

## **CGH Metrology References – Tooling balls attached to the CGH**

Tooling balls are commonly used for positional metrology because the balls themselves have high accuracy (Class 5 balls achieve tolerances of 1.3  $\mu\text{m}$  for diameter and 0.13  $\mu\text{m}$  for sphericity) and because spheres are simple shapes that clearly represent and transfer geometric position. AOM routinely uses precision tooling balls for internal projects, and we now offer them as standard add-ons for our CGHs.

In addition to the four standard 12 mm diameter balls used to couple the CGH to its 6 DoF positioner, we can add two types of tooling balls and three variations of the geometry. The ball variations are:

<b>0.5000 inch diameter balls</b>	<b>0.2500 inch diameter balls</b>
The 1/2" balls fit into precision invar cups that are bonded to the CGH or its frame. These can be provided with either SMRs for laser trackers or with Grade 5 tooling balls for contact measurements.	The 1/4" balls are permanently attached – either mounted to invar seats that are bonded to the CGH or through seats that are fixed to the frame.

The variations in geometry are listed below. The specific locations of the balls are quite flexible and must be specified at the time of the CGH order. Standard accuracy is listed below, but higher accuracy can be achieved by special order.

<b>On the patterned surface</b>	<b>On the CGH substrate, opposite the pattern</b>	<b>On the frame</b>
The balls can be precision bonded on the CGH surface at any location with 2 $\mu\text{m}$ accuracy, contacting the CGH substrate giving near perfect accuracy out of plane. The positions are measured and reported with accuracy of 1 $\mu\text{m}$ .	The balls can be positioned on the unpatterned surface of the CGH substrate with 3 $\mu\text{m}$ accuracy. The positions are measured and reported with 2 $\mu\text{m}$ accuracy.	The balls can be permanently attached on either side of the frame or even on the outside where they can be seen from both sides. The positions are measured with respect to the pattern at AOM with accuracy of 5 $\mu\text{m}$ .

