General Comments on IFE Based Fusion- Fission Hybrids*

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This note addresses some of the considerations for IFE in a generic manner rather than focusing on one particular approach. First we note general R&D needs and then make some comments about specific drivers: lasers, heavy ions (HI) and Z-pinch pulsed power.

All hybrids, including MFE, will have to deal with issues related to the design of the fission blanket (including the fuel form) and the additional constraints it adds creating the fusion source. This is likely covered in detail by the Blanket panel, but we note here the essential requirements for 1) fission product containment 2) efficient neutron utilization to meet both fusion's need for tritium self-sufficiency and the hybrid's mission (fuel production, power multiplication, waste burning, etc.). Materials issues, particularly radiation damage in fusion and fission spectra, desire for high temperature operation, corrosion effects, etc., must be addressed for any IFE or MFE approach. Most of the structural material science issues are common with pure fusion development, so there should be common ground and purpose to be found in this area. MFE must deal with additional issues related to magnetic fields if liquid metal coolants are used. IFE approaches must deal with pulse effects, particularly in the fission fuel where most of the energy is produced. The design of the fission fuel form must take these factors into account. MFE and IFE will also share common R&D needs with respect to the fuel cycle and how the fuel composition and chemistry evolve during the irradiation period. For very deep burn concepts proposing >90 fission of initial metal atoms (FIMA), the changes are clearly dramatic and need extensive R&D.

With respect to IFE hybrids, there is common need to develop systems needed for operation at pulse repetition rates of 0.1 to 10 Hz or higher. For laser and heavy ion driver, target injection and tracking systems are needed. For Z-pinch pulsed power, automated target/replaceable transmission line (RTL) insertion and post-shot debris management are needed. Low cost target manufacturing capabilities must be developed. All of these capabilities must be developed for pure IFE as well, although there will be differences in the IFE and hybrid operating parameters (e.g., required target gains, yield and rep-rate) due to the fission blanket energy multiplication and its impact on overall energy balance. In particular, hybrid will be able to operate with lower target performance than pure IFE.

Laser Drivers – As in pure IFE, high efficiency, low cost lasers capable of operating at high rep-rate will be required. Again, the fission blanket energy multiplication relaxes requirements on efficiency to achieve a given recirculating power fraction. Also, by opening the design space to lower gain targets, the driver energy and cost can be lower for hybrid applications. Efficient beam propagation through post-shot chamber environment and protection of the final optics from target emissions are key issues that will have to be addressed for hybrids as well as pure IFE. Use of lower yield targets for the hybrid, will somewhat reduce the challenges, but R&D is none-the-less needed.

Heavy Ion Drivers – Heavy ion drivers for hybrid applications will also require a comparable level of development as HI drivers for pure IFE, including transport of high beam currents to the target through the chamber. As with lasers, somewhat lower total beam energy and lower target gains and yield will be acceptable. HI driven hybrids may also open the chamber design space to include wetted wall or even thick liquid wall approaches, although a thick liquid wall hybrid would require fission material in the flowing liquid, which raise additional safety concerns.

Pulse Power Drivers – Pulse power concepts for pure IFE operate at lower rep-rate (~0.1 Hz) but higher yields (1000’s MJ) than laser of HI approaches. With the fission blanket energy gain, PP driven hybrids could operate even lower rep-rates (easing RTL replacement) or lower target yields (reducing required PP energy). When amplified by the fission blanket gain, the high yields associated with PP IFE present even greater challenge in the design of the fission fuel and structures that contain it.

In summary, we note the following:

1) Many of the same capabilities that must be developed for pure IFE will be needed for any IFE hybrid approach.
   - High rep-rate, efficient drivers
   - Low cost target manufacturing
   - Target injection and tracking (or rapid RTL replacement for Z)
   - Beam propagation through post-shot chamber environment (laser and HI)
   - First walls that survive short-range target emissions (x-rays and debris)
   - Radiation damage resistant, high-temperature-capable materials
   - Tritium breeding capability
2) The hybrid application relaxes some requirements
   - Lower target gains acceptable
   - Lower rep-rate and/or target yield designs are possible
   - Lower fusion power may reduce 14 MeV neutron damage rate depending on chamber configuration
3) The hybrid introduces new requirements and R&D needs
   - Design of the fission fuel form (capable of very high burn-up in some applications)
   - Design of tritium breeding and fission blankets in an integrated manner (even if they are physically separate, constraints such as tritium self-sufficiency must be met).
   - Containment of fission products
   - Protection of fissile materials
   - Enhanced decay heat and emergency cooling needs

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