Development of a Dry Wall Concept for Laser IFE Chambers

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The first wall of a laser fusion chamber will experience high heat loads pulsed at 5-10 Hz with pulse widths on the order of a few microseconds. This poses a challenging problem for dry wall designs, as the wall will experience high stresses and will thus be susceptible to a variety of failure modes. The primary design concept of the High Average Power Laser (HAPL) project is a ferritic steel first wall coated with tungsten armor. Due to the high heat loads, the armor will experience high temperatures (~2500 C), extensive yielding, and surface cracking. In order to evaluate the ability of this design to provide a suitable lifetime, a series of experiments to simulate chamber conditions using ions, x-rays, infrared heating, and lasers is planned. These experimental efforts will be coupled with numerical modeling to help determine likely failure modes and establish design criteria for chambers.

The modeling is carried out using a commercial finite element code (ANSYS) to analyze the temperatures and stresses in the test coupons for each of the experiments. The heating from the various sources is included as volumetric heating, with the depth profile of the heating depending on the spectra of the incident energy and the stopping power within the tungsten. Temperature dependent properties are used throughout, and bilinear stress-strain models are used for the tungsten. Fatigue analysis is used to estimate the number of cycles needed for cracks to develop at the tungsten surface, and more detailed fracture mechanics analysis, using path integrals, is used to determine the depth to which these cracks are likely to propagate. These models are used to correlate the thermomechanical effects in the samples by comparing the results of the models with those of the post-test characterization. The samples are characterized using surface roughness and crack morphology as the primary characteristics of interest. From these comparisons, we elucidate the failure mechanisms of the steel/tungsten wall and attempt to infer the lifetime of such a wall.

The x-ray, ion, and laser experiments are designed to simulate the surface temperature expected in the HAPL chamber. This will help us to better understand the surface roughening and fracture seen in earlier experiments. The infrared experiments do not have sufficient power to mimic the surface temperatures of HAPL, but they do have sufficient time-averaged power to simulate the thermal and stress histories near the tungsten/steel interface. Hence, this experiment will be useful for addressing such issues as delamination and cracks penetrating the tungsten and reaching the steel. Again, modeling will be used to correlate these results with predictions, allowing us to infer failure mechanisms.

Finally, we also present a model for a larger, cooled component tested with the infrared source. This larger component will allow us to address failure mechanisms that will not be present in coupon tests, but are expected in reactor applications.