BOMEM
Hartmann&Braun

MR Series FT-Spectroradiometers

Alignment Procedures

(Version 1.1)

(IMZ9712)

November 1995

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INTRODUCTION

This manual contains the procedures used to align the MR Series spectroradiometers. The following figures show the MR system from three different angles. You may find it useful to refer to these figures as you carry out the procedures.

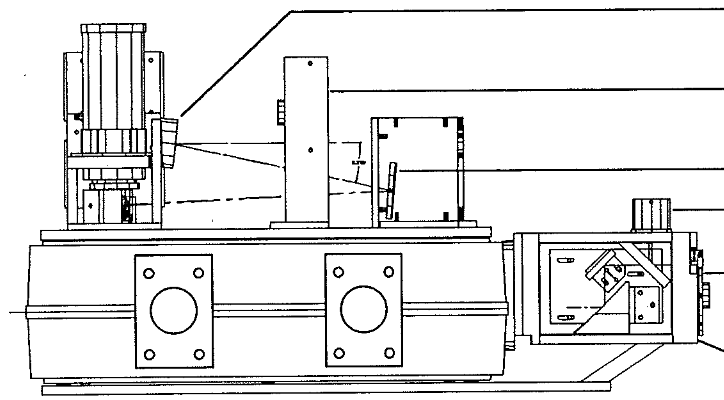

Figure 1. Side view

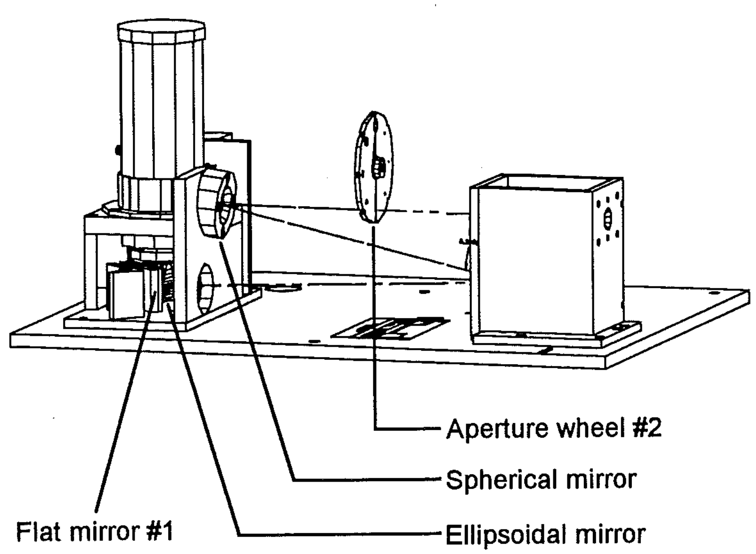

Figure 2. Top plate

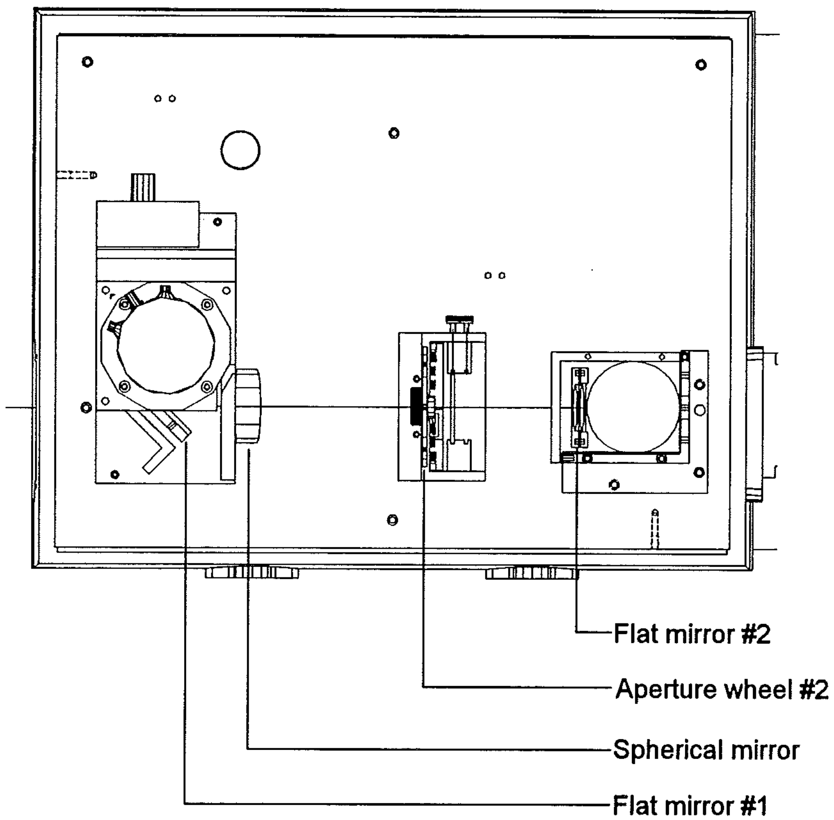

Figure 3. Top view

CCD CAMERA INTERFACE

1. Make sure the lens is correctly positioned in the lens mounting.

The lens is correctly positioned when the image of the 6.4 mm aperture (of aperture wheel #1) fills, and is centered in, the monitor. The lens is designed to be used with cameras of 3 different resolutions—2/3", 1/2", and 1/3" Vidicon.

a) To change the lens position, first remove the 2 large Phillips screws which attach the receptacle to the camera interface (located on the input collimator). Then remove the camera along with the receptacle assembly. Figure 4 shows the receptacle on the camera interface; Figure 5 shows the positions of the various components.

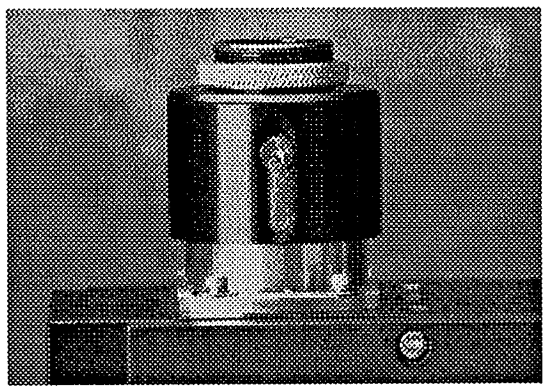

Figure 4. Receptacle on camera interface

b) Loosen the 2 small Phillips screws on the receptacle; this will allow you to change the position of the lens.

c) Adjust the position of the lens, reinstall the assembly, and test the adjustment. Adjusting the lens modifies the size of the image on the screen. It may require several attempts to adjust the lens correctly.

2. The aperture image should have sharp edges.

If it does not, adjust the focus of the camera.

a) Loosen the 2 large Phillips screws on the receptacle assembly.

b) While watching the monitor, raise or lower the camera to adjust the focus, then tighten the screws.

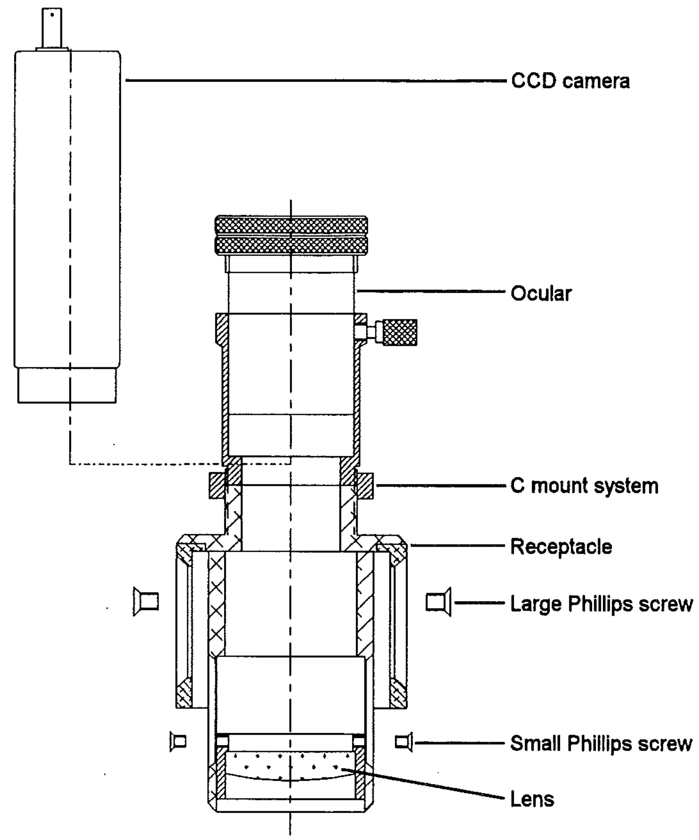

Figure 5. Camera/ocular receptacle assembly (shown with ocular installed)

3. Check that the image of the aperture is centered on the monitor screen.

a) If not, loosen the 4 screws that fix the camera interface to the input collimator.

b) Move the camera slightly forwards, backwards, or to either side, in order to center the camera interface as best as possible.

c) Tighten the 4 screws.

d) Reduce the aperture to 0.8 mm, and check to see if the image is centered on the screen.

4. If the image is still not centered, adjust the beamsplitter.

a) Unscrew and remove the left side (when facing the aperture wheel) plate of the input collimator (Figure 6).

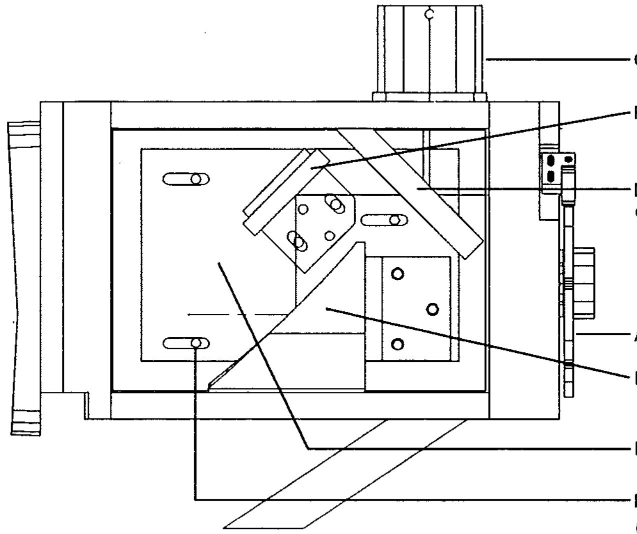

Figure 6. Input collimator with left side plate removed.

b) Loosen the 3 screws on top of the input collimator, just behind the camera interface, which hold the dichroic beamsplitter support.

c) With your fingers, move the dichroic beamsplitter support slightly to center the image on the screen as best as possible. Then tighten the 3 screws.

Note: *Be sure to touch only the aluminum ring around beamsplitter, and not the surface of the beamsplitter. It is preferable to use gloves. The beamsplitter must remain seated in its support.*

d) Repeat step 5, but this time move the camera interface to center the image as best as possible.

Note: *You may have to repeat steps 5 and 6 alternatively several times for best results.*

Do not replace the input collimator side plate until you have completed the input collimator alignment procedure.

INPUT COLLIMATOR

1. If installed, remove the telescope from the input collimator.

2. Install the beam finder light source.

a) Turn aperture wheel #1 (Figure 7) so that the largest aperture is at the top. (This aperture is uncalibrated.)

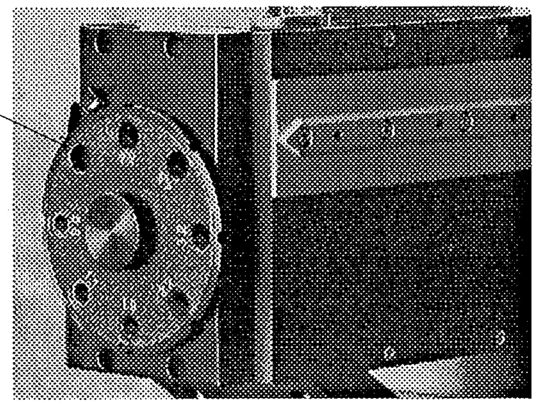

Figure 7. Aperture wheel #1 (on input collimator)

b) Insert the beam finder light source into the largest aperture of aperture wheel #1 and turn on the power supply.

c) Set aperture wheel #2 (Figure 8) to 0.8 mm.

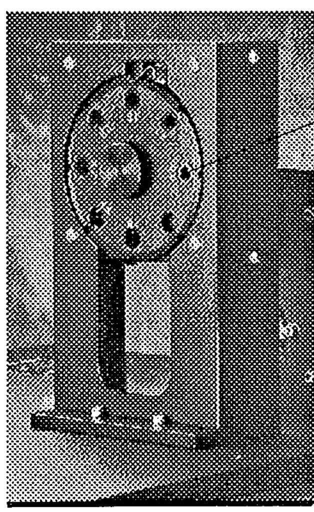

Figure 8. Aperture wheel #2 (on top plate)

3. Check beam alignment.

Reduce the ambient light level as much as possible. Look over the input collimator towards the support for aperture wheel #2. You should see the 0.8 mm aperture through a hole in the support. The light beam should be centered in the aperture.

4. If the light beam is not centered in the aperture, adjust the flat mirror inside the input collimator.

a) Make sure that the left side plate of the input collimator has been removed, and locate the flat mirror (see Figure 6).

b) To move the light beam up or down, relative to the aperture in aperture wheel #2, loosen the 2 socket-head adjustment screws holding the flat mirror and move the mirror slightly. Then tighten the screws.

c) To move the light beam to one side or the other, turn the two set screws on the flat mirror bracket. (For this adjustment, it may not be necessary to loosen the socket-head adjustment screws.)

Note: Be careful not to touch the surface of the mirror.

5. Verify the adjustment

a) Insert the light source in aperture wheel #2, and turn aperture wheel #1 to 0.8 mm.

b) Verify the position of the beam by placing a piece of translucent paper between aperture wheel #1 and the input collimator.

6. Adjust the focal point.

a) The focal point can be adjusted with the white light source inserted at either aperture wheel. The aperture wheel toward which the beam is directed must be set at 0.8 mm.

b) Loosen the 3 screws which hold the focusing plate in the input collimator. Slide the focusing plate back and forth until the beam is focused on the targeted aperture wheel. Tighten the three screws. When this is completed, the input collimator is aligned.

7. Replace the side plate of the input collimator.

DETECTOR MODULE

Note: Perform this procedure from beginning to end without going back to correct previous adjustments. The pictures and schematics included herein illustrate the detector module of the MR100 spectroradiometer. The MR200 detector modules differ mechanically from the MR100 modules although the optical aspect of both modules is identical. Therefore he following alignment principles apply to both type of modules.

1. Prepare the detector module and the dummy can with the light source.

a) Loosen the 2 captive screws that hold the detector module to the top plate of the instrument, then remove the detector module.

b) Place the detector module on a flat table.

c) Remove the 3 Phillips screws that hold flat mirror assembly #1 (the one on the detector module), and remove this flat mirror assembly.

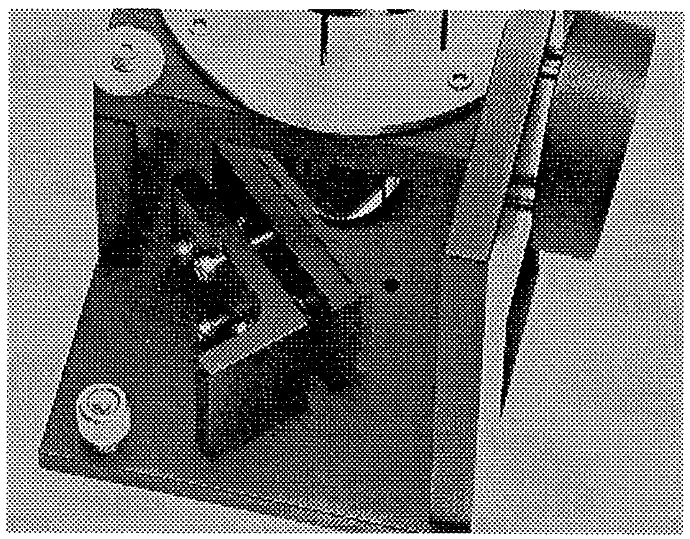

Figure 9. Flat mirror #1

2. Install the dummy (with light source and cross-hair) in place of the detector Dewar.

a) Loosen the circular clamp holding the detector Dewar and remove the latter.

b) Install the dummy can with the light source assembly in place of the Dewar, as in figure 10.

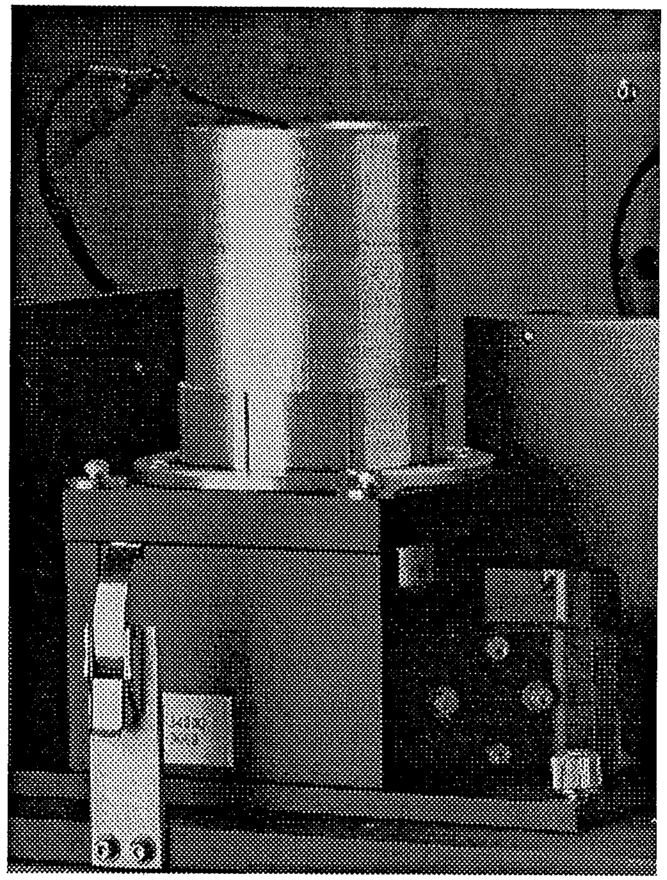

Figure 10. Dummy in place of detector Dewar

c) Connect the light source to the 5 V power supply and turn it on.

3. Set up a target.

a) The target can be any flat, light-colored surface perpendicular to the table top.

b) Draw a horizontal line on the target 2 1/4 in. above the table top.

c) Place the target on the table top so that the distance between the center of the ellipsoid mirror on the detector module and the surface of the target is 22 in.

4. Adjust the dummy to obtain the best image possible of the cross-hair on the target.

a) Grasp the dummy and carefully move it in all three axes until you obtain a round spot of light on the target. Continue adjusting the dummy until the image of the cross-hair on the target is as clear as possible. When properly adjusted, the center of the cross-hair image will be on the line previously defined in 3(b). The idea here is that the position of the light source of the dummy is properly aligned with respect to the foci of the ellipsoidal mirror by verifying that the resulting image at the other foci of the ellipsoidal mirror is circular and without aberrations

b) Tighten all screws somewhat, taking care to maintain a good image on the target. Then tighten all screws firmly and check that the image is still good and that you can see the cross-hair in the image..

5. Replace flat mirror assembly #1 on the detector module assembly.

a) Fasten the flat mirror assembly using the 3 Philips screws.

b) If necessary, adjust the push-pull screws on the flat mirror assembly so that the mirror is parallel to the mirror bracket and spaced 1/4 in. from the bracket.

6. Install the detector module on the top plate of the instrument.

Tighten the 2 captive screws that hold the detector module to the top plate.

7. **Adjust flat mirror #1 so the image is centered on flat mirror #2 (on the top plate assembly—see Figure 3 and Figure 11).**

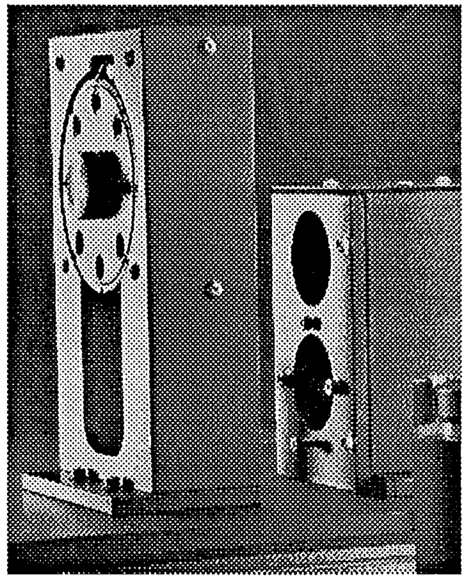

Figure 11. Close-up of top plate assembly.

a) Hold a piece of cardboard (e.g. a business card) just in front of flat mirror #2.

b) Adjust the push-pull screws on flat mirror assembly #1 to move the image, using flat mirror #2 as a guide.

8. **Adjust flat mirror #2 so that the image is centered on the spherical mirror on the detector module.**

a) Hold a piece of cardboard just in front of the spherical mirror.

b) Adjust the push-pull screws on flat mirror assembly #2 to move the image.

9. **Adjust the spherical mirror and check alignment.**

a) If necessary, adjust the push-pull screws on the spherical mirror assembly so that the mirror is parallel to the mirror bracket and spaced 0.14 in. from the bracket.

b) Select the 6.4 mm aperture on aperture wheel #2.

c) Hold a piece of cardboard behind the aperture wheel. By reducing the aperture size, you should eventually see the image of the cross-hair.

Note: If you plan to use a second detector module, install the second detector module and adjust the flat mirror on this detector module only—do not readjust flat mirror assembly #2 on the top plate assembly. In this way, you can change detector modules without having to realign.

10. Remove the dummy and install the Dewar.

a) Leave the screws slightly loose.

b) Connect the Dewar (see Figure 12).

c) Turn on the power.

11. Connect an oscilloscope. (MR100 only. The Align function must be used for the MR200)

a) Remove the preamplifier cover.

b) Connect an oscilloscope between the TP2 SIG test point and the ground pin.

c) Set the preamplifier gain (Figure 13) to maximum, that is, position E.

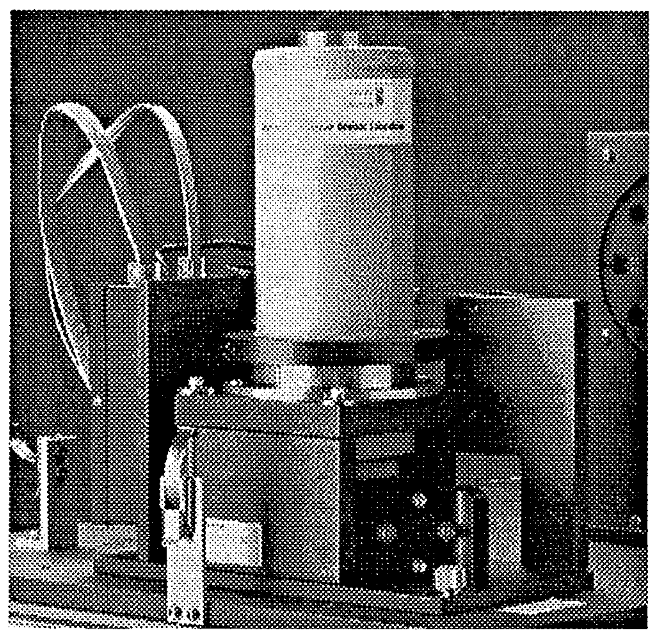

Figure 12. Detector Dewar

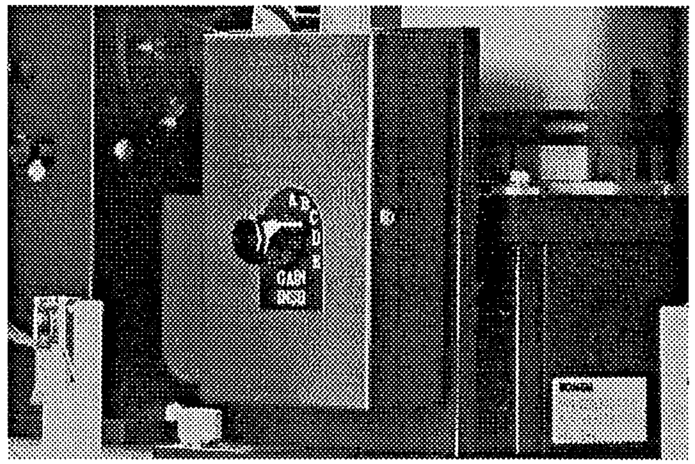

Figure 13. Preamplifier gain control

12. Final adjustment (with cold source—preferred method).

a) Set aperture wheel #1 to an intermediate position, i.e., between two aperture holes so that the instrument is looking at the back of the aperture wheel. This ensures that the instrument sees an ambient-temperature source.

b) Fill the cold source with liquid N_2.

c) Select the 6.4 mm aperture on aperture wheel #2.

d) Carefully move the Dewar in the z-axis (up and down) to obtain the maximum signal level on the oscilloscope or on the computer screen looking at the interferogram ZPD on the status/alignment screen from within the acquisition software. Reduce the preamplifier gain if necessary.

e) Move the Dewar in the x- and y-axes to obtain the maximum signal level on the oscilloscope. Reduce the preamplifier gain if saturation occurs.

Note: You may have to repeat steps d and e several times in order to obtain the maximum signal.

f) Tighten all screws, then replace and tighten the circular clamp, being careful to maintain the signal level.

13. Final adjustment (without cold source)

a) Select an aperture on aperture wheel #1 (use 6.4 mm if no telescope is to be used).

b) Place a black body in front of the aperture so that it fills the aperture. The black body must be placed very close to the aperture and set to 85°C.

c) Carefully move the Dewar in the z-axis (up and down) to obtain the maximum signal level on the oscilloscope.

d) Move the Dewar in the x- and y-axes to obtain the maximum signal level on the oscilloscope or on the computer looking for the ZPD intensity.

e) Tighten all screws, then replace and tighten the circular clamp, being careful to maintain the signal level.

Cold Source

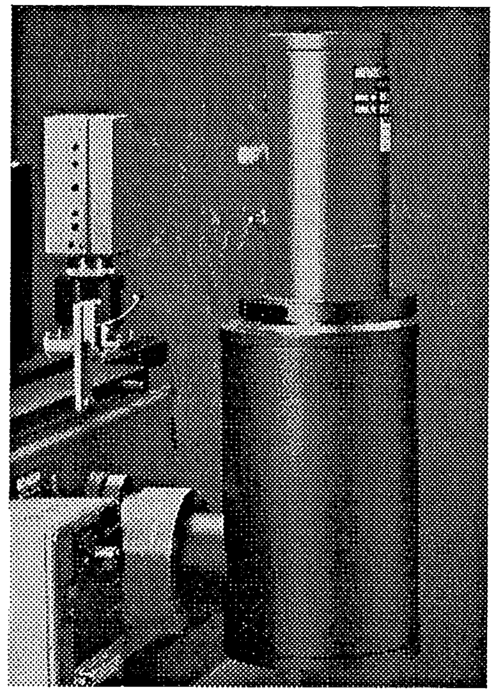

Figure 14. Cold source

1. **Insert the light source into aperture wheel #1.**

2. **Install the dummy (with target) in place of the Dewar.**

   a) Remove the 2 screws in the circular clamp, which holds the Dewar in place (Figure 15).

   b) Loosen the 4 nylon screws in the retaining ring around the Dewar, then remove the Dewar.

   c) Install the dummy provided with the cold source assembly in place of the Dewar, with the target on the bottom.

3. **Check to see if the beam is at the center of the target on the dummy.**

   a) Remove the cold source from the spectroradiometer by first loosening the knurled ring (Figure 15), then carefully pulling the source away from the spectroradiometer.

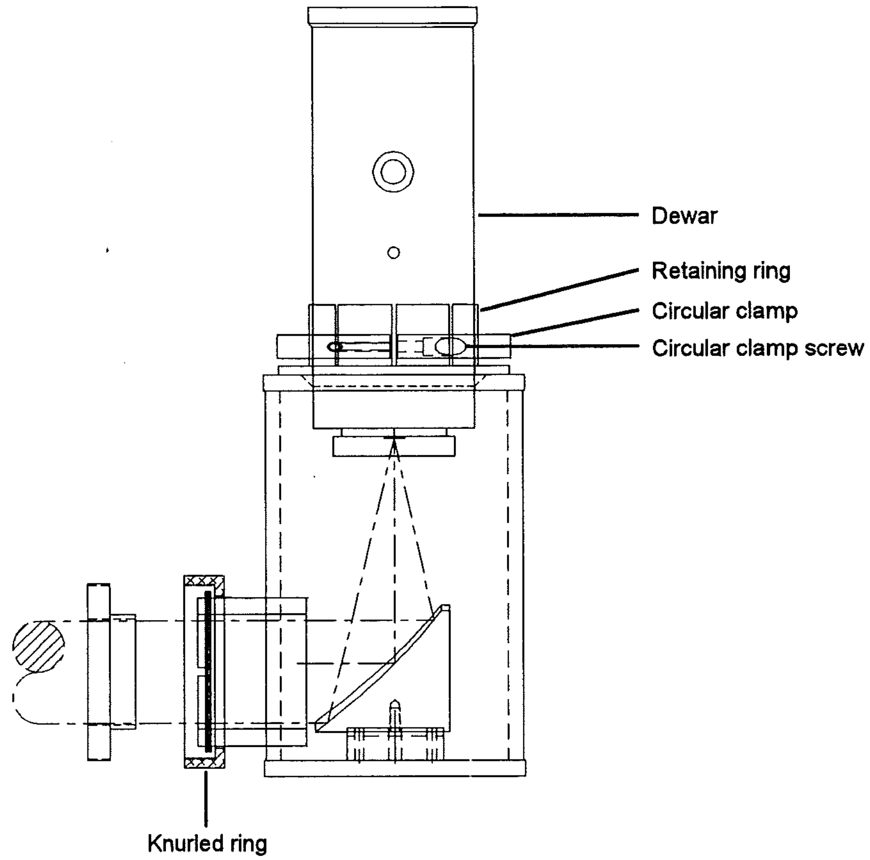

Figure 15. Cold source assembly

b) Remove the base of the cold subtraction source by removing the 4 screws on the bottom, nearest the edge of the base.

c) Loosen the 4 mirror support screws and move the mirror slightly towards the desired position.

d) If necessary, loosen the center screw on the base and tilt the mirror slightly.

e) Replace the base on the cold source, and reinstall the cold source on the spectroradiometer with the dummy in position. Check the position of the beam on the target. If necessary, remove the base and adjust the mirror again.

4. Carry out the vertical alignment of the cold source.

a) Once the cold source is reinstalled, put back the retaining ring, but do not tighten the 4 nylon screws too much.

b) Set aperture wheel #1 to an intermediate position.

c) Using the acquisition/status screen of the acquisition software, maximize the amplitude of the interferogram by moving the Dewar up and down.

d) Once you have found the maximum amplitude, tighten the 4 nylon screws on the retaining ring, and reinstall the circular clamp with its 2 screws.

TELESCOPES

Installation and Alignment

1. Install the telescope on the input collimator.

a) Slide the telescope onto the telescope rails on the input collimator. Install the 6 thumbscrews but do not tighten them.

b) Pull out the telescope as far as possible away from the collimator. See Figure 16.

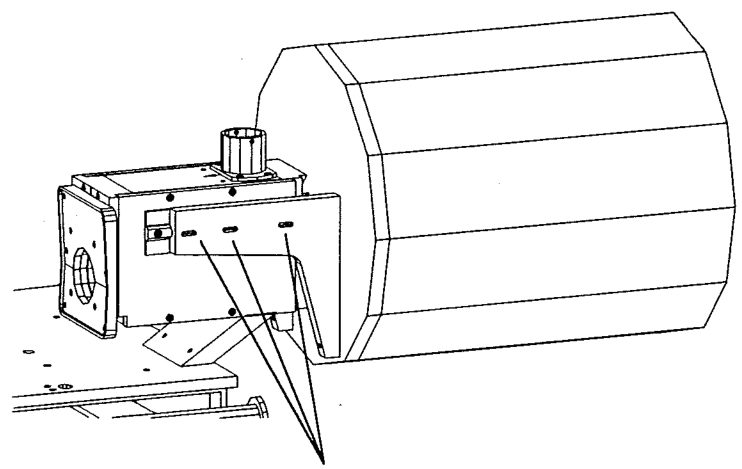

Figure 16. Telescope mounted on input collimator

c) Once the telescope is mounted and positioned, tighten the thumb screws.

2. Align the telescope.

a) Set up a visible light source in front of the instrument.

b) Set up the source to be observed at the following distance:

10 m (for models SMY0300G and IMY0600F)
2 m (for models SMY0400G and IMY0700F)

The source should be placed directly in front of the telescope at exactly the same height above the floor as the center of the input telescope.

Note: This procedure applies whether a CCD camera or an ocular is mounted on the input collimator.

Models SMY0300G, SMY0400G, IMY0600F, IMY0700F

Adjustment of Mirrors Inside the Telescope

1. **Remove the telescope cover.**

2. **Adjust the small flat mirror.**

   a) The small flat mirror (see Figure 17) should first be positioned flat against its bracket, with no space between the mirror and the bracket. If this is not the case, adjust the mirror using the push-pull screws.

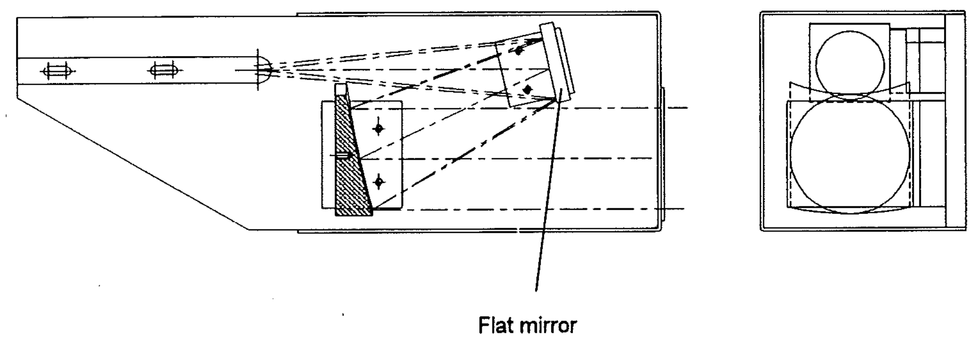

Figure 17. Medium-angle telescope

   b) If you have a CCD camera mounted on the input collimator, adjust the push-pull screws on the small flat mirror so that the image of the source is centered on the screen. If you have an ocular, the image should be centered in the view finder of the ocular.

Note: The CCD camera interface must be properly aligned for this adjustment to be reliable.

   c) Verify the validity of the adjustment by reducing the size of aperture wheel #1 to 0.8 mm. Light should still pass through the aperture.

3. **Optimize the focal point.**

   Locate the focal point by placing a sheet of paper against the back of aperture wheel #1. Slide the mounting bracket back and forth to optimize the focal point as displayed on the paper.

4. **Replace the cover of the telescope.**

Models IMY0400F and SMY0200G

Telescope Adjustment

1. **Set up an object to be observed approximately 30 m away.**

   Note: No mirror adjustment is necessary on these telescopes to center the beam on the aperture wheel.

2. **Optimize the focal point.**

Model IMY0400F:

- Rotate the convex mirror assembly inside the telescope to obtain a sharp definition of the image. See Figure 18.

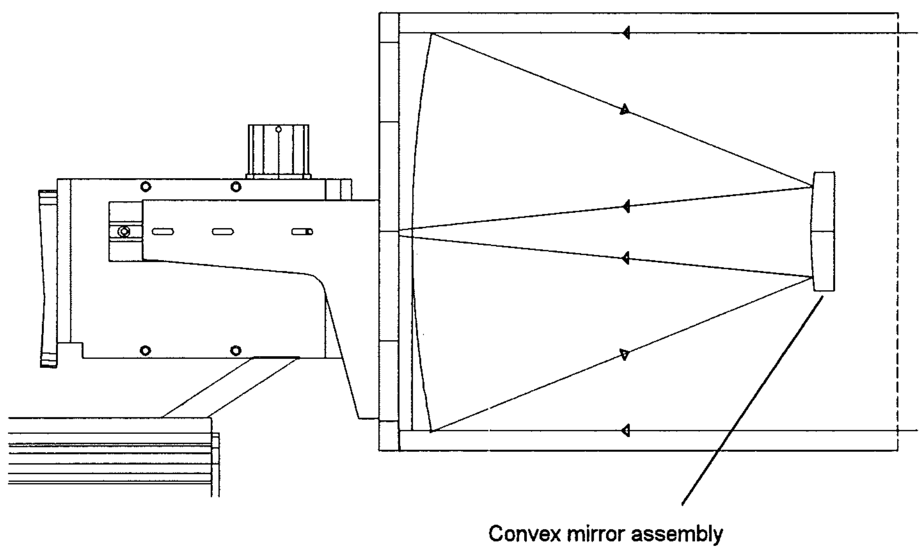

Figure 18. Cross-section of telescope

Note: Do not forget to lock back the convex mirror assembly with the ring mounted on the assembly, once the alignment is completed.

Model SMY0200G:

- Rotate the arm attached to the telescope. To do this easily, first unscrew the extremity of the telescope arm. See Figure 19.

Note: Do not forget to lock back the arm once the alignment is completed.

Note: This procedure applies whether a CCD camera or an ocular is mounted on the input collimator.

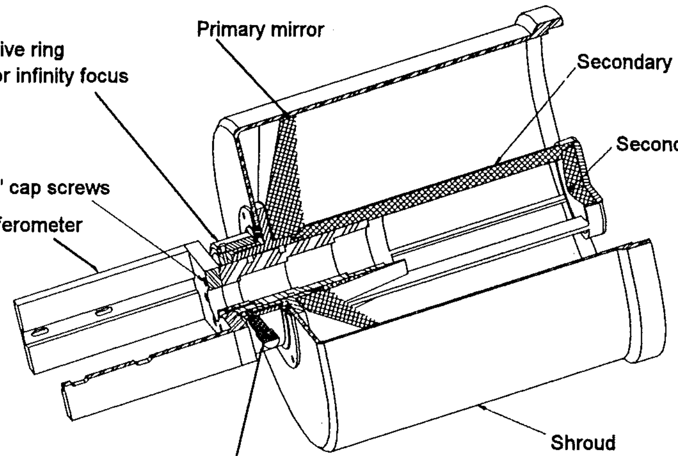

Figure 19. Cut-away of telescope

FIELD-OF-VIEW MEASUREMENT

Purpose

This procedure is to verify the radiometric properties of the instrument and its top plate, and verify that the FOV. mapping test meets specifications on both the *x* and *y* axes. The procedure is normally performed with the input collimator removed. It is possible, however, to do it with the input collimator and a telescope in place, as described below, without affecting the results obtained.

Mapping Test (Uniformity)

Requirements

- tripod or table
- Blackbody Model CI, SR-2-32-SA or equivalent
- 1-meter ruler

Conditions

- no input collimator (45 mrad divergence)
- no telescope
- blackbody set at 1000 K (727°C)
- aperture on blackbody set to 12.7 mm (or as close as possible)
- aperture wheel #2 set to 2.2 mm
- no cold source (use a blank plate as a cold source or a cold source at room temperature)
- interferogram ZPD level between 4.9 V and 2.0 V

Amplitude measurements

1. If the input collimator is not installed, set up the blackbody (the target) 30 ft. away from the instrument and align the instrument with the blackbody. If the collimator and a telescope are installed, use the distance in the following table:

Narrow-angle telescope	Medium-angle telescope	Wide angle telescope
300 ft.	50 ft.	20 ft.

Note: With the narrow-angle telescope, you can use a distance of 150 ft. instead of 300 ft. and move the blackbody (see step 5 below) in steps of 0.5 cm instead of 1 cm.

2. Observing the IR signal amplitude (ZPD intensity) using the alignment/status screen of the acquisition software at a resolution of 64 cm^{-1}, move the blackbody to obtain the highest possible signal amplitude.

3. Reduce the aperture of aperture wheel #2. The signal amplitude should stay almost the same. If not, move the blackbody to obtain more signal. (Since the blackbody aperture is quite small (22.2 mm), the signal amplitude should not change significantly until the aperture of the aperture wheel is reduced to 1.1 mm.) The blackbody will now be placed at the center position (origin of the *x* and *y* axes).

4. Set aperture wheel #2 to 2.2 mm. and note the amplitude at this position.

5. Move the blackbody along one axis in steps of 1 cm and note the amplitude for each position. Do this on both sides of the center position. Repeat for the other axis.

Data analysis

You can analyze the results by plotting a graph of the amplitude (V) versus the position (cm) for both axes. The graph could also be plotted as relative amplitude (%) versus divergence (mrad).

To obtain the relative amplitude, subtract the background amplitude (the lowest measured amplitude) from all measured amplitude values and calculate the ratio of each amplitude with the maximum amplitude, as follows:

$$\text{Relative amplitude} = \frac{\text{measured amplitude - background amplitude}}{\text{max. measured amplitude - background amplitud}}$$

Divergence (mrad) is calculated as follows:

$$\text{Divergence (mrad)} = \frac{\tan^{-1}\dfrac{\text{position (cm)}}{\text{distance (cm)}}}{0.057}$$

since 1 mrad = 0.057 °.

Acceptance criteria

Once the relative amplitudes for both the *x* and *y* axes have been plotted on two separate graphs, you can determine whether the instrument meets the acceptance criteria using the following method.

On each graph, draw a horizontal line through the maximum amplitude, as shown in Figure 20. This is the 100% level. Draw another horizontal line at the 50% level. The TFOV (Total Field of View) is the width of the curve at the 50% level.

Draw another horizontal line at the acceptance level (AL) given in the following table:

Detector type:	MCT	InSb
x-axis acceptance level (AL):	85%	85%
y-axis acceptance level (AL):	80%	75%

The instrument meets the acceptance criteria if the relative amplitude is greater than the acceptance level for at least 70% of the field of view, as shown in Figure 20.

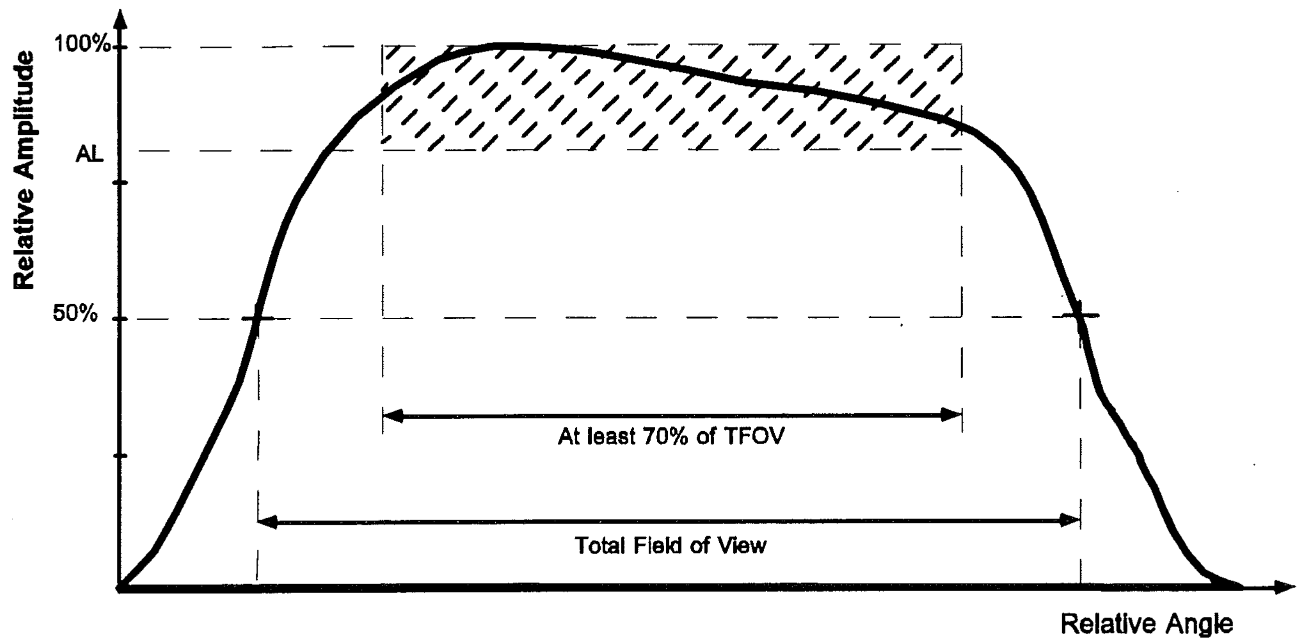

Figure 20. Acceptance criteria graph for one axis

NESR MEASUREMENT

Purpose

The purpose of this test is to measure the total contribution of all sources of noise in the instrument, over the radiance spectrum. This test therefore determines the minimum spectral radiance measurable by the instrument. This minimum is equivalent to the level where the signal-to-noise ratio is unity.

Concept

The NESR (Noise Equivalent Spectral Radiance) is a measurement of all sources of noise in the detection chain of the instrument added together and converted to spectral radiance. Some of the different types of noise that contribute to the NESR are the NEP (Noise Equivalent Power) of the detector, the NEV (Noise Equivalent Voltage) of analog electronic circuits, the quantization noise of the ADC converter, and the photon shot noise from the scene and from the instrument. The total noise level at each wavelength is equal to the square root of the sum of the squares of the noise levels from the individual sources. This noise level, converted to NESR, is the detectivity floor of the instrument.

The measurement method involves acquiring calibrated spectra. All calculations in the calibration software are done using complex mathematics. This allows direct measurement of the NESR in the imaginary part of the calibrated spectrum.

Since the imaginary part of the theoretical radiance spectrum is zero, the measured values in the imaginary part are essentially the representation of the noise, which is spread over the entire spectrum (random noise). We assume that this noise is essentially uniform over a small region of the spectrum, which can be experimentally observed.

During interpretation of the noise distribution in the spectrum, the noise is measured over a certain region of the spectrum. The standard deviation of the noise level is therefore measured over a relatively large number of spectral elements, which provides a good confidence level for the measurement.

To obtain the NESR measurement using this method, you must first perform a two-point calibration of the instrument using the reference blackbody. This a very important aspect in radiometric measurement; refer to the software manual for the theoretic basis and procedures involved.

Method

Equipment required

- Blackbody Model CI, SR-2-32-SA or equivalent

Conditions

The measurement should be carried out under the following conditions:

- no telescope
- resolution: 1 cm^{-1}
- acquisition time: 2 s
- reference source: 50°C
- cold source
- interferogram ZPD level between 4.9 V and 2.0 V (set the preamplifier gains accordingly)

Note: This measurement can be performed with the input collimator installed or removed. In either case, the reference source should completely fill the FOV of the instrument.

Procedure

1. Set the blackbody at 35°C.

2. When the blackbody is stable, acquire a radiometric "cold" reference spectrum at 35°C. Set the number of scans to at least 32 scans for the MR100 and 750 scans for the MR200. This is the first point of calibration.

3. Set the blackbody at 50°C.

4. When stable, acquire a raw complex spectrum at 50°C. Set the number of scans to acquire 1/2 scan (one interferogram from one scanning direction) for the MR100 and 10 scans (20 interferograms representing the sum of 10 scans including forward and reverse scanning directions) for the MR200. This spectrum, once calibrated will be used to determine the NESR.

5. Set the blackbody at 65°C.

6. When stable, acquire a "hot" radiometric reference at 65°C. Set the number of scans to at least 32 scans for the MR100 and 750 scans for the MR200. This will be the second point of calibration. The calibrated spectrum is acquired before the second point of calibration simply because it is faster to heat up the black body than to wait for it to cool down from the second point of calibration back to the calibration level.

7. Perform the calibration of the spectrum acquired at 50°C. The NESR is the imaginary part of the resulting spectrum. It is expressed directly in $W/(cm^2 \cdot sr \cdot cm^{-1})$.

To evaluate the NESR at a given frequency, select an interval containing 100 spectral elements around that frequency, then measure the highest and lowest value. This gives the peak-to-peak NESR. The rms NESR is defined as the peak-to-peak value divided by 6. The NESR should always be measured at the frequency corresponding to the peak response of the detector used for the measurement.

The NESR in the H_2O and CO_2 absorption regions will appear higher due to slight variations of the concentration of these gases in the atmosphere. You should either avoid taking the NESR reading at these frequencies, or interpolate the NESR through these regions. These regions are:

H_2O:	1250 - 2050 cm^{-1} and 3425 - 3950 cm^{-1}
CO_2:	660 cm^{-1} and 2210 - 2400 cm^{-1}

Acceptance criteria

The NESR acceptance criteria for different detectors supplied by Bomem are as follows:

Part #	Detector type	NESR (rms)
-D10x	Narrow Band MCT	5×10^{-8} W/(cm^2·sr·cm^{-1})
-D11x	Mid Band MCT	5×10^{-8} W/(cm^2·sr·cm^{-1})
-D14x	Atmosph. MCT	5×10^{-8} W/(cm^2·sr·cm^{-1})
-D20x	InSb	5×10^{-9} W/(cm^2·sr·cm^{-1})