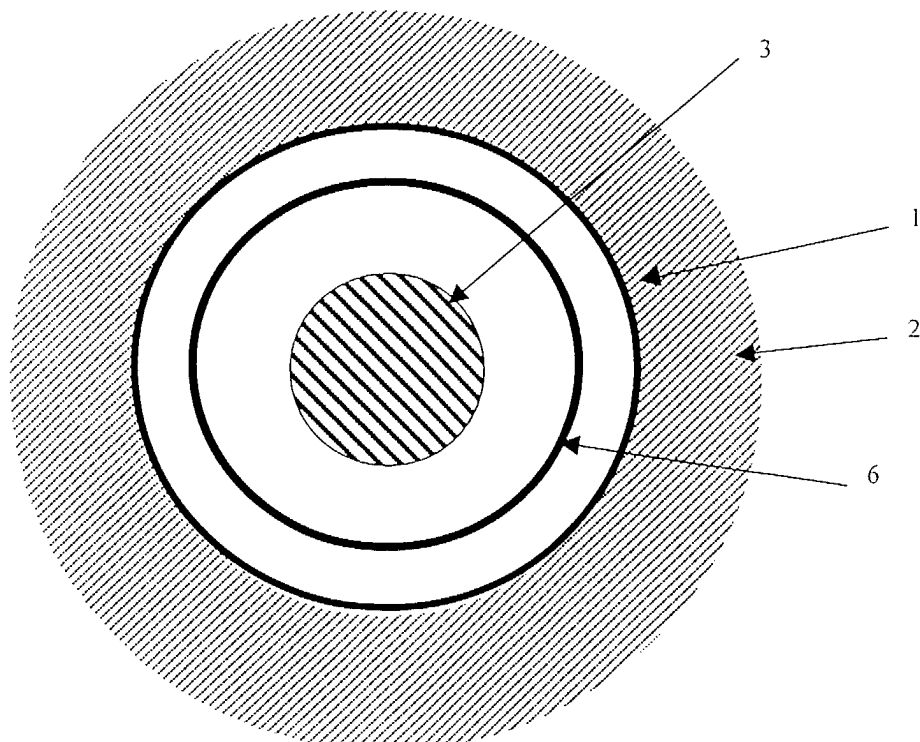


Fig. 4.



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EUROPEAN SEARCH REPORT

Application Number
EP 99 10 7327

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	GB 850 876 A (DOW CHEMICAL CO.) 12 October 1960 (1960-10-12) * page 1, line 29 - line 63 * * page 2, line 22 - line 66 * * page 3, line 111 - line 122 * * page 4, line 71 - line 95 * * page 6, line 96 - page 7, line 8 * * figure 1 * ---	1-4,7	G21G4/02
A	WO 95 24043 A (ION BEAM APPLIC SA ;JONGEN YVES (BE)) 8 September 1995 (1995-09-08) * page 4, line 12 - page 5, line 25 * * page 7, line 1 - line 29 * ---	1,4,5	
A	US 3 778 627 A (CARPENTER J) 11 December 1973 (1973-12-11) * column 5, line 28 - line 64 * ---	4	
A	DATABASE WPI Week 9220 Derwent Publications Ltd., London, GB; AN 92-164686 XP002116849 & SU 786 619 A (V.F. KOLESOV), 15 August 1991 (1991-08-15) * abstract; figure * -----	2,6	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int.Cl.7) G21G H05H
Place of search THE HAGUE		Date of completion of the search 1 October 1999	Examiner Capostagno, E
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03/82 (P4/C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 99 10 7327

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The members are as contained in the European Patent Office EDP file on
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01-10-1999

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 850876 A		BE 567050 A US 3291694 A	13-12-1966
WO 9524043 A	08-09-1995	BE 1008113 A	23-01-1996
US 3778627 A	11-12-1973	NONE	
SU 786619 A	15-08-1991	NONE	