Fractionation of Fusion Fuel in ICF Capsules: Inertial confinement fusion (ICF) ignition target designs typically assume a homogenous layer of an equimolar mixture of deuterium and tritium fuel kept roughly at or just below the triple point. Since each component in this mixture has a different triple point, there may be a tendency for the isotopes to separate (fractionate) into one-isotope-rich regions when the liquid is frozen or the solid sublimes during layering, as shown in Fig. 1.

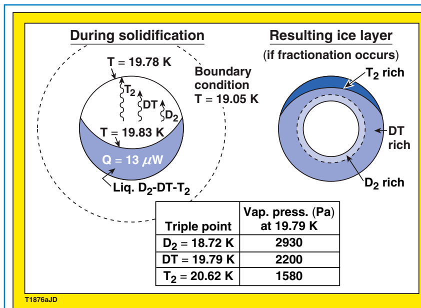

Figure 1. Schematic illustrating possible fractionation in a D_2-DT-T_2 mixture within a cryogenic DT capsule. The triple point of the lighter molecules is lower than that of the heavier ones; this can lead to fractionation at slow rates of solidification.

Fractionation of a hydrogen and deuterium mixture (25% H_2, 50% HD, and 25% D_2) was investigated at LLE on an experimental test bed. A focused beam from a Pb: salt laser tuned to the 3162 cm^{-1} absorption band of D_2 was raster-scanned across a 6-mm-diam, 3-mm-thick sample of the mixture to determine the D_2 concentration as a function of position. The absorption coefficient for D_2 in a H_2–D_2 mixture was found to be exponentially dependent on the D_2 molecular fraction in the mixture (see Fig. 2). It was also found that the absorption coefficient for deuterium in the HD mixture was significantly lower than would be expected from pure D_2 measurements. These effects are attributed to the induced-dipole absorption behavior of deuterium.

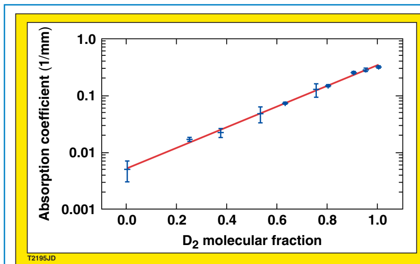

Figure 2. The measured average absorption coefficient of the D_2 in an HD mixture as a function of the D_2 molecular fraction at a wavelength of $\lambda = 3.151\ \mu$m.

From these absorption measurements, D_2 concentration gradients of only 0.02 to 0.05 molecular fraction per millimeter were inferred. A significant difference was observed between the freezing behavior of pure H_2 and D_2 versus HD mixtures. The HD mixtures have to be frozen gradually over an up-to-1-K temperature range to freeze all of the liquid. This is indicative of a completely soluble isomorphic system and as yet another indication that fractionation is incomplete.

To assess the effect of fractionation on target gain, 2-D hydrodynamic simulations of DT implosions were carried out using the *DRACO* code. In these simulations, the north polar fractionation of T_2 within the target was varied up to levels of 100% (complete fractionation). As the level of fractionation was increased past ~30%, the increasing lack of DT at the poles of the target began disrupting the target performance. As shown in Fig. 3, this process can degrade target performance from a gain of 45 for perfect ice down to a gain less than ~10 for the cases with high levels of fractionation. For low levels of fractionation, the ignition and burn phases of the implosion proceed almost completely unaffected by the redistribution of the fusion fuel within the target. It is helpful to note that in most ICF ignition designs the burnup fraction of fusion fuel is typically only in the 10% to 15% range by molecule. Thus, the target performance is relatively unaffected by small changes in the distribution of the fusion-fuel molecules.

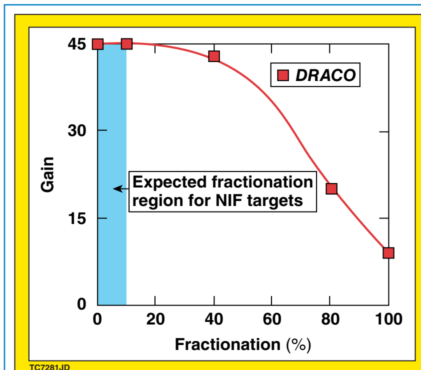

Figure 3. Calculated gain of a baseline direct-drive NIF capsule as a function of fractionation. For these simulations, the north polar region of the ice layer was assumed to be tritium rich.

Based on the HD fractionation measurements, it is expected that the level of DT fractionation on NIF direct-drive ignition capsules will not exceed ~10%. As is illustrated in Fig. 3, this expected level of fractionation should not be a significant factor in the performance of ICF ignition capsules planned for experiments on the NIF.

OMEGA Operations Summary: During December 2005, OMEGA conducted a total of 105 target shots for the following laboratories: LLE (62), LANL (23), LLNL (14), and CEA (6). The LLE shots were for polar direct drive, CRYO, low-adiabat implosion, and shock-timing experiments. The LANL shots included 9 shots for the NIC (Be ablator studies) and 14 HED (off-Hugoniot experiments). All LLNL experiments were for the NIC (Rayleigh–Taylor platform development and cocktail hohlraums), and CEA's shots investigated lined hohlraums. The last week of December was a dedicated maintenance week.

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