MELLES GRIOT

25mm Aperture
Variable Free Spectral Range
Fabry-Perot Interferometer
With
Interferometer Controller 13 FPC 001

Operation Instructions

CONTENTS

1 Introduction

The Melles Griot variable FSR Fabry-Perot interferometer is an instrument which can be scanned or tuned by means of piezo-electric transducers. The easily variable free spectral range, and interchangable mirror sets makes it an extremely versatile laboratory tool, with a wide range of spectroscopic applications. The complete system consists of an optical head (with removable mirror set) and an interferometer controller.

ELECTRICAL WARNING

This system is designed to operate from either 100-120volts or 220-240volts AC power supply input. <u>Do not</u> 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

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

Interferometer Controller

Power input

VOLTAGE	: 100-120 or 220-240 volts, via rear panel selection switch
FREQUENCY	: 50-60Hz
POWER CONSUMPTION	: 50 Watts maximum

Piezo-electric controls

SCAN RATE	: 15 - 220ms ramp risetime (15ms flyback)
SCAN RANGE	: 0 - 200 volts (nominal)
TUNING	: 0 - 200 volts (nominal)
HV OUTPUT	: voltage - 800 volts maximum current - 8mA maximum

Oscilloscope Controls

BLANKING	: 0 volts during ramp, +12 volts during flyback
TRIGGER	: +5 volts pulse at ramp start, -5 volts pulse at flyback start

Detector Amplifier

BANDWIDTH	: DC to 300kHz
NOISE	: 0.5mV RMS.
GAIN (TRANSIMPEDANCE)	: 0 - 75 V/mA , continuously variable
OFFSET	: 0 - ±40 μA signal zeroing and detector current offset
OUTPUT	: 10 volts maximum from 200Ω

Dimensions (nominal)

WIDTH	: 376mm
HEIGHT	: 130mm
DEPTH	: 239mm
MASS	: 7.2kg

Optical Head

Optical Parameters

CLEAR APERTURE	25mm
CAVITY SPACING	<0.5mm to 50mm
FREE SPECTRAL RANGE	>300GHz down to 3 GHz
FINESSE	dependent on mirrors and cavity configuration
MIRROR SCAN RANGE	1.0µm nominal
MIRROR TUNING RANGE	1.2µm nominal
SCAN LINEARITY	<5% nominal

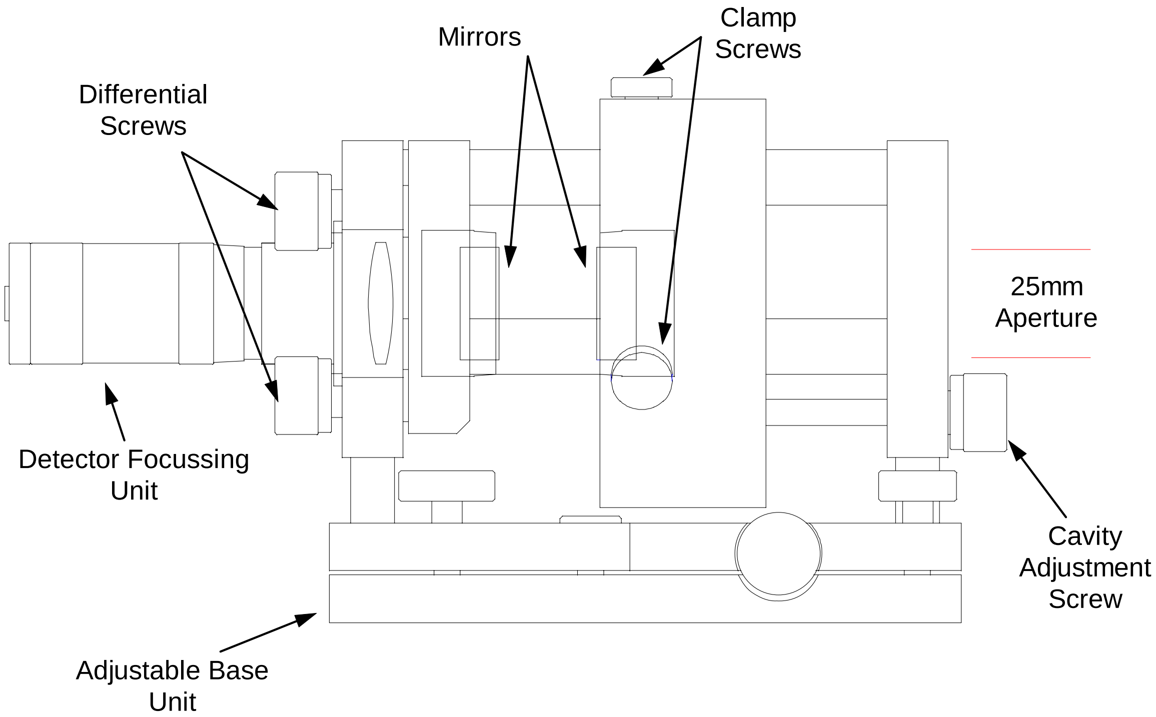
Dimensions (nominal)

LENGTH	230mm (with detector focussing unit) 170mm (without detector focussing unit)
HEIGHT	125mm
WIDTH	91mm
MASS	

3 System Description And Controls

As previously stated the system consists of two main parts.

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 supported by two Invar end plates.

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

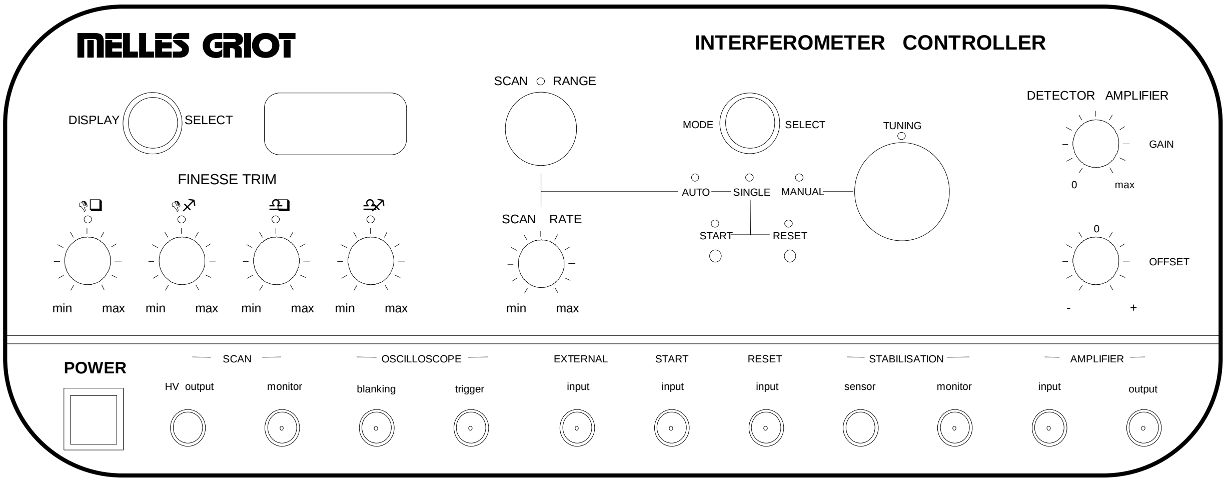
The main body of the instrument, including the other mirror and the piezo-electric transducers, slides on the three bars. The mirror spacing can be readily varied by undoing the three clamp screws, turning the cavity adjustment screw, and then re-tightening the clamp screws (see section 4).

A detector focusing unit can be attached to either 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.

Alternatively the head can be post mounted on posts with an M6 thread. To do this the optical head should be removed from the adjustable base assembly. This is achieved by undoing the two M6 screws which are accessed through clearance holes in the base The head can then be lifted carefully from the base unit to expose the M6 hole in the bottom of each of the support blocks.

Interferometer Controller



This component, generates and supplies the high voltages necessary to govern the movement of the mirrors in the optical head. DC components for mirror parallelism and tuning of the etalon are supplied when the head is in the MANUAL mode, and a ramping component is superimposed on these when in the AUTO or SINGLE mode. Provision is also made for the application of an external control signal, which would then be superimposed on any internally generated voltage.

A photodiode amplifier is also included in the interferometer controller for convenient amplification of signals from the photodetector, if used.

Control Functions

FINESSE TRIM There are four controls in this section, in two pairs. They govern the parallelism of the etalon plates, and thus the maximum finesse of the device. The left hand pair of knobs control the parallelism at the bottom of the ramp, by selectively adding DC levels to the three stacks. The right hand pair of knobs control the parallelism at the top of the ramp by selectively altering the ramp magnitude going to each stack. These two sets of controls thus eliminate errors due to mismatch in the length and extension of the piezo-electric stacks

SCAN RANGE This knob controls the amplitude of the voltage ramp, and thus the plate movement during a scan. It is continuously variable between 0 and about 3 microns of plate movement.The ramp is referenced to its central value, and so a reduction in range has the effect of 'zooming in' on whatever spectral feature is transmitted at the centre of the ramp.

SCAN RATE This controls the risetime of the voltage ramp, and thus the duration of the scan cycle. It is continuously variable between 15 and 220 ms. It has no effect on the flyback time which remains a constant 15 ms. The main use of this control is to match the scan to the timebase of an oscilloscope. Another effect is that the linearity of the scan is better at lower scan rates, though the effects of jitter and drift are worse at low speeds, and so a compromise will need to be sought.

TUNING This adds a DC level to whatever voltages are supplied to the stacks.
When in the AUTO (or SINGLE) mode the effect of this is to move any observed peaks to the left or right when viewed on an oscilloscope. This allows for convenient viewing of the desired spectral features when used in conjunction with the scan rate and scan range controls.
When in the MANUAL mode the tuning control allows the user to tune the filter to the desired passband.

MODE SELECT This button allows the operator to select the desired scanning mode of the instrument. There are three possible modes :

> Auto- in this mode the instrument repeatedly scans in a manner set by *SCAN RATE* and *SCAN RANGE*. *TUNING* controls the position in the ramp cycle of any transmission peaks.
>
> Single - in this mode the instrument will go through one scan when either the *START* button is pressed or the *START* input BNC socket is earthed. The flyback is initiated by either pressing the *RESET* button or earthing the *RESET* BNC input. As before the nature of the ramp is governed by the *SCAN RANGE* and *SCAN RATE* controls.
>
> Manual - in this mode there is no scan and the *TUNING* control is used to select the passband desired.

The first two modes of operation are primarily aimed at users requiring a spectrum analyser, and the third is best suited to those wanting a tuneable optical filter.

DISPLAY SELECT This button determines what is displayed on the LCD meter. The operation of this switch causes the display to cycle through the four FINESSE TRIM controls, the SCAN RANGE control and the TUNING control. The number displayed is a value between 0 and 1000 and is only a reference value. It does not represent an actual voltage.

Detector Amplifier

GAIN This is continuously variable between 0 and 75 V/mA transimpedance gain

OFFSET This adds a current in the range ±40 µA to the detector current, before amplification. This allows zeroing and offsetting of the signal.

The maximum output from the detector amplifier is ±10 volts from a 200 ohm output impedance.

Input/Output Sockets

SCAN HV OUTPUT (PLASTIC SEVEN-WAY) Supplies the high voltage control signals which drive the piezoelectric actuators in the optical head. Under normal working conditions it is perfectly safe, however *there are potentially lethal voltages at this socket and so nothing other than the supplied cable should ever be connected to this socket.(see electrical safety warning on page 2).*

SCAN MONITOR (BNC) Supplies an attenuated version of the ramp signal (0 - 5V) to assist in synchronisation of the oscilloscope when the device is in the AUTO mode.

OSCILLOSCOPE BLANKING (BNC) Provides a signal which can be used to suppress the oscilloscope display during the flyback portion of the ramp cycle. If desired this signal should be connected to the z-axis/z mod socket of the oscilloscope (it is usually found on the rear panel). The signal is 0 volts during the ramp part of the cycle, and +12 volts during the flyback.

OSCILLOSCOPE TRIGGER (BNC) Output consists of a +5V pulse at the ramp start and a -5V pulse at the flyback start. It should be used to provide stable and reliable triggering of the oscilloscope.

EXTERNAL INPUT (BNC) Allows the operator to supply an additional externally generated control signal, which will be superimposed on any internally generated signals (from the ramp and tuning controls). An input of 0 - 10V will give an output of 0 - 1000V at the HV OUT socket.

START INPUT (BNC) Duplicates the function of the start button, but allows the user to synchronise the scan with other external signals or instrumentation. The control is actuated by either shorting the contacts or supplying a +5V pulse to the input.

RESET INPUT (BNC) Duplicates the function of the reset button but allows the user to synchronise the flyback with other external signals or instrumentation. The control is actuated by either shorting the contacts or supplying a +5V pulse to the input.

STABILISATION SENSOR (METAL SEVEN -WAY) Not used with this instrument.

STABILISATION MONITOR (BNC) Not used with this instrument

AMPLIFIER INPUT (BNC) Input for the signal from the photodiode to the photodiode amplifier.

AMPLIFIER OUTPUT (BNC) Output of the amplified photodiode signal.

4 Installation and Operation

Component Checklist

Ensure that all components are present and in good condition. You should receive:
OPTICAL HEAD including adjustable base mount
ETALON MIRRORS in a protective carrying case complete with MIRROR INSERTION TOOLS
INTERFEROMETER CONTROLLER
DETECTOR FOCUSING UNIT
HIGH VOLTAGE LEAD :grey seven way cable used to deliver the high voltage control signals to the head.
FEEDBACK CABLE :Black braided covered cable with metal seven way connectors, used to deliver the feedback error signals to the interferometer controller
MAINS LEAD :three core cable.
DETECTOR LEAD :Fischer coaxial plug to BNC
CARRYING CASE/THERMAL ENCLOSURE

You will also need several (at least 3) standard BNC cables, and an oscilloscope with at least 2 channels.

Choice of Operating Site

Although the interferometer 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 protective case to ensure safe transport. Within the case are the mirrors with their 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 its maximum.
- Open the protective case to reveal the mirror insertion tools fitted over the mirrors (they are a push fit and should be quite tight).
- Using the mirror insertion tool lift one of the mirrors from the case.

- 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.

- Remove the insertion tool 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

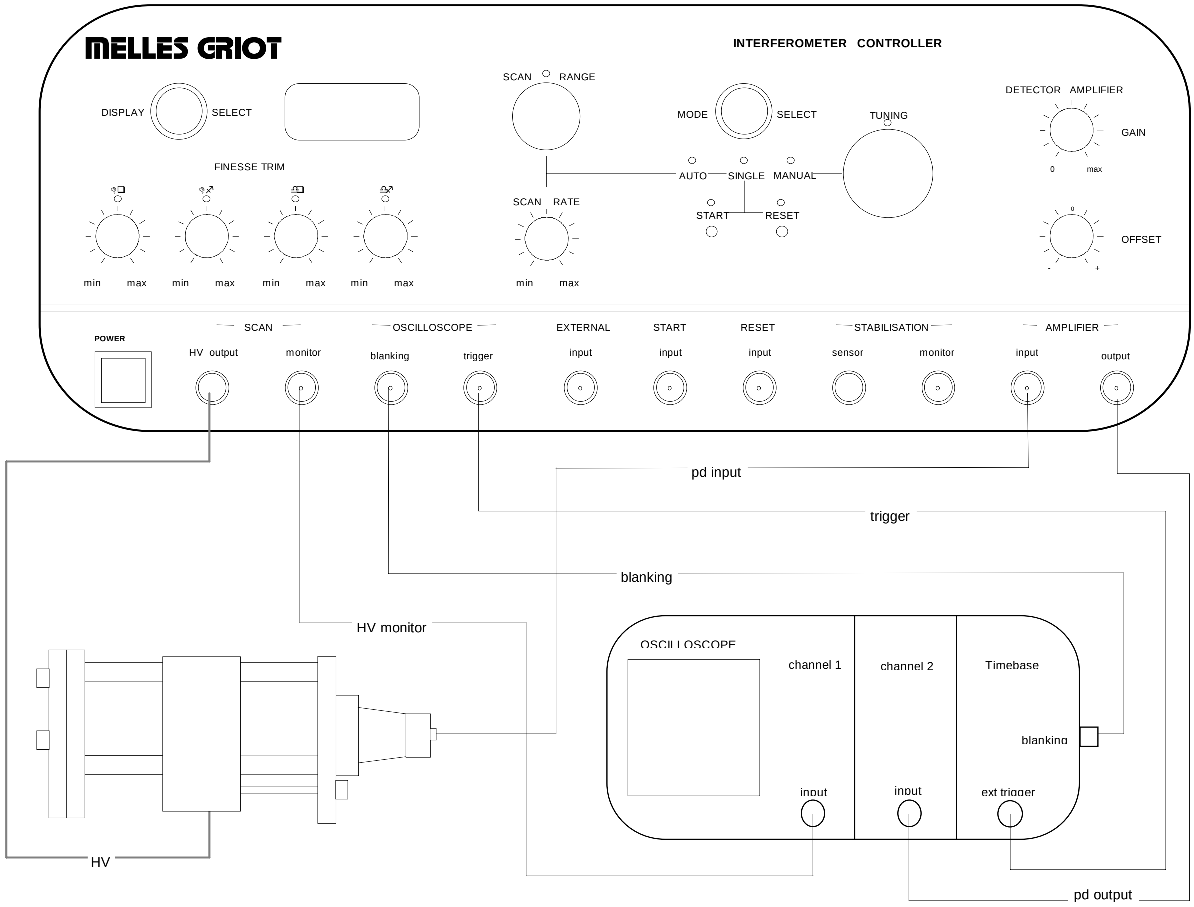
Before making any electrical connections it is important to ensure that the voltage selection switch, on the rear of the interferometer controller, is set to the correct value for your locale. Once this is set the mains lead can be connected. Do not turn on the power yet.

- Connect the high voltage lead between the HV OUTPUT socket on the ramp generator and the input socket on the optical head. The connectors are keyed to ensure correct attachment.

- Connect the detector lead from the photodiode on the detector focusing unit to the detector amplifier INPUT.

- Connect the scan MONITOR output to one channel of an oscilloscope (say channel 2) by means of a BNC cable.

- Connect the oscilloscope TRIGGER output to the external trigger input of the oscilloscope using a BNC cable.



- Connect the detector amplifier OUTPUT to another input channel (say channel 1) of the oscilloscope.

- If desired connect the START INPUT and RESET INPUT sockets to a suitable trigger source.

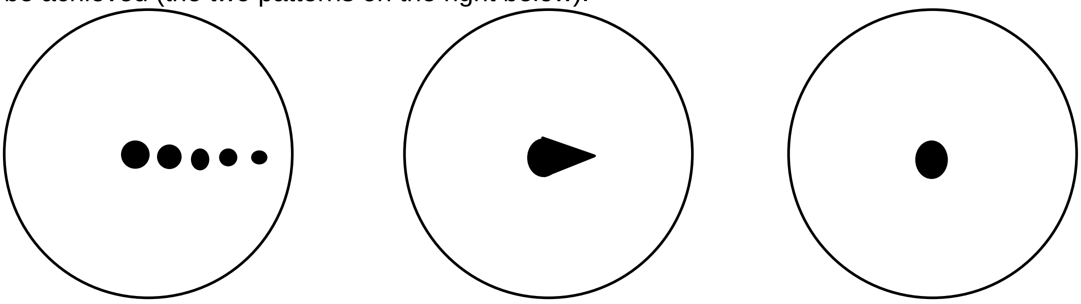
- If flyback blanking is desired connect the oscilloscope BLANKING output to the z-axis/z-mod input on the back of the oscilloscope.

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).

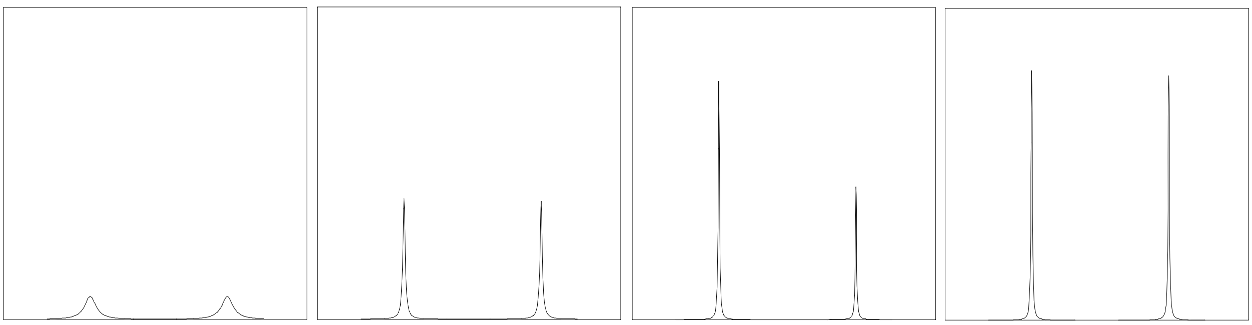
If the source is not a laser, or if it is invisible, then a visible alignment laser such as a HeNe, coincident with the optical axis of the source is very useful. The head is then aligned to this as above.

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 right below).



The detector focusing unit should now be replaced and the power switched on. Setting the scan mode to Auto and the SCAN RANGE and SCAN RATE to their maximum values (that is fully clockwise) the SCAN MONITOR signal should be viewed and the oscilloscope should be adjusted until only one complete rising ramp cycle is visible (the SCAN RATE 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 SCAN MONITOR SIGNAL 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).



a b c d

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 FINESSE TRIM controls on the INTERFEROMETER CONTROLLER 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 $\Delta\theta$ and $\Delta\phi$ controls (c). The peaks at the top of the voltage ramp should then be maximised by means of the $\delta\theta$ and $\delta\phi$ 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 this instrument is the simplicity with which the free spectral range can be varied. This is done by means of a simple three step procedure:

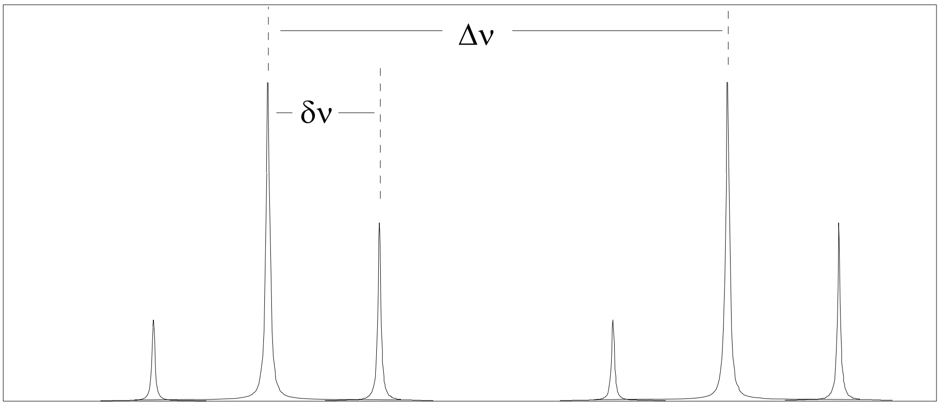
- **Loosen the three clamp screws**. *It is very important that these are undone before any attempt is made to turn the cavity adjustment screw. Failure to do so may cause damage to the three invar bars or other components and make cavity adjustment impossible.*
- Turn the cavity adjustment screw to increase/decrease the mirror spacing to the desired setting.
- Tighten the three clamp screws. *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

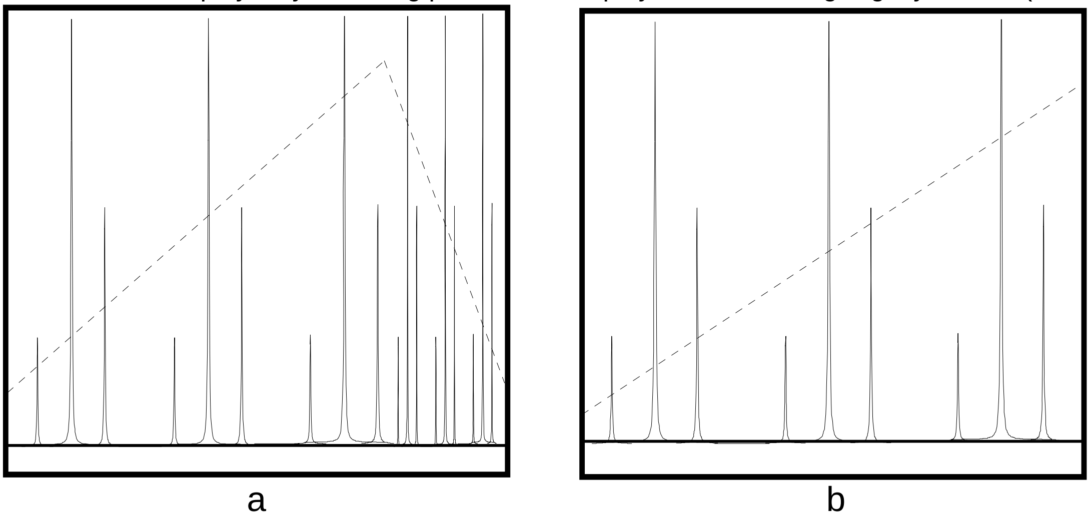
In order to accurately know the free spectral range of the interferometer it is necessary to have an accurate idea of the separation of the mirrors. To do this accurately the following procedure should be adopted.

- 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. 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.

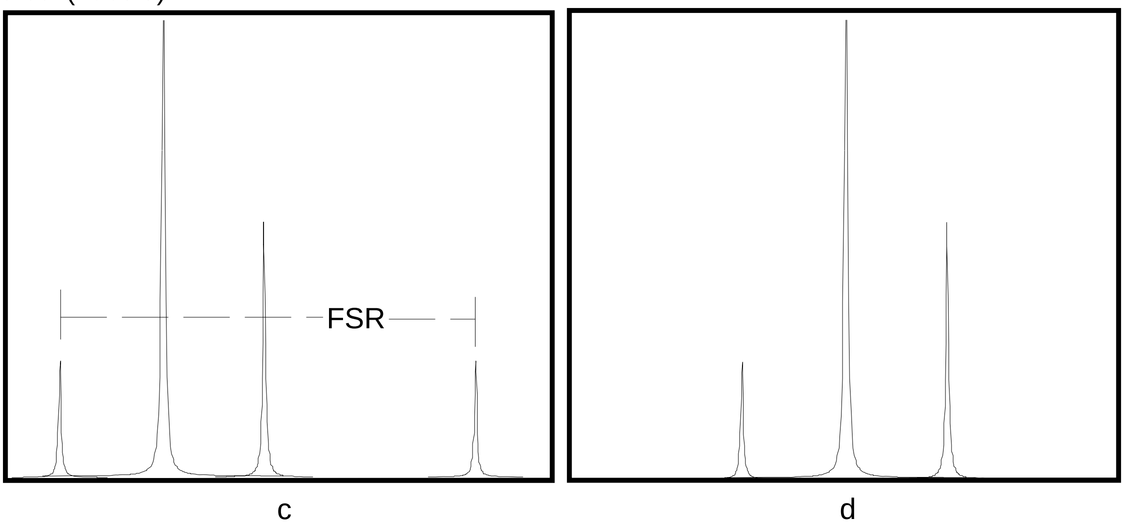


5 Understanding the Display

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 SCAN RATE in order to display only the rising part of the ramp cycle makes thing slightly clearer (trace 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 SCAN RANGE should therefore be reduced (and the TUNING control 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 TUNING control should be used to alter the display to show only the spectrum of interest (trace 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.

6 WARRANTY AND TECHNICAL SUPPORT

Warranty

All Melles Griot products are warranted against defective material and workmanship for a period of twelve months from the date of delivery, unless otherwise specified. Melles Griot will, at its own option, repair or replace without charge any item found to be defective.

Melles Griot supplies comprehensive technical data regarding all of its products. In addition technical assistance is available to aid customers in the selection and use of their products.

Specifications are current at the time of publication, however the right to change and improve products is reserved. There are no limited warranties of merchantability or of fitness for a particular purpose given in connection with the sale of any goods.

Melles Griot does not assume liability for consequential, incidental or special damages. The purchaser's sole and exclusive remedy and the limit of Melles Griot's liability for any loss whatsoever shall not exceed the purchase price paid by the customer for the unit(s) or equipment to which claim is made.

Service, Technical Support, Returns and Repairs

For technical support and service please contact the appropriate Melles Griot sales, service and technical support facility (see list below).

If goods need to be returned please contact the appropriate customer service department and obtain a Customer Return Authorisation Number (CRA Number) prior to any return/repair of goods. Goods must be returned in their original packaging with the CRA number displayed on the outside and all costs of shipment prepaid.

Returns will only be accepted within 30 days of receipt. Goods must be returned to Melles Griot in good condition. A restocking fee will be charged on all goods accepted for return to stock. Melles Griot is unable to accept the return of specially designed non-catalogued goods.

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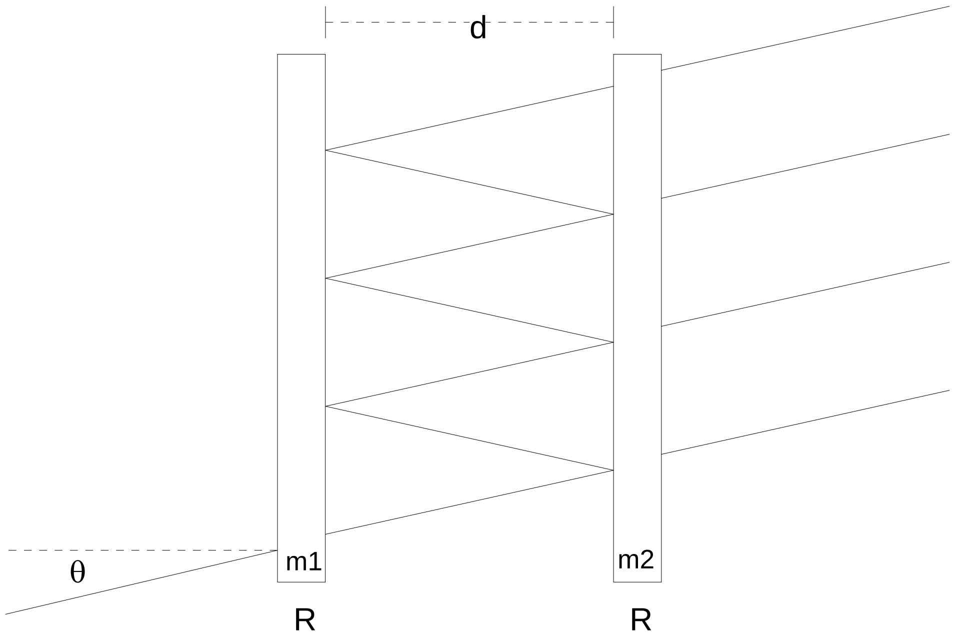
Appendix: Fabry-Perot Etalon Theory

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[1] or Hernandez[2] 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



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

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

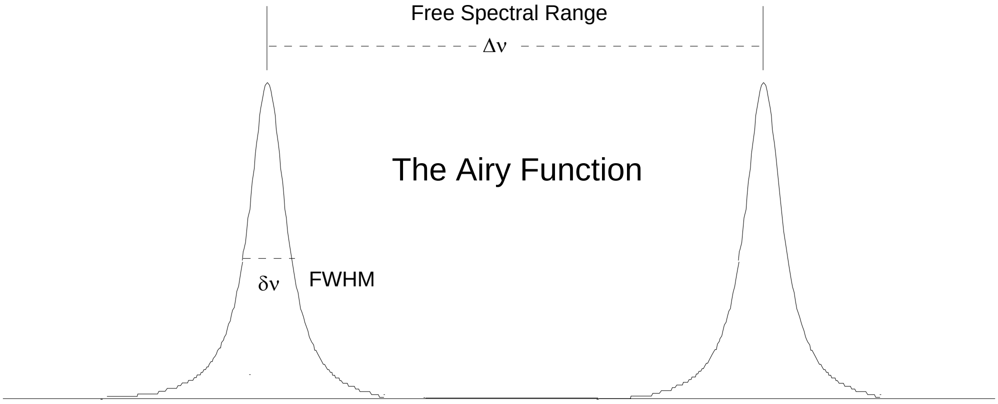
where ϕ is the round trip phase change and is given by

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

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:

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

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

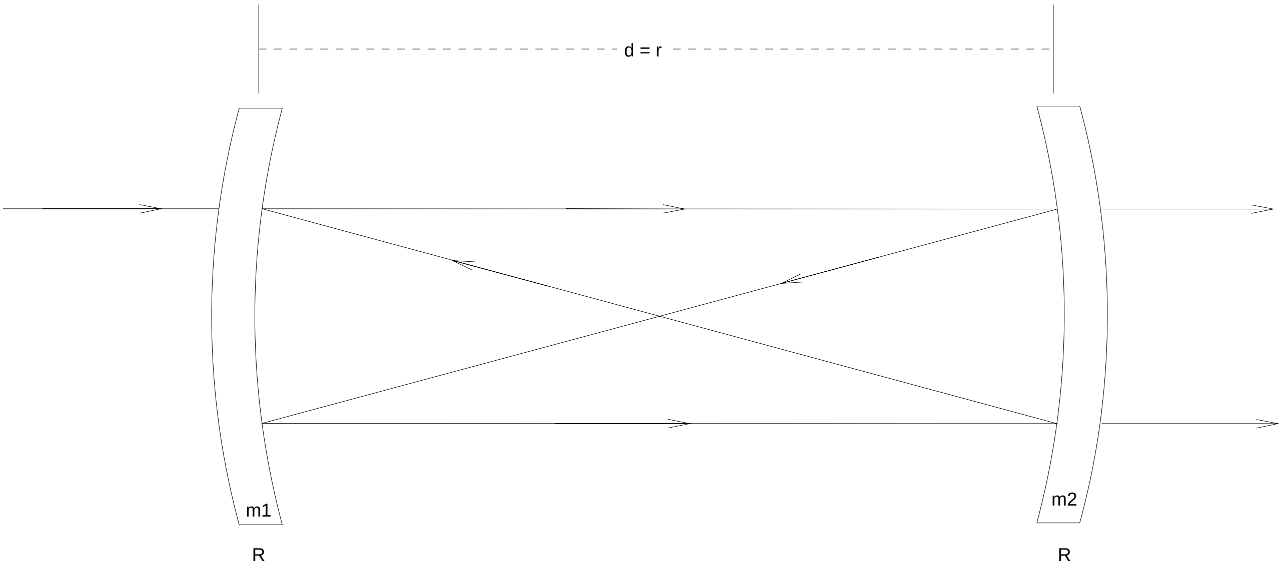
$$\Delta\psi = \frac{1}{2nd}, \text{ in terms of wave numbers (cm}^{-1}\text{)}$$

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

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

and the free spectral range

$$\Delta\nu = \frac{c}{4nd} \quad \text{etc.}$$

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 :

$$F_{div} = \frac{2\pi}{N\Omega}$$

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

$$(1+R^2)\left(\frac{T}{(1-R^2)}\right)^2$$ in the case of confocal etalons.

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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