Laser-based calibration of source-detector geometry for precision γ-ray measurements

V.E. Iacob and J.C. Hardy

A critical ingredient in our measurements of precise branching ratios is the photopeak efficiency of our HPGe detector: The absolute efficiency is known to better than 0.2% over the energy range 50-1400 keV [1] but this high precision cannot be obtained in any on-line measurement in the absence of a strictly controlled source-to-detector distance. All the calibration measurements reported in Ref. [1] have been made at a distance of 151 mm, measured from the source to the edge of the lip on the front-face of the Al container surrounding the Ge crystal (see Fig. 1). Thus, any experiment that needs this precise absolute efficiency must be performed at the same distance.

In the past we determined this distance with a Mitutoyo mechanical inside micrometer set. We placed a flat Al plate over the front of the detector and pressed it against the lip of the detector container; then we adjusted the distance between the plate and the source to the appropriate value set on the micrometer, the source being coaxial with the HPGe crystal and the container.

However, during the past decade, the HPGe detector experienced several loss-of-vacuum incidents affecting the chamber containing the HPGe crystal. The cause was identified to be related to cracks in the glue bonding the thin Be window to the Al container (see Fig. 1). We fixed this by patching the front edge of the HPGe container with Armstrong A-12 Epoxy Adhesive Resin. As an undesired side-effect, this converted the flat lip of the Al container into a hilly surface. The "small" peaks (up to ~0.3 mm), not necessarily located at diametrically opposed locations, made it extremely difficult to define a reference position on the front of the cup containing the HPGe. To overcome this problem, we have moved from the micrometer-based distance calibration towards a system using a laser-sensor, the AR700-8 (by Acuity).

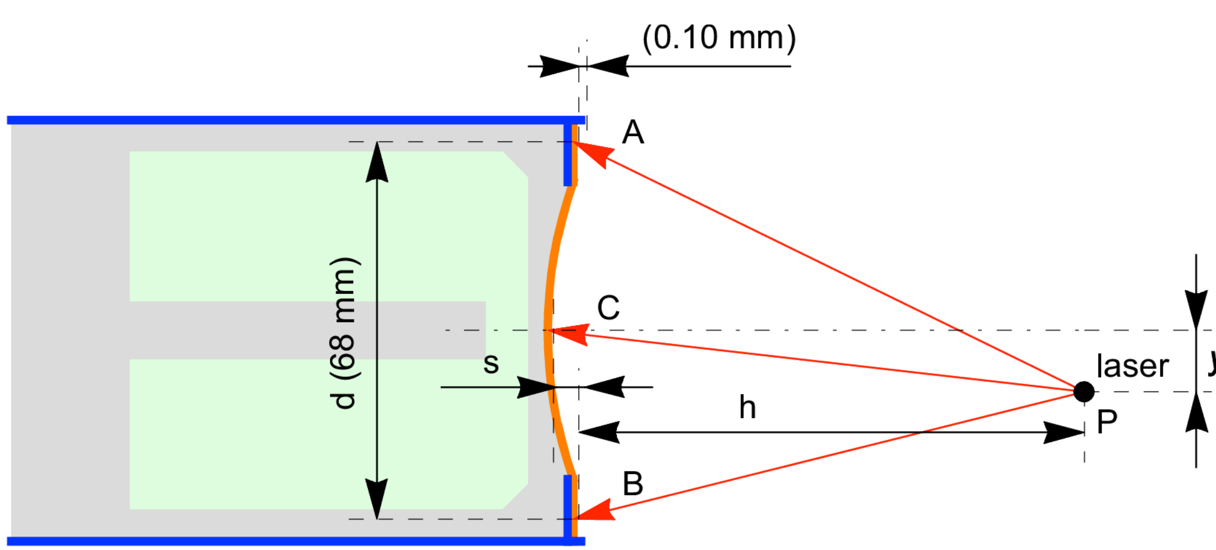

FIG. 1. Top view of the HPGe-Laser assembly. The laser sensor can pivot about the vertical axis P and aim towards points A, B, and C and determine corresponding distances (in red). These along with the distance between points A and B (d = 68 mm) allow for the calculation of the sag "s" of the Be window (orange) and the distance "h" from point P to the plane tangent to the Be window. The geometry of the Al container (blue) includes at its edge the δ = 0.10 mm lip that extends beyond the Be window.

The new laser sensor is mounted on a holder that puts the laser beam in a horizontal plane containing the HPGe axis; the holder can pivot about a vertical axis (point P in Fig. 1), thus allowing for reading distances to the maximum-sag position (in the Be window) and to points on the window that are mechanically supported by the Al seat: These are the distances P-C, P-A, and P-B, respectively, marked in red in Fig. 1. Any unbalance between the P-A and P-B distances makes for an easy test of any off-axis placement (y_0 in Fig. 1) of the pivoting point P. As the distance between the points A and B is known (d_{A-B} = 68 mm) the distance h between the pivot and the plane tangent to the front-face of the Be window is easily calculable. That distance, along with a reading of the distance P-C, yields a measurement of the sag of the Be window. We found that sag to be s = 1.02(5) mm. This establishes the distance along the axis between the center of the Be window and a plane touching the lip of the Al container to be 1.12(5) mm.

In setting up our counting geometry, we place the laser at approximately 500 mm from the detector window and as close to the central axis as possible (*i.e.* y_0 is close to zero). We then place the source in its fixed holder approximately 151 mm from the detector and between the detector and the laser. We then measure the distance from the laser to the source. Next the source is removed and the distance from the laser to the center of the Be window is measured. Finally, the detector is adjusted on its supporting rails until the difference between the two measurements (source distance and window distance) is exactly 152.12 mm. Under this condition, the distance from the source to the plane of the lip of the Al detector-container is exactly 151.0 mm, the precise calibration distance. The active range of the AR700-8 laser-sensor requires that the two distances be between 331 mm and 533 mm.

We note an additional benefit to our using the laser sensor for setting the source-detector distance. Any mechanical micrometer needs to make physical contact at its end-points. In our case this means the micrometer must be in contact with the source and the plate resting on the HPGe container lip. This necessarily adds some small elastic deformations in both source and plate, potentially leading to our determining slightly shorter distances than the true value. Obviously, the laser-based distance reading is free from this source of error.

[1] J.C. Hardy *et al.*, Appl. Radiat. Isot. **56**, 65 (2002); R.G. Helmer *et al.*, Nucl. Instrum. Methods Phys. Res. **A511**, 360 (2003); R.G. Helmer *et al.*, Appl. Radiat. Isot. **60**, 173 (2004).