MELLES GRIOT

OPTICAL SPECTRUM ANALYZER

OPERATOR'S MANUAL

for

CONTROL – AMPLIFIER UNIT 13 SAD 001

WITH OPTICAL HEADS 13 SAB xxx AND 13 SAC xxx

TABLE OF CONTENTS

1. INTRODUCTION TO THE SPECTRUM ANALYSER

The Melles Griot Optical Spectrum Analyser is a confocal Fabry-Perot interferometer system designed to measure the line and mode structure of laser radiation for ease of use and clarity of results.

A complete measurement system consists of the control amplifier unit model 13 SAD 001 together with an analyser head chosen for the appropriate optical spectral range of interest. Analyser heads are available with different spectral scan ranges (Free Spectral Ranges) and are suitable for either free space input (models 13 SAB xxx) or fibre optic input (models 13 SAC xxx).

The spectrum analyser head is tuned and pre-set with the confocal position of the mirrors optimised and calibrated. The input lens and detector may be carefully removed from either end of the the instrument. **Do not** dismantle the analyser head as this may lead to disturbance of the confocal mirror setting and will also expose the mirrors to the risk of damage.

For heads with a free space input it is necessary to use a 4-axis mount which will provide the required degree of transverse and angular adjustments, such as the Melles Griot model 07 HSA 003. Heads with a optical fibre input can be mounted in a cylindrical holder without adjustments, such as the Melles Griot Model 07 HSA 001.

The output of the detector amplifier in the control-amplifier unit should be connected to a one or two-channel oscilloscope.

2 INTRODUCTION TO THE THEORY OF OPERATION

(see figure 1, page 4)

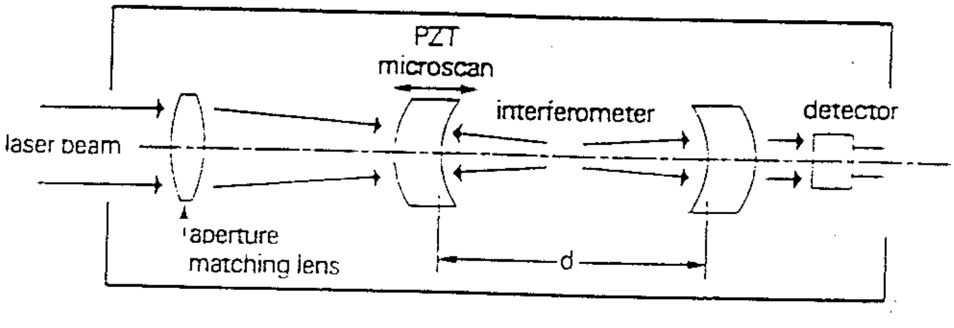
Confocal Fabry-Perot interferometers are essentially ultra-narrow line width filters which produce a series of sharp transmission peaks as the mirror separation is slightly varied with the scanning of the piezo-electric ramp voltage. These peaks occur when the multi-reflected beams within the cavity are all in phase (resonance) at the exit surface. At each reflection a small (>1%) fraction of the incident light is transmitted. When the cavity is on resonance the amplitudes of all of these small fractions combine to give rise to the transmission peak. In the spectrum analyser head these peaks are detected by a high responsivity silicon or germanium photodetector.

With confocal configuration each spectral component of the incoming radiation produces a transmission peak when its wavelength and the cavity mirror separation 'd' satisfy the relation:

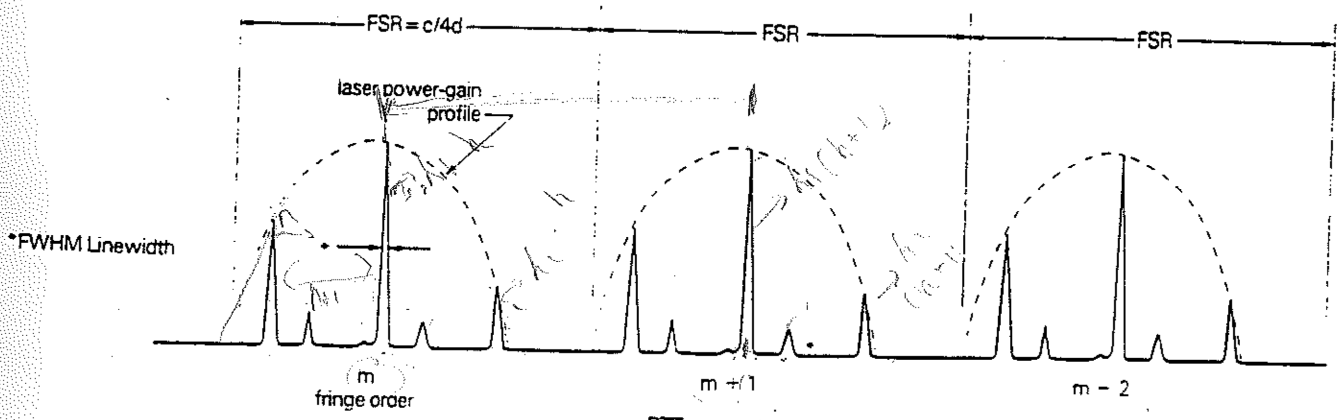
$$d \approx m \lambda/4$$

where 'm' is a large integer called the fringe or interference order. Thus for any wave-length there will be a transmission peak every time the scanning mirror separation gives an integral value of 'm' for that wavelength.

If the ramp scan voltage (and thus the mirror movement) is large enough, there will be a comb of transmission peaks for a given wavelength. For each and every spectral feature there will be a similar transmission comb, and thus a series of identical spectra will be displayed across the screen as the mirror separation is ramped through a series of fringe orders.



Analyzer Head



A HeNe laser spectrum repeated over a scan of three free spectral ranges together with the outline of the laser power-gain profile.

figure 1

Adjacent fringe orders are separated by the Free Spectral Range (FSR), which is given by:

$$FSR = 1/4d \quad \text{in wavenumber terms}$$
$$FSR = c/4d \quad \text{in frequency terms}$$
$$FSR = \lambda^2/4d \quad \text{in wavelength terms}$$

The most commonly used of these being the frequency terms. The separation between peaks is linear in frequency.

It must be noted that if the frequency range of the incoming light is too great (that is > FSR) then there will be overlapping of different fringe orders and the output will be confusing and difficult to interpret. To avoid this the bandwidth or frequency range of the incoming light should be restricted to not more than one free spectral range.

The sharpness of the peaks is an indicator as to the finesse of the instrument. The finesse is limited by the following main factors:

a) Coating reflectivity.
b) Optical defect of the mirrors. ie: lack of sphericity. surface roughness (RMS).
c) Instrument stability, mirror alignment.

Melles Griot Spectrum Analysers have a guaranteed finesse of at least 200 over each specified spectral range.

Equate the **Full Width at Half Maximum** (FWHM) of the fringes with the minimum resolvable bandwidth. This is given by:

$$\text{minimum resolvable bandwidth} = \frac{FSR}{\text{finesse}}$$

Thus for maximum resolution the FSR should be small and the finesse high.

3. PREPARATION FOR USE

3.1 Checklist

With each head package there should be:

1) The specified analyser head consisting of:

   The pre-aligned confocal interferometer head

   The detector

   Either an input lens with pinhole cover

   or a FC/PC fibre input adaptor

   A 50mm Clamp Ring

2) A high voltage connection cable (gold plugs)

3) A detector cable (mini-BNC to standard BNC)

The control/amplifier unit is supplied with a suitable power supply cable

<u>Also needed are:</u>

1) An oscilloscope (either single of dual channel). There are no particular speed requirements; any modern scope (> 1MHz) will suffice. A dual trace scope is useful if it is desired to view the scan ramp voltage as well as the signal trace. A blanking (Z-modulation) input is desirable (though not essential), and a blanking pulse is supplied by the control/amplifier unit to suppress the flyback.

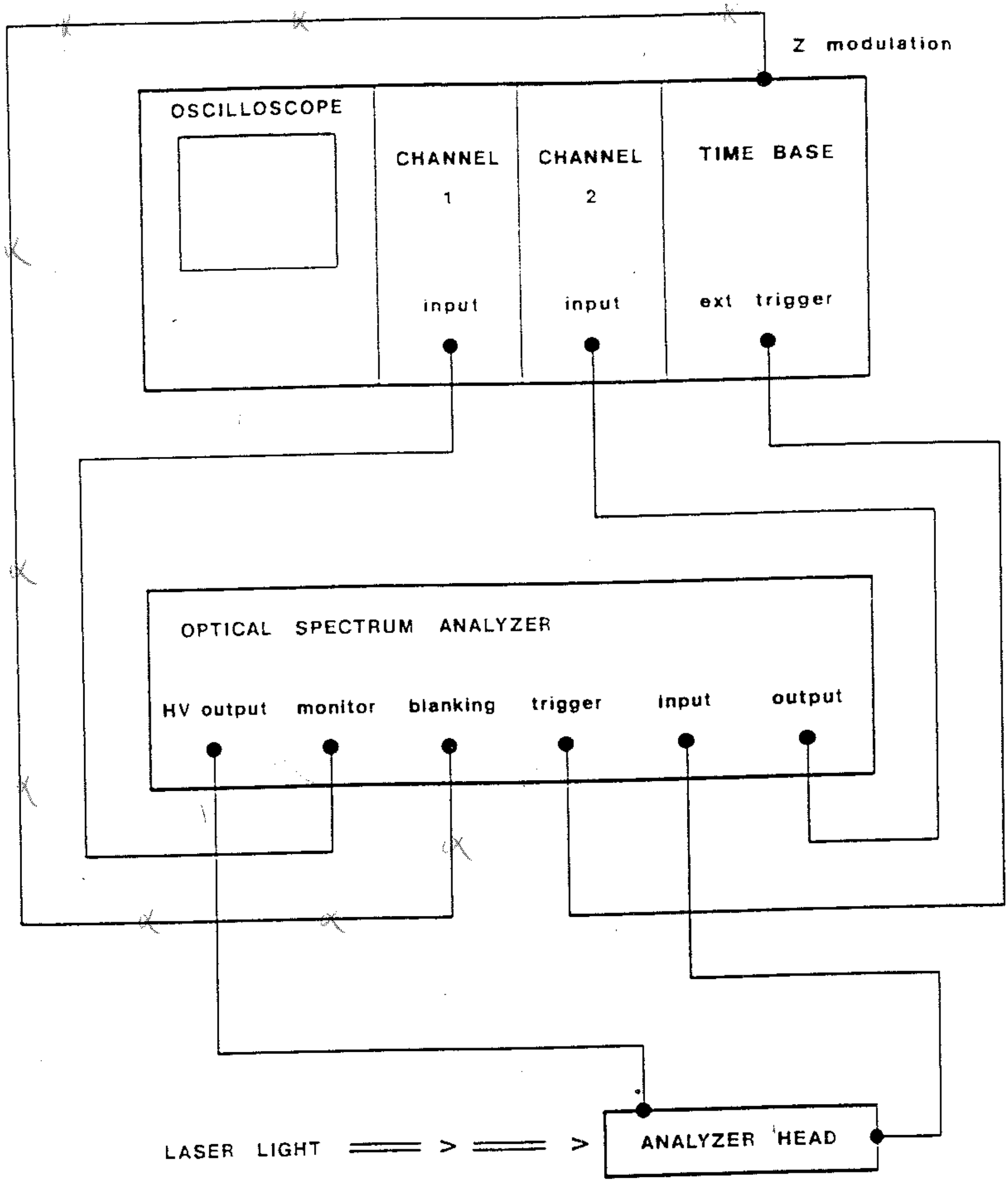
2) Standard BNC leads. At least two are required, but up to four may be used depending on the oscilloscope and the output required by the user.

3.2 Mounting the Spectrum Analyser Head

Heads with a free space beam input option should preferably be mounted in a system which provides four axis of adjustment-two translational in the plane perpendicular to the beam, and two rotational about axis perpendicular to the beam.

Heads with a fibre input can be mounted in any cylindrical holder as no common axis adjustment is necessary.

Melles Griot can supply a variety of mounting options which are suitable for either of these requirements. See section 7.4.



ELECTRICAL CONNECTIONS

figure 2

3.3 Operating Site

To ensure efficient maintenance free operation of the spectrum analyser system, a clean dust-free operating site should be used. Although the head is thermally stable due to its Invar construction, large temperature variations are undesirable, and a stable operating site should be sought. Vibration isolation will improve performance though it is not essential.

3.4 Voltage Selection

The detector/amplifier unit can be used with voltages in the ranges 100-120V or 220-240V. The voltage selection switch is located on the rear of the unit, next to the mains lead input socket.

[**Warning** The correct voltage range **must be** selected before switching the control unit on.]

3.5 Electrical Connections

(see figure 2, page 8)

All of the electrical connections should be made with the control unit switched off.

a) Connect the high voltage output of the control unit to the high voltage input on the side of the analyser head using the high voltage cable (small gold plugs). This supplies the ramp to the piezo-electric stack in the head.

b) Connect the detector amplifier input (standard BNC) to the detector output on the analyser head (mini-BNC) using the detector cable. This supplies the photo detector signal for amplification.

c) Connect the trigger output of the control unit to the external trigger input of the oscilloscope. This supplies a +5V pulse at the start of the ramp, and a -5V pulse at the start of the flyback, to enable reliable triggering of the oscilloscope.

d) Connect the output of the detector amplifier (on the control/amplifier unit) to one of the Y-inputs of the oscilloscope. This allows the display of the signal representing the spectral information discerned by the analyser head. This completes the essential connections. Those below are optional, though they can assist in the interpretation of the spectral information.

e) Connect the scan monitor output on the control/amplifier unit to the second Y-input channel of the oscilloscope (if present). This provides a voltage, equal to one hundredth of the scan ramp voltage, allowing the simultaneous display of both signal and ramp information, which can be helpful in some circumstances.

f) Connect the blanking output of the control/amplifier unit to the blanking input of the oscilloscope (if present). This supplies a Z-modulation pulse causing the flyback to be blanked. In other words the oscilloscope will only display the portion of the trace produced during the ramp. This can be useful in making the display easier to interpret.

4 OPERATING THE SPECTRUM ANALYSER

4.1 Control Function

(see figure 3, page 12)

4.1.1 Scan Controls

Range

This governs the amplitude of the high voltage ramp driving the piezo-electric stack. The effect of this is to reduce/expand the range over which the analyser head scans (in the range 0 - 480nm). This then causes the effect of compression/magnification of the signal trace in the horizontal direction. This makes it possible to "zoom in" on spectral features of interest.

Rate

This specifies the repetition frequency of the ramp. The rate is continuously variable between 6 and 50Hz.

The effect of this on the trace is at a first glance the same as that of the range control, ie. the expansion/compression of the trace. There is a difference however, in that adjusting the rate control is more or less analogous to changing the timebase of the oscilloscope. This factor makes this control particularly useful in matching the speeds of the oscilloscope and ramp, rather than using it to zoom in on features of the spectrum.

(figures 4a, 4b, and 4c, page 12), illustrate the different effects of rate and range controls.

Shift

This governs the amount of DC offset which is superimposed on the ramp. It is continuously variable in the range 0-400V, producing a consequent mirror movement of 0 - 320nm. This has the effect of moving the positions of the transmission peaks with respect to the start of the ramp. This is useful in adjusting the position of the feature of interest to a suitable place on the oscilloscope screen.

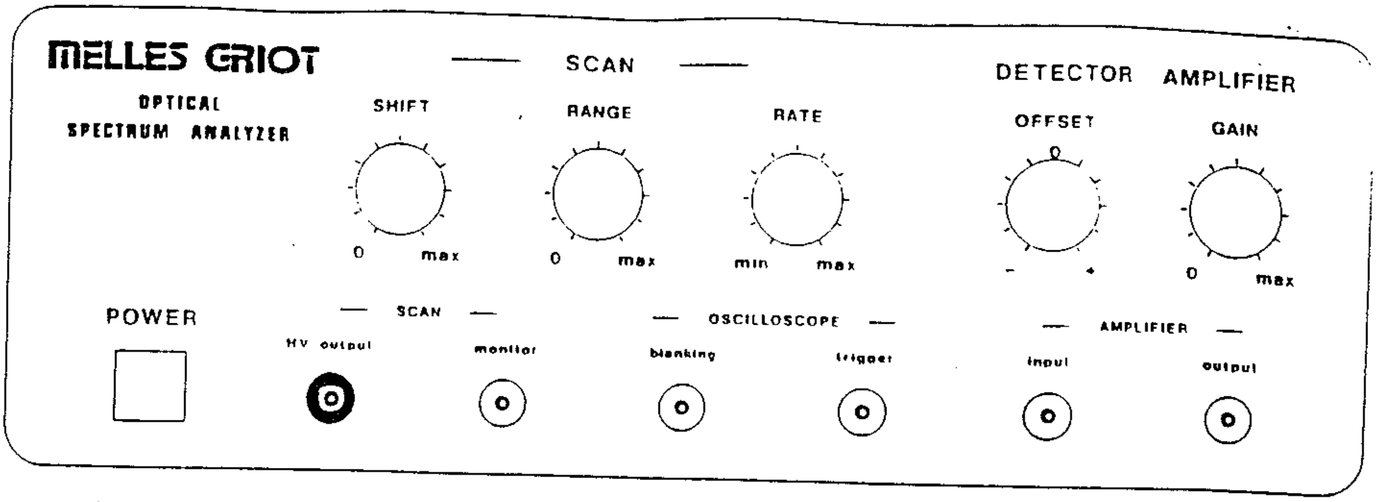


figure 3 control layout

figure 4a

Initial situation : range and rate both at maximum

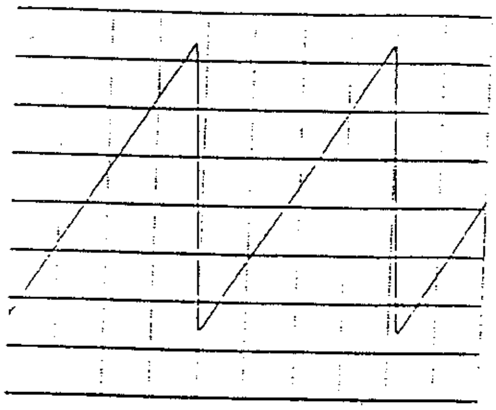


figure 4b

Effect of decreasing range without altering rate

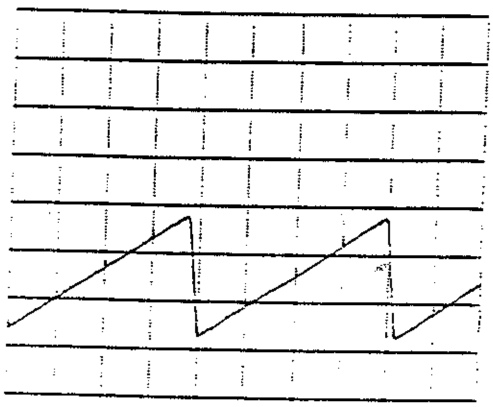
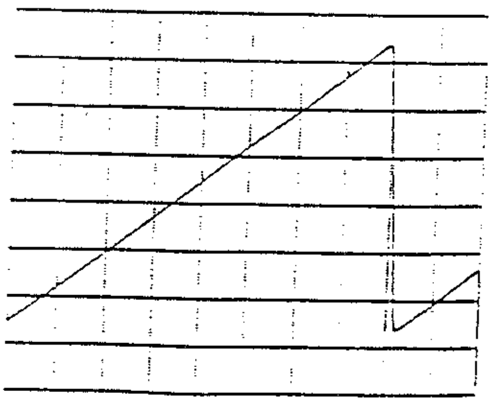


figure 4c

Effect of decreasing rate without altering range



4.1.2. **Detector Amplifier Controls**

Offset

This adds a continuously adjustable current (0-40 μA) to the signal from the detector prior to amplification, allowing the signal trace to be moved up and down on the oscilloscope screen. This enables the signal to be set to a convenient position, in order to ease viewing and/or measurements.

Gain

This governs the gain of the amplifier, which is continuously variable in the range 0-100 μV/nA. This allows the magnitude of the signal to be manipulated so that a convenient viewing/measuring situation can be reached.

4.1.3 **Blanking**

As previously explained the function of the blanking pulse is to cause the oscilloscope to display only the positive side of the ramp and/or the portion of the signal trace associated with it. In figure 5b, Page 14 the trace consists of two groups of peaks, along with a single peak. This could be an ambiguous situation, with the actual relation between the various peaks being unclear. Once the blanking pulse is used (figures 5c & 5d), the situation is much clarified. It can be seen that the trace consists of three single peaks, and the subsidiary peaks present in figure 5b are associated with the flyback portion of the ramp cycle.

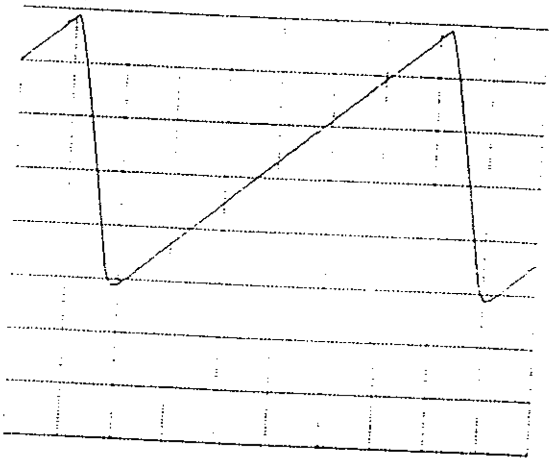
The blanking pulse is particularly useful when it is impossible (or undesirable) to view the ramp at the same time as the signal trace.

4.1.4 **Summary of Control Functions**

Factor	Controlled by
Horizontal position	shift
Vertical Position	offset
Horizontal Magnification	range (or rate)
Vertical Magnification	gain

RAMP

SIGNAL



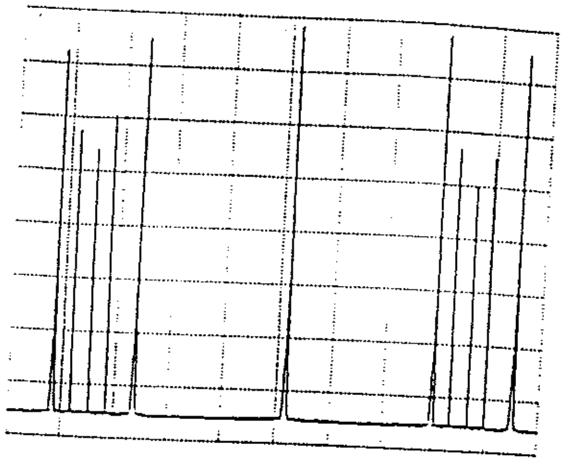


figure 5a

WITHOUT BLANKING

figure 5b

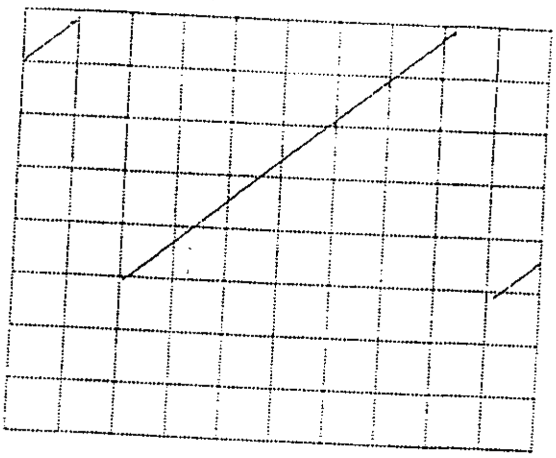


figure 5c

WITH BLANKING

figure 5d

4.2 Alignment of the Spectrum Analyser Head

(see figures 6a-f, page 16)

4.2.1 Free Space Input

This description applies to the 13 SAB xxx models of spectrum analyser head. The head should be mounted in a suitable four axis mount.

The head and the laser source should be mounted on an optical rail or optical table. They should be approximately aligned about a common axis, and then both switched on. To aid alignment the head is supplied with a pinhole lens cap. This helps to locate the laser beam in the central part of the input lens.

The triggering of the oscilloscope should be set as below:

source	external
mode	normal
slope	positive
level	positive (slightly)

The rate and range controls should be set to their maximum values, as should the gain. Set oscilloscope Y-input channels 1 and 2 to DC. The monitor output should be viewed on the oscilloscope (figure 6a), in order to select a suitable timebase setting (1-2ms per division should prove satisfactory). The rate control should then be adjusted until only the upward slope of the ramp is visible. (figure 6b).

The detector amplifier output should then be viewed on the oscilloscope. The sensitivity of the oscilloscope should be set to about 10mV per division initially, in order to make the initial signal easily discernible (the offset control can be used to adjust the position of the trace on the screen). As the alignment is adjusted the sensitivity of the oscilloscope can be decreased to match the magnitude of the signal.

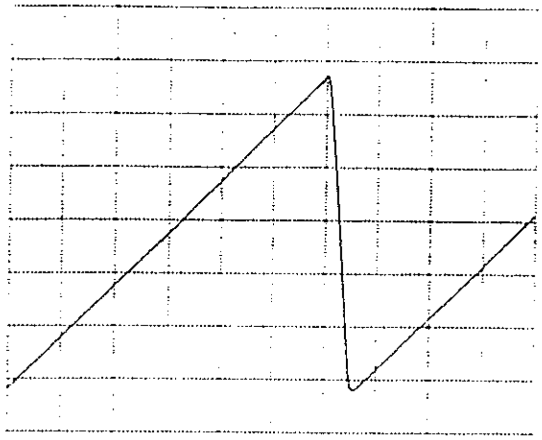


figure 6a

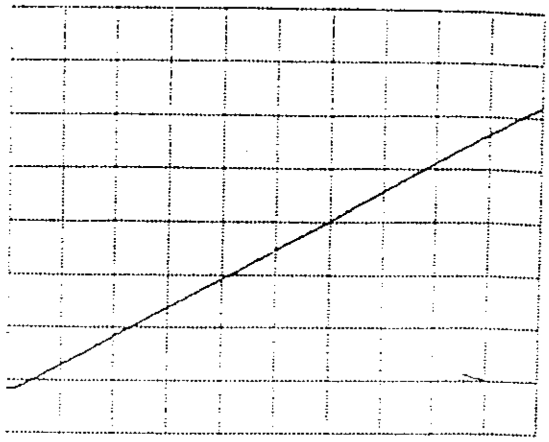


figure 6b

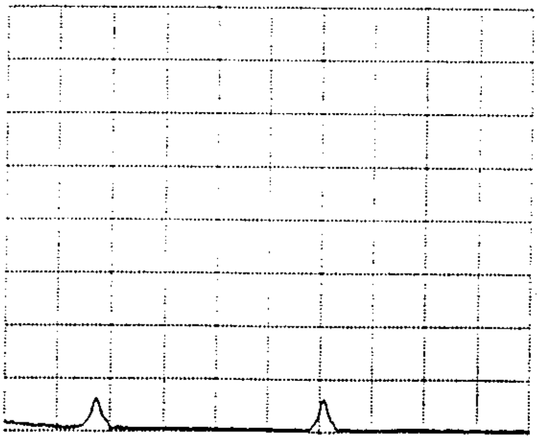


figure 6c

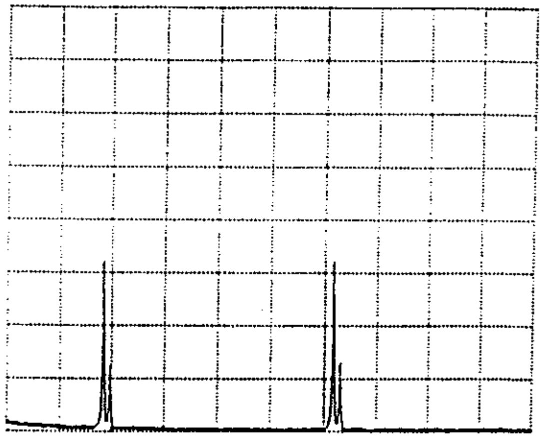


figure 6d

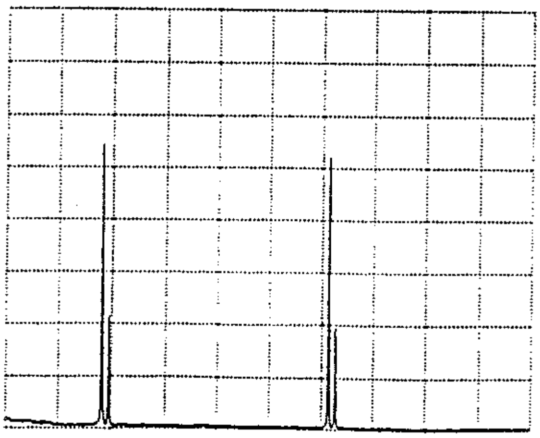


figure 6e

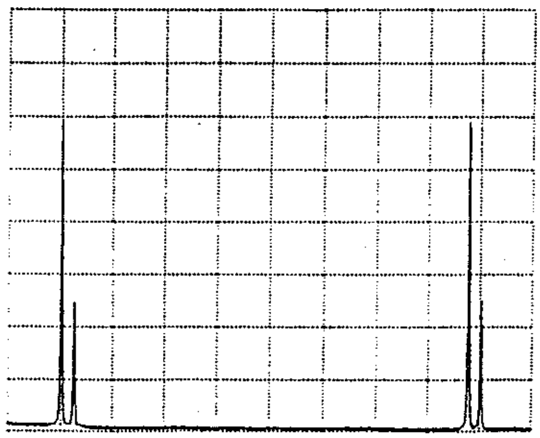


figure 6f

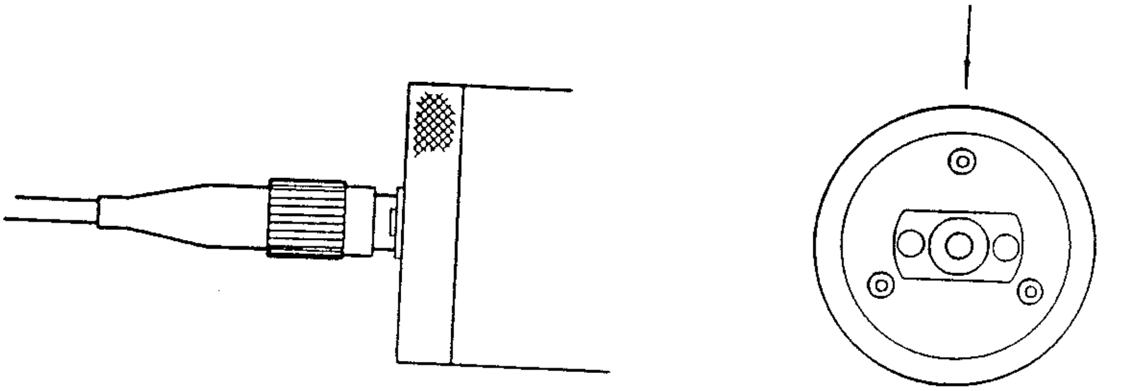
The trace will probably resemble figure 6c. Slight angular adjustments should be made to all axis in turn, whilst observing the trace on the screen, with the objective of increasing the height of the peaks while reducing their width. The peaks should now look more like figure 6d. This process should be repeated until no further improvement is noted (figure 6e). The peaks should now be narrow, tall and symmetrical.

Once the alignment has been optimised, the shift, range, gain and offset controls should be used to adjust the position and scaling of the trace to the desired form (e.g. figure 6f).

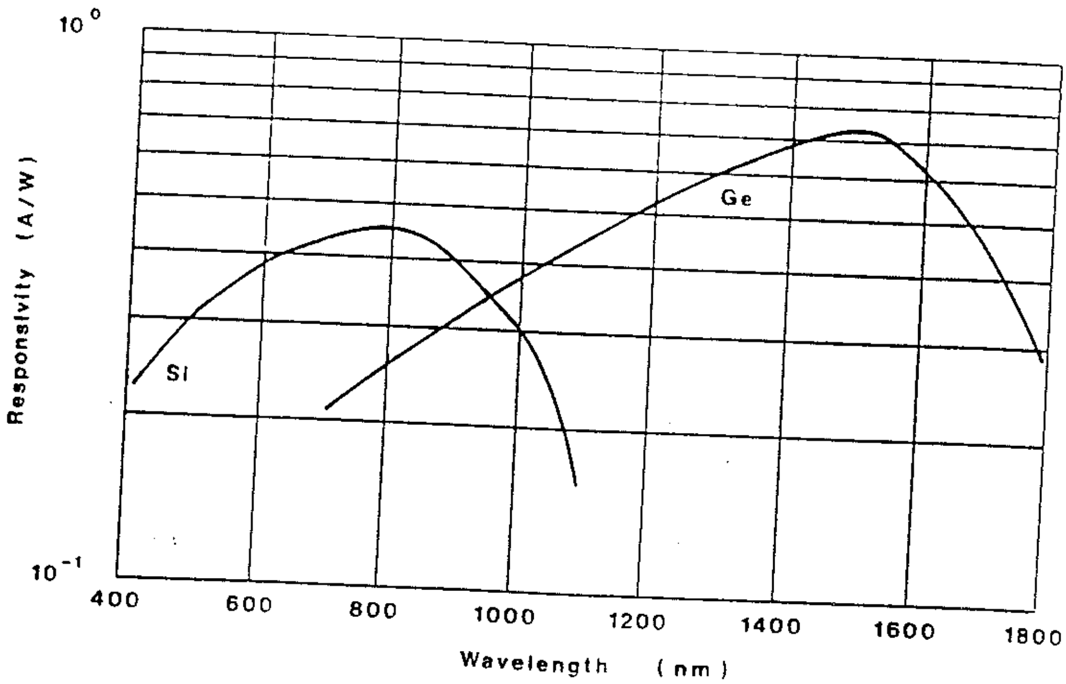
4.2.2 Optical Fibre Input

The procedure for aligning the optical fibre input option (models 13 SAC xxx) is essentially the same as that for the free space input option. The oscilloscope and control unit should be set as detailed in section 4.2.1. It is important that laser light is being transmitted through the optical fibre cable **before** connecting cable to the spectrum analyser optical fibre input adaptor.

When connected the detector amplifier output signal amplitude viewed on the oscilloscope can be optimised by adjusting alignment at the laser end of the optical cable. Alignment adjustments can then be made to the spectrum anlyser optical fibre input adaptor, by use of the three adjusting screws (see figure 7, Page 18). These are adjusted in turn to optimise the transmission peaks as described in section 4.2.1 and figures 6c & 6f, page 16.



OPTICAL FIBRE INPUT ADAPTOR figure 7



RESPONSE CURVES FOR SILICON AND GERMANIUM DETECTORS

figure 8

5. INTERPRETING THE DISPLAY

5.1. Determination of the Number of Laser Modes Oscillating

The interpretation of the information displayed on the oscilloscope screen is a straightforward procedure. Once the method is mastered the optical spectrum analyser provides a simple and direct way of obtaining information about the output structure of a laser. In the trace illustrated in figure 1, Page 4 it is clear that the laser is oscillating in five modes, since there are three identical groups of five lines. Similarly in figure 6f, Page 16 it is clear that the laser (in this case a tuneable HeNe operating at 730nm) is operating in two modes since there are two identical groups of two lines.

There are however cases where some though must be given to the output before it is certain that the correct interpretation has been made.

One such case would be if there were a succession of peaks of equal intensity. This could be due to one of two things:

a) The laser operating in a single mode.

b) The laser operating in two modes of equal intensity, due to their being placed symmetrically with respect to the centre of the gain curve.

If the peaks are in distinct pairs rather than evenly spaced, then the laser is operating in two modes. If they are evenly spaced then the laser is operating in a single mode. This should hold true for nearly all cases. The only exception would be if the intermodal spacing of the laser was exactly half the free spectral range of the spectrum analyser. This is an unlikely situation and if any confusion should occur there are several ways of telling whether or not this is the case. For example the length of the laser cavity could be changed slightly (by altering its temperature for instance).

If the laser was single mode then all of the peaks would behave in the same manner either decreasing or increasing in intensity. If it was two modes one would increase as the other decreased.

If it was impossible or undersirable to alter the cavity conditions then some short calculations as outlined below would ease the interpretation:

Change in length of cavity when 'range' is at maximum

$$\Delta \ell = 480\text{nm}$$

Change in length required to scan through one free spectral range at a wavelength of λ

$$\delta \ell = \frac{\lambda}{4}$$

Therefore when the scan range is at maximum the number of free spectral ranges scanned through in the course of one ramp is equal to :

$$\Delta \ell \ / \ \delta \ell$$

For example if the wavelength is 633nm then approximately three free spectral ranges will be scanned at maximum range.
To make sense of the trace on the oscilloscope all that is required is to count the number of apparent free spectral ranges scanned. Comparison of this with the calculated value will ascertain the correct interpretation.

5.2 Calibration of the trace

Once the number of modes oscillating has been determined, the trace in terms of frequency (or wavenumbers) can be calibrated.

The free spectral range (300MHz, 2GHz, or 10GHz) is the distance between two identical points in adjacent orders as shown in figure 1, page 4.

Using this calibration the intermodal spacing of the laser can be measured directly from the screen of the oscilloscope. The relative intensity of the separate modes can also be directly measured from the screen, since the response of the detector is linear. This means that if, for example there are two modes a) and b), and line a) is twice as high as line b), then mode a) has twice the power of mode b). That is two thirds of the total power of the laser is in mode a), and one third is in mode b).

6. TROUBLESHOOTING

This equipment is designed to be simple to use and trouble free in operation, there should therefore be no major problems with it, provided the instructions are followed. Below are some possible minor problems, and probable solutions to them. If any major problems are encountered please contact your nearest Melles Griot service centre (see section 8).

No traces visible on oscilloscope

1) Check all electrical connections and supply leads.
2) Check that the laser and oscilloscope are switched on.
3) Check that the mains power is switched on and that the green power switch light on the front panel of the control unit is illuminated.
   If not, make sure that the voltage selection switch situated on the rear panel is set at the correct voltage range for your own mains power supply.
   Remove both fuses mounted on the mains input socket and check fuses for continuity, replace as necessary. (Fuse T250 mA, 20 mm).
4) Check that the scan range and rate controls are initially turned to max.
5) Check that the detector amplifier gain control is initially turned to max and that the offset control is in centre position.
6) It is essential that the analyser head and laser source are aligned about a common axis, with the incident beam centred on the pinhole mounted in the input lens cap.

Oscilloscope not triggering

1) Check that the trigger pulse is connected to the external trigger input of the oscilloscope. Check that the trigger selection controls are correctly set.

7 SPECIFICATIONS

7.1 Analyser Heads

Configuration: Confocal mirror pair with piezo-electric driven separation scan and thermally stable Invar construction.

Free Spectral Range: ~~300MHz~~, 2GHz, ~~10GHz~~

$\Delta\nu = \frac{c}{4L} \Rightarrow L = 3{,}7$ cm

Finesse : 200 min~~imum~~

Resolution : $\frac{\text{(Free spectral range)}}{\text{Finesse}}$

Wavelength Ranges : ~~450-550~~, 550-680, ~~700-860, 860-1100, 1050-1250 or 1300-1550~~nm

Input : 8mm diameter aperture with pre-aligned matching lens or FC/PC (single-multi-mode) fibre input.

Detector : Silicon; 450mA/W peak response (@ 850nm)
Germanium; 700mA/W peak response
] See Figure 8, Page 18

Piezo-electric Scan: 0.8nm/Volt, 1000V maximum

Piezo Stack Capacitance : 4.9nF

Lens Cap : Push fit with 1mm pinhole

Head Diameter : 36mm

Head Length : 353mm (300MHz FSR)
140mm (2GHz FSR)
111mm (10GHz FSR)

7.2 Control/Amplifier Unit

Piezo-electric Scan Drive

Range	:	0-600 Volts, continuously variable
Shift	:	0-400 Volts, continuously variable
Rate	:	6-50Hz ramp, continuously variable
HV Output	:	(Range + Shift) at Rate
	:	5.0mA maximum, 0.5mV RMS noise (5MHz Bandwidth)
Monitor	:	$\frac{\text{(HV Output)}}{100}$ 200 Ohms impedance, DC coupled
Blanking	:	0V during ramp.+12v during Flyback
Flyback	:	5ms duration
Trigger Pulse	:	5V positive pulse at ramp start, 5V negative pulse at flyback start. Width 100 μs, risetime 1 μs.

Detector Amplifier

Bandwidth	:	(-3dB) : Dc to 300kHz
RMS Noise	:	0.5mV
Offset	:	Signal zeroing and detector current offset: (± 40 μA), continuously adjustable
Gain	:	0 to 100 μV/nA, continuously adjustable
Output	:	200 ohms impedance, ±10V maximum

Power Input

Voltage	:	110-120 and 220-240 volts, rear panel voltage selection switch
Frequency	:	50-60Hz
Power	:	12 watts, fused on rear panel

Dimensions and Weight

Dimensions	:	270mm(W), 92mm(H), 188mm(L)
Weight	:	3.5kg

7.3. Other Details

7.3.1 Spectrum Analyser Heads

Wavelength Range nm	300MHz	2GHz	10GHz
450-550	13 SAB 003	13 SAB 023	13 SAB 043
550-680	13 SAB 004	13 SAB 024	13 SAB 044
700-860	13 SAB 005	13 SAB 025	13 SAB 045
860-1100	13 SAB 006	13 SAB 026	13 SAB 046
1050-1250	13 SAB 007	13 SAB 027	13 SAB 047
1300-1550	13 SAB 008	13 SAB 028	13 SAB 048

(Free Spectral Range)

The optical spectrum analyser with the appropriate product number chosen from the above table includes the designated analyser head complete with pinhole-cap, the cables connecting the head and controller/amplifier and a removable mounting flange for mounting the head into the optional 4-axis mount or a 50.8mm internal diameter adjuster such as a mirror mount.

7.3.2 FIBRE OPTIC INPUT

For an optical spectrum analyser with an FC/PC fibre optic input adaptor, substitute "C" for "B" in the appropriate product number. Thus 13 SAB 008 has focusing optics suitable for a beam input and 13 SAC 008 008 has a fibre input.

7.3.3 CONTROL/AMPLIFIER UNIT 13 SAD 001

The output of the detector amplifier should be connected to an appropriate display device, such as a single or dual channel oscilloscope

7.4 **Analyser Head Mounts**

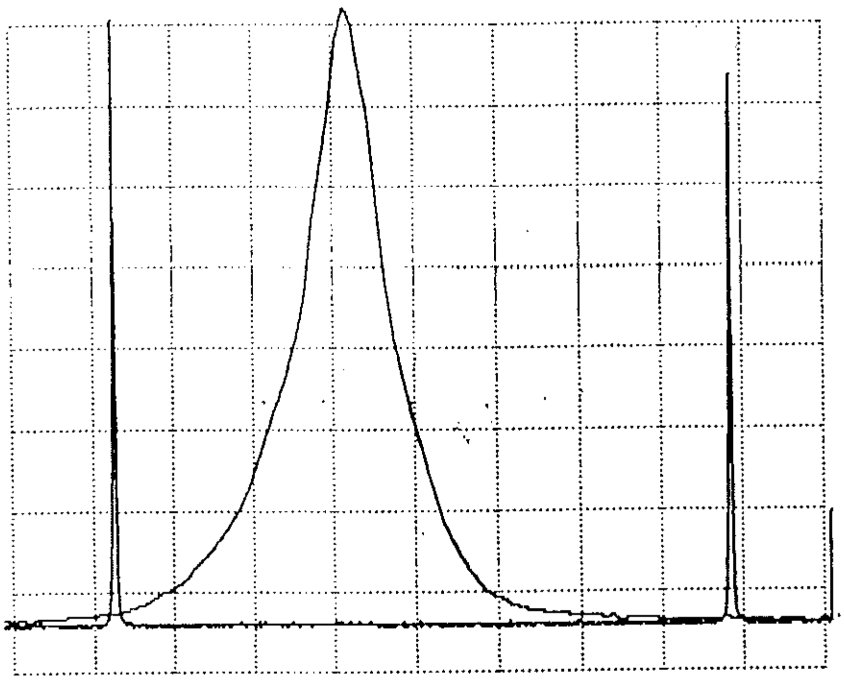
	Inch	Metric
Fixed position cylindrical mounts (suitable for fibre optic input heads)	07 HSA 001	07 HSA 501
Compact 4 axis aluminium mount	07 HSA 003	07 HSA 503
Modular steel and brass mounting system:		
[	07 MAS 015	07 HSA 515
Combination of.........[	07 TSZ 004	07 TSZ 504
[	07 TSS 004	07 TSS 504

All the mounts come complete with four (7mm diameter) mounting holes suitable for use on 50mm/2" centres, along with four M6 or 1/4-20 mounting screws, for metric or inch mounting systems as appropriate.

See the **OPTICS GUIDE** 5 (chapters 23 and 26) and the "Optical Spectrum Analyser" brochure a for full description of mounting equipment.

TECHNICAL OPTICS LTD

Instrument test sheet



Expanded scale x 40

Customer .. M. G. SARL ....

Order No. 920240 ....

Type FIXED CAVITY ....

Serial No. 7023 ....

F.S.R. 10 GHz .... Now 2 GHz ....

Wavelength Range 700 – 860nm ....

Finesse 274 ....

Tested by CAllum ....

Date 23-3-92 ....

Comments

TESTED @ 730 nm

WITH INPUT LENS.