Synchrotron in a box?
Compact AutoEdge equipment in support of National Opacity Campaign and International X-ray Fundamental Parameters Initiative

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Mass attenuation coefficient, or opacity, of elements had been extensively studied from 1920s to 1980s and tabulated into well-known x-ray databases such as NIST-XCOM (Hubbell), NIST-FFAST (Chantler), CXRO (Henke), SNL (Biggs) and LLNL (McMaster). This leads to a common perception that opacity is a solved problem. Our recent effort to integrate all aforementioned databases into a single software platform to facilitate instrument development reveals these databases are consistent only to ~10 percent, sometimes far worse, even for common elements.

On the other hand, a new field of High Energy Density (HED) physics has risen in the last decade, encompassing broad areas from laboratory astrophysics to national security applications, where the energy transport in complex systems is modelled via atomic processes based on opacity values. For example, Jim Bailey's pioneering work on solar opacity using the Z pulse power system found major discrepancies between the solar model and experimental results. The problem is of such importance that a National Opacity Campaign has been expanded on the top 3 US national facilities (Z, NIF, Omega) to chase down errors in either experiment or theory. Such HED experiments require targets with very precise thickness and composition, along with x-ray filters for diagnostic purpose. Any error in the areal density affects the data interpretation and undermines the science under study. Whereas 5-10% certification is routine, 1-2% level areal density certification had been an unobtainable goal, until now.

The problem came in three fronts. (1) With the shutdown of the Brookhaven beamline in 2014, the US program lost its domestic synchrotron access to x-ray transmission measurement. For example, the end users no longer certify critical components such as Dante filters, which would affect the diagnosis of hohlraum x-ray drive. (2) Conversion from x-ray transmission to areal density requires the use of x-ray mass attenuation (cold opacity) databases, which are only accurate to 5-10%. For example, synchrotron measurements, even when available, give different areal values for the same metal foil below and above the x-ray absorption edge, and such targets can be certified to high precision, without high accuracy. (3) As the premium target supplier to the national program, General Atomics must have in-house one-day metrology turnaround time to support production work on tight timeline. Further improvements require both access to new x-ray equipment and an ability to refine the x-ray database.

The desire for a "synchrotron-in-a-box" has matured into a fully automated "AutoEdge" system that pushes the limits of x-ray absorption measurements: (1) Precision is controlled by photon statistics, one-hour data acquisition is adequate to measure 0.5um thick foils to 1% precision. (2) Accuracy is controlled by x-ray database used in data fitting. We developed a methodology to refine x-ray database to ~1% accuracy from 3-17keV energy range. Our measurement on Ni agrees with recent European synchrotron measurement to within ~1%. The work on Fe and Au has also been completed.

In summary, General Atomics is supporting the US HED program with in-house measurement to fill the hole left by Brookhaven. All Opacity targets for NIF/Z are now non-destructively characterized by AutoEdge. GA has joined the X-ray Fundamental Parameters Workgroup coordinated by CEA, PTB and NIST in an international effort to push the frontier of x-ray research. We are planning further equipment upgrades to allow x-ray opacity calibration on gaseous elements.

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