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D-D-T Pellet Laser-Feedback Concepts

by

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A laser-fusion reactor employing deuterium-rich pellets to produce 2.45- and 14-MeV neutrons pumping of a Direct-Nuclear-Pumped Laser (DNPL) as a feedback coupling mode is considered. The DNPL utilizes MeV ions produced by neutron-driven nuclear reactions to pump a laser; and a deuterium-rich (D-D-T) pellet burn by the laser produces neutrons. Hence, the neutrons from one pellet burn drive the laser in order to ignite next pellet by which laser-fusion coupling scheme with DNPL is achieved.

This approach avoids several serious problems encountered in DNPL feedback fusion concepts using DT pellets[1-4] and offers a reduced tritium inventory and reduced neutron damage to materials. While a larger laser energy is required for ignition (vs. D-T), this obstacle is mitigated by the favorable energy-cost scaling of the DNPL compared to a conventional laser.

The use of a DNPL[1] in the feedback mode can play two important and distinctive roles in laser fusion. First, this provides a way to bootstrap the startup without requiring large and expensive energy storage facilities that would be necessary for a conventional laser. Thus, Wells[2] estimates that starting with 1 kJ conventional laser and imploding 300 DT pellets so as they energize a direct nuclear pumped laser having a 1% efficiency would make it possible to bootstrap up to an energy of 1 MJ. The DNPL could subsequently be employed for steady-state operation of the laser fusion device, and this would be its most crucial role.

The neutron economy must satisfy tritium breeding requirements and still provide sufficient neutron flux for laser pumping.

Figure 1 provides DNPL feedback with a deuterium rich (D-D-T) pellet proposed by Miley, et al.[6] This design is intended to provide improved neutron economy compared to D-T pellets and, by reducing tritium breeding requirements, makes it possible to use a special graphite-D_2O blanket that effectively achieves energy storage through a lengthened neutron propagation time[7]. While the D-D-T pellet requires a larger laser energy than a D-T pellet, this obstacle is mitigated by the favorable energy-cost scaling of the DNPL compared to a conventional laser.

The lowest neutron threshold for a DNPL reported to date is $\sim 5 \times 10^{15}$ thermal neut./cm^2-sec[4]. Such fluxes are difficult to achieve with D-T pellets due to the lithium-blanket required for tritium breeding. To avoid this, D-D-T pellets are proposed, i.e., a deuterium pellet containing a D-T "seed" for ignition propagation. Present estimates are that, compared to an equivalent D-T pellet, ~2 times the energy input is required for ignition. However, the added 2.54-MeV D-D neutron production provides an attractive coupling source and allows operation with a tritium breeding ratio <<1. Thus, the present design can utilize a thin lithium section followed by a helium-cooled graphite "moderator-propagator" region. Thickness of graphite blanket along with thermal neutron yields are tabulated in Table I. A bulk of the neutron kinetic energy is recovered as heat processed through a helium-turbine cycle to produce electricity.

Neutronic calculations, based on a reference 100-MJ output per pellet, indicate a neutron production of ~$3x10^{20}$/pellet which, with the present blanket, delivers ~$3x10^{19}$ thermal neutrons to the DNPL. This is adequate to pump, in the feedback mode, a 10% efficient BF_3 fueled laser, or alternately 0.1% or 0.01% efficient UF_6 or AmF_6 fueled systems, respectively.

In conclusion, the D-D-T neutron-coupled DNPL concept is shown to meet the key objectives of energy storage and neutron economy. In common with other laser-fusion concepts, however, a number of other technological problems must be overcome to attain a practical power plant.

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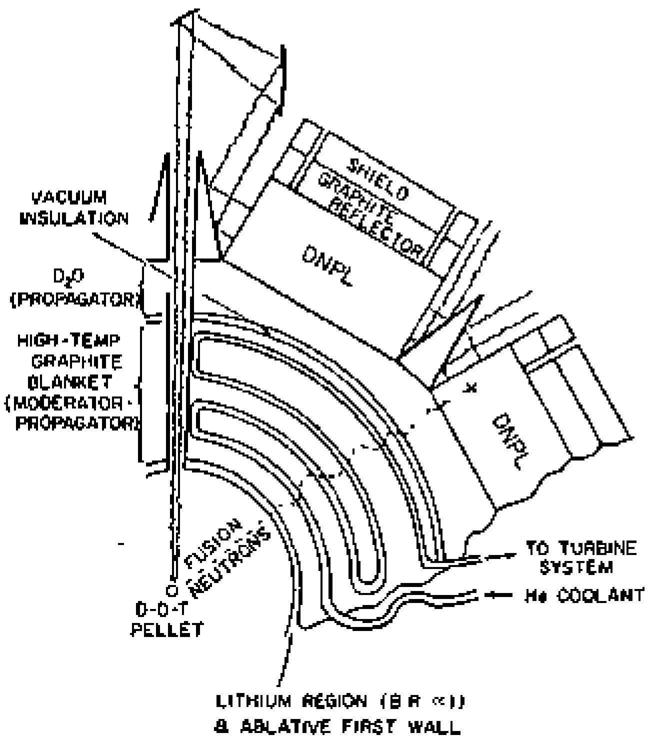

Figure 1. A D-D-T pellet, neutron propagation blanket concept for feedback coupling to a fusion reactor.

Table I. Graphite Blanket
Thermal Neutron Yields
(Based on the 4 Energy Group Calculation)

Blanket Thickness (cm)	Thermal Neutron Yield* ($\int \phi_{TH}\, dt$)	Laser Requirement Satisfied†
70	4.5×10^{19}	Yes
80	2.4×10^{19}	Yes
90	1.1×10^{19}	Yes
100	0.5×10^{19}	Marginal
110	0.24×10^{19}	No
120	0.11×10^{19}	No

†4×10^{18} n for 10% UF_6 at 1 MJ.

*Normalized to a pellet yield of $\sim 3 \times 10^{20}$ fast neutrons/pellet, using a D-D-T pellet design.