Currently there is a spectral responsivity comparison underway between NIST and Centro Nacional De Metrología (CENAM) in Mexico. It is hoped that with the establishment of the North American Calibration Cooperation (NACC) this will be an ongoing intercomparison and will eventually include National Research Council (NRC) in Canada as well. It is also expected that there will be additional intercomparisons among regional groups of Europe, Asia, North America, and South America.

9. Characteristics of Photodiodes Available from NIST

This section describes the characteristics of the silicon photodiodes provided by NIST under Service ID numbers 39071S and 39073S. The physical and electrical characteristics of the photodiodes are discussed and the results of linearity measurements are given. The precision apertures are described and the photodiode fixture mechanical diagrams are shown.

9.1 Hamamatsu S1337-1010BQ

Hamamatsu S1337-1010BQ silicon photodiodes have been supplied by NIST as spectral (power) responsivity standards. NIST currently supplies the Hamamatsu S2281 for this purpose (NIST Service ID number 39073S). As mentioned previously, the Hamamatsu S1337 series diode is a popular diode for radiometric standards and it has been extensively characterized [31, 32]. Hamamatsu describes [65] the S1337-1010BQ as a p-n diode with a 1 cm x 1 cm active area, a fused quartz window, and a ceramic case. The spectral response range is 190 nm to 1100 nm with a peak at 960 nm. The S1337-1010BQ also has a high shunt resistance (dynamic impedance), with a typical value of 200 MΩ and a minimum value of 50 MΩ.

The typical measured spectral responsivity and quantum efficiency are shown in figures 6.2 and 6.3, respectively. The typical spatial uniformities measured at 500 nm and 1000 nm are shown in figure 6.4a and b, respectively. The temperature coefficient of several and S1337 series photodiodes were measured using a temperature-controlled fixture. All of the measurements were made following the typical spectral responsivity procedures at temperatures around 25 °C. Figure 9.1 shows the average temperature coefficient of the Hamamatsu S1337 series photodiode. A second common silicon photodiode series, the S1226, is shown for comparison in figure 9.1 along with the wavelength of peak responsivity for each photodiode.

The linearity of the S1337-1010BQ at 633 nm is shown in figure 9.2 spanning irradiance levels from 0.5 mW/cm^2 to 6.6 mW/cm^2. Each data point represents the ratio of the photodiode responsivity at the indicated irradiance to the responsivity at low power. The linearity was measured by using a beamsplitter to irradiate two photodiodes at approximately a 10:1 intensity ratio, with the diode aperture filled and uniformly irradiated [66]. The linearity is dependent on the irradiation geometry and will differ for spot sizes significantly smaller than the aperture size.

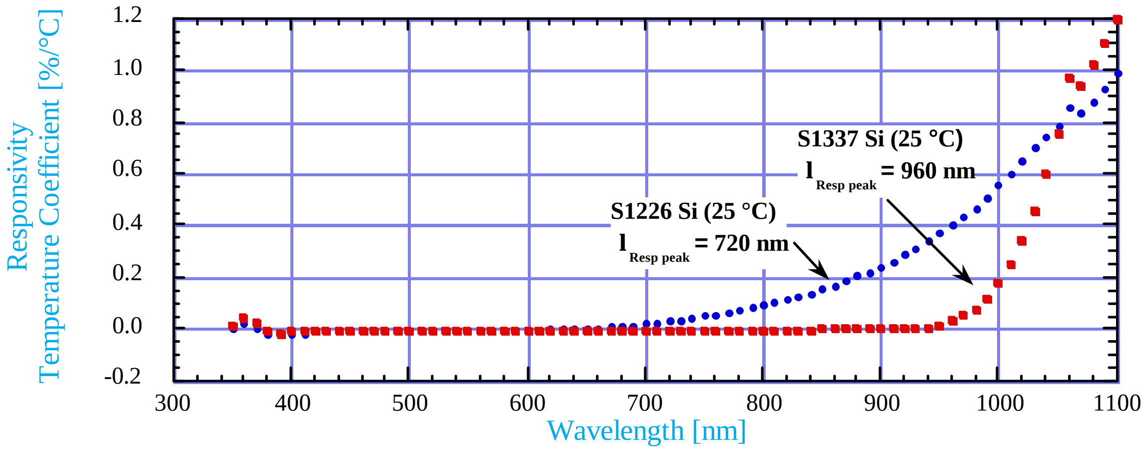

Figure 9.1. Temperature coefficient of silicon Hamamatsu S1226 and S1337 photodiodes.

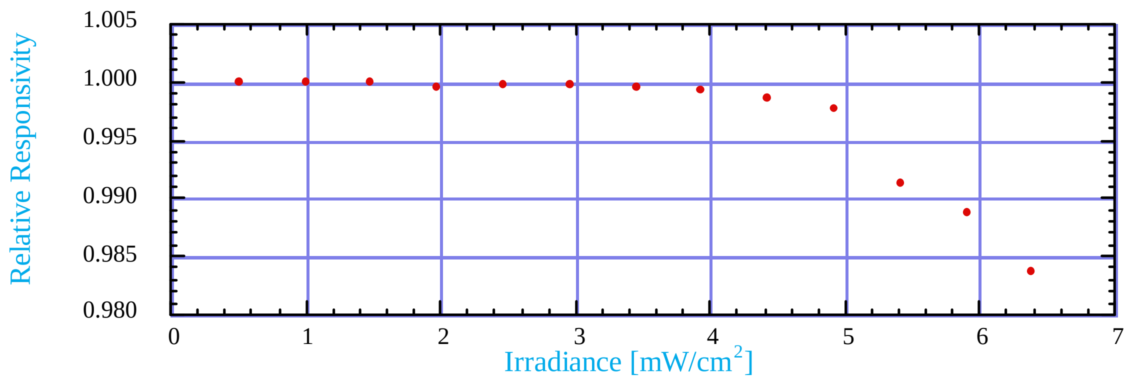

Figure 9.2. Linearity of Hamamatsu S1337-1010BQ at 633 nm.

9.2 Hamamatsu S2281

Hamamatsu S2281 silicon photodiodes are currently provided by NIST as standards of spectral responsivity (NIST Service ID number 39073S). The characteristics are essentially identical to the S1337-1010BQ. Since the S2281 is almost indistinguishable from the S1337, the spectral responsivity and quantum efficiency are not shown in figures 6.2 and 6.3. The significant differences between the two types of diodes are the S2281 has a 1 cm^2 active area that is circular instead of square and it is housed in a metal case with a BNC connector. The BNC case simplifies the photodiode fixture since no electrical wiring is required.

9.3 UDT Sensors UV100

UDT Sensors UV100 silicon photodiodes are provided as spectral responsivity standards in the UV (NIST Service ID number 39071S). UDT Sensors literature [67] describes the UV100 as an inverted channel diode with enhanced resistance to damage from UV radiation. The UV100 has a quartz window, a 1 cm^2 circular active area, and is housed in a metal case with a BNC connector similar to the Hamamatsu S2281. The spectral response range is from 200 nm to 1100 nm with a peak around 760 nm. The typical shunt resistance value is 10 MΩ.

The linearity of the UV100, shown in figure 9.3 at 442 nm, spans irradiance levels from 0.1 mW/cm^2 to 1.1 mW/cm^2 with and without a reverse bias voltage. Each data point represents the ratio of the photodiode responsivity at the indicated irradiance to the responsivity within the linear region. The linearity was measured by using a beamsplitter to irradiate two photodiodes at approximately a 10:1 intensity ratio, with the diode aperture filled and uniformly irradiated [66]. The linearity is dependent on the irradiation geometry and will differ for spot sizes significantly smaller than the aperture size.

The change in the responsivity as a function of bias voltage for this type of photodiode at 442 nm is shown in figure 9.4. For wavelengths shorter than 450 nm, a 1 V bias can be used to improve the linearity of the photodiode without significantly changing the spectral responsivity. There will however be some leakage current which will limit the minimum usable signal.

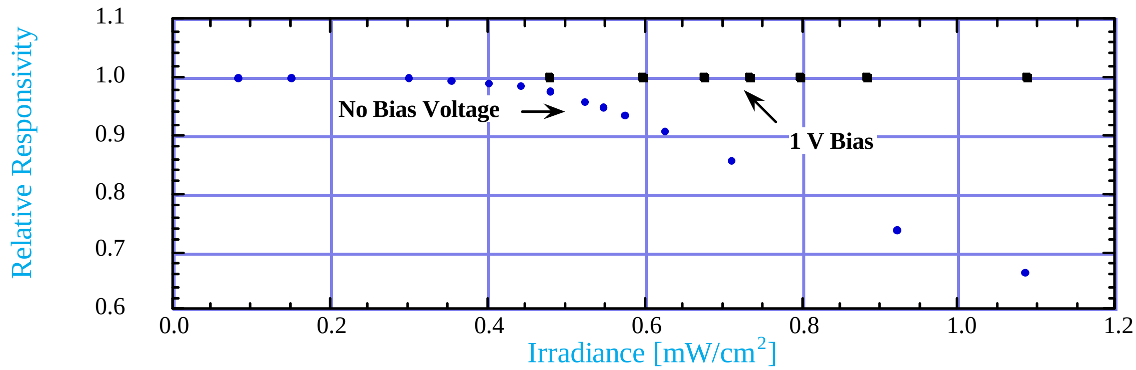

Figure 9.3. Linearity of UDT Sensors UV100 at 442 nm.

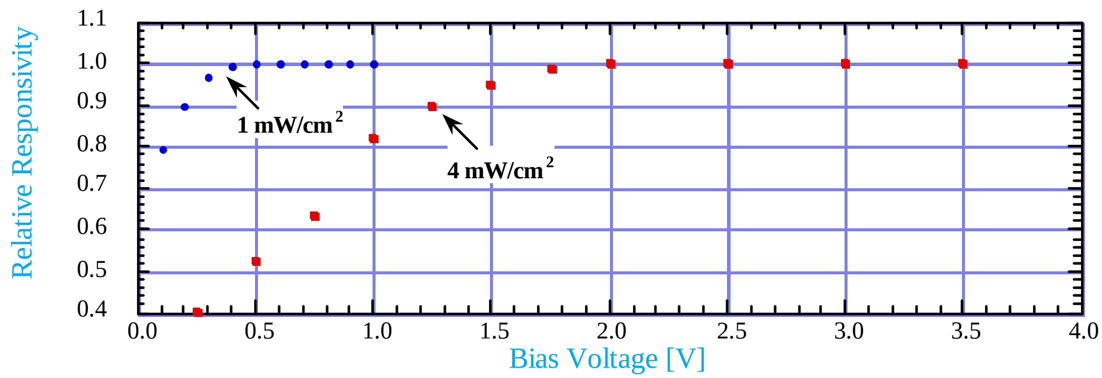

Figure 9.4. Responsivity dependence on bias voltage of UDT Sensors UV100 at 442 nm.

9.4 Detector Apertures

The precision apertures provided with the photodiodes by NIST Service ID numbers 39071S and 39073S are Buckbee Mears part number SK#030483-1073. They are electroformed optical apertures that have a bi-metal construction (copper with a nickel finish on both sides). The aperture is a thin disc with an outside diameter of 13.92 mm (0.5480 in) and an inside diameter of 7.9789 mm (0.31413 in), the specified aperture area is nominally 0.5 cm^2. The apertures are dimensionally measured at NIST in the Fabrication Technology Division in an environmentally controlled laboratory. The aperture diameter is typically measured twice along perpendicular axes. The reported aperture area is the average area calculated from the two (or more) diameters.

The reported aperture area and distance from the aperture plate to the photodiode surface do not enter into the responsivity measurement results because the optical beam underfills the aperture. The uncertainty values reported with the aperture dimensions are expanded uncertainties.

Recently an new method has been reported for measuring aperture areas [68]. This method determines the area by optical comparison and is faster than the mechanical diameter measurements. Some of the apertures provided have been measured in this manner. Soon, all of the apertures will be measured using this new method.

9.5 Detector Fixture Mechanical Drawings

Note: As stated in the Introduction, this document follows the NIST policy of using the International System of Units (SI). The following mechanical drawings were originally prepared in English units and are presented without converting the values shown to SI units.

The detector fixtures for the Hamamatsu S1337-1010BQ and S2281 and the UDT Sensors UV100 silicon photodiodes are designed for convenient handling and use. The fixture housings are black anodized aluminum and the 5.08 cm diameter was chosen as a convenient size for use with common optical table fixtures. Most of the fixtures also have a 1/4-20 threaded hole (not shown in drawings) on the side of the fixture for a standard optical table post. Each fixture has an engraved serial number on the back. Black anodized aluminum covers (not shown) were added later to protect the photodiodes (and apertures) during storage and shipment.

The Hamamatsu S1337-1010BQ fixture design includes space to couple the photodiode anode and cathode to a BNC connector. Figure 9.5 shows the mechanical diagram for the fixture body. Figure 9.6 shows additional pieces for holding the diode lead sockets and BNC connector. Figure 9.7 is an exploded view of the fixture including the photodiode, aperture, and aperture plate.

The UDT Sensors UV100 and Hamamatsu S2281 photodiodes are housed in metal BNC cases. This simplifies the fixture and reduces the construction time since no electrical wiring is required. The mechanical diagram for the UV100 and S2281 diodes is shown in figure 9.8.

The precision apertures are attached to a black anodized aluminum plate. Figure 9.9 shows the first design for the aperture plate. This was found to scatter light onto the diode when light struck the countersunk area around the aperture. An improved design shown in figure 9.10 has been used since 1993. Later productions of the aperture plate are engraved with the detector fixture serial number facing the diode.

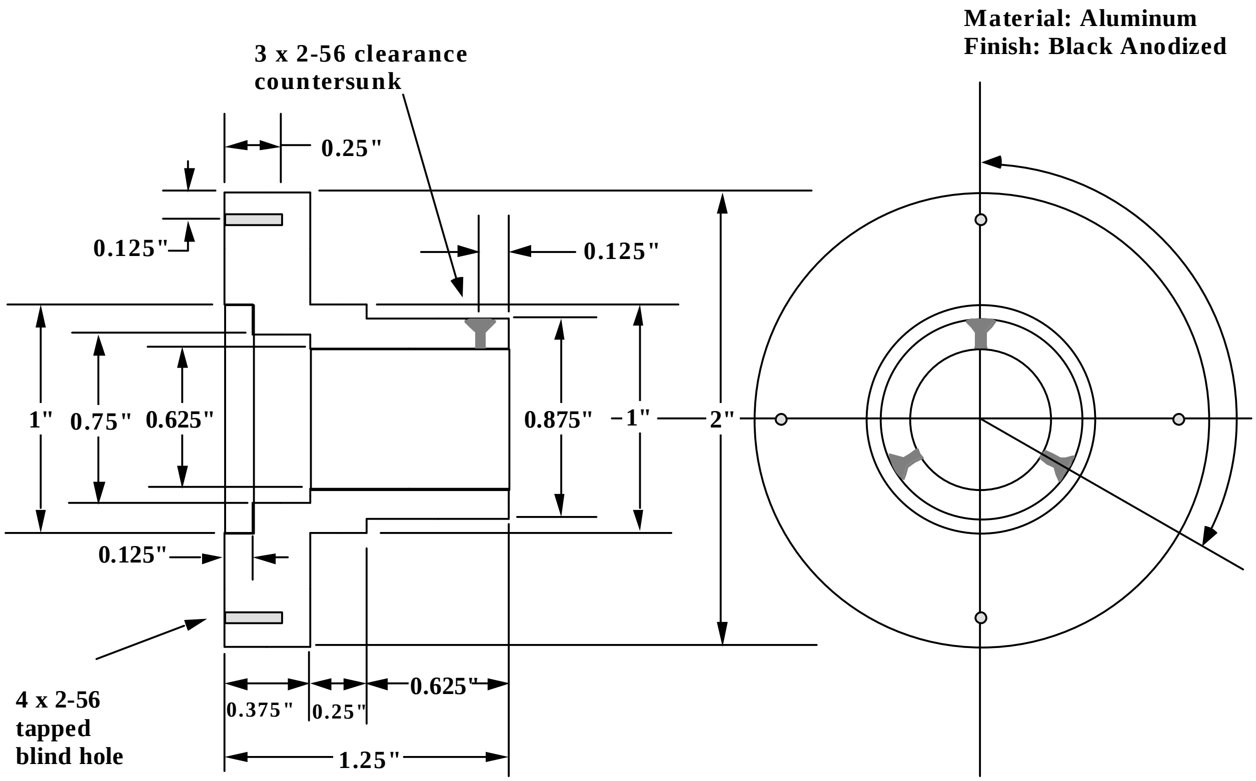

Figure 9.5. Mechanical diagram of Hamamatsu S1337-1010BQ fixture body.

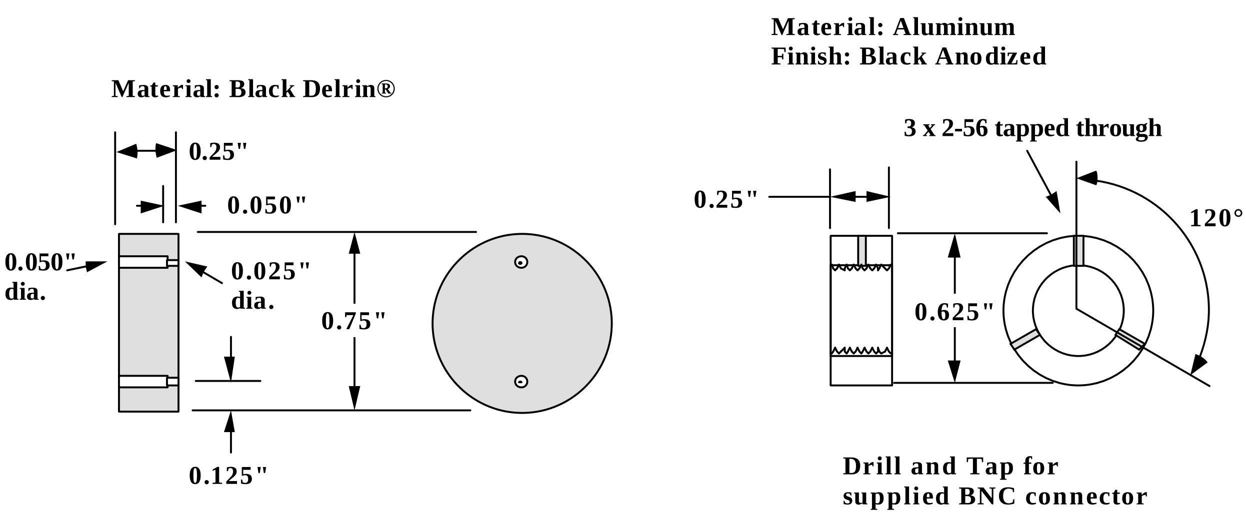

Figure 9.6. Mounting pieces for the Hamamatsu S1337-1010BQ photodiode and BNC connector.

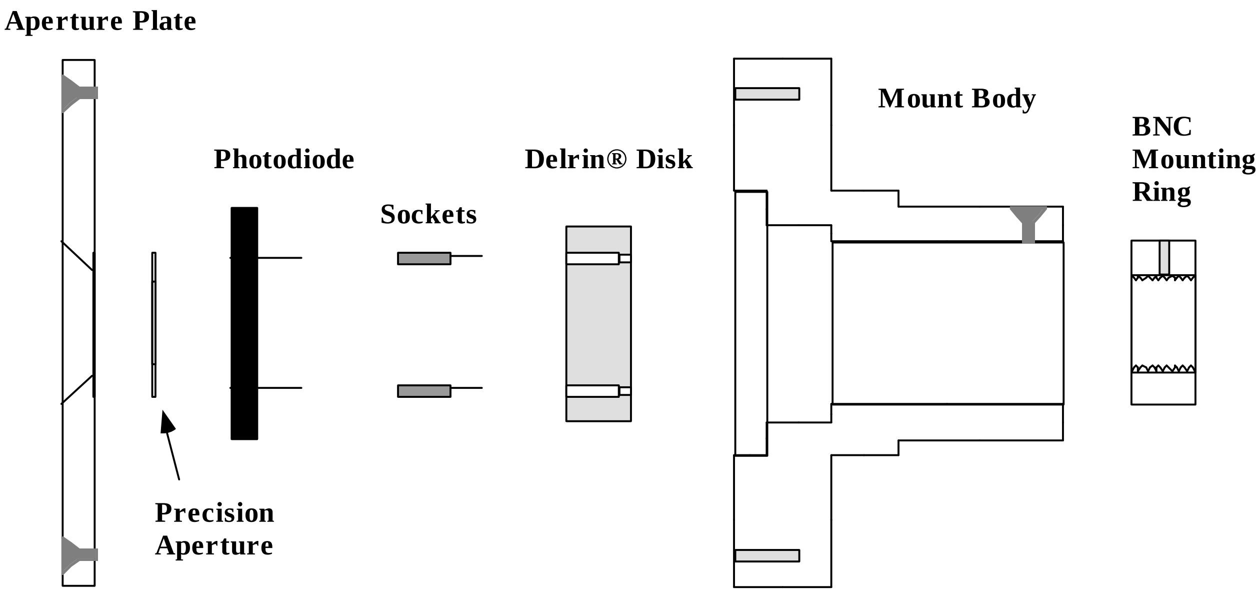

Figure 9.7. Exploded view diagram of Hamamatsu S1337-1010BQ fixture.

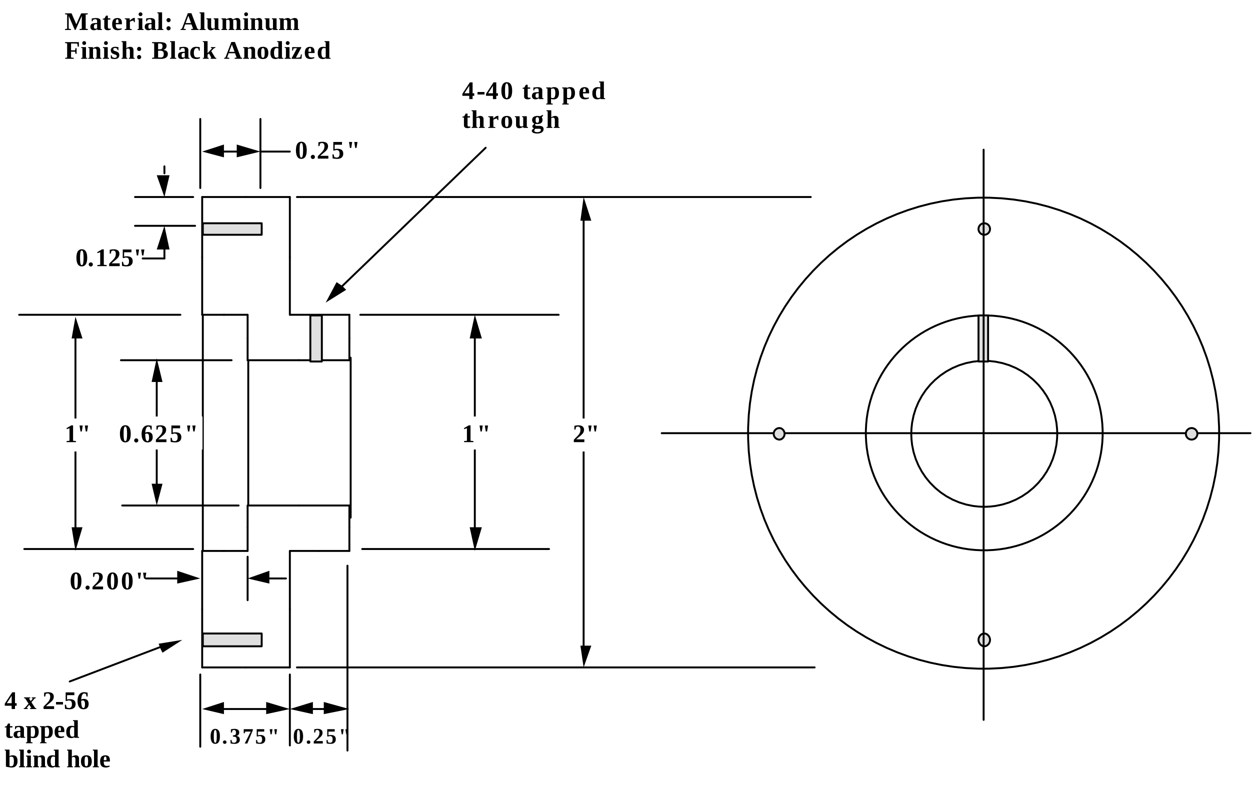

Figure 9.8. Mechanical diagram of UDT Sensors UV100 and Hamamatsu S2281 fixture.

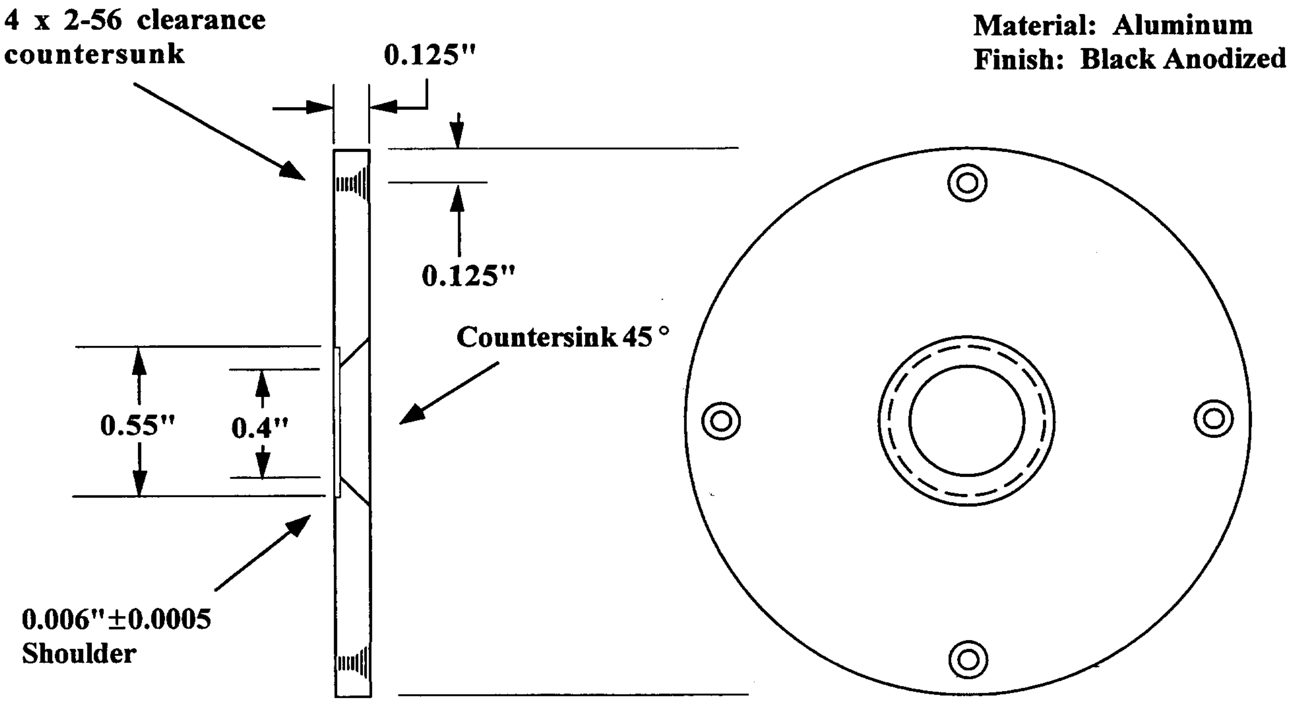

Figure 9.9. Mechanical diagram of pre-1993 aperture plate for detector fixtures.

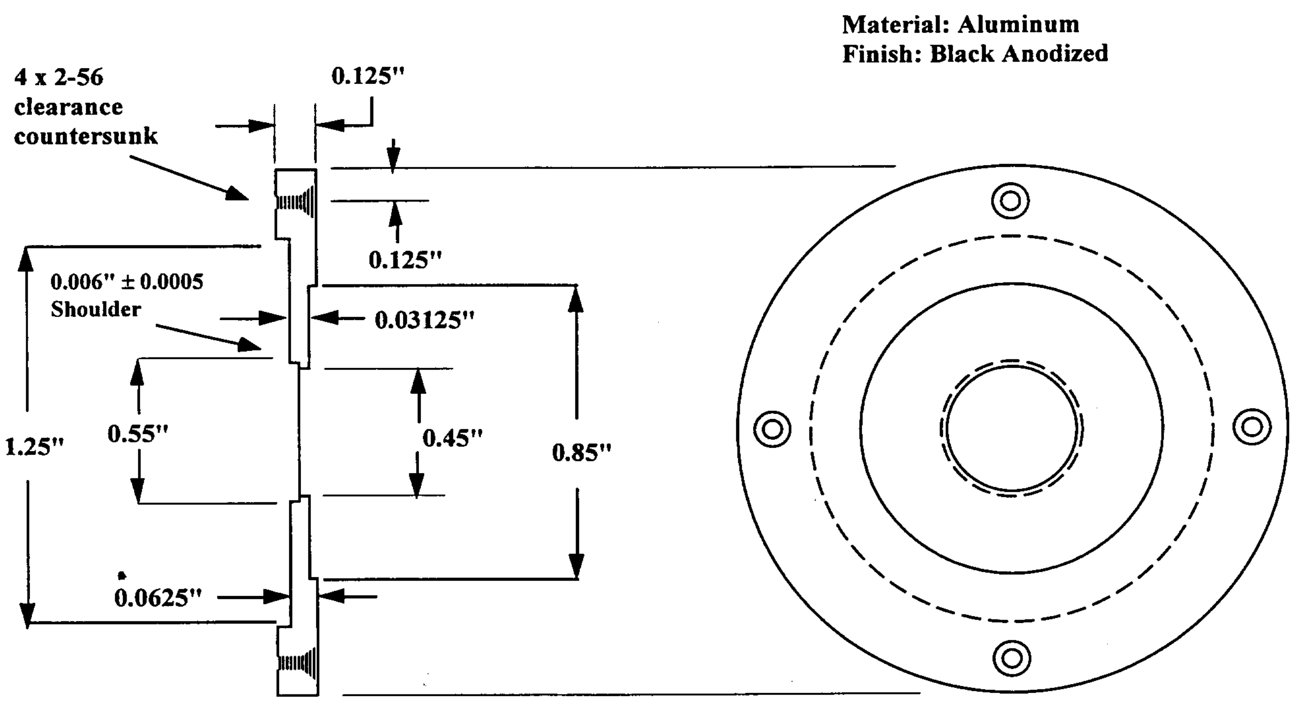

Figure 9.10. Mechanical diagram of present aperture plate for detector fixtures.