Mono Instrument Services Ltd.
Technical Report

Perkin Elmer 983/G Detector Replacement	**Rev:** 2.0 **Issue Date:** Sept 6 / 2002 **Author:** D. Bevington

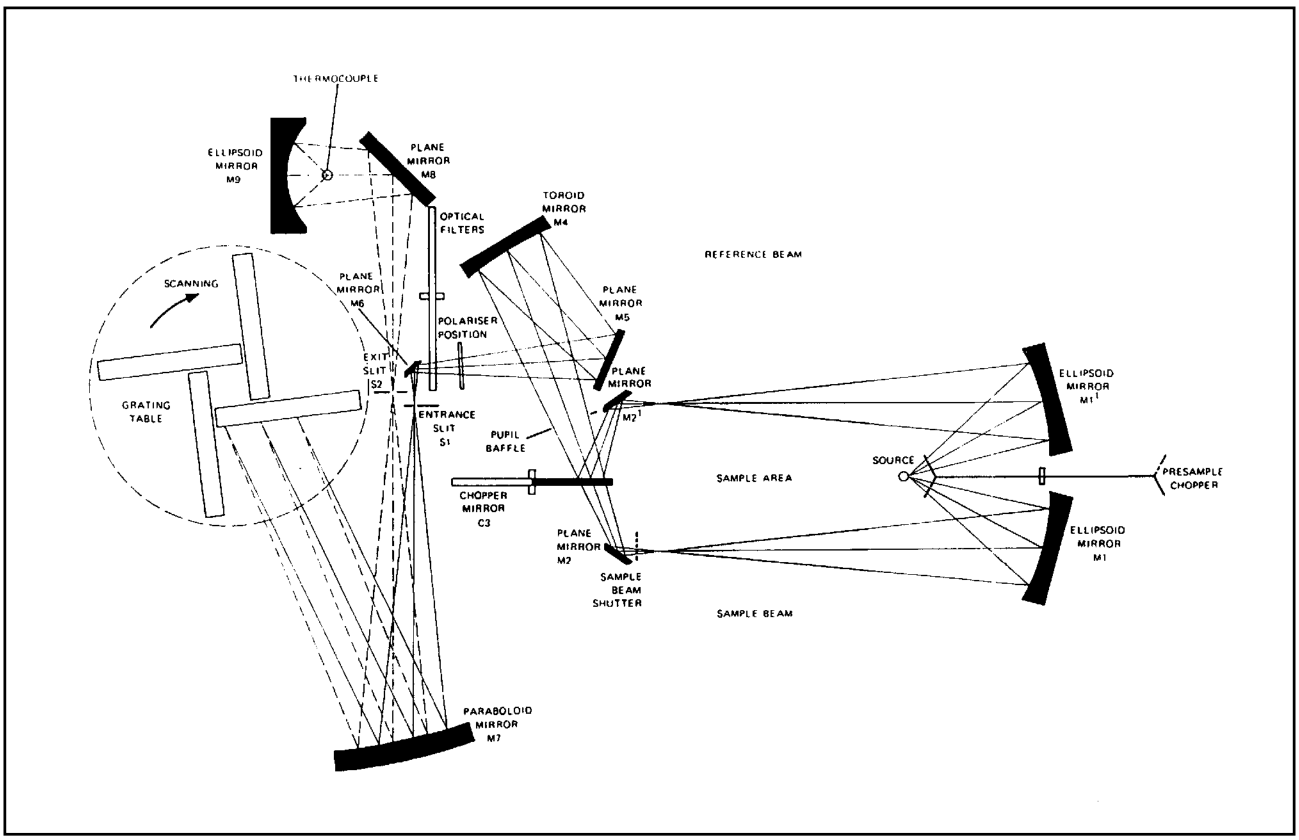
Purpose:

The purpose of this endeavour is to prolong the usable life of the Perkin Elmer 983/G Infrared Spectrophotometer by developing a replacement detector assembly.

Background:

The Perkin Elmer Corporation (PE) was an industry leader in the design and manufacture of dispersive (grating) style infrared spectrophotometers. These instruments have a wide variety of applications. In industry, they are an essential quality assurance tool for monitoring raw materials and finished goods. Because of their ability to define major structural groups of chemical compounds, they have gained wide acceptance in quantitative and qualitative analysis and R&D. With the introduction of Fourier Transform Infrared Spectrophotometer (FTIR) in the early 80's, it appeared that the dispersive type of instrument was immediately antiquated. The several well-documented advantages of FTIR were indisputable and the increase in computing power in the early 80's made FTIR an affordable alternative.

Figure 1.1 983/G Optical Schematic



One particular dispersive model, made by PE, gained popularity with the physical sciences market. The Model 983/G. Figure 1.1 shows the optical path utilized. Sample and reference beams were continuously compared in both the fully open and fully closed states. This ratio-recording principle was employed over the frequency range of 5000 to 180 cm^{-1}. The 983/G was the culmination of years of instrument development begun at PE in the 1960's with the model 180 and in the 1970's with the 580B.

In particular, the thin film optics manufacturing sector adopted the 983/G as the industry standard for high accuracy transmission and reflection measurements of optical materials. Regrettably this type of instrument is no longer in production. The current market replacement FTIR style instrumentation incurs systematic errors when measuring solid samples. This has been well documented and as such, the FTIRs are unreliable for accurate, repeatable transmission and reflection measurements. Efforts are underway to resolve the systematic errors. To date, they have not been totally resolved and the 983/G remains the industry standard and in use.

As well as being no longer in production, the 983/G is no longer supported by the manufacturer. In particular, the thermocouple detector used on the 983/G is no longer available.

This report shall describe how current detector technology could be utilized in creating a replacement detector assembly for the 983/G. Of particular interest is a side to side comparison of the performance of the PE thermocouple to the system proposed in this report. This new detector has the capability of prolonging the life of the 983/G indefinitely without reliance on the original equipment vendor.

Concept to Product:

Pyroelectric detectors are currently in use for a wide variety of applications. Their features are low noise with linear and stable response. With adequate pre amplification, a pyroelectric detector can be utilized in the 983/G optical path at a suitable focal point. This concept utilizes a technology that would be readily available.

The original 983/G design incorporated an exit port for the optical beam that resides behind Plane Mirror M8. (Refer to figure 1.1) This concept proposes that if mirror M8 was removed, the infrared beam would travel directly out the exit port to a separate focal point. The F4.2 monochromator used in the 983/G would put the alternate focal point at a manageable distance from the exit slit. Conceptually, if an ellipsoid mirror were placed at this point, one could capture the full IR beam and focus it on a pyro-electric detector. The resulting signal could then be amplified to a level that the existing 983/G signal electronics would readily accept.

As well, this alternate optical path is non-destructive. The original thermocouple remains intact and aligned. By changing one connector and replacing plane mirror M8, the original detector configuration can be restored.

The MARK I detector is an assembly that mounts onto the rear wall of the 983/G. The assembly incorporates an enclosure that is purge tight. Within the enclosure is an off axis ellipsoid with alignment adjustments. Protruding from the enclosure is the detector / pre-amplifier assembly. These have adjustments for focus and amplifier gain.

Results:

Data was accumulated using the RS-232-C interface in the 983/G. GRAMS/386 software, with the Corbett driver for the 983/G command set, controlled the instrument functions.

The scans acquired were industry specific performance specifications. They are as follows:

1. Peak to Peak noise measured at 4000 cm^{-1}.
2. Polystyrene spectra in Scan Mode 4 Noise filter 1 from 4000 to 180 cm^{-1}.
3. Stray light at 2920 cm^{-1} measured with 2 polystyrene films stacked in the sample beam.
4. Stability of the instrument zero.
5. Industry sample of Calcium Fluoride and Zinc Selenide coated filters

These parameters constitute a typical performance validation for a commercial optical measurement laboratory and are in large part excerpts from actual tests. The enhanced results are summarized in tabular form in the conclusions section.

Peak to Peak Noise measured at 4000 cm^{-1}

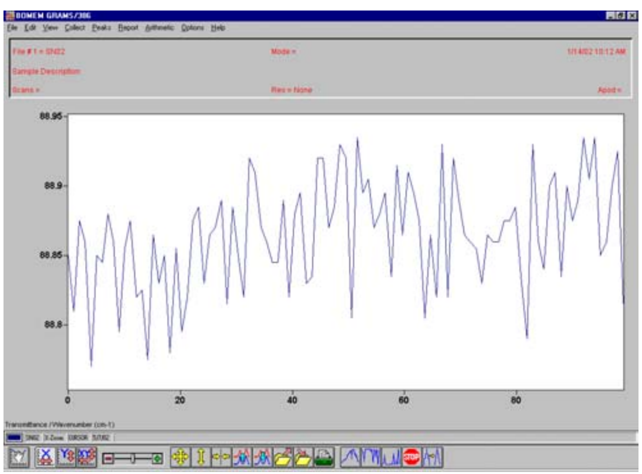


Figure 1.3
PE Thermocouple

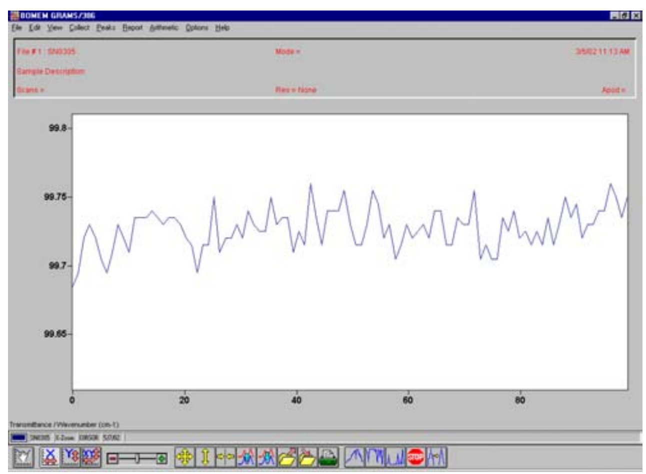


Figure 1.4
Mono Mark I Detector

The instrument was set up in Scan Mode 1, Noise Filter 4 at 4000 cm^{-1} in %Transmittance Double-beam mode. The Perkin Elmer thermocouple detector signal and the chopper phasing were both optimized. The instrument was left on for 30 minutes with a dry air purge.

Using GRAMS/386 software, the instrument was set to collect 100 data points in Time Drive mode.
The resulting trace in Figure 1.3 shows a peak to peak noise level of 0.15 %T.

The test was repeated using the Mono Mark I detector. Plane mirror M8 was removed and the Mark I detector mounted onto the beam exit port of the 983G. The detector signal and chopper phasing were both optimized. The method conditions were the same and the resulting trace in Figure 1.4 shows a peak to peak noise level of 0.06 %T.

Detector	**Peak to Peak noise (%T)**	**Signal to Noise Ratio**
Thermocouple (Figure 1.3)	0.15	667:1
Mono Mark I (Figure 1.4)	0.06	1667:1

The Mark I detector improved signal to noise by a factor of 2.6.

<u>Polystyrene spectra in Scan Mode 4 Noise filter 1 from 4000 to 450 cm^{-1} / Mark I Detector</u>

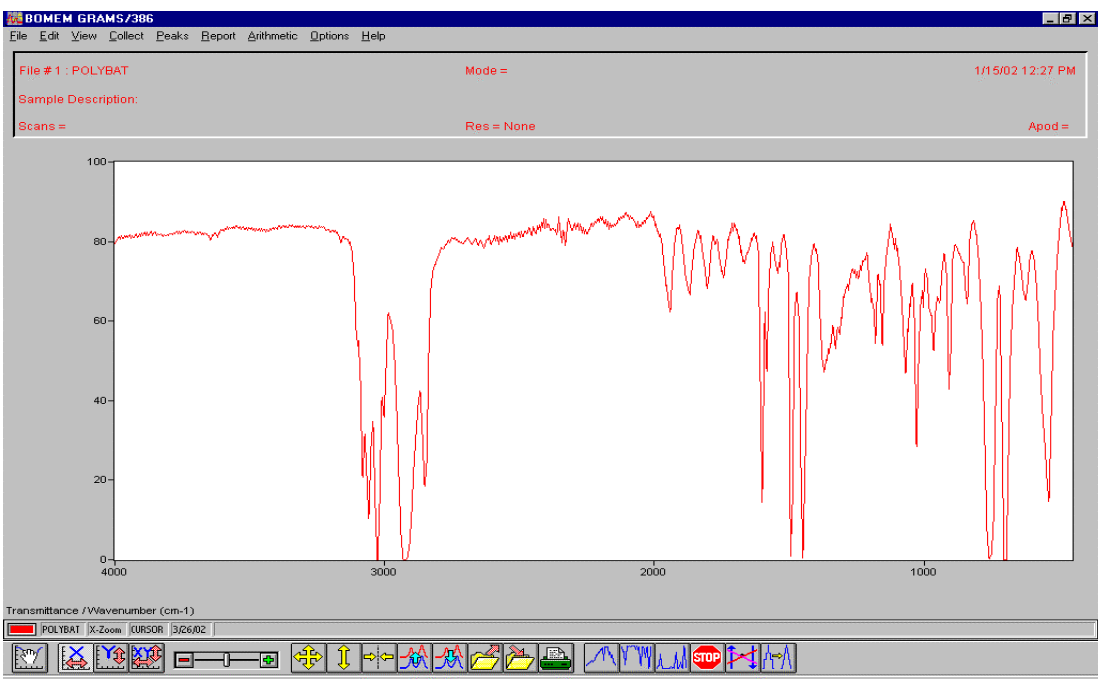


Figure 1.5

The polystyrene film used in Figure 1.5 was NIST Standard Reference Material # 1921. Polystyrene is an excellent material for assessing overall instrument performance. Industry has adopted it as a wavelength accuracy and stray light standard.

<u>Stray light at 2920 cm^{-1} measured with 2 polystyrene films stacked in the sample beam.</u>

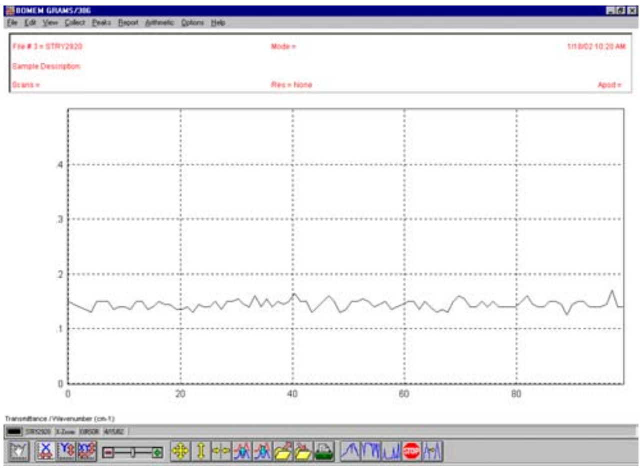


Figure 1.6
PE Thermocouple
Level = .13 %T

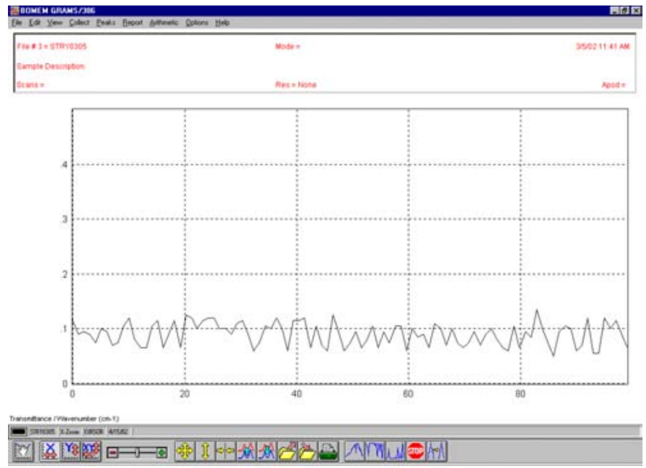


Figure 1.7
Mono Mark I Detector
Level = 0.08 %T

Figure 1.6 and 1.7 demonstrate that the stray light in the 983/G is actually improved with the Mark I Detector. This will improve the accuracy of measurements of highly absorbing samples such as anti-reflectors and cut off filters.

<u>Zero Stability at 4000 cm^{-1} / Mark I / Scan Mode 1 Noise Filter 4 for 20 minutes</u>

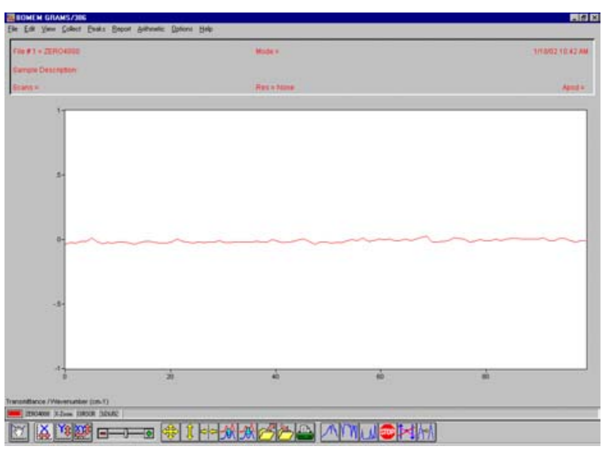
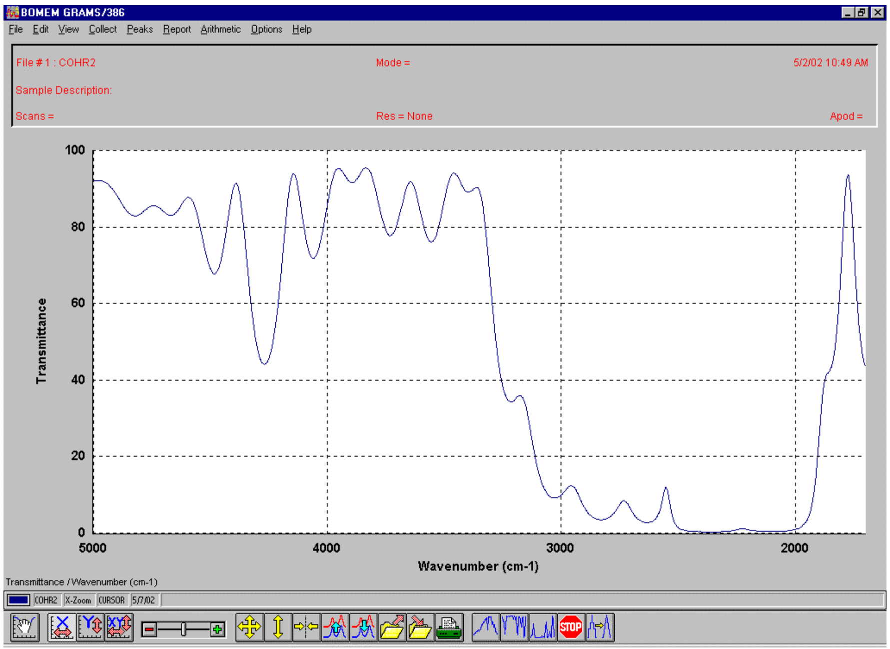
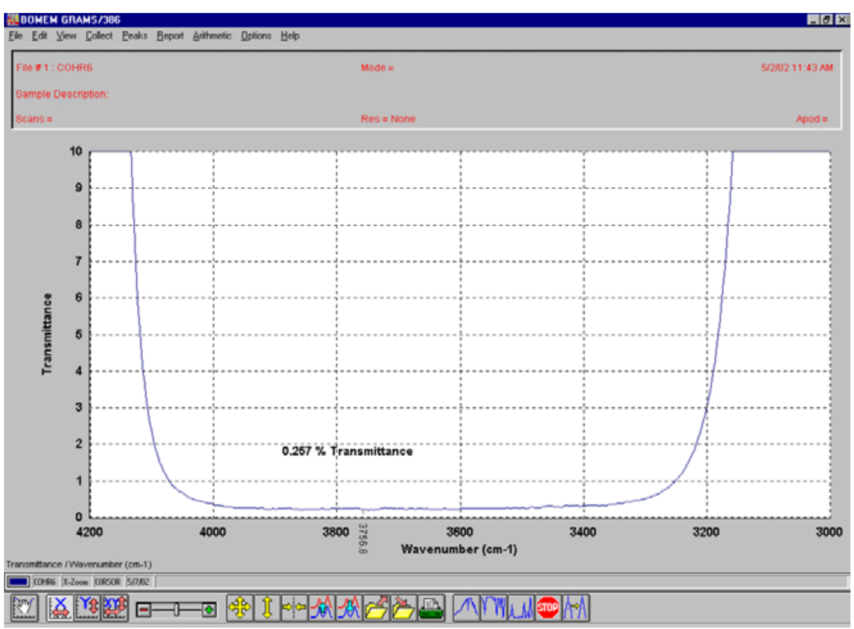


Figure 1.9

Calcium Fluoride Filter measured a 0° incidence in Scan Mode 1 Noise Filter 4 / Mark I Detector



Zinc Selenide measured at 6° Incidence Scan Mode 1 Noise Filter 4 / Mark I Detector



Features and Benefits:

The most significant feature of the side to side comparison of the Mark I Detector and the PE Thermocouple was the improved signal to noise ratio. This can impact a measurement lab in several ways.
The lower signal to noise can allow the metrologist to expand the ordinate scale of measurement. This may allow some difficult measurements, such as anti-reflectors, to be more accurately quantified.

The greatest benefit will be for the thin film optical coating production lab.
The lower noise will allow faster scan times. A case study was performed on the Mark I detector vs. the PE Thermocouple on a production sample of Zinc Selenide. The results follow this text. This sample was measured in the transmission mode with the sample at a 6^o incidence to the infrared beam.
The test 983/G was setup with the PE thermocouple and both the signal and chopper phasing were optimized. The zero was set and the sample run in Scan Mode 1, Noise filter 16. The sample was scanned over the range of 4200 cm^{-1} to 3000 cm^{-1}. The production specification for this sample is a transmission of < 0.5 %T at 2.79 microns. The scan time for this analysis was **8.0 minutes**. (Refer to Figure 2.0)
Now the experiment was repeated with the Mark I detector. The only difference was that the Noise Filter was set to 4 instead of 16. (Refer to figure 3.0) The scan time for the second run was **2.0 minutes**.

The results demonstrate, with no data manipulation, that comparable results were obtained ***in 75% less time !***

Theoretically, sample throughput could increase 4 fold.

Figure 2.0

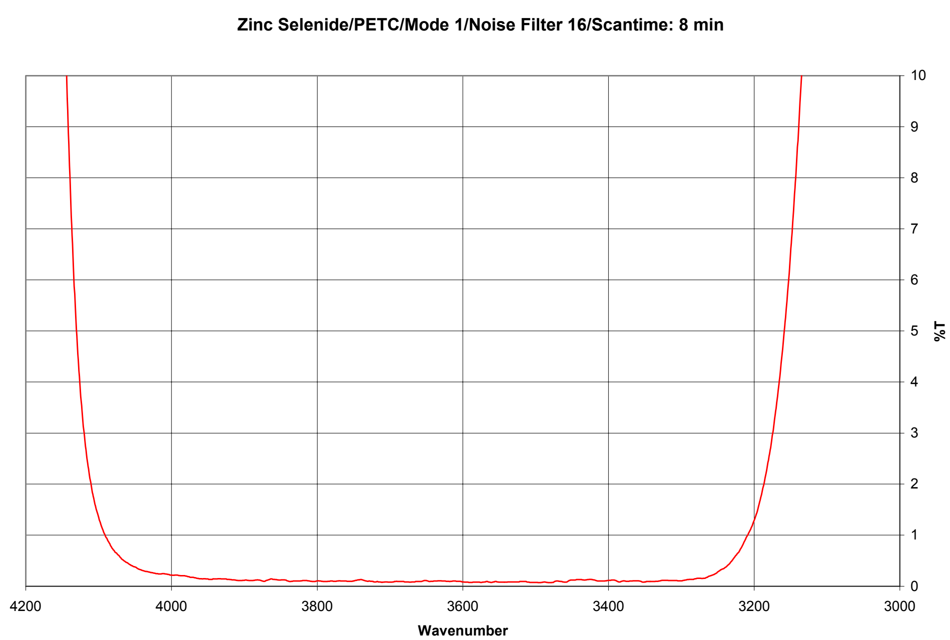
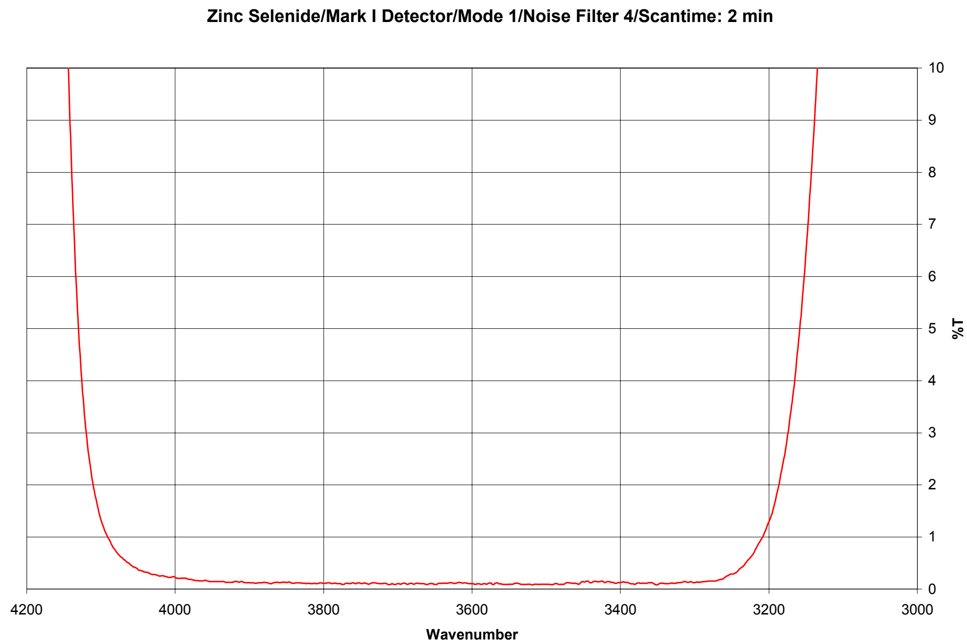


Figure 3.0



Conclusion:

The Mono Mark I Detector, in its production phase, has proven to meet or exceed critical performance criteria for the 983/G Infrared Spectrophotometer. In particular the areas where detector performance has the greatest impact. Signal to noise, stray light and zero stability. The wavelength accuracy, resolution and repeatability were within original published limits. However, these criteria are more opto-mechanically dependent and less on the detector sensitivity and response.

The Mark I detector, utilizing the alternate beam path, a high throughput optic and variable gain control could improve the performance and sample throughput of any 983/G Infrared Spectrophotometer and prolong the life of the instrument indefinitely.

Summary of Enhanced Results

Performance Criteria	OEM Assembly Specification	Thermocouple Detector	Mark I Detector
Noise %T peak to peak	</= 0.2	0.15	0.06
Stray Light at 2920 cm^{-1} %T (2 Poly films)	< 0.5	0.13	0.08
Production Scan Time for comparable noise levels	na	8.0 minutes	2.0 minutes

References:

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6. Perkin Elmer 983/G Service Manual, Part Number L106-9301