Instruction Manual for Wavemeter
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CAUTION: USE OF CONTROLS OR ADJUSTMENT OR PERFORMANCE OF PROCEDURES OTHER THAN THOSE SPECIFIED HEREIN MAY RESULT IN HAZARDOUS RADIATION EXPOSURE.
1. INCOMING INSPECTION

A. Visual

The Wavemeter™ has been packaged in a special carton designed to give maximum protection during shipment. If the outside of a shipping carton is damaged, notify your shipping department immediately. The shipping department may wish to notify the carrier at this point.

If the shipping carton is undamaged externally, the instrument should be removed from the carton. If any damage is evident visually or if any rattling can be heard when the instrument is shaken lightly, notify your shipping department and Burleigh Instruments, Inc. It is advisable to save the special cartons for future storage or transportation.

B. Operational

IMPORTANT: Before plugging in the instrument check that the 115/230 VAC switch on the rear panel is correctly set for the line voltage. Incorrect setting can permanently damage the instrument.

Turn on the power switch and listen for any unusual noises. A slight repetitive noise should be detectable from the motor driven slide as the internal interferometer scans back and forth. Some of the front panel displays shown in Figure 1 should also be lit or flashing.

Open the attenuator completely and place a piece of paper in front of the input aperture. A red laser beam should be detected. Finally push and hold each test button. DISPLAY TEST 1 should produce either .63299 µm or 15798.00 cm⁻¹ on the display in HIGH RESOLUTION depending on whether the WAVELENGTH or FREQUENCY mode is selected. In LOW RESOLUTION the display should show either .63299 µm or 15798.00 cm⁻¹. ERROR TEST 2 should light all digit segments, both the µm and cm⁻¹ indicators and all error lights as in Figure 1. The LOW INPUT, HIGH INPUT, RANGE ERROR, and REF ERROR will flash. The VAC ERROR light is found only on the WA-20.

If the Wavemeter passes all of the above checks and the REF ERROR light goes off when the ERROR TEST 2 button is released, the instrument is ready to use. Otherwise refer to the service and troubleshooting sections of this manual.

C. Quality Control

It should be noted that the Wavemeter has undergone several stages of inspection, test and calibration before shipment, including a burn-in of the electronics at elevated temperatures for 5 to 7 days (minimum). After burn-in the instrument received a complete final test and calibration prior to shipment. Problems can occur, however, and should a problem arise during the warranty period, Burleigh’s policy is to repair any instrument within one week of receipt at the factory. Following repair the instrument will be run-in or the electronics burned-in again before rechecking and returning.

2. APPLICATION

The Burleigh Wavemeter is designed for simple, automatic and precise measurement of the wavelength or frequency of continuous wave (cw) lasers. By comparison, the use of conventional spectrometers for wavelength determination requires much more operator manipulation. Moreover, spectrometers are typically 100 times less accurate. Instead of a mechanical calibration, the Wavemeter directly compares the wavelength of the unknown laser with that of an internal prealigned He-Ne laser. This comparison measurement is made repeatedly and updated on the display every 1.6 or 0.8 seconds (for 60 Hz line frequency). Only .1 milliwatt of laser power through the 2mm input aperture of the Wavemeter is required to make a measurement for most laser wavelengths.

A typical experimental set-up is shown in Figure 2. A small portion of the laser to be measured is coupled into the Wavemeter by a beamsplitter. The alignment of the laser to the Wavemeter is facilitated by a red tracer beam from the He-Ne laser inside the Wavemeter. This tracer beam is polarized so that when properly preadjusted, insertion of a simple polarizer as shown is sufficient to prevent the tracer...
beam from affecting the laser or the experiment. Continuous automatic monitoring of the laser wavelength can be performed while the laser is tuned or measurements are made in the experimental region.

The tracer beam makes alignment of the Wavemeter trivial. The chassis has three adjustable feet with lock nuts. The two feet on the aperture side permit raising or lowering the aperture to the height of the incoming laser beam; a third foot on the opposite side allows alignment of the tracer beam emitted from the Wavemeter back along the incoming beam until both beams are superimposed.

Once aligned, setting the wavelength range and adjusting input intensity using the Wavemeter controls are all that is necessary to initiate automatic wavelength or frequency readout. This is facilitated by a group of error lights shown in Figure 1 that indicate any necessary operator action. Adjustment for the correct level of input intensity is made by moving a built-in 0-2 Neutral Density variable attenuator until both the LOW INPUT and HIGH INPUT indicators are extinguished. If the WAVELENGTH RANGE controls or RESOLUTION switch is incorrectly set a RANGE ERROR indicator lights up. These three indicators flash on and off when activated to make them highly noticeable during an experiment. Whenever any one of them lights up, indicating that wavelength determination may be incorrect, the display is not updated but holds the last valid measurement, the instrument memory is erased and another measurement performed. Thus no false information is ever displayed or read out.

A fourth error indicator checks the performance of the internal He-Ne reference laser. The REF ERROR lights if the He-Ne laser is out of alignment or has failed. It flashes if a problem exists with the electronic signals associated with detection of the reference laser.

On the WA-20 there is a VAC ERROR light on the front panel that indicates when the pressure in the vacuum chamber exceeds approximately 10 torr and the chamber should be pumped out.

Two push buttons are provided on the front panel to quickly test Wavemeter functions. DISPLAY TEST 1 when depressed overrides all error sensors and introduces the signal from the reference laser into the circuitry that normally measures the input laser signal. Consequently in the HIGH RESOLUTION mode the vacuum wavelength (.632991 mm) or frequency (15798.00 cm\(^{-1}\)) of the He-Ne reference laser is displayed as a verification that all associated circuitry is functioning properly. In the LOW RESOLUTION mode the same results should be obtained but reduced in magnitude by a factor of 10. The ERROR TEST 2 push button produces artificial error signals that activate all four (five on the WA-20) error circuits and demonstrate at any time that these functions are operating. At the same time all digit segments light as well as the pm and cm\(^{-1}\) indicators to verify that all LED's are functional. The ERROR TEST display is demonstrated in Figure 1.

On the Wavemeter rear panel there are two INPUT/OUTPUT PORTS. I/O PORT 1 provides all front panel control and display signals for interfacing to other instruments. I/O PORT 2 permits direct inspection of detector signal levels and critical timing signals utilized in realignment of the optical system should it be necessary. I/O PORT 2 can also be used to introduce a signal from an external detector if the standard internal detector is replaced by one external to the Wavemeter enclosure. An exit aperture is provided in the rear panel for this feature.

The WA-20 model includes a VACUUM PORT and VACUUM VALVE on the rear panel for evacuating the measurement chamber. A mechanical vacuum pump capable of reaching <1 torr pressure is all that is necessary. The WA-20 is Helium leak tested to hold a vacuum (< 10 torr) for one week so that frequent evacuation is unnecessary.

Both the WA-10 and WA-20 Wavemeters can be used for measuring laser wavelengths in the range from 4µm to 1.0µm. In either instrument the value displayed is the vacuum wavelength (or frequency) but since the WA-10 does not include a vacuum chamber enclosing the interferometer the
accuracy varies over this range by as much as ± 5 parts in 10^6 due to the wavelength dependence of the refractive index of air. Because the WA-20 actually measures the wavelength in vacuum it is accurate to ± 1 part in 10^6. Its range of measurement can be extended to 4µm in the infrared by a simple substitution of the optional WA-200 infrared beamsplitter and detector assembly.

3. DESCRIPTION

The Burleigh Waverimeters consist of a scanning Michelson interferometer coupled to a specially designed fringe counting system that includes fringe rate multiplication for high precision wavelength determination.

A. Optical Design

The optical layout is shown schematically in Figure 3. The wavelength (or frequency) of an input laser is compared to that of a reference He-Ne laser by simultaneously passing both beams through the Michelson interferometer consisting of the beamsplitter, mirrors M3 and M4 and two retroreflectors. The He-Ne laser is built into the Wavermeter and prealigned with the interferometer optics. Part of the reference laser beam is reflected out through the input aperture after passing through the interferometer as a "tracer beam" to be used for aligning the input laser beam. This alignment ensures that the input beam follows precisely the same path (in the opposite direction) through the interferometer.

The interferometer is scanned by moving a pair of retroreflectors mounted back to back on a motor driven slide. The scanning assembly travels almost two inches but only a small fraction of each cycle is necessary for a wavelength determination. The instrument is designed to perform each measurement at a point in the motion of the slide where the velocity is almost constant and the optical path difference between the arms of the interferometer is small. The latter condition is most important for measuring the wavelength of lasers with broad linewidths and consequently short coherence lengths.

As shown in Figure 3 the retroreflectors cause a displacement of the paths through the interferometer that permits separate detection of the two counter-propagating beams, i.e. the reference laser and the input laser. The two beam paths are actually vertically displaced in the Wavermeter so that the reference laser is detected by the upper photodiode mounted behind the beamsplitter assembly while the input laser is detected by the lower detector. The signal detected in either case is sinusoidal of varying frequency superimposed on a D.C. background. The peak-to-peak amplitude of the signals (fringe contrast) must be sufficient for accurate detection and counting while the D.C. level must not exceed that value which would saturate the detectors and related electronics. The proper intensity of the input laser beam is displayed by the front panel LOW and HIGH INPUT indicators. The LOW INPUT light goes off when the peak-to-peak signal amplitude is high enough and the HIGH INPUT light comes on if the D.C. signal is too high. A graded neutral density filter mounted on a slide just behind the aperture provides a simple means for attenuating the input laser beam so that the proper signal level conditions can be met.

The reference laser is linearly polarized and normally set horizontal. The emitted tracer beam is therefore polarized in a horizontal plane and if the input laser beam is vertically polarized (or has a strong vertically polarized component) the tracer beam intensity can be reduced if desired by insertion of a polarizer set in front of the aperture as depicted in Figure 2. For use with a horizontally polarized input laser the internal He-Ne laser can be rotated in its mount to provide a vertically polarized tracer beam.

In the WA-20 the complete Michelson interferometer is enclosed in a vacuum chamber. When evacuated below 10 torr pressure no correction due to refractive index variation in air is necessary for the complete wavelength range from 0.4µm - 4µm. A pressure transducer mounted on the chamber wall activates a VAC ERROR light on the front panel if the pressure exceeds 10 torr. The WA-10 interferometer is covered only by a dust cover. In this case the Wavermeter displays the vacuum wavelength but a small error (less than ± 0.003nm) may exist due to the difference in the refractive index of air between the reference wavelength and that of the input laser. For this reason the accuracy of the WA-10 is specified at ± 0.003nm over the wavelength range from 0.4µm - 1.0µm.

Either the WA-10 or WA-20 can be modified for use with an external detector. This may be necessary for low intensity sources. Removal of the plug in the rear panel and use of an optional detector assembly that includes a special exit window for the WA-20 will permit the input laser signal to be detected outside the Wavermeter. The signal derived from an external detector can be introduced through I/O PORT 2. A peak-to-peak amplitude exceeding 1 volt is required.

B. Electronics

Wavelength or frequency determination is made by counting the number of fringes of the input laser simultaneously with those of the reference He-Ne laser for which the wavelength is accurately known. The scheme for doing this is shown in Figure 4.

Both the reference and input laser beams are separately detected in the interferometer and the A.C. component of each fringe signal is converted to pulses in a zero-crossing fringe detector. The pulses are fed into a phase-locked frequency multiplier which multiplies the count rate 16 times. This increases the accuracy 16 times over simply counting fringes.

These signal processing sections also generate the error indicators as shown in Figure 4. The REF ERROR circuit is activated directly whenever the amplitude of the reference signal is too weak or flashes if the phase-lock circuitry does not remain locked to the input frequency during a measurement. The REF ERROR light therefore generally indicates a weak or misaligned reference He-Ne laser. The LOW and HIGH INPUT errors are generated from the fringe detection circuitry as described in the previous section. The RANGE ERROR denotes a loss of frequency lock in the input signal phase-lock multiplier during a measurement. It can usually be corrected by adjustment of the front panel WAVELENGTH RANGE and FINE ADJUST controls or the RESOLUTION switch.
Figure 3

WAVEMETER OPTICAL SCHEMATIC
The pulse trains from both the input and reference channels pass through a mode selector which is set to display WAVELENGTH or FREQUENCY determined by the front panel switch. The mode selector directs one signal into a preset counter and the other into a gated display counter. Initially cleared, the display counter is gated on for the time it takes to count a preset number of pulses from the other channel in the preset counter. At the end of each counting cycle the information in the display counter is transferred to the display, provided no error signals have been generated in the input channel to inhibit the display gate.

The principle of operation is based on the relationships:

\[ N_0 \lambda_0 = N \lambda \quad \text{and} \quad N_0 f = N f_0 \]

where
- \( N_0 \) = number of pulses from reference channel
- \( \lambda_0 \) = reference laser wavelength
- \( f_0 \) = reference laser frequency
- \( N \) = number of pulses from input channel
- \( \lambda \) = input laser wavelength
- \( f \) = input laser frequency

For the reference He-Ne laser the vacuum wavelength \( \lambda_0 = 0.632991 \mu m \) and frequency \( f_0 = 15798.00 \text{cm}^{-1} \). By counting to \( N = 632991 \) on the preset counter and counting \( N_0 \) on the display counter the Wavemeter displays the wavelength (with correct decimal placement) of the input laser since:

\[ \lambda = \left( \frac{N_0}{N} \right) \lambda_0 \]

Similarly by counting to \( N_0 = 1579800 \) on the preset counter and counting \( N \) on the display counter the Wavemeter displays the frequency (with correct decimal placement) of the input laser since:

\[ f = \left( \frac{N}{N_0} \right) f_0 \]

Set-up and operational checks on the electronic circuitry are provided on both Wavemeter models. The sinusoidal fringe signals from either detector can be accessed directly through I/O PORT 2 as well as the gate signal that determines the measurement interval. Two test push buttons are provided on the front panel. DISPLAY TEST 1 alters the mode selector so that the reference laser signal is directed into both counters. If all counter functions are working correctly the Wavemeter will display \( 0.632991 \mu m \) in the wavelength mode or \( 15798.00 \text{cm}^{-1} \) in the frequency mode as long as the button is depressed. In the low resolution mode the corresponding display is \( 0.63299 \mu m \) or \( 15798.0 \text{cm}^{-1} \). A change of \( \pm 1 \) in the least significant digit during this test is not abnormal. ERROR TEST 2 generates signals in all error circuits that simulate those error conditions so that all error indicators flash or light up. At the same time all LED's of the display are tested.

All front panel display and error information is accessible electronically at I/O PORT 1 on the rear panel for interfacing to a computer or recording device. Details are provided in the circuit schematics and specifications section of this manual.

4. HOW TO USE THE WAVEMETER

After initial inspection the model WA-20 Wavemeter chamber should be evacuated before use. Connect a mechanical vacuum pump to the rear panel vacuum port using the supplied O-seal fitting. (An in-line cold trap is recommended to prevent pump oil vapors from entering the chamber and coating the optical components). With the Wavemeter on the VAC ERROR light will go off when the pressure goes below 10 torr. Continue pumping for five minutes to ensure that the chamber is well evacuated before closing the VACUUM VALVE and removing the pump.

With power on and no input beam the display may be only partially lit. The LOW INPUT light (and possibly the RANGE ERROR light) should flash. Perform DISPLAY TEST 1 and ERROR TEST 2 as described in the previous section.

Alignment and operation of the Wavemeter is very simple. Place the instrument on a stable surface with the input aperture at a height close to that of the laser beam to be measured. Turn on the instrument and open the attenuator so the tracer beam can be observed emitted from the input aperture. Raise or lower the two leveling feet on the aperture side or adjust the input laser until the input beam is centered on the aperture. Adjust the third foot on the Wavemeter to accurately superimpose the tracer beam on the input beam. The two beams should be centered on one another within one diameter of the tracer beam over a distance of one meter. Lock all three feet on the Wavemeter.

The Wavemeter requires approximately 0.1 milliwatt power input through the 2 millimeter aperture at which point the LOW INPUT light should turn off. If the input power is too high the HIGH INPUT light will come on. Adjust the attenuator slide until both the LOW and HIGH INPUT lights are extinguished.

Set the WAVELENGTH RANGE switch in the correct position for the input laser. If the linewidth of the laser is suspected to be broader than 2GHz select the LOW RESOLUTION readout. If the RANGE ERROR light continues to flash adjust the FINE ADJUST control until it goes off. At this point the Wavemeter should display the wavelength or frequency as selected by the front panel switch. The display will update once every 1.6 seconds if the A.C. line frequency is 60 Hz; every 2.0 seconds for 50 Hz.

A Fast Update Modification is possible in the 0.4 to 1.0 micron wavelength range or in the LOW RESOLUTION setting between 1.0 and 4.0 microns (see Section 7). In this case the display will update every 0.8 seconds at 60Hz A.C. line frequency; 1.0 seconds at 50Hz.

In some cases when the wavelength of the input laser is close to the extreme of a wavelength range setting it may be necessary to switch to the next range. Any such adjustment that extinguishes the RANGE ERROR light is permissible.

It is not uncommon for the RANGE ERROR light to flash on occasionally due to RF interference or noise spikes on the A.C. line. When measuring the wavelength of a jet-stream dye laser occasional bubbles in the dye flow will cause very short intensity interruptions that will also cause the RANGE ERROR light to light. In such instances the Wavemeter will not
update but continue to display the last valid data and make another measurement in 1.6 or 0.8 seconds. Sometimes a slight realignment of the Wavemeter with respect to the input beam will optimize fringe contrast and reduce the frequency RANGE ERROR occurrences.

When both the LOW INPUT and RANGE ERROR lights flash continuously for all settings of the ATTENUATOR, WAVELENGTH RANGE and FINE ADJUST SETTINGS it may be that the coherence length of the input laser is too low. In such a case switch to LOW RESOLUTION operation.

If the RANGE ERROR indication cannot be extinguished connect an oscilloscope to the pin 3 of I/O PORT 2 (ground the oscilloscope on pin 1) and examine the input signal. A sinusoidal signal should be observed that varies in frequency as the interferometer scans. A peak to peak amplitude greater than 1 volt should be observed with no sudden changes in intensity except when the retroreflectors change direction of travel. Adjust the Wavemeter alignment to the input beam for a maximum peak to peak amplitude. Examine the signal for excessive noise. The Wavemeter circuitry is designed to accept approximately 30% amplitude noise. More excessive amplitude noise on the input laser intensity will cause the RANGE ERROR to be triggered repeatedly. In such cases the laser amplitude noise must be reduced.

The input laser must emit a single frequency or several spectral lines within a narrow bandwidth. For lasers with a broad linewidth it will not be possible to measure the wavelength (or frequency) in the HIGH RESOLUTION mode because the coherence length of the laser is insufficient to generate enough fringes in one scan of the interferometer. The existence of a short coherence length will be evident from the sudden rise and fall in the fringe envelope of the input signal observed at I/O PORT 2. As a general rule the laser linewidth should be less than 2 GHz for a HIGH RESOLUTION measurement and less than 20 GHz for a LOW RESOLUTION measurement. If the laser linewidth is too broad for the selected resolution range the RANGE ERROR will trigger repeatedly.

The Wavemeter can be modified to operate with broader linewidths (up to 200 GHz). Consult the factory for details.

The REF ERROR light should extinguish after turning the Wavemeter on and remain off. If not the reference He-Ne laser is either misaligned or not working. First check for an emitted tracer beam. If the tracer beam is on, look at the signal at pin 6 of I/O PORT 2 while grounding the oscilloscope at pin 1. A varying frequency sinusoidal waveform should be observed with almost constant peak to peak amplitude greater than 1 volt. A flashing REF ERROR indicates either a slight internal misalignment of the reference laser that will cause large amplitude variations on the signal at I/O PORT 2 or a problem with the reference signal electronics. Consult the service and troubleshooting sections of this manual in either case.

The VAC ERROR light (WA-20 only) will come on when the pressure in the chamber rises above 10 torr. This should only happen after several days of use and indicates that re-evacuation is necessary for the specified accuracy.

5. SERVICING

A. Alignment of Interferometer Optics

The Wavemeter is designed to be highly stable against misalignment of internal optics. Realignment should not be necessary under normal operation except when optical components such as the beamsplitter assembly are replaced. In such cases or in the event that realignment does become necessary the following procedure should be followed. Refer to Figures 5-7.

1. Remove the Wavemeter top cover and the dust cover over the periscope. It will be necessary to unplug the ribbon cables from both rear panel I/O ports to remove the dust cover. Reconnect the narrow cable, move the attenuator slide to the full open position in order to expose the inside surface of the aperture. After opening the vacuum valve remove the top cover of the vacuum chamber and the vacuum covers behind both interferometer mirrors, (WA-20 only). On the WA-10 simply remove the large square dust cover on the interferometer. CAUTION: Removal of these covers exposes the internal He-Ne laser beam when the Wavemeter is turned on. Do not stare into the beam and beware of direct reflections from objects introduced into the beam paths.

2. Turn on the Wavemeter power switch and observe the path of the reference He-Ne laser beam. If the reference laser does not light or flickers refer to the troubleshooting section of this manual.

3. The reference laser beam comes up through the periscope assembly from the laser tube mounted below the interferometer baseplate. Check first that the beam comes out of the center of the periscope aperture at a height 38mm (1.5") ± .5mm above the baseplate. Raise or lower the top periscope mirror mount to achieve the proper height. If the beam is off the center of the periscope aperture consult section 5B on Reference Laser Replacement for realignment instructions.

4. Tape a piece of paper in front of the interferometer mirror M4 closest to the front panel. Observe the path of the laser beam that is transmitted through the beamsplitter and reflected off the other uncovered mirror M3 into the moving retroreflector. The beam should be centered in the lower hole of the beamsplitter mount at a height of 38mm above the baseplate. (The beamsplitter assembly can be vertically adjusted to center the height of the beam in the lower hole). If the beam is displaced sideways loosen the periscope mounting screws, rotate the periscope and retighten the screws to obtain proper alignment. Vertical adjustment of the beam is accomplished by slightly loosening the three cap screws with spring washers on the upper periscope mirror mount and adjusting the #2-56 set screws.

5. The retroreflector translates the beam up approximately 12.5mm so that after a second reflection off the mirror it passes through the upper hole on the beamsplitter mount and over the periscope. It should strike the attenuator assembly close to the input aperture and may be observed to move back and forth synchronized with the movement of the retro-
Figure 5
Top View
Figure 6

PC Boards
reflector slide. Adjust the alignment screws behind the mirror until the spot on the aperture assembly is stationary, i.e. does not move as the retroreflector slide scans back and forth.

6. The final step is to direct the reference laser beam out through the center of the input aperture. Vertical translation is achieved by fine adjustment of the #2-56 set screw on the periscope mirror mount closest to the aperture; horizontal translation is produced by turning all three alignment screws on the interferometer mirror M3 in or out by the same amount. Clockwise rotation of all three screws moves the spot on the aperture to the right, counterclockwise moves it to the left. After each mirror translation it will be necessary to realign the mirror so the spot again does not move with the motion of the retroreflector. To be perfectly aligned the spot should be centered on the aperture and stationary. Then carefully tighten the cap screws to secure the upper periscope mirror.

7. A similar alignment procedure must be performed for the other beam path in the interferometer. Cover the mirror M3 and observe the beam reflected off the beamsplitter to the mirror M4 nearest the front panel. After loosening the one large screw with the spring washer that secures the beamsplitter assembly on its kinematic mounting plate, adjust the tilt of the beamsplitter with the set screws in the base until the reflected beam is reflected off the mirror, retroreflector and beamsplitter back to the input aperture.

8. Align the mirror M4 so that the spot at the aperture is stationary. Then center the spot on the aperture by tilting the beamsplitter for vertical displacement or translating the mirror using the alignment screws for horizontal displacement. As before, clockwise adjustment of all three mirror alignment screws moves the spot at the aperture to the right, counterclockwise moves it to the left. Again realign the mirror after each displacement to stop the movement of the spot due to the retroreflector motion. When this beam too is stationary and centered on the aperture carefully tighten the large beamsplitter mounting screw.

9. Remove the paper from the first beam path. Both beams should now be superimposed, transmitted through the input aperture and centered on the top detector mounted in the beamsplitter assembly. If not repeat necessary steps in the above procedure.

10. As a final optimization observe the signal at pin 6 of the small I/O connector (I/O PORT 2) on the rear panel with an oscilloscope having > 1 MHz bandwidth. Pin 1 on the same connector should be used to ground the oscilloscope probe. A sine wave signal with a frequency that varies with the speed of the retroreflectors should be observed. Alternate adjustment of the two interferometer mirrors to maximize the peak-to-peak amplitude of the sine wave while keeping the amplitude as constant as possible. (Note: variation in amplitude is caused by periodic misalignment of one beam to the other with the motion of the retroreflectors). When the alignment is optimized the peak-to-peak signal amplitude should exceed 1 volt throughout the cycle of the retroreflector movement.

11. To check that the alignment is also optimized for an input laser, observe the signal on pin 3 of I/O PORT 2 with another laser (possibly He-Ne) aligned with the Wavemeter in the normal manner for wavelength measurement.

12. Carefully replace all covers and recheck the signals at I/O PORT 2.

13. Disconnect all cables from I/O PORT 2 when in use to prevent introduction of extraneous electrical signals.

B. Reference Laser Replacement

In the event that the He-Ne laser inside the Wavemeter will not come on, or becomes weak or intermittent first consult the troubleshooting section of this manual. If it is determined that the plasma tube must be replaced the following procedure should be followed. Refer to Figure 7.

1. Unplug the unit. Removal of the bottom cover exposes sources of high voltage.

2. Unscrew the attenuator slide control knob and invert the Wavemeter on a soft surface. Remove the feet and bottom cover plus the dust cover over the periscope.

CAUTION: Removal of these covers exposes the internal He-Ne laser beam when the Wavemeter is turned on. Do not stare into the beam and beware of direct reflections from objects introduced into the beam path.

3. Remove the drive belt and interferometer drive pulley.

4. Unsolder the heavy red and black leads where they are joined between the laser tube and laser power supply.

5. Unbolt the mounting brackets and remove the laser tube.

6. Loosen the laser mounting brackets at the baseplate and install the replacement laser tube reversing the above procedure. Make sure that the soldered connections on the black and red leads are carefully insulated with heat shrink tubing or electrical tape. Voltages exceeding 10 kV are present on the red wire when the power is switched on.

7. Rotate the laser for the desired polarization (standard set-up is horizontal). The laser beam is polarized in the direction of the wire coming out of the front end of the plasma tube. Carefully tighten all laser tube mounting screws.

8. Plug in the instrument and switch on the power so the laser tube comes on. Check that the laser beam is directed into the center of the periscope aperture. If not readjust the position of the laser tube mounting brackets on the baseplate and raise or lower the lower periscope mirror height as necessary by loosening the screws with spring washers and adjusting the small set screws.

9. If the lower periscope mirror was moved it must be realigned with the small set screws so that the He-Ne laser beam comes out in the center of the aperture on the top periscope mirror mount. When correct alignment is achieved carefully tighten all screws.
Figure 7
Bottom View
10. Replace the lower periscope dust cover and interferometer drive assembly. Remove the top covers over the interferometer and push lightly on the top end of the drive shaft to insure that the large drive pulley goes on as far as possible.

11. Replace the bottom Wavemeter cover and refer to section SA to complete the realignment of the interferometer optics.

C. Installation of WA-100 or WA-200 Options

Changing beamsplitter/detector assemblies in the Wavemeter is very easy. Access to the beamsplitter mount is described at the beginning of Section 5. The location is shown in Figure 5.

CAUTION: Performance of the PbSe infrared detector can be degraded by exposure to fluorescent light. Short intervals of exposure will have no permanent effect but exposure time should be minimized. Always store the WA-200 detector assembly in a dark enclosure when not in use.

NOTE: Do not use acetone to clean detectors. If necessary wipe lightly with a cotton swab dipped in denatured alcohol.

With the power off, disconnect the Detector Board connector and loosen the large centrally located cap screw in the base of the beamsplitter mount. Carefully lift the beamsplitter assembly out and store in a clean dry container. Use the same large cap screw and spring washer to mount the new beamsplitter assembly by reversing the procedure making sure the screw feet locate correctly in the beamsplitter mounting base.

Realign the interferometer optics as described in Section SA. Once this alignment has been carried out on a beamsplitter assembly it should be possible to reinstall that beamsplitter with very little realignment.

IMPORTANT: When using the WA-200 IR Option position the wires running from the Detector Board along the bottom of the vacuum chamber as far away from the Detector Board as possible. The high impedance of the IR Detector can cause extraneous pick-up of the reference signal if these wires run too close to the Detector Board.

D. Instructions for WA-205/WA-215

When the WA-205 or WA-215 Detector Board is mounted in the Wavemeter the input laser beam, after passing through the interferometer, is emitted from a hole in the Wavemeter rear panel. This permits the use of any external detector capable of detecting the interference fringe signal of the input beam. The signal from the external detector is introduced to the Wavemeter via I/O PORT 2 pin 3 (with detector ground connected to pin 1). For best results the detector should have a small aperture and be mounted as close to the Wavemeter as possible.

External Detector Requirements:

- Output Voltage (AC) $\geq 1$ volt peak to peak
- Output Current $\geq 3$ mA
- Frequency Response $\geq 1$ MHz (wavelength range 0.4 to 1.0\(\mu\m))$ and $\geq 500$ KHz (wavelength range 1.0 to 4.0\(\mu\m))$

E. Installation of WA-210

The GPIB Interface Card is installed directly over the PLL Printed Circuit Board inside the Wavemeter. Unscrew the attenuator knob and remove the Wavemeter top cover. Disconnect the ribbon cable to I/O PORT 1 and remove the 25 pin "D" connector.

To install the GPIB Board replace the four # 6-32 screws that secure the PLL Board with the four hex metal standoffs provided and use the screws to mount the GPIB Board above the PLL Board. Connect P6 on the Display Board to P6 on the GPIB Board with the short ribbon cable provided. Mount the IEEE 24-pin connector in the I/O PORT 1 rear panel hole and connect the attached ribbon cable to P7 on the GPIB Board. Set the address switches for correct device number and replace the Wavemeter cover. Instructions on the use of the Wavemeter GPIB Interface are covered in a separate manual.

F. Troubleshooting

The Burleigh Wavemeter has been designed for ease of troubleshooting and repair. Critical components are mounted in sockets for easy checking and replacement. As shown in Figure 6 the Counter Board is mounted on hinged posts so it can be tilted up for access to circuitry on the Phase Locked-Loop (PLL) Board below. The following is a troubleshooting guide.

CAUTION: Removal of the Wavemeter bottom cover exposes A.C line voltages that are dangerous. Always disconnect the A.C. power before removing the bottom cover and reconnect power only as necessary for testing.

1) Low Voltage Power Supply Check

Test points are provided on the Power Supply Board shown in Figure 7 for checking the output of all low voltage regulators. Referenced to chassis ground:

- Test point 2 $+5$ v
- Test point 3 $+12$ v
- Test point 4 $+12$ v (Laser Power)
- Test point 5 $-12$ v

If all power supplies are functioning, use the individual circuit board schematics to check power supply voltages on all other printed circuit cards. If inconsistencies are discovered check connectors and cables for continuity.
2) Laser Power Supply Check

If a malfunction of the laser power supply is suspected it can be tested separately. Follow steps 1 through 4 in Section 5B to disconnect the laser plasma tube. CAUTION: The laser power supply output is capable of developing 10 kv. Keep leads well away from other conducting surfaces. Measure the voltage between the red (positive) high voltage lead and the black lead (ground) with a high voltage probe capable of withstanding > 10 kv. A value close to 10 kilovolts should be measured. If a high voltage probe is not available connect a 1000 Megohm and 1 Megohm resistor in series across the high voltage leads in place of the laser, with the smallest resistor closest to the black wire. A voltage of approximately 10 volts should be measured across the 1 Megohm resistor. If the voltage measured is much less than specified the power supply is defective and must be replaced.

3) Reference Signal Check

Ground the oscilloscope to pin 1 of I/O PORT 2 and check for a varying frequency, sinusoidal waveform at pin 6 with a peak-to-peak amplitude exceeding 1 volt. If no signal is detected inspect for loose connections between the Detector Board and PLL Board. If signal is weak but detectable perform an optical realignment as described in Section 5A above. Otherwise replace the photodetector and associated amplifier (LM318) on the Detector Board.

4) Input Signal Check

Align the Wavemeter with a He-Ne laser (or other appropriate laser source) and follow the instructions given above for the Reference Signal. The input signal is detected at pin 3 of I/O PORT 2.

5) Timing Check

Verify that the timing signal from the timing gate (Fig. 5) exists at I/O PORT 2 pin 9. It should be a +5v pulse of approximately 0.6 seconds duration (0.7 seconds for 50HZ AC line frequency). With the Fast Update Modification (see Section 7) the duration of the timing signal is approximately 0.3 seconds (0.35 seconds at 50HZ). If absent check connections to the timing gate or replace the gate and U15 on the PLL Board.

6) Counting Window Check

At pin 5 of I/O PORT 2 another +5v pulse should be observed that is delayed with respect to the timing (trigger) pulse. This “Window” encompasses the duration of the counting period. Its position and duration may change with different combinations of WAVELENGTH RANGE, RESOLUTION or measurement mode: WAVELENGTH or FREQUENCY.

With a He-Ne input laser and the WAVELENGTH RANGE set to .4 -.7μm the window pulse should occur near the center of the timing pulse. The “Window” pulse is generated by U13, U14 and U15 on the Counter Board.

To optimize operation of the Wavemeter in the LOW RESOLUTION mode to accept the maximum laser linewidths it may be necessary to adjust the timing of the Counting Window. Refer to the Signal Timing Diagram enclosed with this manual.

(i) Attach an oscilloscope to pin 3 of I/O PORT 2 as described in Section 5C(4) to observe the input signal (ground oscilloscope to pin 1). Trigger the sweep of the oscilloscope on the start of the timing signal pulse, pin 9.

(ii) If the input laser has a linewidth much greater than 2 GHz a distinct maximum in the input signal envelope will be observed as shown on line 5 of the Signal Timing Diagram.

(iii) With the front panel switch set for LOW RESOLUTION observe the counting window timing on pin 5 of I/O PORT 2 and adjust potentiometer R6 on the Counter Board until the counting window coincides with the maximum amplitude of the input signal.

(iv) For proper operation of the Wavemeter the amplitude of signal envelope should exceed 1 volt peak-to-peak throughout the counting window interval.

(v) Observation of more than one maximum in the input signal envelope is evidence of a multi-frequency laser input.

7) Phase-Locked-Loop Check (PLL Board)

a) Reference Channel: Trigger the oscilloscope on the signal at pin 6 of I/O PORT 2 and check for a +5v square wave of varying frequency at U3, pin 1. Verify that a similar signal exists at pin 3 of U3 locked in frequency to that at pin 1 for some portion of each scanning cycle. If no signal appears at pin 1 replace U1 or U2. If signal locking cannot be achieved replace U3, U4, U5 or U6.

b) Input Signal Channel: With a He-Ne laser input to the Wavemeter repeat the above tests for signals at pins 1 and 3 of U9 using pin 3 of I/O PORT 2 to trigger the oscilloscope. In this case the fraction of each scanning cycle that the signals remain locked in frequency should vary with settings of the WAVELENGTH RANGE controls. If no signal appears at U9, pin 1 replace U7 or U8. If signal locking cannot be achieved replace U9, U10, U11 or U12.

8) Counter Board Input Check

Use a large bandwidth (> 10 MHz) oscilloscope to check that pulse trains of varying frequency appear at the inputs on the Counter Board U1, pin 1 and 4. The amplitude of the pulses should exceed 3.0 volts. If not check connections between the PLL and Counter Boards or replace U13 on the PLL Board.

9) Counter Board

If the Counter Board is suspected of having a bad I.C. refer to the circuit schematics to check for pulses at the input pin of each I.C. counter; U2, U5, U7, U8, U9, U10, U11 and U12.
10) Vacuum Error Circuit (WA-20 only)

Adjustable resistor R17 near the top of the display board establishes the set point for the pressure sensing circuitry. If the VAC ERROR light does not function properly upon pumping out the chamber first check for loose connections or broken wires to the transducer and then reset R17 as follows. Attach a vacuum gauge and external valve to the pumping line so that the chamber pressure can be read on the gauge. Pump out the chamber to a pressure of 10 torr (0.4" Hg) and adjust R17 such that the VAC ERROR light just turns on at this pressure.

11) Other Checks

The following table contains hints for rapid troubleshooting.

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Corrective Procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blown Fuse</td>
<td>Check 115/230 VAC switch. Replace fuse: if fuse blows again disconnect power and use an ohmmeter to check for shorts on each circuit board. If this is inconclusive isolate each board and reconnect one by one until fuse blows again to locate the bad board.</td>
</tr>
<tr>
<td>Display Intensity is Weak or Flickers</td>
<td>Check 115/230 VAC setting. Check for broken wires or loose connections between circuit boards. Test Power Supply voltages.</td>
</tr>
<tr>
<td>Reference laser will not come on</td>
<td>Check connector P1 between the Power Supply Board and the laser power supply for loose connections. Check +12v supply to laser (Test point 4 on Power Supply Board). If low replace Q3 or C7. Check laser power supply as described in Section SC (2). Replace laser plasma tube.</td>
</tr>
<tr>
<td>Reference laser output is intermittent (usually accompanied by a buzzing noise)</td>
<td>Check for low AC line voltage. Check connector P1 between the Power Supply Board and the laser power supply for loose connections. Check for open ballast resistor (&gt; 75kΩ) between laser tube and power supply. See Section 5B before disconnecting laser. Replace laser power supply.</td>
</tr>
<tr>
<td>LOW INPUT light will not extinguish</td>
<td>Examine signal at I/O PORT 2 referring to Section SC(4). Realign optics. Replace photodetector and associated amplifiers (LM318). Replace U14, U15, U16 or CR2 on PLL Board.</td>
</tr>
<tr>
<td>HIGH INPUT light will not extinguish</td>
<td>Reduce input laser intensity. Replace U14, U15 or U16 on PLL Board.</td>
</tr>
<tr>
<td>RANGE ERROR continues to flash</td>
<td>Check WAVELENGTH RANGE and FINE ADJUST settings. Switch to LOW RESOLUTION range. Verify that laser linewidth is less than 20GHz. Check the low resolution window timing. Refer to section SC(6). Check for excessive laser amplitude noise (refer to Section 4). Eliminate sources of RF interference. Realign reference laser internally with input aperture for a more accurately centered tracer beam.</td>
</tr>
<tr>
<td>REF ERROR light stays on</td>
<td>Verify that the reference laser power is greater than 0.5 mW and does not flicker. Realign interferometer optics. Check reference signal input. Replace U1, U2, U18 or CR4.</td>
</tr>
<tr>
<td>REF ERROR light flashes</td>
<td>Interferometer alignment needs fine adjustment. Reference laser output is intermittent. Check reference signal input and phase-locked-loop circuitry.</td>
</tr>
<tr>
<td>VAC ERROR light will not respond to changes in chamber pressure (WA-20 only)</td>
<td>Check VAC ERROR circuitry as described in SC(10). Replace vacuum transducer.</td>
</tr>
<tr>
<td>DISPLAY TEST 1 repeatedly produces the same incorrect display</td>
<td>Check for a malfunction in counting or presetting of one or more I.C. counters.</td>
</tr>
<tr>
<td>DISPLAY TEST 1 produces incorrect display that changes radically</td>
<td>Look for loose connection between PLL and Counter Boards. Check for weak pulse amplitude into counters on the Counter Board. Pulses from U1, U15 and U16 should exceed 3.0 volts, pulses from U4 should exceed 7.0 volts. Poor test switch contact.</td>
</tr>
<tr>
<td>ERROR TEST 2 does not light all display elements shown in Figure 1</td>
<td>LED indicator needs replacement. Check for broken connection. Bad component on the Display Board. Problem in circuit associated with unlit error indicator. Bad test switch contact.</td>
</tr>
</tbody>
</table>
6. SPECIFICATIONS

Model   WA-10   WA-20
Wavelength Range  0.4 - 1.0µm  0.4 - 1.0µm std
                   1.0-4.0µm with IR
                   option
Input Power Required  0.1mW  0.1mW
                     (dependent on
                     wavelength)
                     approximately
                     approximately
Readout Precision
High Resolution  .001µm or .01cm⁻¹ .001µm or .01cm⁻¹
Low Resolution  .01µm or .1cm⁻¹ .01µm or .1cm⁻¹
High Resolution Accuracy (for laser linewidth < 2GHz)
  0.4 - 1.0µm  ± .003nm  ± .001nm
  1.0 - 4.0µm  N/A  ± .004nm
Low Resolution Accuracy (for laser linewidth < 20GHz)
  0.4 - 1.0µm  ± .01nm  ± .01nm
  1.0 - 4.0µm  N/A  ± .04nm
Display
  Update Period: Normal Operation
  60Hz A.C. line  1.6 seconds  1.6 seconds
  50Hz A.C. line  2.0 seconds  2.0 seconds
  Update Period: Fast Update Modification
  60Hz A.C. line  0.8 seconds  0.8 seconds
  50Hz A.C. line  1.0 seconds  1.0 seconds
Input Attenuator  Variable ND 0-2 Variable ND 0-2
Input Aperture  2mm  2mm
Input Beam Height  6.4”  6.4”
                      (Adjustment Range)  (±.3”)
Vacuum Hold Time  N/A  7 days
Vacuum Fitting  N/A  CAJON 3/4"-VCO
Connectors (see Figure 8)
I/O PORT 1  25 - pin “D”  25 - pin “D”
I/O PORT 2  9 - pin “D”  9 - pin “D”
Power Requirements  115/230VAC  115/230VAC
                   (± 10%) 50/60Hz  (± 10%) 50/60Hz
Fuse  1A, slow-blow  1A, slow-blow
Weight  33 lbs  38 lbs
Dimensions (ind. feet)  8” x 17” x 12”  8” x 17” x 12”
I/O PORT 1
(HI = 5 volts)

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Designation</th>
<th>Pin No.</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>D6 scan</td>
<td>14</td>
<td>D5 scan</td>
</tr>
<tr>
<td>2</td>
<td>D4 scan</td>
<td>15</td>
<td>D3 scan</td>
</tr>
<tr>
<td>3</td>
<td>D2 scan</td>
<td>16</td>
<td>D1 scan</td>
</tr>
<tr>
<td>4</td>
<td>D0 scan</td>
<td>17</td>
<td>BCD 1</td>
</tr>
<tr>
<td>5</td>
<td>BCD 2</td>
<td>18</td>
<td>BCD 4</td>
</tr>
<tr>
<td>6</td>
<td>BCD 8</td>
<td>19</td>
<td>Resolution (LO = HIGH, HI=LOW)</td>
</tr>
<tr>
<td>7</td>
<td>Load</td>
<td>20</td>
<td>Scan clock</td>
</tr>
<tr>
<td>8</td>
<td>End of scan</td>
<td>21</td>
<td>Low input</td>
</tr>
<tr>
<td>9</td>
<td>High input</td>
<td>22</td>
<td>Range error</td>
</tr>
<tr>
<td>10</td>
<td>Ref error</td>
<td>23</td>
<td>Vacuum error</td>
</tr>
<tr>
<td>11</td>
<td>Mode select</td>
<td>24</td>
<td>+ 12 volts</td>
</tr>
<tr>
<td></td>
<td>(LO=µm, HI = cm⁻¹)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>+ 5 volts</td>
<td>25</td>
<td>Ground</td>
</tr>
<tr>
<td>13</td>
<td>Decimal point</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

I/O PORT 2

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ground</td>
</tr>
<tr>
<td>2</td>
<td>Ground</td>
</tr>
<tr>
<td>3</td>
<td>Input signal</td>
</tr>
<tr>
<td>4</td>
<td>Ground</td>
</tr>
<tr>
<td>5</td>
<td>Counting Window</td>
</tr>
</tbody>
</table>

Reference Signal
Ground
Ground
Ground
Timing Signal
7. OPTIONAL ACCESSORIES

WA-100 Visible Option

The WA-100 VIS option includes a beamsplitter assembly and detector/amplifier circuit board designed for wavemeter operation over the wavelength range from 0.4 to 1.0μm. This option comes standard with model WA-10 and WA-20VIS Wavemeters.

WA-200 Infrared Option

The WA-200 IR Option includes a beamsplitter assembly and detector/amplifier circuit board. The beamsplitter is specially designed for a reflectivity of approximately 50% over the wavelength range from 1.0 to 4.0μm and at the wavelength .633μm of the He-Ne reference laser. The WA-200 Detector Board includes a PbSe infrared detector with appropriate circuitry as well as a visible detector for the reference laser.

WA-205 External Detector Option for WA-10

The WA-205 is a detector board designed with a through aperture for transmitting the input laser beam to an external detector (not included) behind the Wavemeter.

WA-210 IEEE-488 Bus Interface

The Wavemeter GPIB Interface card enables the Wavemeter series WA-10, WA-20 to be used as a basic talker in any computer/controller system which conforms to the IEEE-488/1978 standard. The seven digits of numeric information as well as decimal point location and error information are encoded in standard ASCII format.

WA-215 External Detector Option for WA-20

The WA-215 includes the WA-205 detector board plus an exit window for mounting on the WA-20 vacuum chamber.

WA-230 I/O Interface Cable

The WA-230 is a 6 foot ribbon cable plus bulkhead connector to facilitate interface of Wavemeter I/O PORT 1 to other instruments. One WA-230 is provided with each Wavemeter.

WA-10-L Low Resolution Modification

The WA-10-L is a low resolution modification of the Wavemeter (normally applied to a WA-10) that permits use with cw or mode-locked lasers having linewidths up to 200 GHz (approximately 7 cm⁻¹). It consists of wiring modifications and component substitutions on two of the Wavemeter circuit boards that reduces the Wavemeter readout resolution by a factor of 10:

High Resolution Readout: 0.01nm or 0.1cm⁻¹  
Low Resolution Readout: 0.1nm or 1cm⁻¹

This modification can be ordered at the time of purchase at no extra cost. Existing Wavemeters can be modified to the L-version at the factory or by ordering a conversion kit that includes modified circuit boards and timing blade with installation instructions.

Fast Update Modification

Any Wavemeter manufactured after August 1983 may be modified for faster update when it is to be used only in the 0.4 to 1.0 micron wavelength range or only in the LOW RESOLUTION setting for wavelengths from 1.0 to 4.0 microns. Faster update is accomplished as follows:

1) Remove the bottom Wavemeter cover and change the drive belt to the larger pulley on the motor spindle.

2) Loosen the motor mounting screws to adjust the belt tension so that the belt deflects one quarter to one half an inch when light pressure is applied from the side.

3) Retighten the motor mounting screws.

4) Remove the interferometer cover and remount the black interferometer drive bar (see Fig. 5) in the hole provided 1.1 cm from the center of the drive wheel so the distance travelled by the retroreflectors is reduced.

5) Change C4 on the Counter Board to 1μf (note the polarity).

6) Add 120 kohms in parallel with R11 above U9 on the Display Board.

To use WA-20 in HIGH RESOLUTION for wavelengths between 1.0 and 4.0 it is necessary to convert back to slow update mode by reversing the above steps.

8. WARRANTY

Burleigh Wavemeters are warranted against defects in material and workmanship for a period of one year after date of delivery and the return of Burleigh’s warranty card. During the warranty period, Burleigh will repair or at its option, replace parts which prove to be defective when the instrument is returned prepaid to Burleigh Instruments, Inc. Before return of an instrument always call Burleigh for approval of the return. The warranty will not apply if the instrument has been damaged by accident, misuse, or as a result of modification by persons other than Burleigh personnel.

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