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INSTRUMENTATION FOR DETECTOR SPECTRAL / SPATIAL UNIFORMITY MEASUREMENTS

By Ronald W. Craft and Robert M. Bronson, Jr.

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Instrumentation for Detector Spectral / Spatial Uniformity Measurements

Ronald W. Craft and Robert M. Bronson, Jr.

Optronic Laboratories, Inc., Research and Development
4470 35th Street, Orlando, Florida 32811

ABSTRACT

The information presented in this report describes an instrument which is used for precision measurements of detector spectral response and spatial response. Emphasis will be placed on detector spatial uniformity measurements.

To allow spatial uniformity testing at selected wavelengths, an instrument was designed by applying existing spectral response instrumentation technology with the addition of special exit optics, a dual axis motorized positioning table, and supporting software. Supporting components consisted of a computer controlled radiometer and a monochromator with a high intensity light source attached.

Spectral response is determined by measuring the wavelength response photosensitivity of a stationary specimen to the irradiance of a calibrated monochromatic light source over the wavelength range of interest at evenly spaced intervals. Data is presented in a pictorial format by graphing the RESPONSE versus the WAVELENGTH.

Detector spatial response is determined by measuring the variation in photosensitivity over the surface of the test detector by moving the detector in an X,Y grid at evenly spaced intervals under a small monochromatic spot of light. Several versions of the instrument were built and test results are provided which represent data from the spatial uniformity testing of Ge, PbS, and PbSe detectors. Data acquired is presented as a 3-Dimensional surface map by plotting the RESPONSE versus the X POSITION versus the Y POSITION.[1,4]

1. INTRODUCTION

Detectors are used in a wide range of scientific and industrial applications. Such applications sometimes require an irradiated area which is less than the sensitive region of the detector or the detector may be irradiated by nonuniform beams. Under these circumstances, repeatable measurements can best be achieved by using a spatially uniform detector.

For the purposes of this report, a uniform detector is defined as a detector which yields constant response over its active area at a wavelength of interest. The allowable response deviation should be determined by the requirements of the specific application.

A detector spatial scanning instrument, as illustrated in figure 1, will allow the uniformity of a detector to be precisely analyzed and classified. Detectors can then be sorted into various grades of average uniformity based upon their classification.

Those benefitting from such a system would be detector manufacturers and optical system designers. From a manufacturing point of view, a detector spatial scanning system would provide helpful information which could be used to evaluate fabrication processes; to perform quality assurance; or to provide individual detector classification for specific requirements. Optical system designers would also benefit by using a detector spatial scanning system to perform uniformity inspection and verification so that nonuniform detectors could be identified.

The following information describes an instrument which was designed with the above requirements as guidelines and is currently being used for precision measurements involving both detector spectral response and detector spatial uniformity response. The focus of this report is detector spatial uniformity response. For information pertaining to spectroradiometric measurements, see Schneider.[2]

2. SYSTEM COMPONENTS

The detector spatial uniformity scanning system consist of six key components. A lamp source with a precision power supply, a double monochromator for delivery of a monochromatic light source, specially designed exit optics, X-Y positioning table with custom designed detector mounting fixtures, a radiometer, and a microcomputer with control and data reduction software. (See Figure 1.)

The light source used is a mirror imaging source optics module illuminated with a 150W quartz halogen lamp. Lamp power source is provided by a precision current source configured to continuously deliver 5 amps with stability of 0.02% and accuracy of 0.1%. The lamp filament is collected by mirror optics and focused at the entrance slit of a research grade double monochromator.[3] (See Figure 2.)

The monochromator provides a user specified monochromatic light source ranging from .28 microns in the ultraviolet range, to 20 microns in the far infrared by selection of different diffraction gratings and appropriate sources.[3] (See Figure 3.)

Quartz lens exit optics were designed to deliver the monochromatic light to the surface of a detector with an image reduction ratio of 5:1. (See Figure 4.) For example, a circular source with a 1.5 millimeter diameter at the exit port of the monochromator would be reduced to a circular image with a .3 millimeter diameter at the surface of the test detector. The circular source can be varied in size with interchangeable apertures.

Versatile mounting fixtures were designed to facilitate many different detector packages so that a large variety of detectors could easily be tested with minimal effort. Three types of detector handling methods were accommodated: Wafers, individual die, and packaged types. A vacuum chuck with adjustable dual axis positioner and .0001 inch probe needles were used to test wafers, and individual cut die. Socketed machined fixtures were fabricated to fit various sizes of packaged detectors. (See Figure 5.)

The mounting fixtures are easily attached to the surface of the X-Y computer controlled positioning table. The X-Y positioning table is a 50mm x 50mm precision ball-screw table driven by dual closed loop geared servo motors with optical encoders. Table movement resolution and accuracy is 0.01 mm.[4] The complete assembly is permanently secured such that the monochromatic image would be properly focused onto the surface of the test detector. Visual inspection of the detector mounting fixtures is provided by a microscope mounted to one side.

The response of the test detector is measured by a precision autoranging radiometer capable of measuring signals from 10E-13A to 10E-4A with an accuracy of 1%.[3]

A microcomputer is used as an instrument controller and data acquisition device. Software was designed to provide an easy interface between the user and the instrument so that operation of the instrument would be as simple as possible. Measurement results are displayed or plotted in the form of a 3D surface pictorial.

For information pertaining to the monochromator, computer controlled wavelength drive and radiometer, see Goebel.[3]

3. DETECTOR RESPONSE UNIFORMITY MEASUREMENT TECHNIQUE

Detector response uniformity measurements require the acquisition of responsivity from many points on the detectors surface while using a constant source of illumination. Before measurements can begin, it is necessary to build a template, or a surface map for the detector so that the acquired data can be properly mapped to the correct location on the surface of the detector. The template used by the instrument described in this report is a square grid with data acquisition occurring at each point of intersection with maximum limits being 50mm X 50mm. The user of the instrument can control the external dimensions of the grid as well as the internal intervals of the grid. Thus the user can control the resolution of the surface pictorial acquired for the detector. Results are optimum when the interval between measurements is equal to or slightly greater than the diameter of the irradiating spot. Thus the irradiating area is always less than the area of a grid cell. (See figure 6.)

The collection of one data point for response uniformity measurements of a detector is achieved by recording the response of a detector while irradiating a small portion of the detector with a monochromatic light source. The irradiated area is determined by the exit optics of the system. For the particular instrument presented here, the source is a circular spot which could be varied in size with interchangeable apertures and is focused to the surface of the detector.

For collection of a complete response uniformity measurement, the detector is temporarily mounted to the surface of the previously described X-Y positioning table and its signal is connected to the radiometer allowing continuous signal monitoring. Under computer control, the detector is positioned, via the X-Y positioning table, at evenly spaced intervals under the irradiating source. At each position, a response measurement is recorded and mapped to the correct location. Acquisition continues until data at all grid intersections have been recorded.

4. DETECTOR RESPONSE UNIFORMITY DATA PRESENTATION

Uniformity measurement data can be analyzed by many different methods. This application resulted in the use of two such methods, a 3D surface pictorial and report generation for tabular presentation.

The 3D surface pictorial provides an accurate depiction of the sensitive region of a detector. The pictorial is created by normalizing the data where zero represents the "no response" measurement and one represents the highest response measurement. The normalized data is then presented with a 3D surface pictorial by plotting the X position versus the Y position versus the normalized response.[1,4] The pictorial is easily displayed or plotted so that visual inspection can be used to identify a detectors sensitivity profile. The sensitivity profile of a Ge detector at 0.9 microns is shown in figure 7.

Detector response uniformity data is also available in a tabular format. This allows the uniformity of the test detector to be precisely determined numerically. One can identify the physical coordinates of the sensitive region as well as the responsivity deviation in that region. This data can be interpolated to yield the area of the uniform zone of the detector. A data file can be generated for further reduction if necessary.

5. RESULTS

During the system evaluation, numerous scans were performed. Testing occurred using the above configuration with all key components. Various types of detectors were tested with emphasis being placed on Ge detectors. Preliminary data suggested that detector spatial uniformity varies with wavelength and that spatial uniformity testing should occur over the detectors full spectral range.

Figure 8 is the result of a spatial uniformity scan of a Ge detector at room temperature at a wavelength of 1.5 microns. From visual inspection, the detector response appears to be uniform at 1.5 microns. Figure 9 is the same detector as shown in figure 8, except the spatial uniformity scan was performed after changing the irradiating source to 1 micron. Figure 9 displays the same detector with a nonuniform response at 1 micron.

Other results provided are spatial uniformity scans for PbS and PbSe detectors. See figure 10 for the PbS detector and figure 11 for the PbSe detector.

6. ADDITIONAL APPLICATIONS

After the prototype instrument was designed and fully integrated, extensive performance and reliability research was conducted. During that time techniques were developed which lead to an instrument variation that allowed spatial uniformity measurement of a diffuse light source. Other variations of the instrument have been considered, such as a configuration for measuring the uniformity of reflectance or transmittance for a specimen.

The system configuration for source uniformity analysis included a diffuse light source such as a integrating sphere, a dual axis positioning station, a silicon detector with a small area of 1mm diameter, and a photopic filter set. A simplified illustration is shown in figure 12. The detector housing includes a 0.5mm entrance aperture to provide a narrow field of view. The computer controlled positioning table is then used to position the detector at evenly spaced intervals such that the optical output from the diffuse light source is completely measured. Data is accumulated and manipulated in exactly the same way as described earlier. Results from source uniformity testing on the exit port of a sphere source is shown in figure 13.

Other modifications could be made to the instrument that would allow researchers to test the uniformity of a samples reflectance or transmittance. Transmittance uniformity measurements could occur by focusing the optical output from a monochromator or some other light source at the center point of a samples area. A suggested configuration is shown in figure 14 for transmittance uniformity. A detector would then be used to measure the transmitted light. The sample would be mounted on an X-Y positioning station such that the optical beam passes directly through the sample and is collected by a detector. Systematic positioning and acquisition would be identical as described in previous sections. The differences in the resultant data could then be classified as the transmittance variation which would in turn lead to the characteristics of transmittance uniformity. Similar techniques could be applied to determine the reflectance characteristics of a material. A suggested reflectance uniformity measurement system is show in figure 15.

7. SUMMARY

An instrument was described that allowed spatial uniformity measurements for a detector. An overview of the system design was to use monochromatic light with special exit optics to deliver a focused spot with minimum diameter to the surface of the detector. The computer controlled positioning table is used to systematically position the detector at evenly spaced intervals such that the entire surface of the test detector is scanned. Detector output is recorded at each location during the scan. Once the detector has been completely scanned, special software is used to display a 3-D surface map of the tested detector.

Tests performed using this instrument indicated that in some cases, detector uniformity changed dramatically as a function of wavelength suggesting that spatial uniformity testing should be performed over the detectors full spectral range.

8. ACKNOWLEDGEMENTS

Recognition is deserved by Mr. Dennis Hull of Optronic Laboratories for mechanical design of the exit optics assembly and the detector mounting fixtures.

9. REFERENCES

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2) Schneider, William E.. "Automated Spectroradiometric Systems: Components and Applications." Test & Measurement World (May/June 1985).

3) Goebel, David G.. "DESIGN AND CALIBRATION OF AN INFRARED SPECTRORADIOMETER". PROCEEDINGS IMTC/85 - IEEE Instrumentation and Measurement Technology Conference. 85CH2159-2 (1985): 229-231.

4) Florida MicroSystems, INC. Consultation for motion control and 3D graphics (1988). Orlando, Florida.

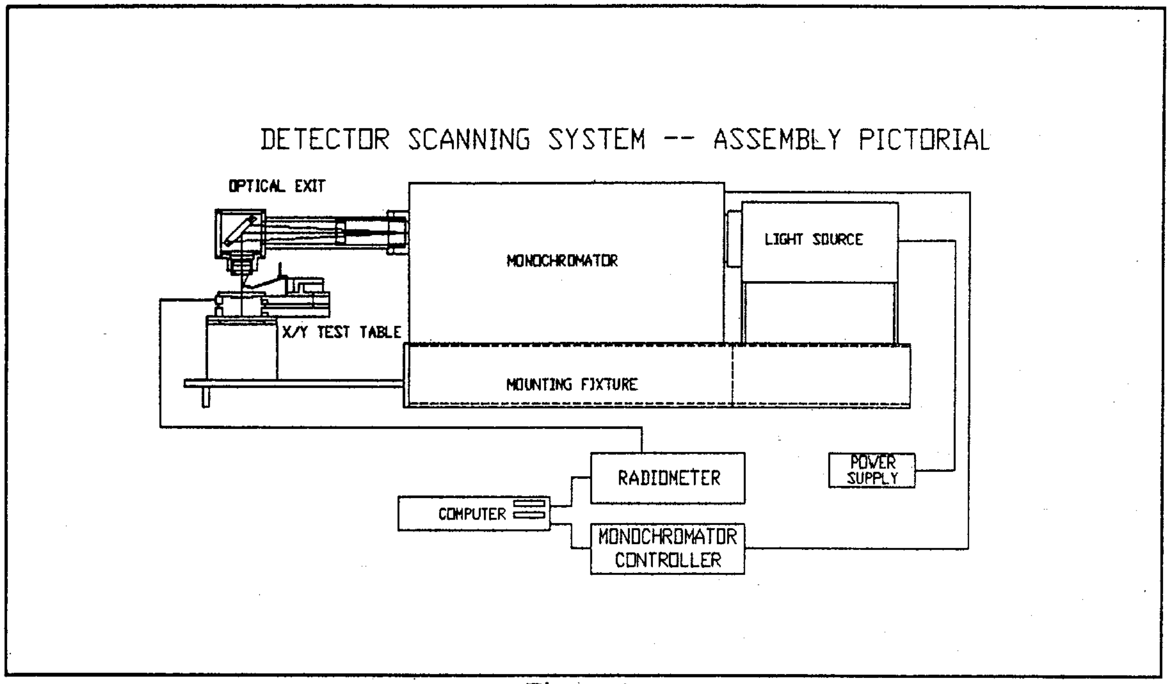


Figure 1.

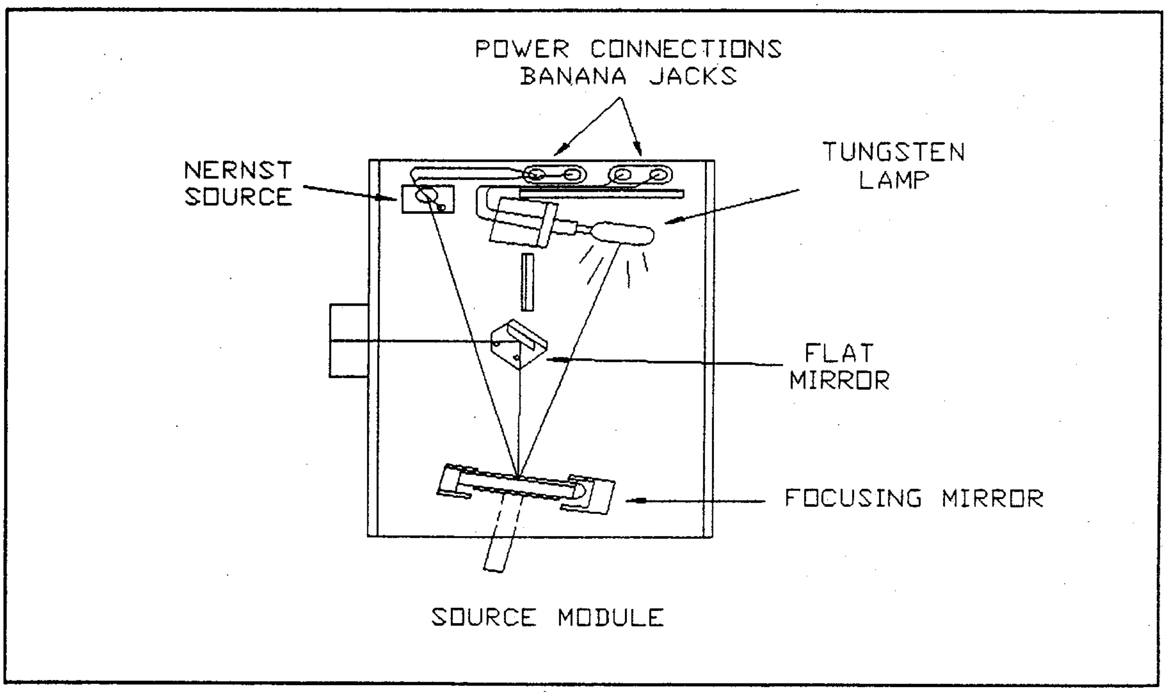
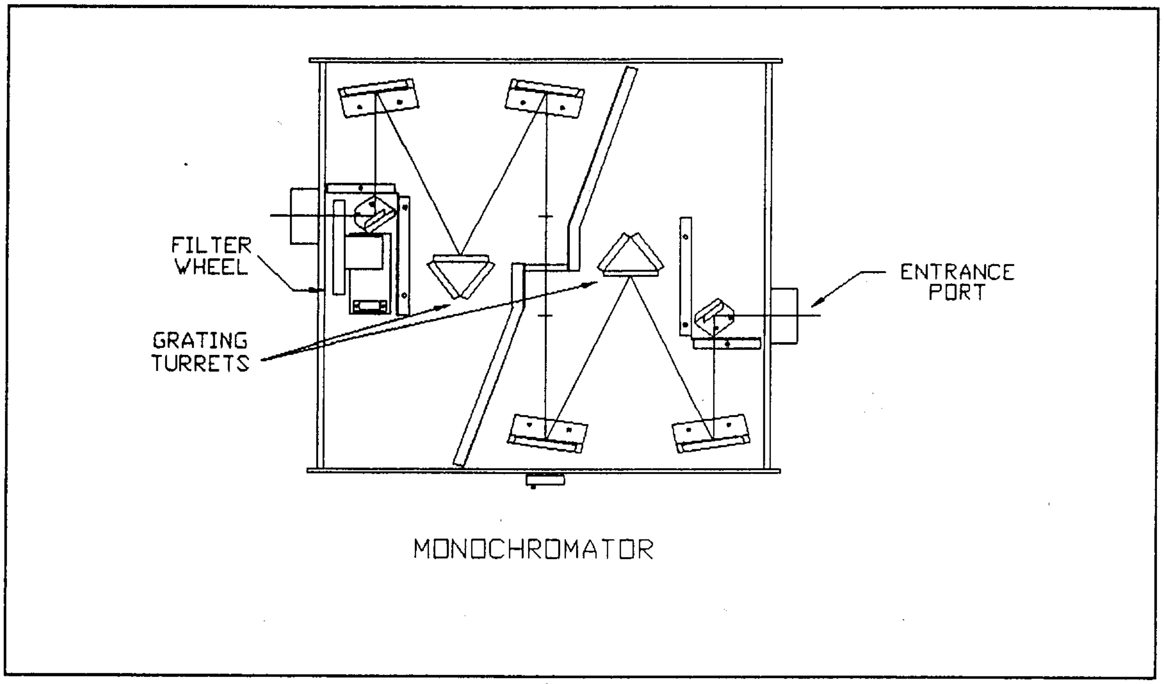


Figure 2.



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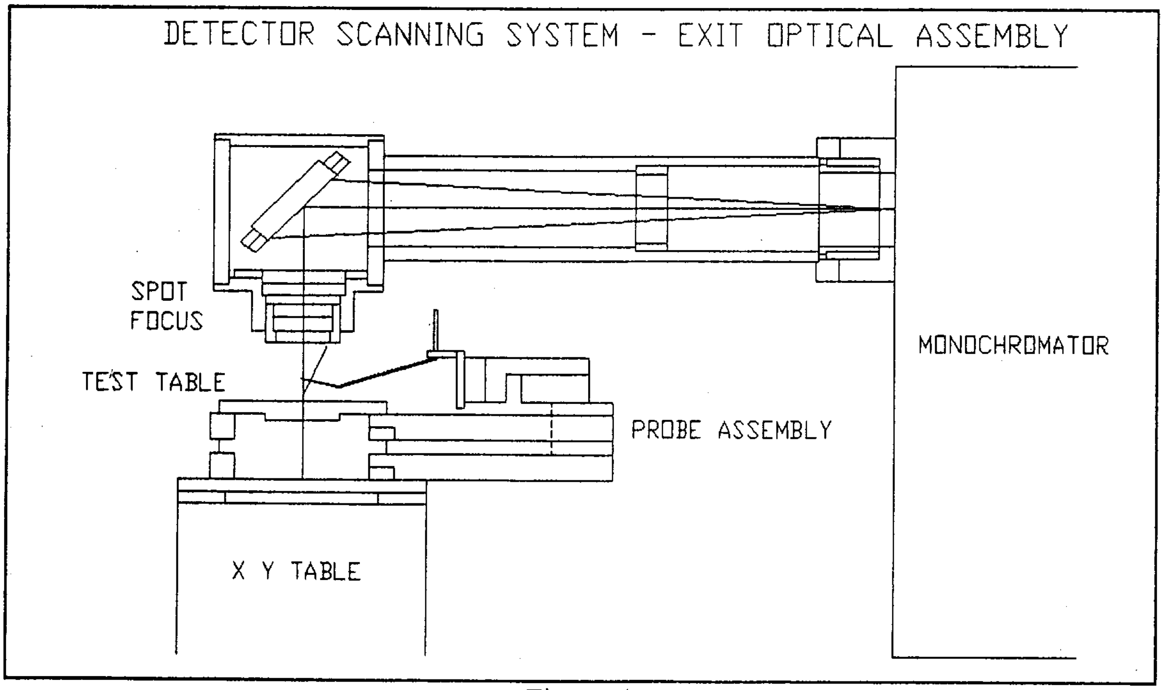

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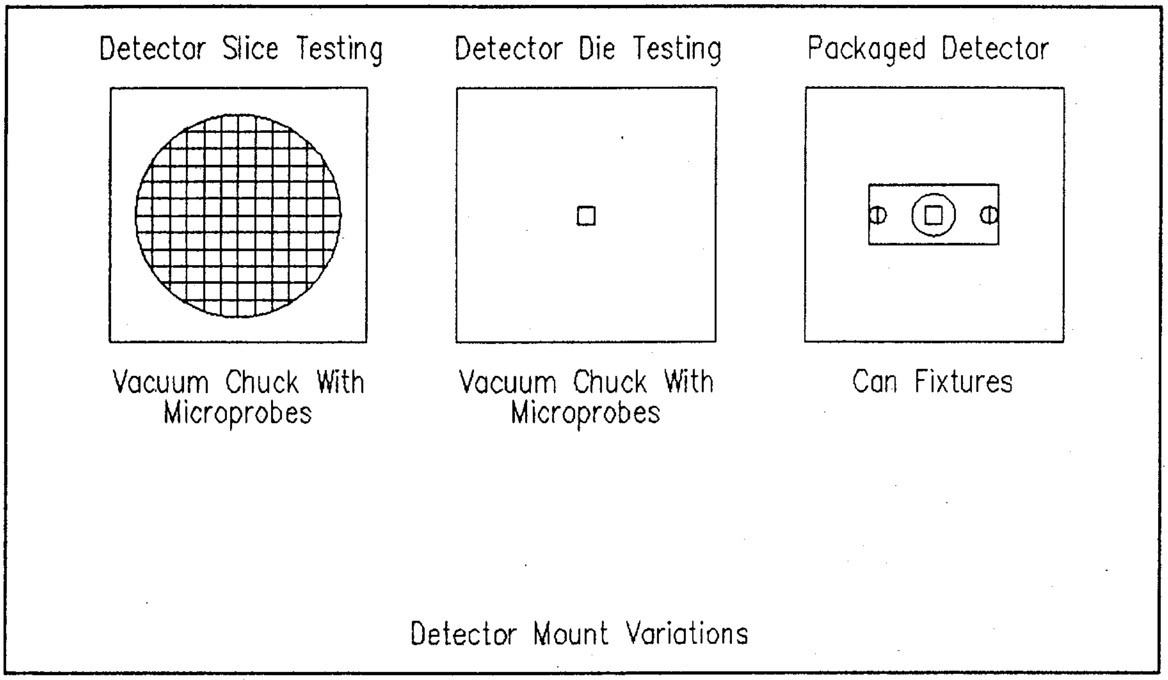

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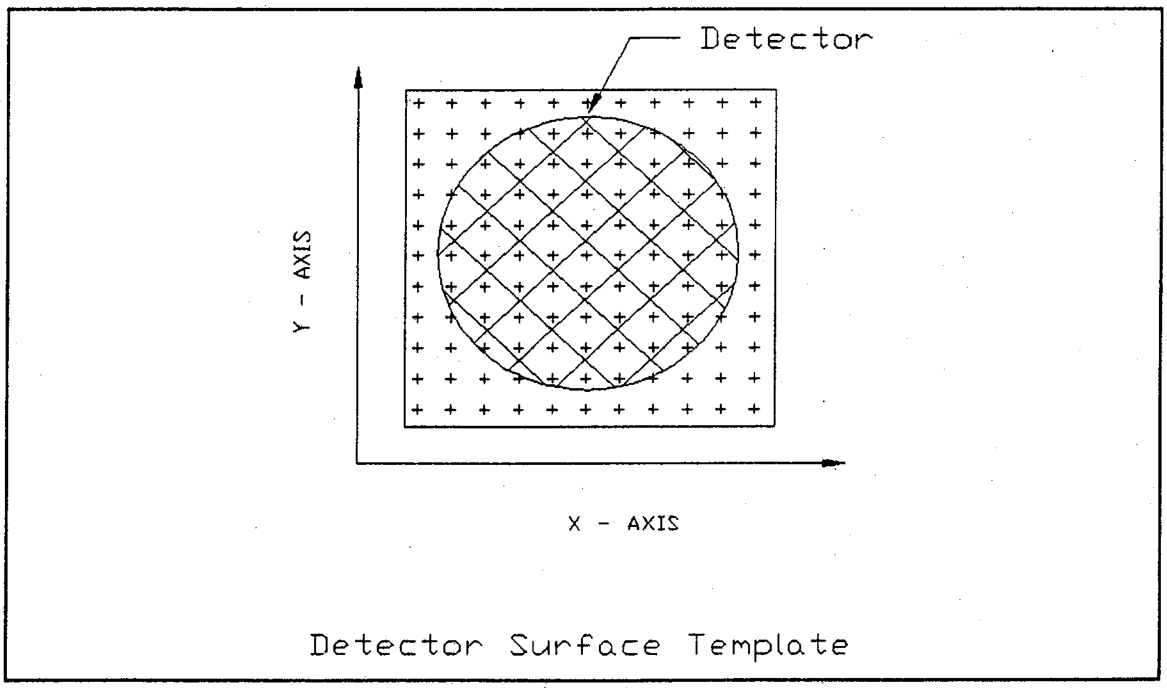

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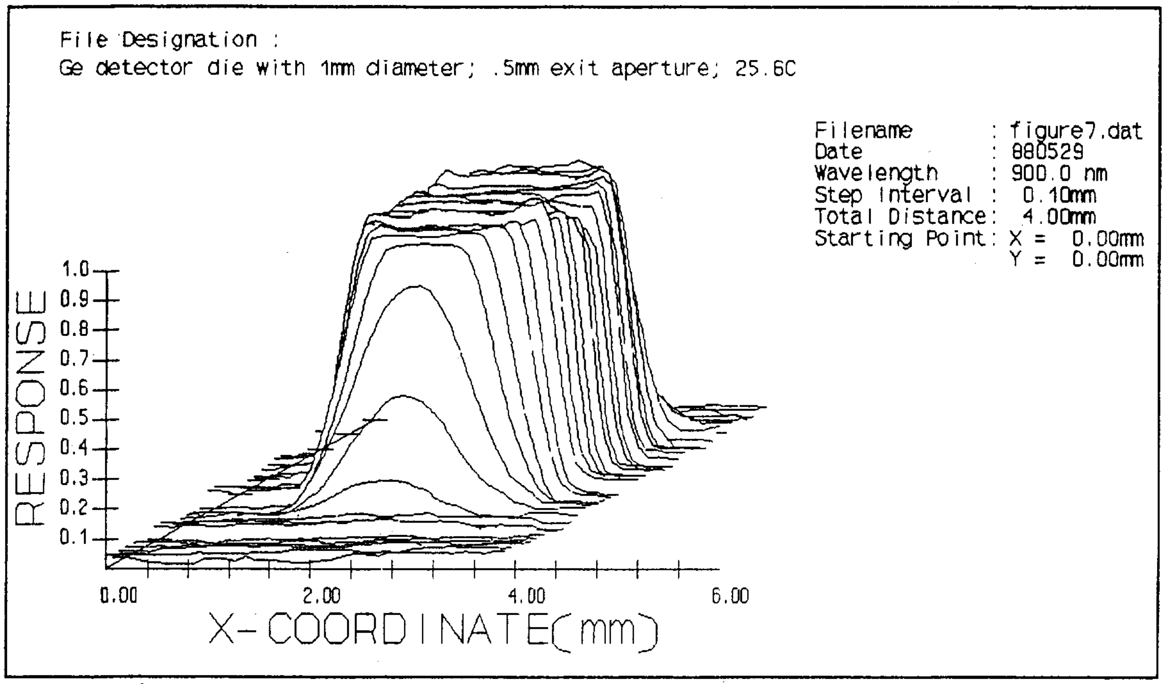

Figure 7 - Ge DETECTOR UNIFORMITY PROFILE AT .9 MICRONS.

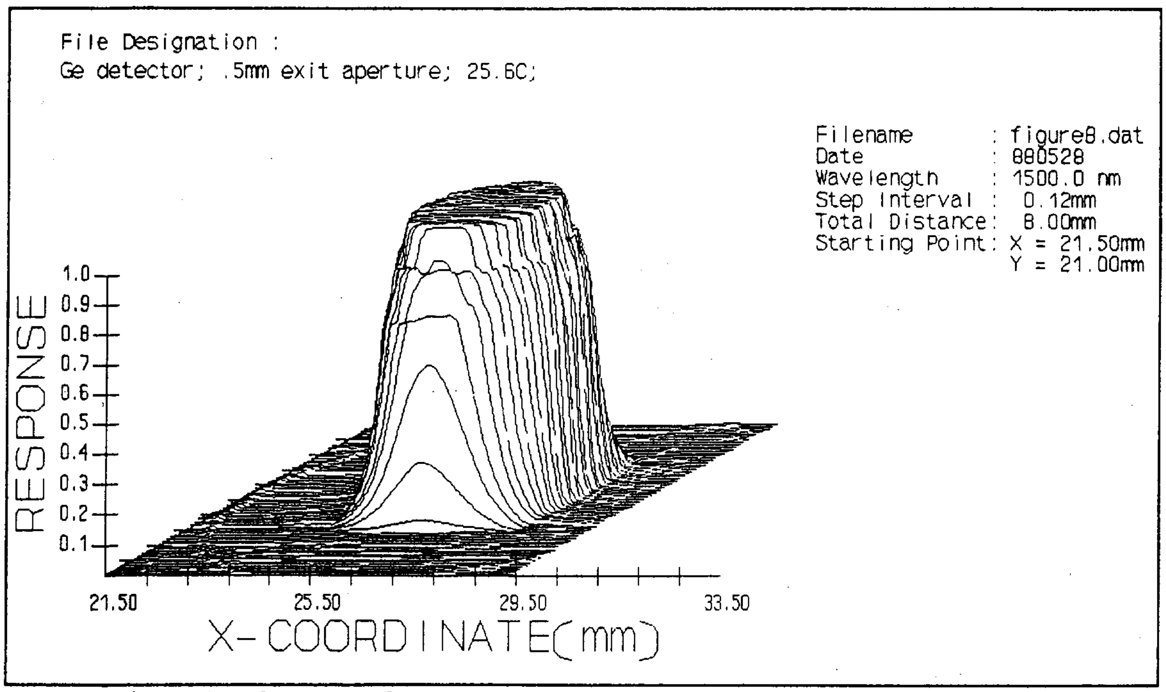

Figure 8 - Ge DETECTOR UNIFORMITY PROFILE AT 1.5 MICRONS.

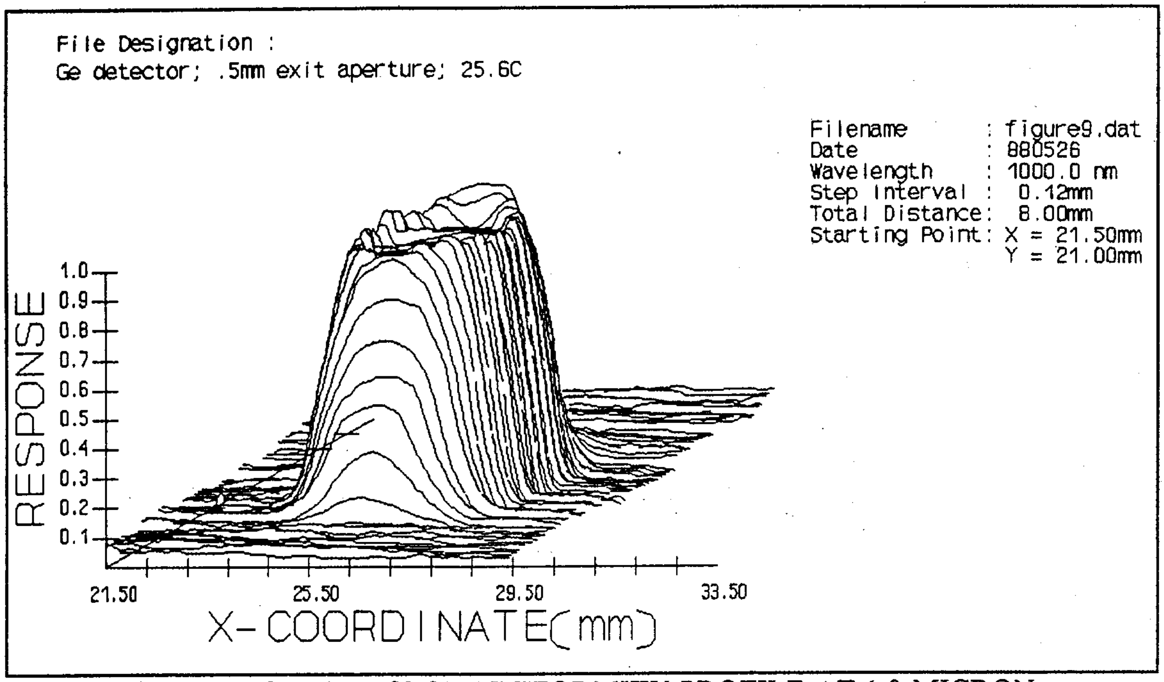

Figure 9 - Ge DETECTOR UNIFORMITY PROFILE AT 1.0 MICRON.

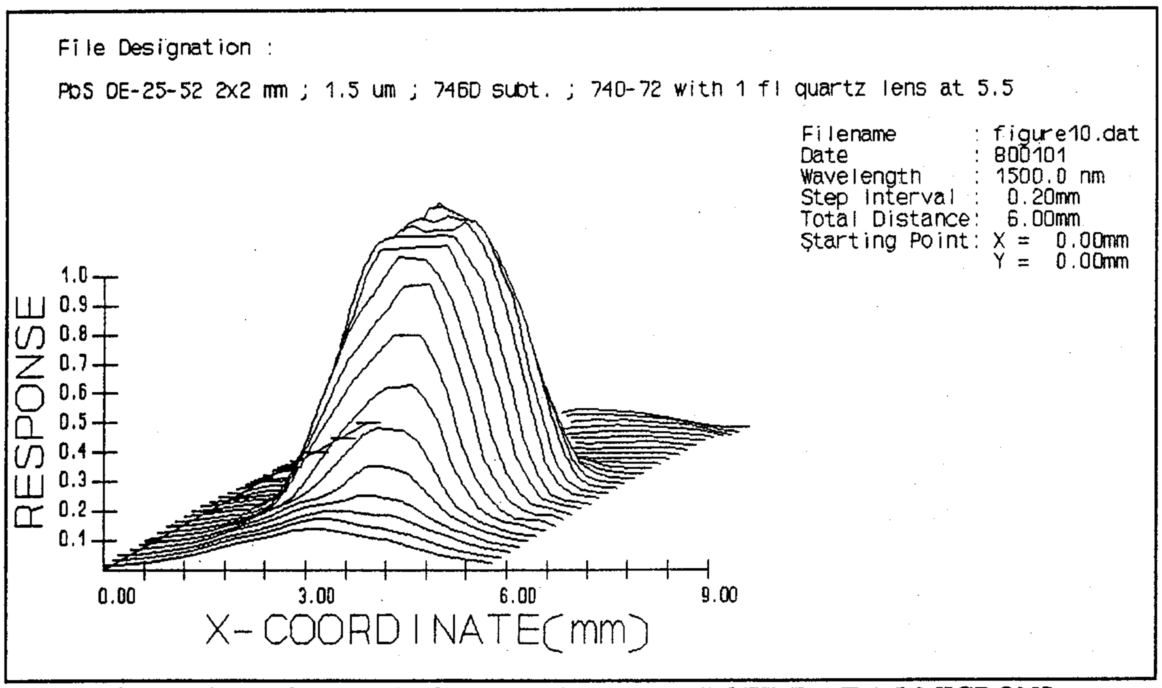

Figure 10 - PbS DETECTOR UNIFORMITY PROFILE AT 1.5 MICRONS.

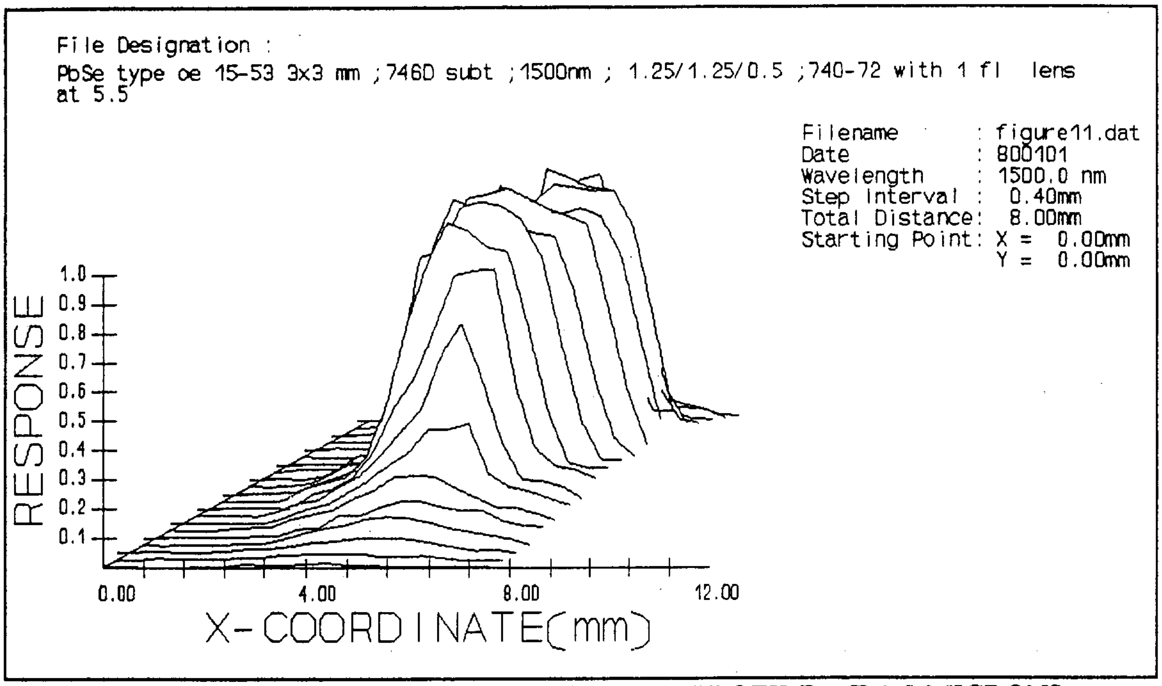

Figure 11 - PbSe DETECTOR UNIFORMITY PROFILE AT 1.5 MICRONS.

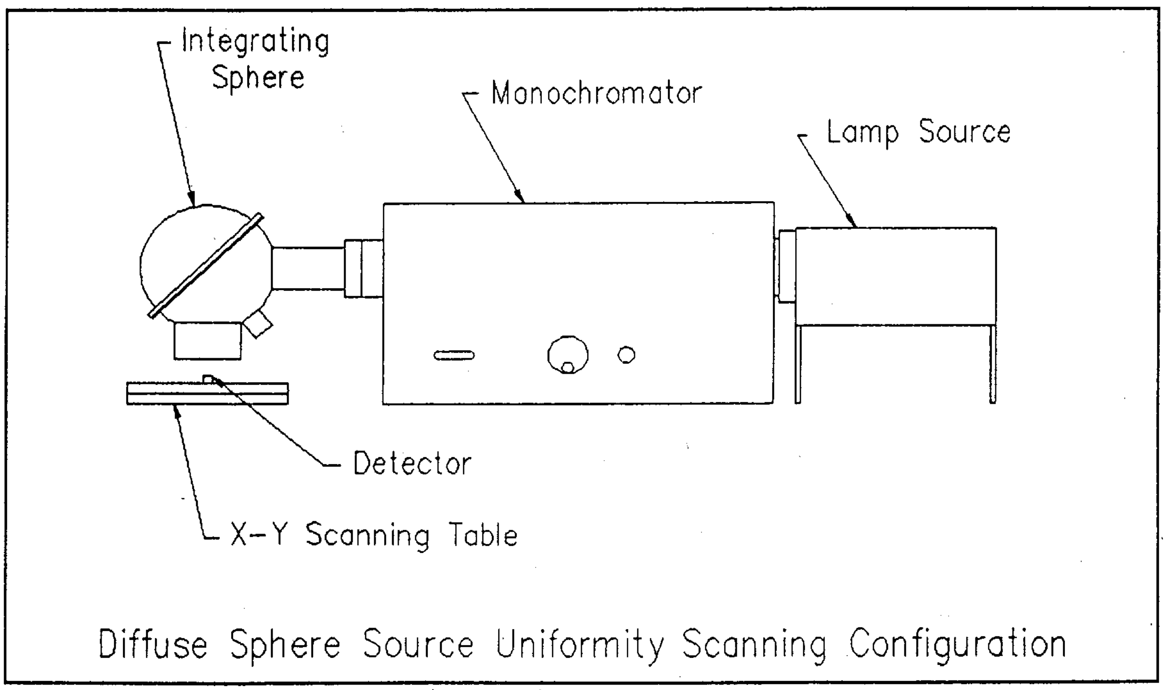

Figure 12.

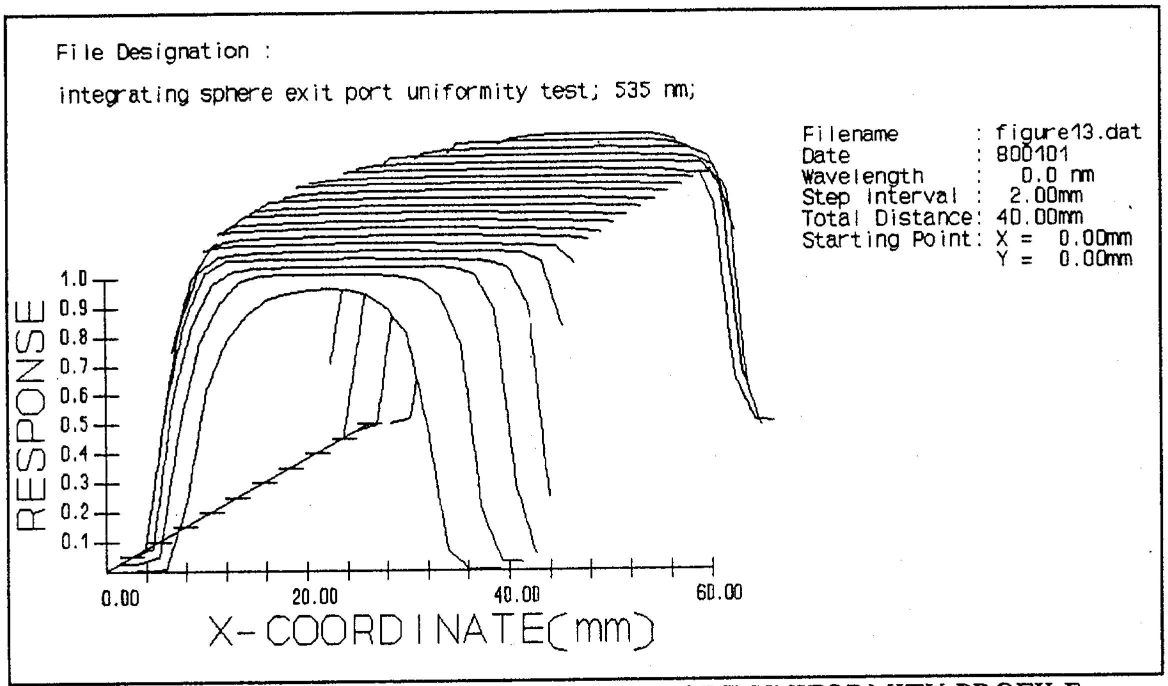

Figure 13 - INTEGRATING SPHERE EXIT PORT UNIFORMITY PROFILE.

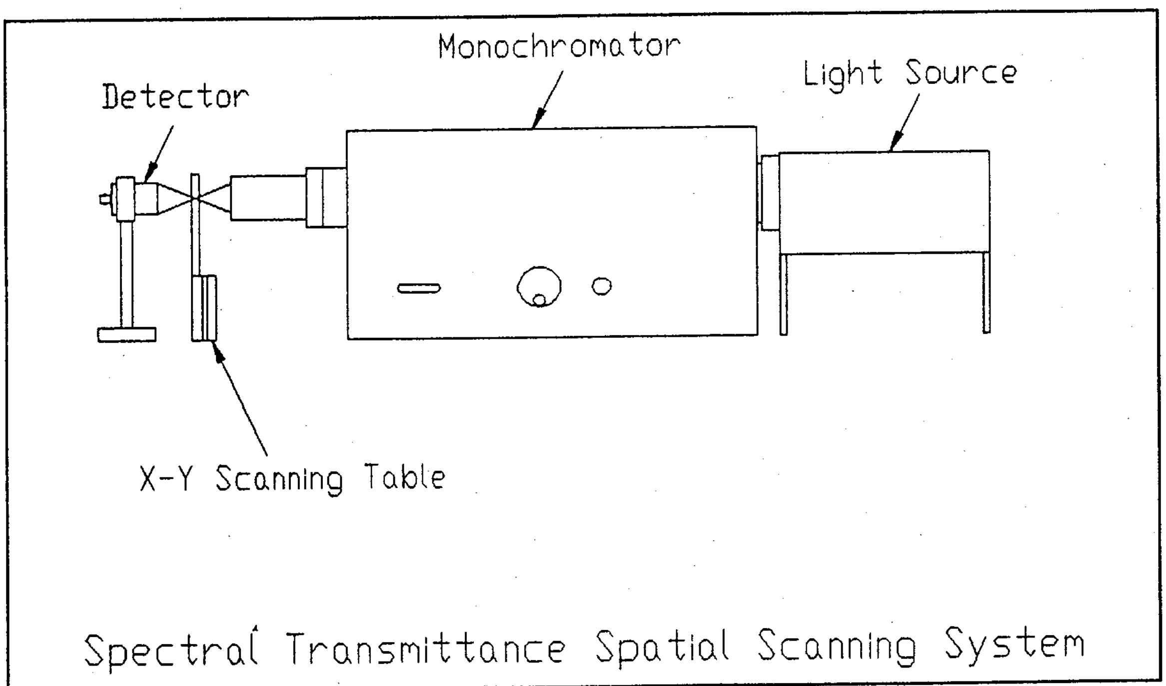

Figure 14.

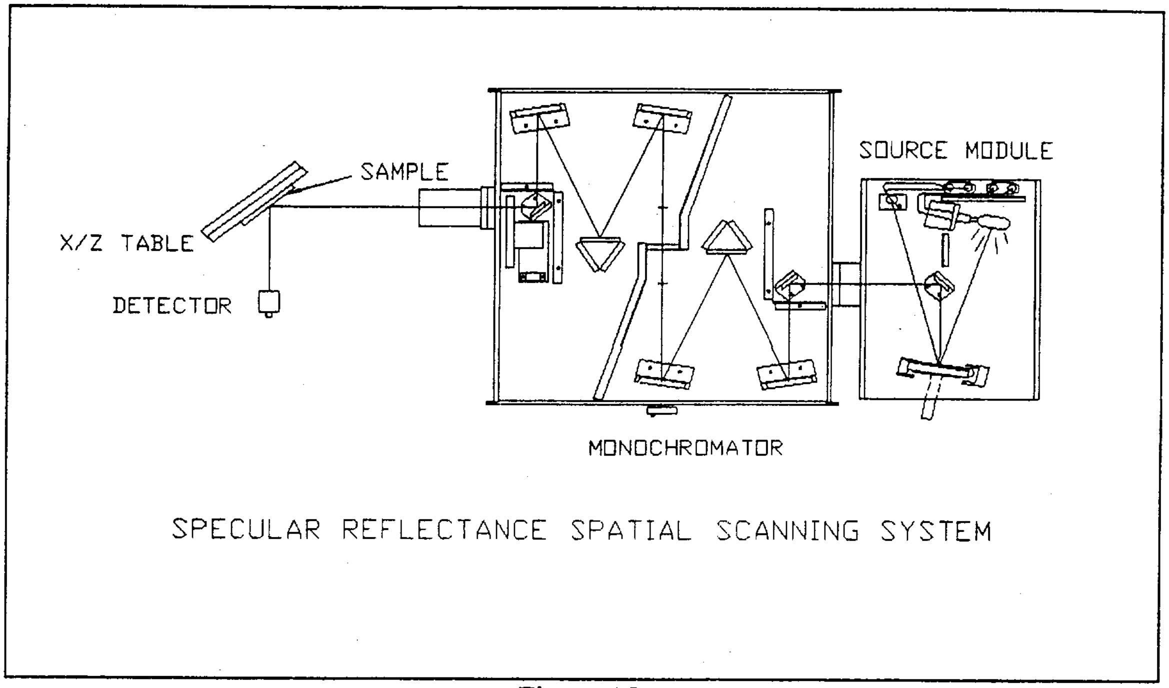
SAMPLE
SOURCE MODULE
X/Z TABLE
DETECTOR
MONOCHROMATOR
SPECULAR REFLECTANCE SPATIAL SCANNING SYSTEM

Figure 15.