High gain target designs for inertial fusion energy

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1 Executive summary

Several published inertial fusion power plant studies have stated the need for target designs capable of achieving gains of approximately 100× (where gain = fusion energy output/laser energy delivered) at repetition rates of $\sim$ 16 Hz [1]. Such targets must be inexpensive to fabricate ($\sim$ 20-40 cents per target) and they must withstand the target injection process without compromises to the target's quality. For instance, most high gain target designs require the DT fuel to remain below 20 K even though the chamber wall temperature can be as high as 800 K. Furthermore, achieving significant fuel burnup requires the assembly of a large DT fuel areal density ($\rho R > 3g/cm^2$) at an ignition relevant temperature of $\sim$ 10 keV. In the standard hot spot ignition scheme, such areal densities can only be achieved either by increasing the energy coupled to the fuel (which is often limited by the driver) or by lowering the fuel adiabat (which can be problematic since low adiabat designs are more vulnerable to the target and drive imperfections seeding the growth of hydrodynamic instabilities). To address some of these issues, we propose the following five research questions which could be addressed via the allocation of adequate designer time and computational resources:

1. Target designs utilizing liquid DT instead of solid DT[2, 3] are attractive since they circumvent the need for the costly β layering process[4]. Taking target imperfections and drive asymmetries into account, under what conditions (driver energy, implosion velocity, vapor pressure, and fuel adiabat) can liquid DT foam targets ignite and achieve high gains?

2. Target melt during injection is an issue that could potentially affect the feasibility of imploding directly driven targets in the chamber. Can the use of a radiation shield around the capsule circumvent this problem?

3. Low adiabat inertial fusion designs are sensitive to all perturbation seeds, including the fill tube. Is there a way to redesign the shape of the fill tube to reduce its damaging effect on the implosion?

4. To survive target injection, an indirectly driven target will likely need to be held by a thicker tent than what is fielded on current experiments on the National Ignition Facility. Can a high gain design be achieved with such a tent?

5. Two-sided target illumination could be useful since it would decrease the volume associated with the final optics assembly. More importantly, the target would be consistent with a thick liquid wall reactor concept with a 30 year lifetime and an order-of-magnitude lower induced radioactivity than magnetic fusion chambers. Can a high gain indirect drive design be achieved with two-sided illumination by careful design of the hohlraum?

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