MELLES GRIOT

Technical Optics Ltd.

FPI-25 Fabry-Perot Interferometer

with

FPZ-3 Ramp Generator

Operation Instructions

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1 Introduction

The Technical Optics FPI-25 is a Fabry-Perot interferometer which can be scanned or tuned by means of piezo-electric transducers. The easily variable free spectral range makes the FPI-25 an extremely flexible laboratory tool, with a wide range of spectroscopic applications. The wide 25mm aperture means that even weak sources are not a problem, and the long integration times associated with many remote sensing applications can be reduced.

The transducers are controlled by means of high voltage signals obtained from the FPZ-3RG ramp generator unit. The various drive signals provided by the FP-3RG allow the optical head to be used in various ways, making it a versatile spectroscopic instrument. The plate spacing can be ramped rapidly making the head useful for the real time spectral analysis of CW laser sources. When a slower ramp speed is employed a time-averaged spectrum of a pulsed laser may be obtained.

If the plates are not ramped then the FPI-25 can be used as a tunable filter, which has excellent performance with regard to both bandwidth, and contrast ratio, making the device ideally suited to applications where high discrimination is needed.

ELECTRICAL WARNING

This system is designed to operate from either 110-125volts or 220-250volts AC power supply input.

Do not** **attempt to operate the instrument until the voltage selector has been correctly set (see section 5).

Failure to correctly configure the power input module may result in serious damage to the instrument.

The high voltages delivered from the HV out socket on the interferometer controller are potentially very dangerous, and although completely safe in normal use, misuse could be hazardous.

LASER SAFETY WARNING

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This apparatus is normally used to filter the output from laser sources. The operator should be familiar with the appropriate laser safety procedures and regulations. In particular it should be noted that a portion of the laser beam incident on the optical head will be reflected. This can be hazardous, and both incident and reflected beams should be enclosed if necessary.

2 Specifications

Ramp Generator

Power Input

VOLTAGE	110 - 125V or 220 - 250
FREQUENCY	50 - 60Hz
POWER CONSUMPTION	120VA

Piezo-electric Controls - Bias

OFFSET	0 - 450V
TILT	0 - 550V
OUTPUT IMPEDANCE	1MΩ

Piezo-electric Controls - Ramp

RAMP EXTENT	0 - 1000V
TRIM RANGE	0 - 15% of ramp extent
RAMP RATE	0.01 - 100 V/ms
FLYBACK RATE	100 V/ms
DRIVE CAPABILITY	2.5mA per channel

Dimensions

WIDTH	435mm
DEPTH	265mm
HEIGHT	100mm

Optical Head

Optical Parameters

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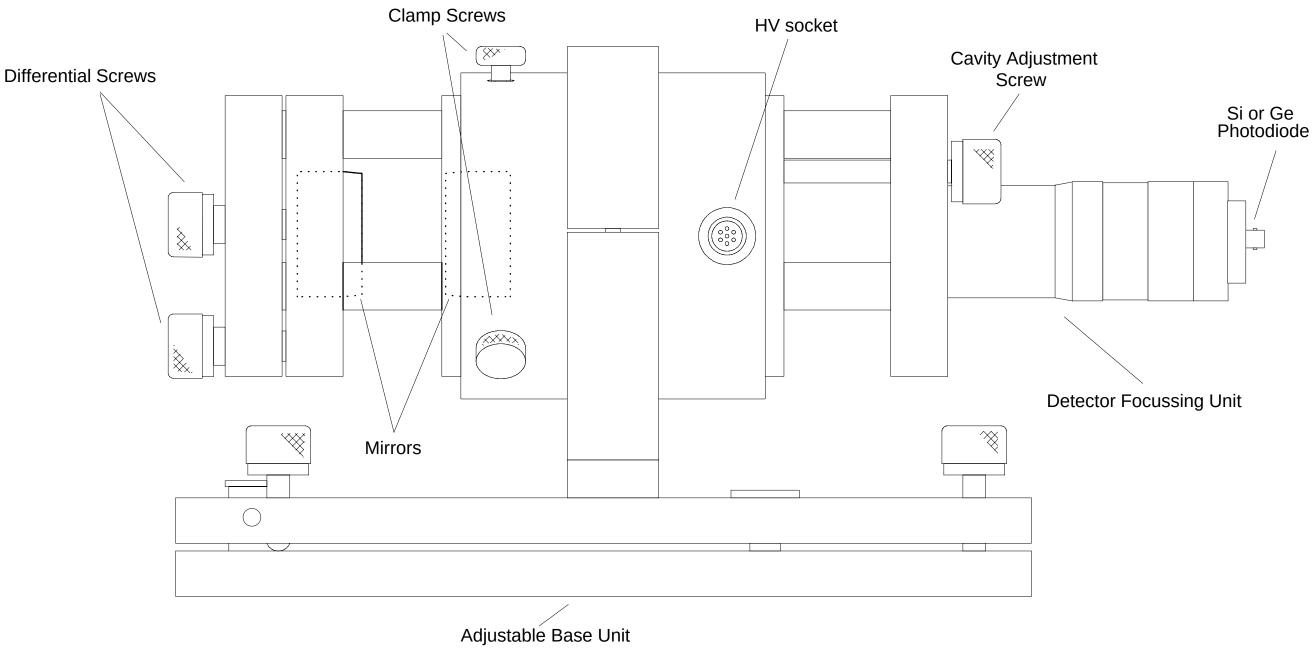
MODEL	**W1000**	**W2000**	**W3000**
Clear Aperture	25mm	25mm	25mm
Minimum Cavity Spacing	<0.5mm	<0.5mm	<0.5mm
Maximum Cavity Spacing	60mm	100mm	150mm
Maximum FSR	>300GHz	>300GHz	>300GHz
minimum FSR	2.5GHz	1.5GHz	1GHz
Finesse		dependent on mirrors and cavity configuration	
Mirror Ramp Range		1.8μm in LOW extension range - 6μm in HIGH extension range	
Mirror Offset Range		1.8μm	
Scan Non-linearity		< 5% nominal	

Dimensions

Length	308mm	348mm	398mm
Height		146mm	
width		120mm	

3 System Description and Controls

FPI-25 Optical Head



This, the most important component, houses the optics and the piezo-electric transducers which scan them. It consists of an Invar tri-bar structure supporting Invar endplates and body.

A fine pitch differential screw assembly is attached to one end, in which one of the mirrors is mounted. This allows for coarse (in optical terms) adjustment of the parallelism of the interferometer (see section 4).

The main body of the instrument, including the other mirror and the piezo-electric transducers, slides on the three bars. The mirror spacing can be readily varied by undoing the three clamp screws, turning the cavity adjustment screw, and then re-tightening the clamp screws (see section 4).

The range over which the device can be scanned can be set to either LOW, suitable for working in the UV-VIS-NIR range, or HIGH for the IR region. The scanning range is selected by means of a toggle switch on the optical head.

A detector focusing unit can be attached to the differential end of the interferometer, collecting light from the full 25mm aperture of the instrument, and focusing it onto a photodiode (either silicon or germanium).

The complete assembly is held on an adjustable base unit, allowing fine variations in the alignment to the optical source to be made.

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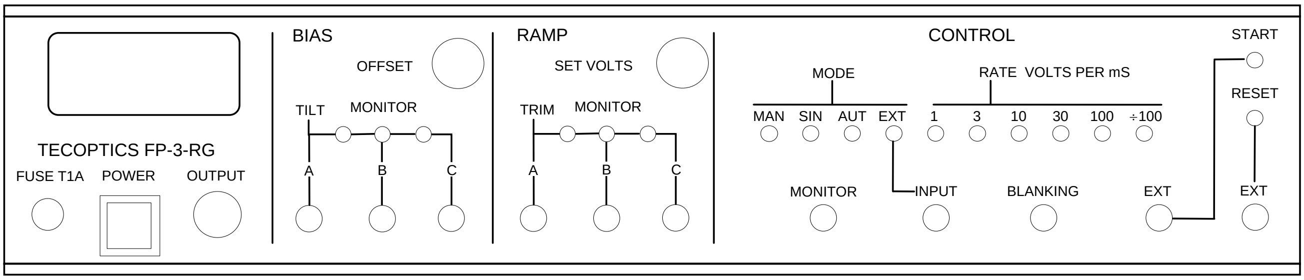
FP-3 Ramp Generator



The FPZ-3 ramp generator provides all of the voltage signals necessary to control the FPI-25 optical head. There are six high voltages required, which are of two different types:

Firstly there are three bias signals which set the high degree of parallelism required for successful operation of Fabry-Perot etalons, and also provide offset to allow the fringe peaks to be moved relative to the start of the ramp.

Secondly there are three ramp signals which provide the scanning ability of the etalon. These ramp signals are individually trimmed to maintain the parallelism set by the bias signals.

A full description of the controls and how they effect the voltages follows.

Control Functions

There are three banks of controls on the front of the FPZ-3 ramp generator.

BIAS

OFFSET This single turn rotary control applies a common voltage signal to the stacks supporting the non-scanning mirror. This allows the operator to change the positions of the transmission peaks relative to the start of the ramp, when the FPI-25 is being used as a spectrum analyser. When being used as a tuneable filter, it provides the tuning function, allowing the user to select the desired passband.

TILT These three controls each supply an individual voltage to one of the three stacks on which the non-scanning mirror is mounted. They allow the plane of the mirror to be adjusted to achieve the necessary parallelism of the etalon.

RAMP

Set Volts This ten turn rotary control varies the amplitude of the common ramping signal to the stacks supporting the scanning mirror. Using this control the operator can set the extent of the mirror movement, and thus the scan.

Trim These three controls are used to adjust the ramp signals going to each individual stack in order to maintain the parallelism set by the tilt controls.

The six interdependent Monitor switches select which of the bias (tilt + offset) or ramp (set volts + trim) signals is displayed on the digital volt meter and sent to the monitor BNC socket (attenuated by a factor of 100). For high ramp speeds the DVM does not respond fast enough to follow rising and falling voltage and so it will display an average value over the ramp cycle (approximately half the maximum ramp voltage).

CONTROL

Manual (man) When depressed this switch disables the ramp signal and allows the device to be used as a tuneable filter. Tuning is brought about by means of the offset control.

Single (sin) This mode lets the user send the optical head through a single ramp cycle. The ramp starts when the Start button is pressed and the voltage rises from zero to the amplitude set by the set volts control. It returns to zero when the Reset button is pressed. Alternatively both the start and reset functions can be carried out by means of the corresponding BNC sockets.

Automatic (auto) When operated this switch causes the ramp voltage to continually cycle, from 0 to set volts at the ramp rate, and then back to zero at the flyback rate. This is the mode used most commonly to operate the etalon as a spectrum analyser.

External(ext) This mode allows the operator to control the drive signal by supplying a voltage at the Input BNC socket. An input of 0-10V gives an output of 0-1000V (with a maximum slew rate of 100V/ms). This input is subject to the trim controls in the same way as the internally generated ramp signal.

Rate This bank of four interdependent switches and one independent switch give a wide range of ramp rates from 0.01V/ms to 100V/ms. This allows the head to be driven at a convenient scanning speed for a wide range of applications. This control only effects the auto and single modes.

Input/Output Sockets

There are five BNC sockets and one multiway socket on the front of the ramp generator, and one three way DIN socket on the rear panel.

Output   This multiway connector supplies the six high voltage signals which drive the piezoelectric stacks in the optical head. Since there are potentially lethal voltages present it should only be used with the supplied high voltage cable.

Monitor   This socket gives access to an attenuated (by a factor of 100) analogue of one of the six high voltage signals driving the stacks. The particular one delivered is governed by which of the monitor buttons is depressed.

Input   This socket allows the user to supply an external control signal in place of the internally generated ramp. It is used when the FPZ-3RG is in the ext mode. An input of 0-10V gives an output of 0-1000V.

Blanking   This socket supplies a signal which can be used either for triggering an external instrument (such as an oscilloscope) or for blanking the flyback portion of the ramp cycle on such an instrument. It takes the form of a positive going voltage (0-15V) at the time of reset (i.e. the top of the ramp in the auto mode)

External Start, Reset   These two sockets perform exactly the same function as the Start and Reset buttons. They are operated either by a +1.5V pulse, or by shorting their contacts.

Auxiliary input (on rear panel)   This allows the operator to supply an additional signal to the ramp stacks. This can take the form of, for instance, a feedback signal to improve the stability of the head, or a perturbing signal to introduce dither onto the transmission. There are three inputs, one for each of the ramp channels. An input of 0-10V gives an output of 0-1000V.

4 Installation and Operation

Component Checklist

Ensure that all components are present and in good condition. You should receive:
FPI-25 OPTICAL HEAD including adjustable base mount
ETALON MIRRORS in protective carrying case complete with
MIRROR INSERTION TOOL
FP-3 RAMP GENERATOR
DETECTOR FOCUSING UNIT
HIGH VOLTAGE LEAD :grey seven way cable used to deliver the high voltage control signals to the head.
MAINS LEAD : three core cable.
DETECTOR LEAD
CARRYING CASE/THERMAL ENCLOSURE

You will also need several (at least 3) standard BNC cables (not supplied), and an oscilloscope with at least 2 channels.

Choice of Operating Site

Although the FPI-25 is a relatively robust device, it must be remembered that it is an optical instrument and as such the choice of operating site is important. In particular the area must be clean and as dust free as possible, since optical coatings are by their nature sensitive to contamination by dust particles.

Since the instrument works by the interference of light, vibrations are to be avoided wherever possible. Their presence will result in the fringes becoming unstable. As a result of the open structure of the instrument it is quite sensitive to draughts and changes in temperature, causing drift and loss of parallelism, and thus the site should be as stable in temperature and draught free as possible.

If the case is used as a thermal enclosure these adverse effects will be considerably reduced, but not eliminated, and so it is always wise to minimise their occurrence by correct choice of site. To use the case in this way remove the handle and invert the lid, placing it on a stable surface. Remove the foam insert from the lid to reveal a rectangular recess into which the base of the instrument should be fitted. The thermal windows, if ordered should then be fitted into the cicular holes at either end of the case (blanked off with wooden inserts for shipping and storage). After removing its main foam insert, invert the case and lower it gently over the instrument as a cover.

Inserting the Mirrors

The mirrors used in Fabry-Perot instruments are of a very high quality, care must be taken when handling them. The area must be dust free and ***under no circumstances must the mirror surface be touched***. Any dust on the mirror surface can be removed by the use of a gentle air blower. ***Never attempt to clean the mirrors with physical contact or by the use of solvents as this will cause irreparable damage to the coating*.**

The mirrors are supplied housed in a case to ensure safe transport. Within the case are the mirrors with insertion tools fitted. The fitting of the mirrors is a relatively simple process which should provide no problems if handled with care. The procedure is as follows:

- Loosen the three clamp screws on the optical head and, using the cavity adjustment screw increase the separation between the main body of the interferometer and the differential assembly to about 100mm.
- Remove one mirror from the protective case. The mirror should have an insertion tool fitted over the reflective surface (it is a push fit and should be quite tight).
- Holding by the insertion tool screw the mirror cell into the threaded hole on the inner side of the main body of the instrument, facing the differential assembly. Take care when locating the screw threads on the mirror cell to those in the instrument that they do not become crossed. The mirror cell should screw in smoothly. Do not overtighten.
- Carefully remove the insertion tool, by gently pulling and turning clockwise, and repeat the procedure with the other mirror, fitting it to the differential assembly, facing the first mirror. Replace the insertion tools in the case for safe keeping.

Electrical Connections

Before making any electrical connections it is important to ensure that the voltage selection switch, on the rear of the FPZ-3RG, is set to the correct value for your locale. Once this is set the mains lead can be connected. Do not turn on the power yet.

- Connect the high voltage lead between the output socket on the ramp generator and the input socket on the optical head. The connectors are keyed to ensure correct attachment.
- If the detector focusing unit is to be used, connect the detector lead from the photodiode to the photodiode amplifier (for instance the Technical Optics DA-1 detector amplifier).
- Connect the amplifier output to one input channel (say channel 1) of the oscilloscope.
- Connect the monitor output to another channel of the oscilloscope (say channel 2) by means of a standard BNC cable (not supplied).

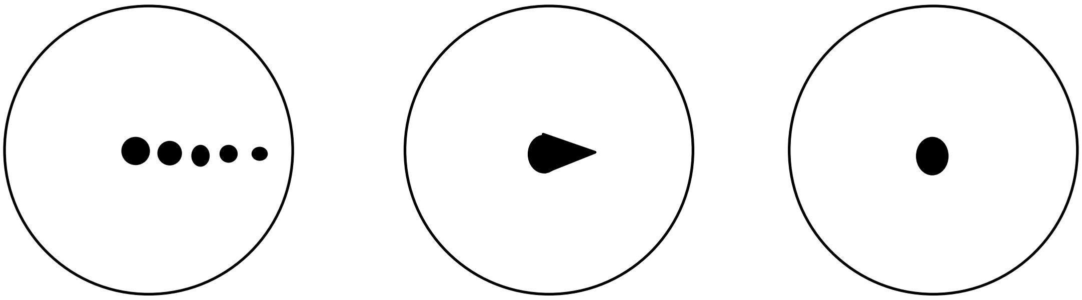
- ○ If desired connect the blanking output to the trigger input and/or the z-axis input of the oscilloscope.
- ○ If desired connect the external start and reset sockets to a suitable trigger source.

Alignment of the Optical Head

There are two aspects to aligning a tuneable Fabry-Perot. Firstly the etalon must be aligned to the input. The easiest way to do this is to use the source laser, if it is visible, and align the head so that the incident ray is reflected back on itself (either optical isolation or some slight misalignment may be necessary to prevent the back reflection from causing modal instability in the laser).

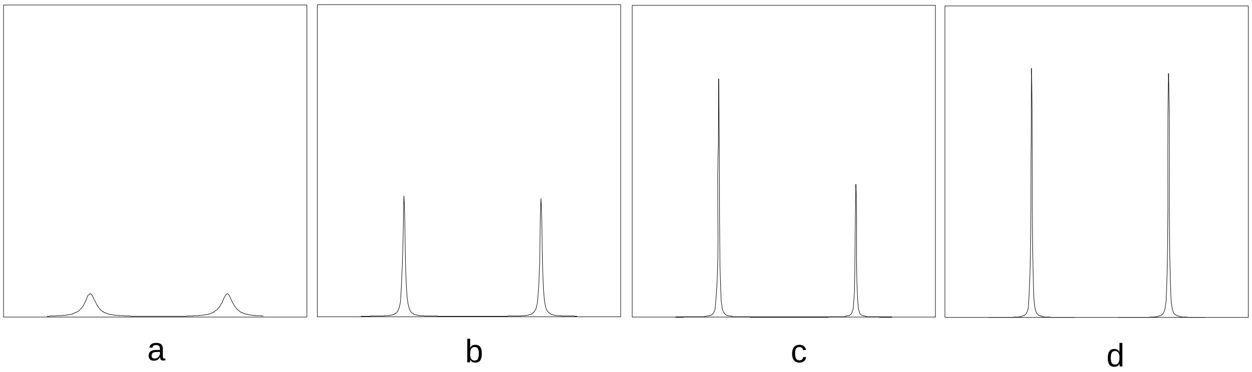
If the source is not a laser, or if it is invisible, then a visible alignment laser such as a HeNe, coincident with the optical axis of the source is very useful. The head is then aligned to this as above.

The second aspect of the alignment procedure is the alignment of the two plates to one another to give the high degree of parallelism required for effective etalon performance. The first stage in achieving this is best realised by using either the source of interest if it is visible, or the alignment beam if used, and shining it in the centre of the aperture. The detector focusing unit should be removed and the transmitted pattern should be displayed on a translucent screen such as ground glass, or a piece of white card. A pattern of dots similar to the that on the left below will be seen. The three differential screws should be adjusted until the pattern of dots first becomes a single blurred non-circular spot, and then the nearest to a single circular spot that can be achieved (the two patterns on the left below).



The detector focusing unit should now be replaced and the power switched on. Setting the scan mode to AUT, the RAMP SET VOLTS to its maximum value (that is fully clockwise) and RATE to their maximum values (that is fully clockwise) the MONITOR signal should be viewed (with one of the ramp channels A, B or C selected) and the oscilloscope should be adjusted until only one complete rising ramp cycle is visible (the oscilloscope timebase control may need to be adjusted slightly to remove any flyback portion of the ramp from the display). The detector amplifier output signal should now be viewed (the MONITOR is not needed now and may be switched off if desired).

The detector signal should look similar to that shown below in (a) (only two peaks are shown here for clarity, though more may be present in practice).



The differential screws should be adjusted slightly to maximise the height of the peaks (b). When no further improvement can be obtained with these coarse adjustments, the TILT and TRIM controls on FP-3 RAMP GENERATOR should be used. Firstly the height of the peaks at the bottom of the voltage ramp (i.e. the left of the oscilloscope screen) should be maximised by means of the TILT controls (c). The peaks at the top of the voltage ramp should then be maximised by means of the TRIM controls (d). This process should be repeated in a cyclic manner until no further improvement is achieved. The mirrors are now aligned and the instrument is ready for use.

Adjustment of the Mirror Spacing

One of the greatest advantages of the FPI-25 is the simplicity with which the free spectral range can be varied. This is done by means of a simple three step procedure:

- Loosen the three clamp screws. ***It is very important that these are undone before any attempt is made to turn the cavity adjustment screw. Failure to do so will cause damage to the three invar bars and make cavity adjustment impossible.***

- Turn the cavity adjustment screw to increase/decrease the mirror spacing to the desired setting.

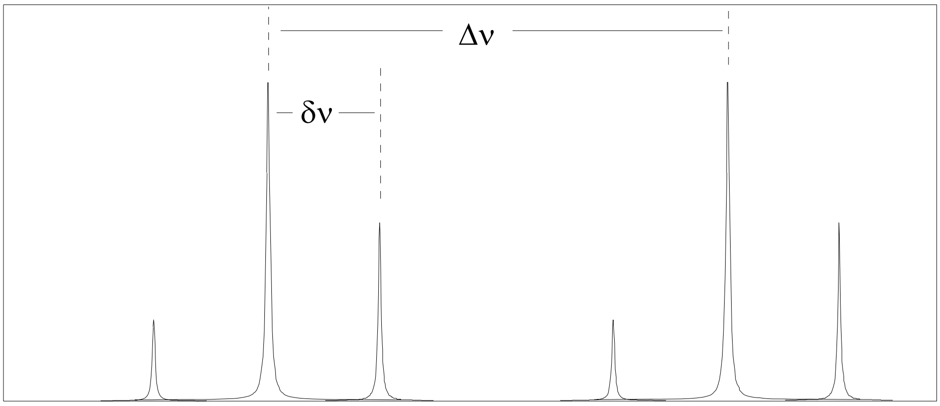
- Fasten the three clamp screws finger tight. ***It is important that the screws are not over tightened as this may cause damage to the surface of the invar bars****.*

The instrument should now be left for half an hour to an hour to let any residual mechanical stresses to dissipate. After this time the mirrors can be re-aligned by using the previously described technique.

Calibration of the mirror spacing

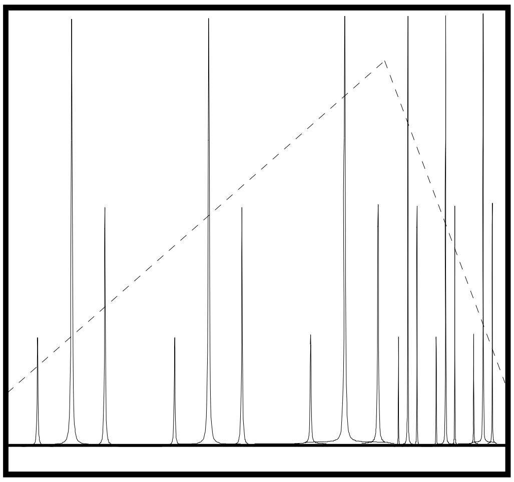
In order to accurately know the free spectral range of the FPI-25 it is necessary to have an accurate idea of the separation of the mirrors. To do this accurately the following procedure should be adopted.

- Set the mirror spacing to approximately 20 - 30mm, realigning the mirrors as before.
- Examine the output from a laser source of known mode spacing (a HeNe with two or three modes is ideal for this purpose).
- Using the scan range and tuning controls adjust the display until only two sets of modes are displayed.
- Since the mode separation, $\delta\nu$, is known the free spectral range, $\Delta\nu$, be easily calculated.
- Using vernier callipers, or some such accurate measuring instrument, measure the separation between the differential plate which carries one mirror, and the main body of the instrument (take care not to touch the mirror faces). Do this at three points about the circumference and take the average value.
- From the relation giving the free spectral range of a planar Fabry-Perot etalon, (FSR = c/2d) the actual mirror spacing can be calculated.
- The difference between this calculated value and the measured value gives a correction factor which can be applied to any future spacing, allowing the actual mirror separation (and thus the free spectral range) to be calculated for any value of the separation between the differential plate and the main body.

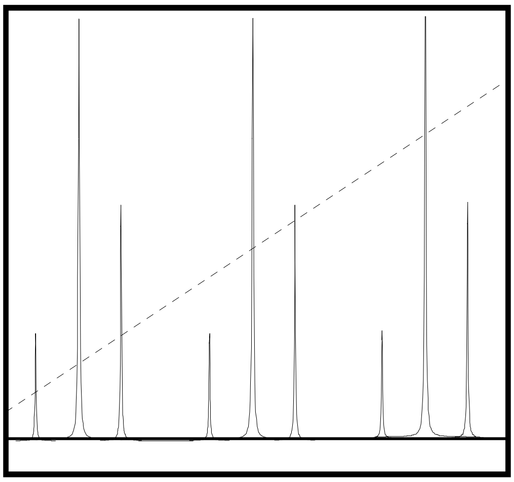


5 Understanding the Display

The pattern of peaks displayed on the oscilloscope can at first glance seem confusing, particularly if the flyback section of the ramp cycle is visible (trace a below). Adjustment of the oscilloscope timebase and the RATE in order to display only the rising part of the ramp cycle makes things slightly clearer (trace b)

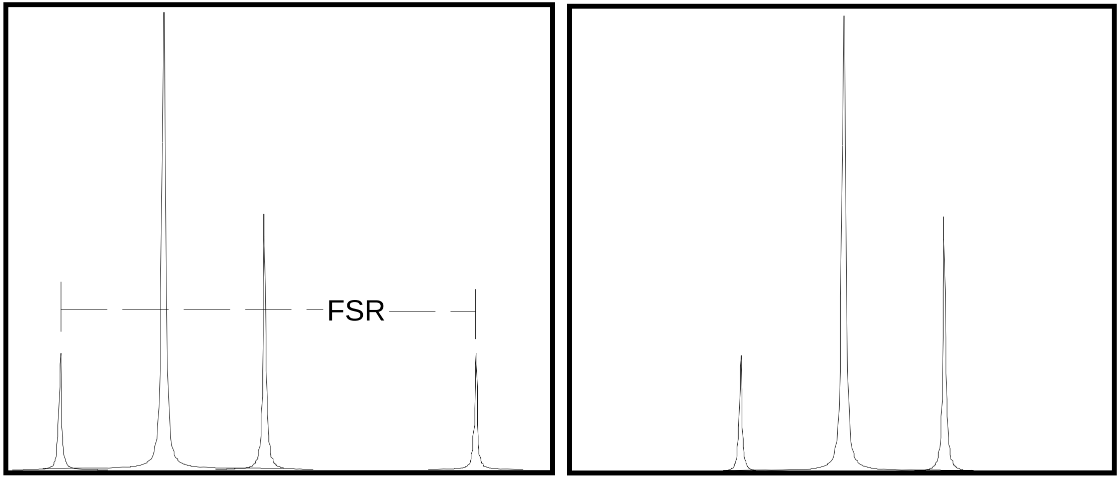


a



b

The pattern is seen to consist of (in this case) three identical sets of peaks. This means that the mirror spacing has changed by sufficient to scan the instrument through approximately three free spectral ranges. The information obtained from each free spectral range is identical, and so scanning more than one is not really a useful exercise. The SET VOLTS should therefore be reduced (and the OFFSET control and oscilloscope timebase adjusted) until only one complete spectrum plus one mode from the adjacent spectrum are visible (trace c). This allows the oscilloscope to be calibrated, since the distance (in frequency) between the single peak and its corresponding peak in the complete spectrum is equal to the free spectral range. After the oscilloscope has been thus calibrated, the OFFSET control should be used to alter the display to show only the spectrum of interest (trace d).



c

d

From trace d we can see that in this example the spectrum consists of three evenly spaced modes of different intensities, which is typical of the output of, for example a HeNe laser. The mode separation, and the relative amount of power in each mode can thus be assessed, and with the aid of a polariser their planes of polarisation can be deduced.

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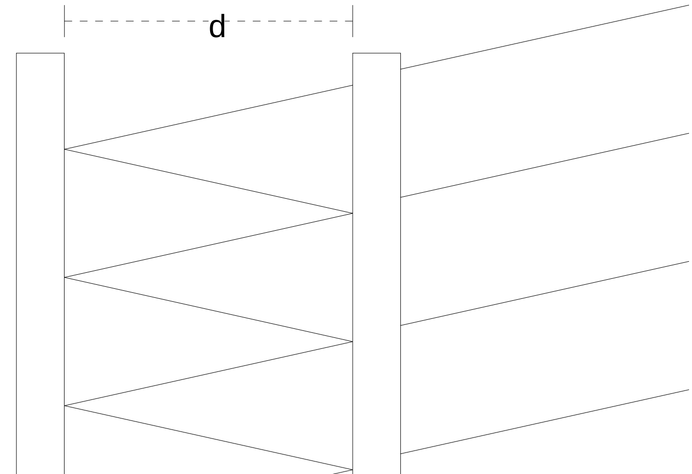
Appendix: Fabry-Perot Etalon Theory

This brief outline of some of the various aspects of the operation of the Fabry-Perot etalon is not intended to be an exhaustive treatment of the subject. A fuller explanation, including the derivation of the various formulae involved, can be found in any of a number of optical texts. For more detailed background on specifics of operation either Vaughan[i] or Hernandez[ii] is to be recommended.

The Fabry-Perot etalon is an interferometer made from two mirrors facing each other. There are two basic classes, those using flat mirrors, and those using spherical mirrors. The two most commonly utilised formats are:

1. the planar mirror configuration
2. the confocal configuration, a specific subset of the general spherical mirror format, in which the two identical spherical mirrors are separated by their radius of curvature.

The Planar Fabry-Perot



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The planar system, as illustrated above, consists of two flat mirrors of reflectivity R. Light enters from the left at an angle θ. The multiply reflected beams interfere, with constructive interference, and thus resonance occurring when the beams are all in phase with one another at the second mirror m2.

The equation governing the performance of the Fabry-Perot is called the Airy function and can be expressed for perfect lossless mirrors as follows:

$$T = \left[1 + \frac{4R}{(1-R)^2} \sin^2\left(\frac{\phi}{2} \right) \right]^{-1}$$

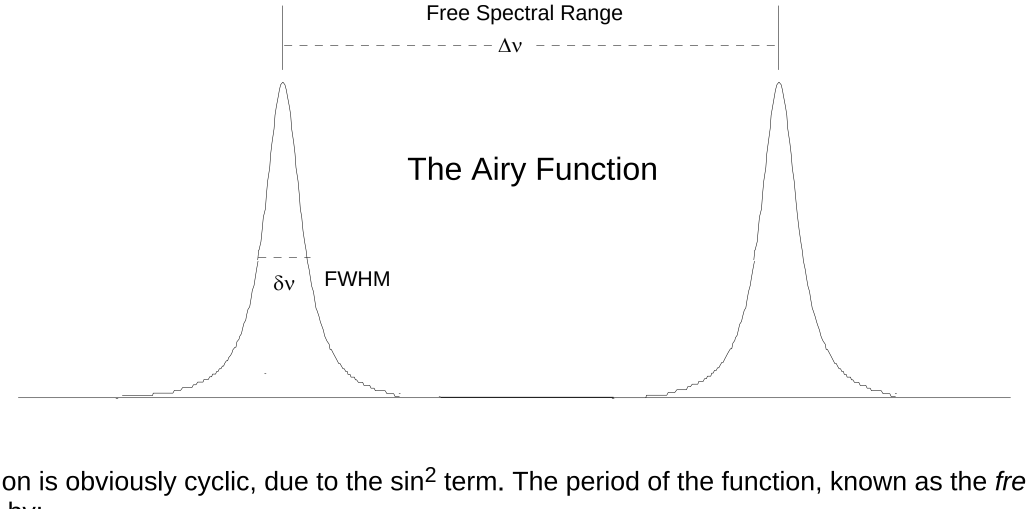
where ϕ is the round trip phase change and is given by

$$\phi = \frac{2\pi}{\lambda} 2nd\cos\theta.$$

If any phase change on reflection is ignored, resonance can be seen to occur when

$$2nd\cos\theta = m\lambda$$

where n is the refractive index between the mirror plates, and m is an integer. That is resonance occurs when a whole number of wavelengths fits into one round trip of the cavity.



The airy function is obviously cyclic, due to the $\sin^2$ term. The period of the function, known as the *free spectral range* is given by:

$$\Delta\nu = \frac{c}{2nd}$$, in terms of frequency

$$\Delta\lambda = \frac{\lambda^2}{2nd}$$, in terms of wavelength

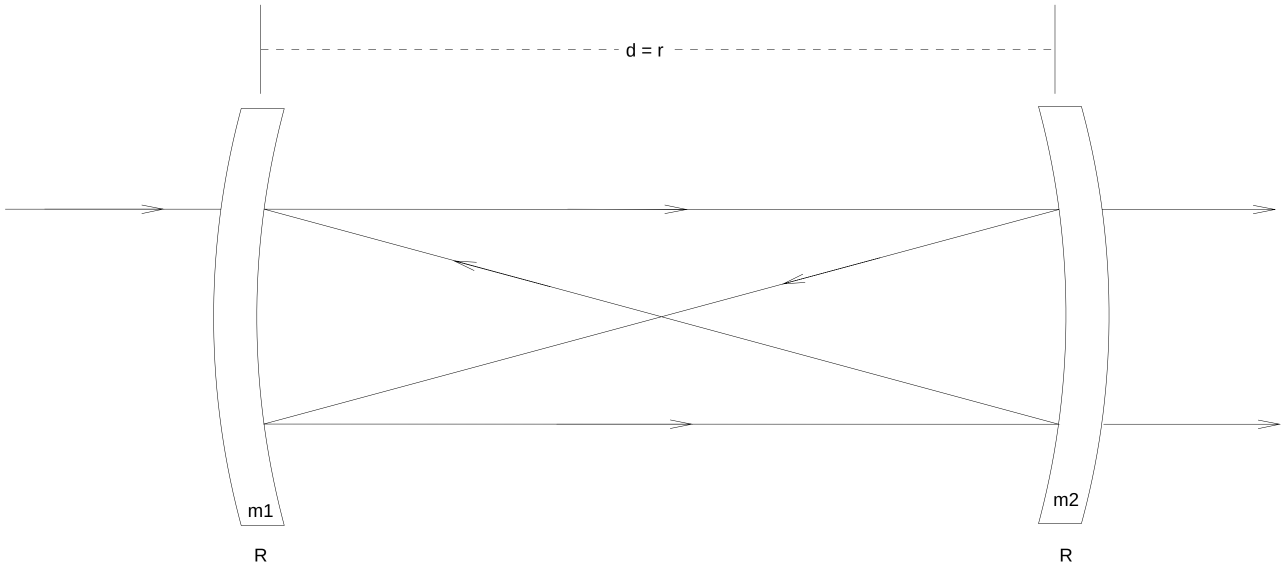
$$\Delta\psi = \frac{1}{2nd}$$, in terms of wave numbers (cm^{-1})

The sharpness of the resonance is basically governed by the reflectivity of the mirrors. A very useful term in describing the performance of an etalon is the *finesse*. This is the ratio of the free spectral range, $\Delta\nu$, to the full width at half maximum (FWHM) of a resonance peak, $\delta\nu$. This ideal reflectivity finesse, F_r, is given by:

$$F_r = \frac{\pi\sqrt{R}}{(1 - R)}$$

The resonance condition can be altered, and the etalon tuned, by changing any one of the wavelength, the spacing, the refractive index, or the angle of incidence. All of these factors have been used at one time or another to tune the resonance of Fabry-Perots. The two most commonly used schemes are varying d, usually by means of piezo-electric transducers or other such devices, or varying θ, the angle of incidence, either by tilting the etalon, or by dispersing the light with a lens or scattering material, and thus producing the set of characteristic circular fringes.

The Confocal Fabry-Perot



The confocal Fabry-Perot as illustrated above is formed by two spherical mirrors separated by their radius of curvature. The analysis of the operation is broadly the same as that for the planar etalon. There are some significant differences however :

- Each round trip takes four passes of the cavity instead of two, and so in the formulae for the Airy function and the free spectral range, 2d is replaced by 4d.
- Each beam undergoes twice as many reflections in each round trip, and so in the formulae for the Airy function and the finesse, R is replaced by R^2.
- The mode structure of the confocal cavity is degenerate, and therefore the device is insensitive to angle of incidence (at least in the paraxial approximation).
- The theoretical maximum transmission is of the order of 50%, instead of unity for the planar case.

We therefore have for the confocal cavity:

The Airy function

$$T = \left[1 + \frac{4R^2}{\left(1 - R^2\right)^2} \sin^2\left(\frac{\phi}{2}\right)\right]^{-1}$$

where ϕ is the round trip phase change

and is given by
$$\phi = \frac{2\pi}{\lambda} 4nd \cos\theta .$$

The reflectivity finesse
$$\mathrm{F_r} = \frac{\pi \mathrm{R}}{\left(1 - \mathrm{R}^2\right)}$$

and the free spectral range
$$\Delta\nu = \frac{c}{4nd} \quad \text{etc.}$$

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Defects and Their Effect on Finesse in Planar Etalons

The finesse relation above only applies in the ideal case of perfectly flat, perfectly parallel plates used in a perfectly collimated beam of light, an ideal situation which is never of course achieved. In real systems the finesse is limited by both the plate and beam quality.

There are three types of plate related defect which can have a detrimental effect on the finesse of the instrument by broadening the passband. These faults are characterised by the limiting defect finesse which arises as a consequence of their presence.

The first of the defects ascribed is the effect of spherical bowing of the plate, with a maximum displacement from the ideal plane surface δt_S .The defect finesse is given by :

$$F_{ds} = \frac{\lambda}{2\delta t_s} = \frac{K_s}{2}$$

with the magnitude of the defect expressed in terms of fractional wavelength ($\delta t_S = \lambda / K_S$).

The second defect is the presence of microscopic surface irregularities, which are assumed to have a Gaussian distribution in magnitude, of RMS deviation :

$$\sqrt{\left(\delta t_g^2\right)}$$

which, if expressed in terms of wavelength as before gives rise to a defect finesse :

$$F_{dg} = \frac{K_g}{4.7}$$

The third factor is the parallelism of the plates, with a skewness over the aperture of the etalon of $\delta t_p = \lambda / K_p$ giving rise to a defect finesse of :

$$F_{dp} = \frac{K_p}{\sqrt{3}}$$

In normal circumstances, these three defects are all present and their overall effect gives a total defect finesse F_d by combining thus :

$$\frac{1}{F_d^2} = \frac{1}{F_{ds}^2} + \frac{1}{F_{dg}^2} + \frac{1}{F_{dp}^2}$$

At small mirror spacings it is the effects of spherical and parallelism defects which are usually the limiting factor on finesse.

The light which passes through an etalon is, in general not perfectly collimated, and this also has the effect of broadening the halfwidth of the transmission peak. This leads to another limit on the finesse, originally termed the aperture finesse (so named since the aperture of the device effectively limits the range of angles over which the light can diverge). A preferable term is divergence finesse since most often it is the divergence of a laser source which is the limiting factor in instruments. The divergence finesse, F_{div}, is given by : $F_{div} = \dfrac{2\pi}{N\Omega}$ where Ω is the solid angle of the cone of light traversing the device, and N is the order of the interference. In terms of a laser's full divergence angle, θ :

$$F_{div} = \frac{\lambda}{d\theta^2}$$ where d is the mirror separation.

At large plate separations it is the effect of beam divergence which tends to be the limiting factor on finesse.

The outcome of these various limiting factors is to give rise to an effective finesse, F_e , which is always less than the ideal reflectivity finesse, F_r, and is defined by the relation :

$$\frac{1}{F_e} = \left[\frac{1}{F_r^2} + \frac{1}{F_d^2} + \frac{1}{F_{div}^2}\right]^{1/2}$$

Reduction in Transmission

An alternative way of writing the airy function is : $$T = \left[1 + \left(\frac{2F}{\pi}\right)^2 \sin^2\left(\frac{\phi}{2}\right)\right]^{-1}$$

This version of the function has the advantage that it describes the performance of an etalon (either planar or confocal) in real terms, when the ideal, reflectivity finesse F_r is replaced by the real, effective finesse F_e.

If this function is used it can be readily seen that a departure in performance from the reflectivity finesse does not just cause a reduction in the resolution of the instrument. A decrease in peak transmission is also apparent. The factor by which the transmission is reduced is approximately :

$$\left[1 - \frac{(1+R)}{2}\left(1 - \frac{F_e}{F_r}\right)\right]$$

This relation is true for a planar Fabry-Perot. An analogous one can be found for the confocal case by the usual method of replacing R with R^2.

Absorption in Coatings

Another effect which degrades transmission is the fact that even today's high quality multilayer dielectric coatings are not totally lossless. A small fraction of the light incident on the mirror is lost due to scatter and absorption. This can have a significant effect if very high reflectivity mirrors are used, when the transmission of the mirrors is of the same order of magnitude as the losses. The transmission is then further reduced by the factor : $\frac{T^2}{(1-R)^2}$

in the case of planar etalons, and

$$\left(1+R^2\right)\left(\frac{T}{\left(1-R^2\right)}\right)^2$$

in the case of confocal etalons.

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Choosing a Fabry-Perot

The above discussion hopefully gives some idea of the potentials and limitations of the Fabry-Perot interferometer. A few final points should be made on the important parameters to be considered when deciding on the form of instrument to use.

- It is almost always necessary to ensure that the free spectral range of the instrument is wider than the spectral extent of the source to be examined/filtered.
- If transmission is the most important parameter of the device, then finesse, and thus resolution or bandpass may have to be compromised, due to the constraints introduced by defect finesse.
- Conversely, if finesse is the prime concern then transmission expectations will probably need to be lowered.
- If a narrow free spectral range is required, then a confocal system is probably the best choice, since its diffraction losses are much smaller.
- If a high finesse (>100) is required a confocal system is usually best choice, since its lower diffraction losses and insensitivity to small angular misalignments make it easier to achieve high finesses.
- If a wide free spectral range (>10GHz) is required then a planar system is the best (and often only) choice, due to the fact that there is little to limit how close together the plates can be placed.
- If the device is to be used as a filter then a planar system is generally best, due to the relatively undistorted transmitted beam, and higher potential maximum transmission.
- Considering planar etalons, at small plate spacings (<1mm) a small aperture/beam spot size is desirable (smaller effect of spherical and parallelism defects), and at larger plate spacings a wider aperture is desirable (reduced beam divergence).

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[i] J. M. Vaughan ; THE FABRY-PEROT INTERFEROMETER History, Theory, Practice and Applications.
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[ii] G. Hernandez ; FABRY-PEROT INTERFEROMETERS
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