Nuclear Reaction Control and Shielding Systems based on Radiation Guiding in Active Nano-Structures

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ABSTRACT

The actual nuclear reactors are using heavy concrete shielding, in order to reduce the radiation outside the active zone. The main radiation attenuation method is called mass-attenuation, because no matter (with some approximation) what material we are using, in order to get a radiation attenuation ratio, about same mass is required, no matter if it is hydrogen, water or tungsten for electromagnetic radiations with energies above 300 keV, inside gamma ray domain.

For neutron attenuation, light, neutron absorbent materials are used for shielding surrounded by gamma absorbent shielding, which all together makes the nuclear power source heavier by 2 to 10 times.

The novel material relies on trapping the gamma radiation and neutrons inside specially engineered nano-structures, which guides it along the structure, changing its direction without changing its energy.

This material is useful in radiation imaging, non-imaging concentrators, and radiation modulators.

The shield made of the new material is lighter that the actual shielding, and it may be used as reactivity control device, having a response time in micro-seconds being by at least 1000 times faster than the actual reflective drums, allowing the nuclear reactor power (amplitude) modulation up to MHz frequencies, good for strategic neutrino communication systems.

Keywords: radiation-guide, nano-structures, reactor-shield, active-shield, radiation concentrator, neutrino-communication, reactor-power-modulation

1 INTRODUCTION

The absorption of the gamma ray is due to an energy dependent processes that relies on mass conversion by pairs production, Compton, Photo-electric.

Fig. 1 shows the matching of Electro-Magnetic radiation at various energies with various materials and energy domains. The interest for shielding is mainly for energy domain covered by X rays and low energy Gamma rays.

The wavelength for photons becomes equal with the inter-atomic distances at energies over 100 eV up to 1keV, in the soft X ray domain. For neutrons this dimensional matching happens at energies in meV domain, where epithermal and fast neutrons wavelength is smaller then the lattice inter-atomic distances making these particles have high penetration in materials. Atomic electronic excitations are a consequence of photopeack X ray absorption, Compton scattering, electron-pozitron pair-generation.

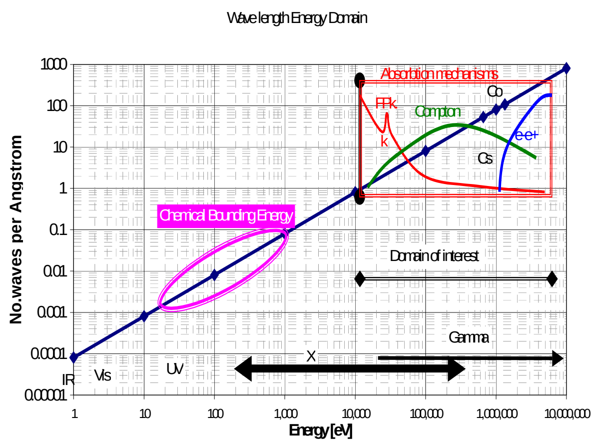

Fig. 1 - Energy and associated waves numbers

For gamma rays the attenuation is mainly called mass – that means that the type of the substance does not matter so much. In X and low energy gamma domain, the electronic orbital resonance offers attenuation peaks that can be used to enhance the effectiveness of the material.

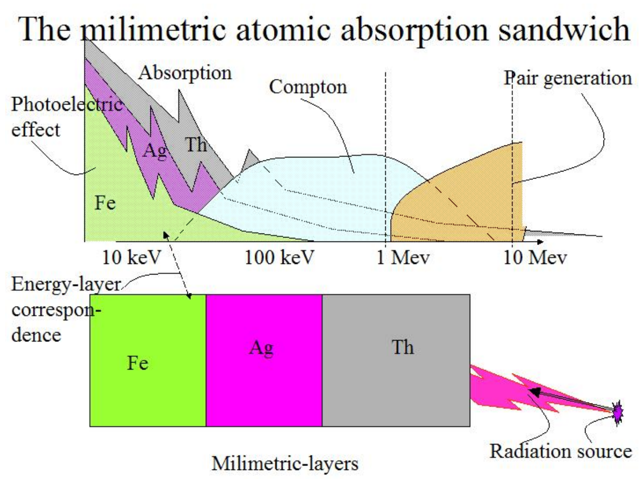

Fig. 2 – Energy degradation multi-material sandwich

These materials are grouped in sandwiches as shown in bottom of Fig. 2 making a structure known as "radiation degradation" layers. able to effectively degrade radiation up to 150 keV. This is the "classical" scheme based on atomic absorption and attenuation materials.

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The necessity of degradation layers occurs due to the fact that the primary high-energy radiation interacting with the shielding materials is producing lower energy radiation.

The structure is used for low and ultra-low background gamma measurement chambers, but is not work efficient for radiation energies higher than 200 keV and neutrons.

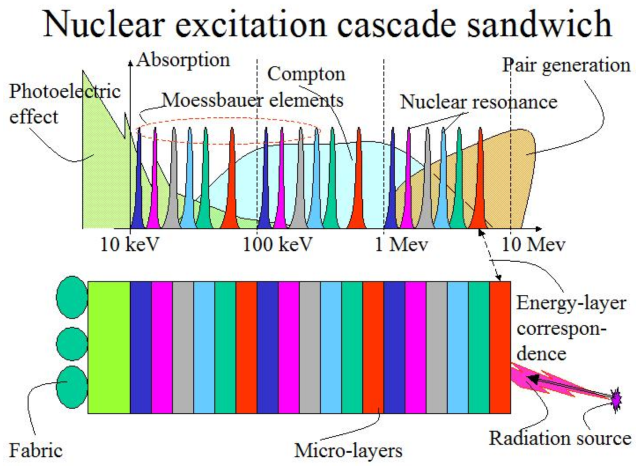

Fig. 3 – Resonant multi-elemental sandwich

Many elements exhibits nuclear resonance for gamma absorption in the domain 100 keV-1.5 MeV, used in the Moessbauer spectroscopy. The lines of emission and subsequent absorption resonance are narrow and distributed over the energetic spectrum as shown in Fig. 3. Absorption-re-emission based materials starting on the face towards the radiation with layers exhibiting nuclear resonance at high energies followed by lower-energy layers, such as a high energy photon to be absorbed in the first layer, reemitted and reabsorbed, until transformed in IR and phonons.

2 NANO-GYRATORS

Trapping gamma particles in nano-srtuctures in order to turn them a collective interaction at grazing angle is required, in order to make gamma rays see wave-guides in the crystalline structures and to be driven and deflected inside the molecular structures acting together.

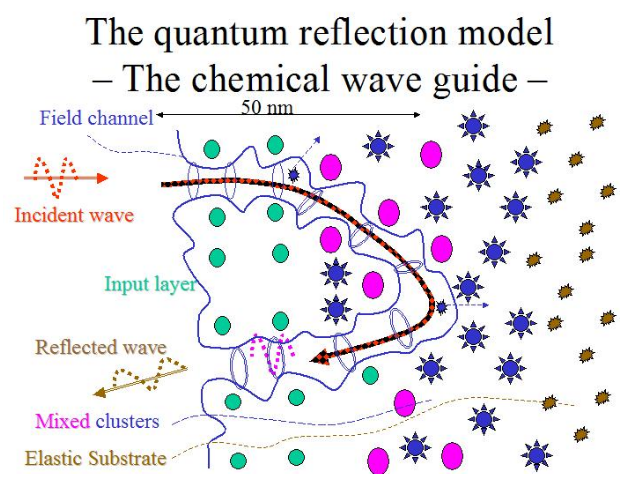

Fig. 8 – Nano-structured wave guide

The impulse transferred by the field interaction to each atom has to be under the elastic limits, heating the lattice without damaging it. The radiation will be channeled inside the molecular wave-guides having the propriety of slightly turning and gyrating it towards outside the layer by a combination of resonant structure with small turning by mild grazing angle Compton collisions, as shown in Fig. 8.

The neutrons will mainly interact with the magnetic component of the nano-structure’s molecular field acting like a FODO structure and bounce them back towards center of the structure [1], as shown in Fig. 9.

Similar effects may be obtained in bended nano-wires.

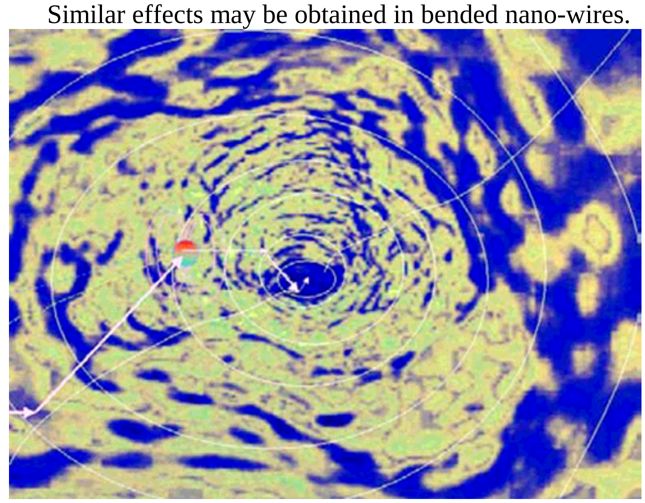

Fig 9. Artist view of a neutron dipole interacting with magnetic moments of the atomic orbital structure

The interaction process a 90 deg. Gyration, enough to achieve shielding is complicated, due to resonances and quantum effects. The condition to produce absorption free shielding is to cover the entire incidence surface with channeling wave-guides entry stages, therefore no mater the position or the incidence angle the radiation is trapped in a wave guide and controlled. Any angle that deflects the radiation from the protected volume is good enough, without being necessary to return the radiation by fully reversing its direction.

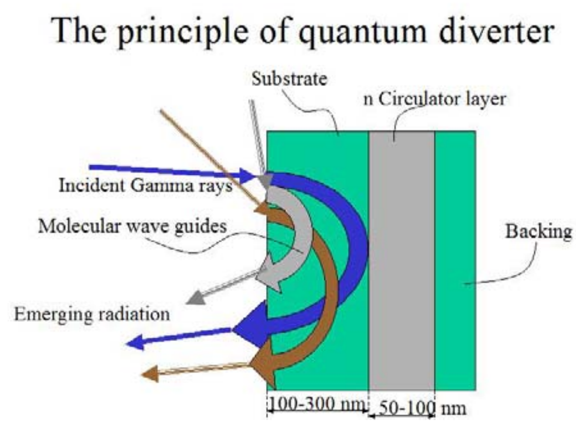

Fig. 10 – Gyration and shielding

Fig 10 shows the operating principia of a complex nano-structured composite material proposed for electrical controlled shielding, generating a new type of nuclear reflectors with increased electronically controllable albedo/transmission ratio and ultra light nuclear shielding, which opens the way towards portable nuclear power sources based on fission and hybrid fusion-fission power sources.

3 APPLICATIONS

As Fig.11 upper side shows the gamma and neutrons are guided inside molecular wave guides that can be perturbed by a quantum diverter, when electrically excited introduces supplementary quantum states that generates electrically controlled scattering or kicks-out the channel the trapped particles, becomeing an active n-γ direction control device.

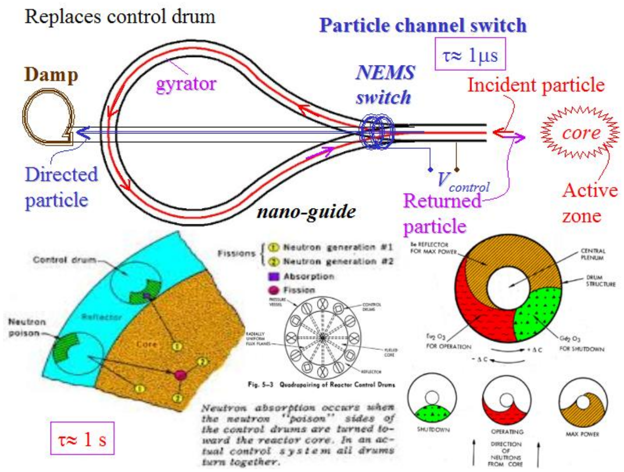

Fig. 11 – Active NEMS gyrator nano-channel guides

Fig. 11 bottom, shows rotatying reflective/absorbant n drums used for nuclear reactor criticality control, being slower by 1000x than electronically controlled n-gyrators

Fig. 12 shows a comparative analysis of various shielding methods that can be used to enhance the shielding capabilities making the shield lighter.

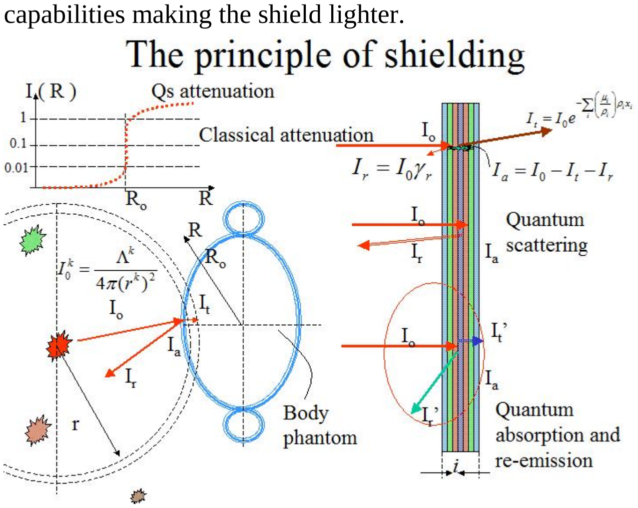

Fig. 11 – Various shielding methods

Using classical mass attenuation to produce a shielding suit to cut by 75% ^{60}Co radiation needs 10 cm thickness if made of lead, 7 cm for tungsten giving a weight of about 800kg for a whole body suit.

Resonant quantum absorption and reemission process using the Mossbauer lines is enhancing the process but can not cover all the spectrum, because the lines are very narrow and requires a large diversity of materials posing chemical stability and safety issues. The novel type of absorption by channeling offers a potential reliable ultra light wide band shielding material to be used in the future.

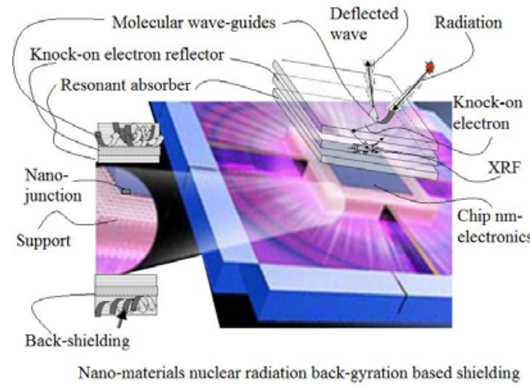

Fig. 13 – Electronics shielding principle

The neutron channeling was identified by 30 years ago [2] and was under continuous development [3] with emphasis on the novel possibilities offered by the nanostructures [4], as Fig. 13 shows a shielding to prevent electronics single event upset, in n-γ radiation fields, enabling very thin shield with electronically controlled transmission/reflection. This will improve also the reactor design and shielding, and to further reduce the critical mass to less than 1/10th of the amount used in actual explosive devices; a new generation reactor becoming critical with less than 50g of ^{239}Pu. The incorporation of the electronically controlled reflectors minimizes the critical mass and shielding dimensions making possible the production of ultra-small nuclear power sources [5] ideas deriving from the actual researches on radiation channeling [6] with very promising outputs.

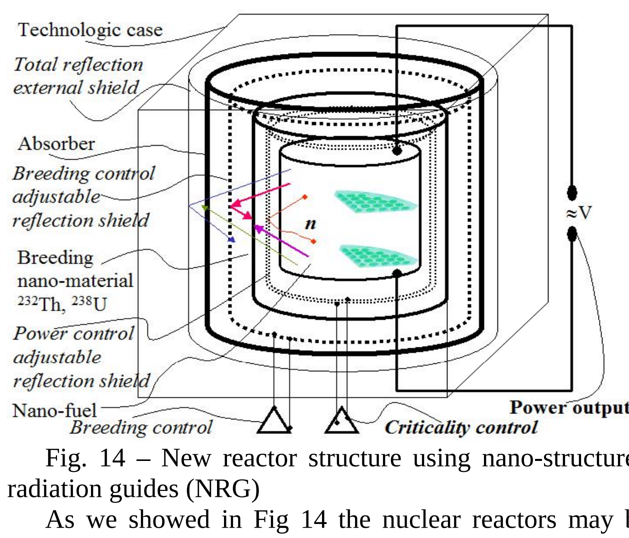

Fig. 14 – New reactor structure using nano-structured radiation guides (NRG)

As we showed in Fig 14 the nuclear reactors may be made very small, in 1-2 ft diameter at acceptable weights less than 1 ton and powers in accordance with constructive materials safety limits, but the shielding remains the biggest obstacle in their potential applications.

If the nano-guides for nuclear radiation mainly neutrons and gamma will work successfully the nuclear reactor shield size might be reduced from 6 ft down to 2-4 inches thus reducing the dimensions of the nuclear reactor from about 30 ft to less than 3 ft for about 1GW of power[7,8].

Fig. 12 shows the internal structure of a ideal nuclear reactor, where the shielding and the control is made electronic by using electro-reactive channeling structures. The reactor contains two electronically controllable albedo active shields that regulate the criticality and breeding rate and along with the operating power.

Escaped neutrons are transmitted to an absorber material for transmutation purposes and are totally reflected inside the reactor. In this conditions the criticality mass becomes very small – estimated at 50 g of 239Pu or 233U for several MW of power in about a 1ft radius.

It is known to have 1MW-day power it is necessary to burn out about 1 g of pure fuel (^{233}U, ^{235}U, ^{239}Pu, etc), that have to be added daily or disclosed by withdrawing the absorption rods or control drums to the nuclear reactor because the critical mass does not burn, it has to be maintained there to assure the continuity of the nuclear fission process, and this is increasing with the burnup.

There are many other applications of electro-turbo-fan nuclear powered systems, such as: stratospheric aerodromes, magnetic levitation rolling super highways, space power and propulsion, etc. all based on the success of electrical controlled nano-shielding. All these devices are in the very incipient stage of development theoretical concept development phase. The autonomous vehicles predictions seems to have about the same science basis as French novelist Joules Verne by 200 years ago when he wrote about fantastic travels underwater and by air in “Around the Earth in 80 days”, but the reality of neutron channeling complex application is a present fact [9] with a tremendous development. In the last 30 years since the Channeling effect was identified more than 500 papers have been published on the subject as result of many experiments in all the great laboratories of the world.

4 CONCLUSIONS

The nano-structures have significant chances of success in channeling the energetic gamma ray and neutrons in a controlled manner becoming a material of interest for radiation focusing, shielding, and albedo control in the next 50 years.

Our theoretical developments and predictions showed the possibility of creating the appropriate nanostructures to channel the gamma rays and neutrons in a controlled manner.

The development of advanced shielding will be beneficial for space applications as well for the terrestrial mobile nuclear power applications.

T The structure presented in Fig. 19 (A) is presenting the operating principle of the radiation guiding structure that gyrates the radiation, changing its direction by a collective interaction along the nano structure without changing its energy significantly. The nano-channel has input structure acting similar to a horn antenna in microwave that increases the capture zone, and channels the radiation and when it reaches the n-circulator layer it may be unperturbed if the layer is in position pass forward, or may be diverted and go along the layer. The transition of the “layer” from one state to another is done by an electric signal, the layer’s material being electro-sensitive.

If the nano-guide is customized for neutron guiding, the switch feature realized by the quantum diverter using the electro-sensitive layer called “n-circulator”, becomes a very important one, because the structure may be assembled in blankets surrounding the active zone, and may be used instead a control rod, with the difference as its response time is by 3-4 orders of magnitude shorter than that of the actual electro-mechanical or explosive actuated systems. These structures are tiny, several tens of micron thick, but their coverage factor is not perfect, therefore they mast repeated and about 300 layers have to be added, making the thickness of the reflective foil of about 1 mm thick and driving to an electrically controlled albedo of 0.0001 up to 99.999%, and a t_{on}/t_{off} time in ns domain.

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