A Self-Cooled Lithium Blanket Concept for the HAPL Conceptual Laser IFE Power Plant

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The High Average Power Laser (HAPL) program is carrying out a coordinated effort to develop Laser Inertial Fusion Energy (Laser IFE) based on lasers, direct drive targets and a dry wall chamber. A primary focus of the study is the development of a tungsten-armored ferritic steel (FS) first wall (FW) which must accommodate the ion and photon threat spectra from the fusion micro-explosion. Only a thin region of the armor (10-100 μm) will experience the highly cyclic photon and ion energy deposition transients. The first wall structure behind the armor as well as the blanket will operate under quasi steady-state thermal conditions, very similar to MFE conditions. This allows the possibility of making full use of information from the large international MFE blanket effort in adapting a blanket for the laser IFE case. Scoping studies of several blanket concepts compatible with the chosen FW protection scheme are ongoing as part of a first phase effort with the goal of converging on the most attractive concept(s) for more detailed integrated studies during a second phase. One of the concepts considered as part of this initial effort is a self-cooled lithium blanket. This is an interesting concept when applied to IFE (as contrasted to MFE) since the absence of magnetic field allows the designer to take advantage of the high heat transfer capability of lithium without the MHD issue.

The geometry of the chamber is near cylindrical. For the example reactor size assumed in the analysis, the radius of the chamber is 6.5 m at the mid-plane and tapers to 2.5 m at the upper and lower extremities. The blanket consists of banks of rectangular tubes (or submodules) arranged vertically extending the whole height of the chamber. The FW of the submodule is 0.35cm thick ferritic steel, which has a 0.1 cm thick tungsten armor layer diffusion bonded to it facing the target. The rectangular tubes vary in width and depth to accommodate the shape of the chamber. Concentric with the outer tube, is another inner tube situated inside the submodule and separated from the outer wall to form an annular channel. The outer wall (including the FW) is cooled with Li which is admitted at the bottom of the blanket, flows through the annular gap to the top and then returns to the bottom at low velocity through the large center channel provided by the second concentric tube. This permits to some extent the decoupling of the lithium outlet temperature from the wall temperature. To facilitate maintenance and accommodate the numerous (~60) beam ports, a number of submodules are lumped together to form a module. The middle submodule in each module has the same width top to bottom, and contains the beam ports. Behind the blanket modules is a ferritic steel vacuum chamber, which will be cooled with He gas. Preliminary neutronics analysis shows that a blanket of at least 47 cm is required in order to make the vacuum chamber a lifetime component. Assuming a 200 dpa limit, the blanket will have a useful lifetime of 10 full power years. The thickness of the vacuum chamber is 50 cm which allows for rewelding at the back. The overall tritium breeding ratio (TBR) is estimated to be 1.1. The blanket is coupled to a Brayton power cycle through a Li/He heat exchanger. Details of the scoping study of this blanket are presented in this paper.