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Non-destructive analysis of DU content in the NIF hohlraums

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The advantage of using depleted uranium (DU) hohlraums in high-yield deuterium-tritium (DT) shots at the National Ignition Facility (NIF) is addressed by Döppner, *et al.*, in great detail [1]. This DU based hohlraum incorporates a thin layer of DU, ~7 μm thick, on the inner surface along with a thin layer of a gold coating, ~0.7 μm thick, while the outer layer is ~22 μm thick gold. A thickness measurement of the DU layer can be performed using an optical microscope where the total DU weight can be computed provided a uniform DU layer. However, the uniformity of the thickness is not constant throughout the hohlraum since CAD drawing calculations of the DU weight do not agree with the computed values from optical measurements [2]. Therefore, a non-destructive method for quantifying the DU content in hohlraums has been established by utilizing gamma-ray spectroscopy. The details of this method, along with results from several hohlraums, are presented in this report.

Experimental

Hohlraums

Three hohlraum sets (two halfraums per hohlraum, **Error! Reference source not found.**) were obtained from the target fabrication team at the NIF (Table 1). The individual weights were measured gravimetrically. The calculated (calc.) weights of the halfraums and the DU content were computed using a simplified model (DU is a cylinder with a thin Au liner inside and a thick Au layer outside) of the hohlraum and thicknesses provided in the bill of materials, if available.

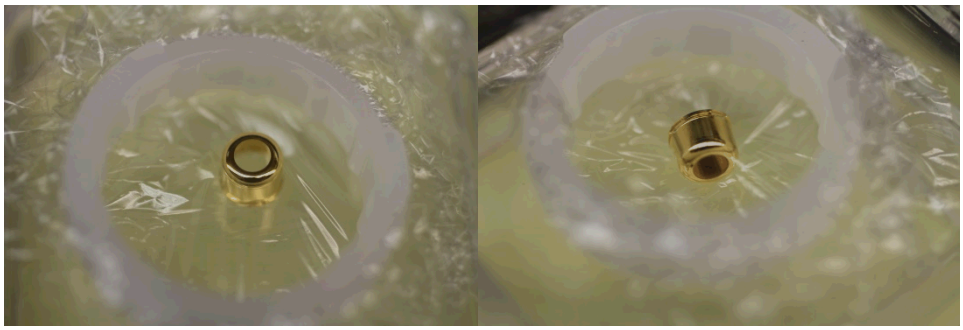

Figure 1. A hohlraum set, two halfraums, as received from the target fabrication team at the NIF.

Table 1. List of the halfraums and their respective weights (measured and calculated).

NIF Part #	NIF Serial #	Measured Weight (mg)	Calc. Weight (mg)	Calc. DU Weight (mg)	Calc. DU (wt%)
AAA12-106236-AA	31730010	81.9	-	-	-
AAA12-106238-AA	31750008	64.4	-	-	-
AAA12-106238-AA	31750017	73.8	43.5	11.3	25.9
AAA12-106238-AA	31750018	75.1	46.3	14.7	31.7
AAA12-106236-AA	31750019	70.6	45.0	13.2	29.4
AAA12-106236-AA	31750020	76.5	45.7	13.8	29.4

Gamma-ray Spectroscopy

Radiation counting was performed with HPGe detectors at the Nuclear Counting Facility (NCF) at the Lawrence Livermore National Laboratory. The halfraums were mounted upright on aluminum planchets with the laser entrance hole (LEH) facing towards the detector face. The samples were counted for 3 days at a distance of 3 cm from the detector face. The NCF utilizes the GAMANAL evaluation tool for the measurement of absolute radiation decay rates [3]. In order for the GAMANAL software to properly correct for sample geometry, distance and self-attenuation of the gamma-rays originating from uranium isotopes and their decay daughters, a detailed sample description was required (weight, density, material, area). As an approximation for the non-destructive analysis, the halfraum shape was converted to a flat disk of gold with the same measured diameter/weight as the halfraum while assuming material composition of pure gold. Furthermore, this approximation was examined by dissolving one of the samples (serial#31730010) and re-analyzing by gamma-ray spectroscopy through the use of a standard counting geometry (10 mL sample solution in a cylindrical shaped container having an area of 10 cm^2).

For the determination of DU content, the characteristic gamma-rays associated with U-235 and Pa-234m (assuming it was in secular equilibrium with its grand-parent, U-238) were used to calculate the number of atoms and/or weights of U-235 and U-238, respectively. The uncertainty for the uranium atom ratios includes one-sigma counting statistics and reported uncertainties in nuclear data [4] while the final weights of U-235 and U-238 also include a 2% absolute uncertainty of the HPGe detector efficiency.

Results and Discussion

The cross-calibration of the geometry approximation for the non-destructive analysis of DU content in the halfraums confirmed that the evaluation of the halfraum shape as a solid disk of gold is sufficient, Table 2. Comparison of the DU content in the halfraum (serial#:31730010) from two different counting geometries.Table 2. The difference in the final DU wt% of the halfraum from these two different counting geometries was <0.5%, for wt% values that have ~3% uncertainty.

Table 2. Comparison of the DU content in the halfraum (serial#:31730010) from two different counting geometries.

Sample	DU Weight (mg)	235/238 (atom %)	Halfraum Weight (mg)*	DU (wt%)
Whole	18.1 (±3.1%)	0.208 (±2.9%)	81.9	22.1 (±3.1%)
Dissolved	18.0 (±3.1%)	0.219 (±2.8%)	81.9	22.0 (±3.1%)

*gravimetric measurement

Therefore, the results as summarized below (Table 3) are from non-destructive analyses of the halfraums. The DU wt% from gamma-ray spectroscopy measurements are relatively close to those calculated from measured thicknesses (Table 1) but the total DU weight is significantly different (up to 40%). The measured U-235/U-238

atom ratio percent, ~0.2 %, clearly indicates uranium material that is depleted in U-235 in comparison to its natural isotopic abundance (0.725 %).

Table 3. The DU content in the six halfraums.

NIF Part #	NIF Serial #	DU Weight (mg)	235/238 (atom %)	Halfraum Weight (mg)*	DU (wt%)
AAA12-106236-AA	31730010	18.1 (±3.1%)	0.208 (±2.9%)	81.9	22.1 (±3.1%)
AAA12-106238-AA	31750008	15.7 (±3.3%)	0.205 (±3.2%)	64.4	24.4 (±3.3%)
AAA12-106238-AA	31750017	18.9 (±2.8%)	0.200 (±2.6%)	73.8	25.5 (±2.8%)
AAA12-106238-AA	31750018	20.9 (±2.6%)	0.205 (±2.0%)	75.1	27.7 (±2.6%)
AAA12-106236-AA	31750019	19.7 (±2.9%)	0.177 (±2.9%)	70.6	27.8 (±2.9%)
AAA12-106236-AA	31750020	21.8 (±2.8%)	0.197 (±2.5%)	76.5	28.4 (±2.8%)

*gravimetric measurement

Conclusion

This short report summarizes the results from a non-destructive analysis of the DU content in the NIF hohlraums. The hohlraums were analyzed as a pair of halfraums by directly counting with HPGe detectors and quantifying U-235 and U-238 through the characteristic gamma-rays associated with their decay schemes. The results from this work clearly demonstrate a straight-forward non-destructive method for quantitatively assessing the DU content in the NIF hohlraums.

References

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