Alignment Cube With One Diffractive Face

Only one theodolite is needed instead of two.

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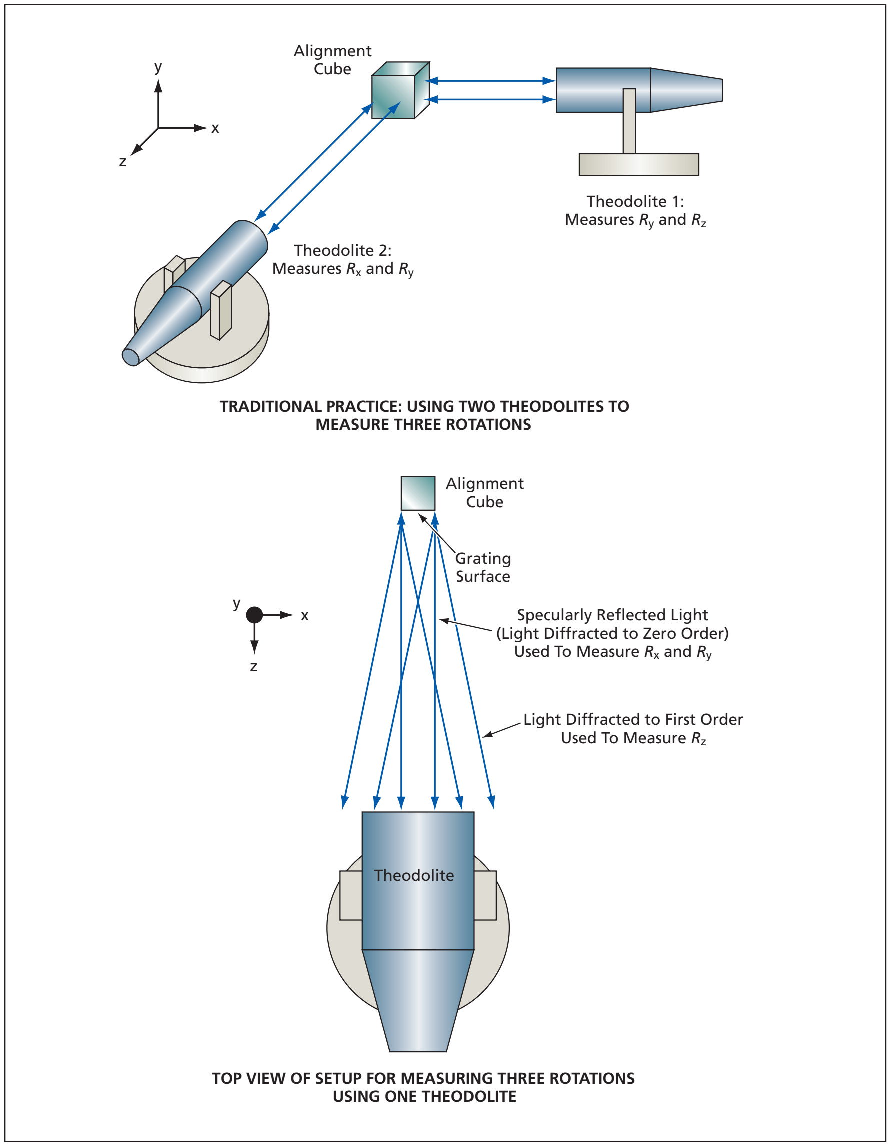
An enhanced alignment cube has been invented for use in a confined setting (e.g., a cryogenic chamber) in which optical access may be limited to a single line of sight. Whereas traditional alignment-cube practice entails the use of two theodolites aimed along two lines of sight, the enhanced alignment cube yields complete alignment information through use of a single theodolite aimed along a single line of sight.

Typically, an alignment cube is placed in contact with a datum surface or other reference feature on a scientific instrument during assembly or testing of the instrument. The alignment cube is then used in measuring a small angular deviation of the feature from a precise required orientation. Commonly, the deviation is expressed in terms of rotations (R_x,R_y,R_z) of the cube about the corresponding Cartesian axes (x,y,z). In traditional practice, in order to measure all three rotations, it is necessary to use two theodolites aimed at two orthogonal faces of the alignment cube, as shown in the upper part of the figure. To be able to perform such a measurement, one needs optical access to these two faces. In the case of an alignment cube inside a cryogenic chamber or other enclosed space, the optical-access requirement translates to a requirement for two windows located along the corresponding two orthogonal lines of sight into the chamber. In a typical application, it is difficult or impossible to provide two windows. The present enhanced version of the alignment cube makes it possible to measure all three rotations by use of a single line of sight, thereby obviating a second window.

Commercially available alignment cubes are usually made of glass or metal and have linear dimensions of about 1 in. (≈2.5 cm). The faces are reflective and highly polished and are orthogonal to within an angular tolerance of about 10 arc seconds. In traditional practice, one utilizes the specular reflections from the observed faces.

An alignment cube according to the present innovation is made from a commercially available alignment cube by forming a diffraction grating on the face that is to be observed. This can be done either by using a ruling engine to machine grating grooves into the face or by attaching a replica grating to the face. The light from the theodolite striking this surface is diffracted into many orders. The light diffracted to zeroth order is the specular reflection; it gives the same alignment information (concerning the rotations about the axes perpendicular to the line of sight) as does the light reflected from a traditional alignment cube. The light diffracted to higher orders creates additional image components in the theodolite field of view. The horizontal and vertical displacements of these components are related in a known way to the rotation about the line of sight. Hence, as



Two Theodolites are needed to measure rotations about all three Cartesian axes in traditional practice using a purely specular alignment cube. Applying a diffraction grating to one face of an alignment cube makes it possible to measure all three rotations using a single theodolite.

depicted schematically in the lower part of the figure, a single theodolite can be used to measure rotation about all three axes.

The amplitude and spatial period of the grating should be optimized for the peak wavelength (e.g. ≈540 nm) of the light source in the theodolite and for the viewing geometry as limited by the edge of the window (if any) in the intended application. Prior to use of the alignment cube, it is necessary to perform a calibration in which the orientations of the remaining polished sides are measured with respect to the orientations of the specular reflection and the pertinent non-zero grating orders. If the cube is to be used during cryogenic operation, then the cube is placed in a small chamber at the anticipated operating temperature and the calibration is repeated. If these measurements show the calibration to be consistent in the presence of thermal cycling, then the alignment cube can be used as described above to measure all three rotations.

This work was done by Raymond G. Ohl, Henry P. Sampler, Carl R. Strojny, and John G. Hagopian of **Goddard Space Flight Center** *and Joseph C. McMann of ManTech International Corp. Further information is contained in a TSP (see page 1).*
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