Fabry-Perot Interferometer
Contents

1 Overview 3

2 Safety Issues 3
   2.1 Eye hazard .................................................. 3
   2.2 Electrical hazard .......................................... 3

3 Theoretical Background 4
   3.1 The plane mirror resonator ................................. 4
   3.2 The confocal resonator .................................... 7
   3.3 The stability of an optical resonator ..................... 8

4 Setup an equipment 10
   4.1 Equipment .................................................. 10
   4.2 Practical procedure of the experiments ................. 11
      4.2.1 Alignment of the Fabry-Perot resonator with spherical mirrors ... 11
      4.2.2 Characterization of the resonator with spherical mirrors .......... 13
      4.2.3 Alignment of the Fabry-Perot resonator using plane mirrors ....... 13

5 Goals of the experimental work 15
   5.1 Characterization of a confocal setup with $r = 75$ mm ........ 15
   5.2 Characterization of a confocal and concentric setup with $r = 100$ mm .... 16
   5.3 Characterization of the plane mirror setup .................. 16
   5.4 Investigation of the stability criterion ..................... 17

A Preliminary questions 17

B Final questions 17
1 Overview

The Fabry-Perot interferometer was invented in 1897 by Charles Fabry and Alfred Perot. In contrast to other, more conventional types like the Michelson or Mach-Zehnder interferometer, the Fabry-Perot arrangement acts as an optical resonator which may result in an extremely high spectral resolving power $\frac{\lambda}{\delta \lambda}$ up to $\sim 10^7$ for optical wavelengths $\lambda$. In this way, state-of-the-art Fabry-Perot cavities may exceed the resolution of classical diffraction gratings by a factor of $\sim 100$ and provide irreplaceable tool in particular for studies of the hyperfine structure in atomic spectra.

![Figure 1: Charles Fabry (1867-1945), left, and Alfred Perot (1863-1925), right, were the first physicists to construct an optical cavity for interferometry.](http://photonics.usask.ca/photos)

2 Safety Issues

2.1 Eye hazard

The HeNe laser used in this lab provides a cw output of 2.5mW. Please, use appropriate laser safety goggles in order to avoid damage to your eyes. It is recommended to discard any reflecting accessories like watches and jewelry. Do not look directly into the laser beam. Use the key switch at the laser power supply due to high voltage risks (20 kV).

2.2 Electrical hazard

The piezo actuator is operated at 150V, its power supply may cause an electric shock. Do not remove the associated BNC cable from the back of the control unit PTC 1000!
3 Theoretical Background

Fabry-Perot cavities make use of curved and plane mirrors as well, depending on their field of application. Whereas spherical mirrors are commonly employed for confocal schemes especially, the very basics of optical resonators are better studied by means of elementary plane surface reflections. We thus start with a brief description of that case and switch over afterwards to peculiarities of confocal cavities.

3.1 The plane mirror resonator

We consider two plane mirrors with equal reflectivities $0 < R < 1$ in a parallel arrangement separated by a distance $d$ from each other. A plane wave with an amplitude $E_e$ falls onto a mirror with an angle of incidence $\alpha$. At each mirror surface, the beam is partially reflected (amplitude coefficient $r < 1$) and transmitted. The scheme is sketched in Fig. 2. The phase difference $\Delta \phi$ between two adjacent beams $E_i$ and $E_{i+1}$ depends on the mirror distance $d$ and the refractive index $n$ of the dielectric medium:

$$\Delta \phi = \frac{4 \pi}{\lambda} n d \cos \alpha.$$  \hspace{1cm} (1)

We assume $n = 1$ for an air-filled resonator from now on. The output may be written as the coherent superposition of all amplitudes $E_i$ with $0 \leq i < \infty$, since an effectively infinite number of interfering waves is assumed for mirror reflectivities near 1. The total transmitted amplitude $E_a$ results as

$$E_a = \sum_{n=0}^{\infty} E_n = T E_e \sum_{n=0}^{\infty} R^n e^{-i n \Delta \phi} = \frac{T E_e}{1 - Re^{-i \Delta \phi}},$$  \hspace{1cm} (2)

Figure 2: Multi-beam interference at two parallel mirrors with the reflectivity $R$, separated by the distance $d$. 

![Figure 2: Multi-beam interference at two parallel mirrors with the reflectivity $R$, separated by the distance $d$.](image-url)
where the initial amplitude $E_e$ is transmitted twice: $E_0 = T E_e$. If there is no absorption, we have $T + R = 1$ and the transmitted intensity is given as

$$I_T = I_e \frac{(1 - R)^2}{(1 - R)^2 + 4R \sin^2(\Delta \phi/2)},$$

for an incident intensity $I_e \propto |E_e|^2$. Obviously, the phase difference from Eq. (1) determines the transmitted wavelengths $\lambda_m$ in the $m$th order:

$$m \lambda_m = 2d \quad \text{with} \quad m \geq 1,$$

for an incidence angle $\alpha \to 0$. This condition defines an optical resonator, tuned by an adjustable mirror distance $d$. We may write Eq. (3) in an alternative form normalized to the incident intensity $I_e$:

$$I_T = \frac{1}{1 + (2/\pi)^2 F_R^2 \sin^2(\Delta \phi/2)} \quad \text{with} \quad F_R \equiv \pi \frac{\sqrt{R}}{1 - R},$$

This function is plotted in Fig. 3. The *finesse* $F_R$ quantifies the optical quality of the resonator made of perfectly polished and adjusted plane mirrors. However, even well-aligned resonators with plane mirrors are severely restricted to $F \lesssim 50$ unless high-precision mirrors are used. The contribution of mirror irregularities which cause unwanted phase shifts at each reflection may be denoted by $F_q$. An elementary theory of these surface imperfections is discussed in Appendix A. From an experimental point of view, the finesse describes

![Figure 3: Normalized transmission of a Fabry-Perot resonator for various values of the finesse $F \leq 77$ as a function of the phase difference $\Delta \phi$. A monochromatic light source is presumed.](image)

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**Figure 3:** Normalized transmission of a Fabry-Perot resonator for various values of the finesse $F \leq 77$ as a function of the phase difference $\Delta \phi$. A monochromatic light source is presumed.
the ratio between the free spectral range (FSR) $\delta \nu$ and the spectral resolution $\Delta \nu$ of the instrument in the frequency domain:

$$F \equiv \frac{\delta \nu}{\Delta \nu} \text{ with } \delta \nu \leq c/(2d),$$

where $c$ denotes the vacuum velocity of light and the equality $\delta \nu = c/(2d)$ holds for plane mirrors. $\Delta \nu$ is usually defined as the full width (FWHM) of the resonance. The finesse $F$ also indicates the effective number of interfering beams within the cavity.

Since all light rays slightly diverge from their source due to the limited spatial coherence, plane-mirror cavities always produce concentric ("Haidinger") interference rings rather than single on-axis spots. Such rings are shown in Fig. 4a. From their radial intensity distribution, characteristic parameters of the setup may be obtained [1]. Following Fig. 2, the condition

$$2d \cos(\alpha_p) = m \lambda \text{ with } p = 1, 2, 3, \ldots$$

yields interference maxima for certain incidence angles $\alpha_p$ and integer numbers of $m$. Let the innermost ring be denoted by the index "0". From Eq. (7) we get

$$2d \cos(\alpha_p) - 2d \cos(\alpha_0) = (m - m_0) \lambda.$$

The parallel transmitted light is focused to the image plane by a lens with a focal length $f$. Thus, we get the diameter $D_p$ of the $p$th interference ring in the paraxial approximation:

$$D_p = 2f \tan(\alpha_p) \approx 2f \alpha_p \text{ for } \alpha_p \to 0.$$  

**Figure 4:** (a) Concentric interference rings of a Fabry-Perot cavity with plane mirrors for two closely spaced spectral lines [http://commons.wikimedia.org]. (b) Functional dependence of the squared diameters $D_p^2$ on the ring number $p$. 

6
Combining the Eq. (8) and (9), we get a linear dependence of the squared diameter $D_p^2$ on the ring number $p$ (see Fig. 4b):

$$D_p^2 = 4f^2 \frac{\lambda}{d}(p + \varepsilon) \quad \text{with} \quad \varepsilon \equiv \alpha_0^2 \frac{d}{\lambda}$$  (10)

The quantity $0 \leq \varepsilon < 1$ is called the *excess*, which can be obtained from the axis intercept of the graph in Fig. 4b. On the other hand, the slope $\tan \gamma$ of the function from Eq. (10) yields the ratio $\lambda/d$.

The visibility of the rings is defined by the following function:

$$V(r) = \frac{I_{\text{max}}(r) - I_{\text{min}}(r)}{I_{\text{max}}(r) + I_{\text{min}}(r)}.$$  (11)

### 3.2 The confocal resonator

The finesse as defined in Eq. (5) is valid for a constant cavity spacing $d$ across its lateral dimensions. On-axis beams would thus receive the same optical path length as parallel off-axis rays when propagating through the resonator. In contrast, easily aligned confocal arrangements as shown in Fig. 5a are made of spherical mirrors and cause various path lengths depending on the distance of the ray from the optical axis. Beams which enter the confocal cavity with an off-axis parameter $\varrho > 0$ would experience an optical path difference of $\varrho^4/4r^3$, where the radius of curvature is denoted by $r$ [1].

A general expression for the total finesse $F_t$ of confocal cavities may be thus written as

![Confocal Resonator Diagram](image)

**Figure 5:** (a) Geometry of confocal cavities made of two identical spherical mirrors. The mirror distance $d$ equals the radius of curvature $r$. The parallel input beam is effectively transmitted without divergence and $\rho$ is the off-axis parameter. (b) Amplitude of the electric field within the confocal resonator in the case of resonance.
\[
\frac{1}{\mathcal{F}_t} = \sqrt{\left(\frac{1}{\mathcal{F}_R}\right)^2 + \left(\frac{1}{\mathcal{F}_q}\right)^2 + \left(\frac{1}{\mathcal{F}_i}\right)^2} \quad \text{with} \quad \mathcal{F}_q \rightarrow \infty \quad \text{and} \quad \mathcal{F}_i = \frac{\lambda 4r^3}{4 \varrho^3},
\]
(12)

where mirror irregularities \( \mathcal{F}_q \) have been neglected. Obviously, the reflective term \( \mathcal{F}_R \) limits the total finesse for perfectly aligned resonators and on-axis rays: \( \mathcal{F}_t \leq \mathcal{F}_R \).

Fig. 5b gives an imagination of the electric field amplitude within the resonator. Note the strong field enhancement due to multiple back and forth reflections. A more detailed analysis considers the mode spectrum inside of the cavity. Following [1], the spatial amplitude function can be written by means of the Hermitian polynomials \( H_n \)

\[
A_{mn}(\vec{r}) \propto H_m(\sqrt{2w^{-1}x})H_n(\sqrt{2w^{-1}y})e^{-\frac{1}{2}(\rho/r)^2 - i\phi(\vec{r})} \quad \text{with} \quad m, n \in \mathbb{N}_0
\]
(13)

where the Gaussian beam width \( w(z) \) is given as \( w^2(z) = w_0^2(1 + (2z/d)^2) \) with \( w_0^2 = \lambda d/2\pi \). The polar coordinates are defined as \( \vec{r} \equiv (\rho \cos \theta, \rho \sin \theta, z) \), assuming the origin \( \vec{r} = 0 \) in the center of the cavity. Obviously, the Rayleigh length \( z_0 = \pm \pi w_0^2/\lambda \) coincides with the axial mirror position \( \pm d/2 \). Using \( \xi_0 \equiv 2z_0/r \), the phase function in Eq. (13) is in general given as

\[
\phi(\vec{r}) = \frac{2\pi}{\lambda} \left[ \frac{1}{2}(1 + \xi_0) + \left(\frac{\rho}{r}\right)^2 \frac{\xi_0}{1 + \xi_0^2} \right] - (1 + m + n) \left[ \frac{\pi}{2} - \arctan \left( \frac{1 - \xi_0}{1 + \xi_0} \right) \right]
\]
(14)

In case of resonance, \( \phi(\vec{r}) = q\pi \) with \( q \in \mathbb{N} \) is required. Since \( r \) equals the mirror distance \( d \) and \( \xi_0 = 1 \), we find on the optical axis (\( \rho = 0 \)) the eigenfrequencies from \( c = \lambda \nu_{qmn} \):

\[
\nu_{qmn} = \frac{c}{2d} \left[ q + \frac{1}{2}(m + n + 1) \right].
\]
(15)

For the free spectral range follows:

\[
\delta \nu = \frac{c}{4d} \quad \text{for} \quad 2q + m + n + 1 \in \mathbb{N},
\]
(16)

in contrast to plane mirror cavities which are characterized by the twofold free spectral range, as described by Eq. (6). It should be noted that the values \( \nu_{qmn} \) from are degenerated, since the integers \( q, m, n \) are not unique. Fig. 6 illustrates some modes.

### 3.3 The stability of an optical resonator

The stability of an optical resonator depends on the geometry of the system. Aside from confocal arrangements, several other configurations allow stable operation, e.g. the concent-
The general condition for a stable cavity is given as

$$0 \leq g_1 \cdot g_2 \leq 1 \quad \text{with} \quad g_i = (1 - d/r_i)$$

for two mirrors with the radii of curvature $r_1$ and $r_2$ with the stability parameters $g_i$. This equation is illustrated in Fig. 7. Resonators are stable, if their stability parameters lie within the gray area. Resonators, which parameters lie on the black line, are still stable, however small disturbances can cause the resonator to become unstable.

**Figure 6:** Amplitude distributions $A_{mn}(\vec{r})$ in the cavity center, i.e. $z = 0$, for the fundamental axial mode $\text{TEM}_{00}$ and higher transversal modes $\text{TEM}_{mn}$ with $1 \leq m + n \leq 3$ in the confocal resonator.

**Figure 7:** Stability of optical resonators consisting of two mirrors with the radii of curvature $r_1$ and $r_2$ separated by the distance $d$. The stable regions are gray underlayed and include the zero point.
4 Setup an equipment

4.1 Equipment

- With an output power of 2.5 mW, the He-Ne laser is classified as a class 3B laser. The laser provides a temperature-dependent doublet emission line around 632.8 nm whose components are linearly polarized in perpendicular directions.

- Three pairs of mirrors are provided, two spherical sets with radii of curvature $r$ of 75 mm and 100 mm, respectively; and one set of plane mirrors. The reflectivity of the mirrors is 96% for each set.

Please, do not touch the mirror surfaces! The coatings are extremely damageable and expensive. Handle the mirrors with care and wear single-use gloves whenever you mount and replace the mirrors. For cleaning - even from dust etc. - special one-way lens tissues must be used. Ask your supervisor!

In each mirror set, one of them is mounted on an axial piezo translator. The piezo ceramic actuator is driven by a maximum voltage amplitude of 150 V and provides an open loop sensitivity of approx. 0.05 nm for 5 mV noise and a maximum stroke of $13/8 \mu$m. The length of the actuator is 26 mm.

- The piezo actuator may be controlled with respect to the amplitude, an offset and the frequency when moved back and forth according to a periodical delta voltage. Figure

![Figure 8: Front panel of the control unit PTC 1000. In the "photo amplifier" unit, the gain may be varied within 0.1 and 2500. The frequency of the piezo triangle voltage can be set between 50 Hz and 100 Hz. [2]](image-url)
8 illustrates the front panel of the control unit PTC 1000. The high voltage connector (BNC) for the piezo is located on the back, as well as the piezo voltage monitor and the trigger signal output.

- The output signal of the silicon photo diode (Siemens BPX 61) is amplified using the control unit PTC 1000. The device has an active area of 2.65 x 2.65 mm² which is sufficient to collect the unfocused laser light (FWHM ≈ 1 mm) without excessive losses. Its spectral range of sensitivity is given as 400 nm ≤ λ ≤ 1100 nm, with a maximum around 850 nm.

**Although all measurements can be performed under daylight conditions, no direct sunlight or artificial room illumination should hit the photo diode in order to ensure an optimized contrast!**

- We use a Tektronix TDS 2012B oscilloscope with a bandwidth of 100 MHz. The amplified signal of the photo diode should be displayed on one channel, the second channel is reserved for the piezo triangle voltage. The oscilloscope is triggered externally by the control unit PTC 1000. Screen shots can be saved by using the oscilloscope software on the PC and the "get the screen" function.

- For beam expansion and imaging there are different lenses available: two convex lenses with focal lengths of $f = 60$ mm, $f = 150$ mm and one concave lens with $f = -5$ mm.

- A polarizer mounted in a rotation stage is provided for measurements of the mode spectrum of the HeNe laser.

- The CMOS camera (Thorlabs DCC1545M) has a resolution of 1280 x 1024 pixels with a pixel size of 5.2µm x 5.2µm.

### 4.2 Practical procedure of the experiments

#### 4.2.1 Alignment of the Fabry-Perot resonator with spherical mirrors

A thorough alignment of the resonator components along the optical axis is essential for successful measurements. In Fig. 9 an overview of the basic resonator setup is shown. It consists of the laser, the two resonator mirrors and the photodiode. Follow the following steps for the alignment of the resonator:

- Remove all tabs from the optical rail (1), except for the laser (3).

- Mount now the piezo-driven resonator mirror on the tab, make sure to place on the pinion gear. The clamping screw has to be slightly loosened in order to use the distance adjustment. Align now the back reflection using the adjustment screws (A).
Figure 9: Basic setup of the Fabry-Perot resonator: (1) optical rail, (2) laser with mounting, (3) laser power supply, (4) fixed resonator mirror, (5) piezo-driven resonator mirror, (6) control unit PTC 1000, (7) photo diode, not displayed: polarizer. (A) marks the adjustment screws of one of the mirrors, (B) marks the knob for distance adjustment. [2]

- In order to align the left resonator mirror (4), first, place it the other way around (pointing towards the laser instead of the second resonator mirror), and adjust the back reflection. Then, turn it around to normal position. The mirror distance should be coarsely set.

- Mount the photo diode (7) at the right end of the optical rail. The signal of the photo diode is put on channel 1 of the oscilloscope. On the control unit (6), the photo amplifier should be set to "DC coupling", the gain factor should be set to 50, and the gain variation to a center position.

- Switch on the piezo translator by setting the amplitude on the control unit (6) to a medium value. Frequency and offset should be set to a medium value, and the profile is set to a triangle function. The piezo voltage is put on the second channel of the oscilloscope.

- Slightly re-align, if needed, the back reflection of the resonator at the laser output.

- Now optimize your alignment using knob (B) for fine tuning the mirror distance and (A) for the angle of the mirrors until you reach the highest finesse. An ideal result is shown in Fig. 10. The amplitude of the piezo translator should be adjusted so that on
Figure 10: Oscilloscope display for two different cases: (a) controller switch on (no laser light reaches the photo diode). (b) Observable traces for an aligned resonator with a high finesse.

the oscilloscope only two sets of resonance peaks (consisting each of two modes) are within the rising slope of the piezo voltage. In case of any clipping of the resonance peaks, reduce the gain variation.

4.2.2 Characterization of the resonator with spherical mirrors

For the characterization of the resonator the distance of the interference peaks as well as the FWHM of the peaks has to be measured (see Fig. 10). This is done by using the CURSER function of the oscilloscope. For reference, save the image of the oscilloscope screen showing the measurement results (use the "get screen" function on the computer). Do the same for the measurement of the piezo expansion rate.

For the investigation of the modal spectrum of the laser use the provided polarizer, and mount it on the optical rail between laser (3) and the first resonator mirror (4). Take care, during the warm-up time of the laser tube, the mode spectrum of the HeNe emission varies. In particular, the relative intensities of the closely neighbored lines can oscillate on time scales of several seconds. You should wait with your measurements until the equilibrium is reached.

4.2.3 Alignment of the Fabry-Perot resonator using plane mirrors

For the plane mirror resonator the setup needs to be adjusted. To allow for an easier alignment, the beam needs to be expanded. Also, in order to measure the Haidinger rings, a camera instead of the photo diode is used. In Fig. 11 the setup for the plane mirror resonator is shown. The following steps are required for alignment:
Figure 11: Setup for the plane mirror resonator: (1) optical rail, (2) laser with mounting, (3) laser power supply, (4) fixed resonator mirror, (5) piezo driven resonator mirror, (6) control unit PTC 1000, (8) & (9) beam expander, (10) focusing lens, (8) CMOS camera, not displayed: polarizer. [2]

- Remove all tabs from the optical rail (1), except for the laser (2).

- Expand the beam, building a telescope using a concave lens (8) \((f = -5 \text{ mm})\) and a convex lens (9) \((f = 150 \text{ mm})\) with a distance of 145 mm. By adjusting the distance of both lenses, make sure the output beam has a constant diameter. Compare the beam diameter directly behind the telescope and at a further distance (at the wall).

- Now mount and align the resonator mirrors similar to the resonator with spherical mirrors: mount first the piezo-driven mirror (5), align the back reflection. Afterwards, mount the left resonator mirror (4) the other way around, and again align the back reflection. Set the mirror in normal position, optionally, correct the back reflection. Set the mirror distance to a value of \(d = 20 \ldots 30 \text{ mm}\).

- Mount the CMOS camera (11) at the end of the optical rail, and mount the focusing lens \((f = 60 \text{ mm})\) (10) in front of it. Set the distance to approximately to the focal length of the lens. Using the "uc480" software, display the camera image on the computer monitor.

- By adjusting the mirror angle (adjustment screws (A)) and the mirror distance (knob (B)), adjust the resonator so that you can see a concentric fringe pattern on the screen.
Set the polarizer into the laser beam (between beam expander optics (9) and the resonator (4)) and adjust the angular position so that you see only one mode (the two modes should have different ring diameters). Try to optimize the fringe pattern in symmetry, sharpness and interference contrast. For alignment, you can use the option for visualizing horizontal and vertical image cross section of the camera software. Finally, save the image for further analysis. Fig. 12 shows an example of a recorded camera image and the respective cross section.

![Figure 12: Analysis of the Haidinger rings: (a) recorded camera image, (b) cross section through the center of the ring system reveals the peaks and minima.](image)

5 Goals of the experimental work

In general, all calculations must be documented by original measurement data, i.e. tables, figures and appropriate print-outs or oscilloscope screen shots. Please, note important setup data like mirror distances and settings of the control unit PTC 1000 as well. Remember to estimate the errors of all measurement data you are taking.

5.1 Characterization of a confocal setup with $r = 75$ mm

1. Build up and align the Fabry-Perot interferometer with the confocal setup with $r = 75$ mm using a mirror distance of $d = r$. Measure the actual distance $d$ of the mirrors.

2. Measure the time distance $\delta \tau$ between two adjacent peaks of the same laser mode and measure the FWHM of both peaks (take the mean value!).

3. Calculate the finesse $F$, the free spectral range $\delta \nu$ and the spectral resolution $\Delta \nu$. Use the relation $\delta \tau/\Delta \tau = \delta \nu/\Delta \nu$.

4. Using the mirror reflectivity $R$ and $d = r$, calculate the theoretical values for $F_R$, $\delta \nu$ and $\Delta \nu$. Compare experimental and theoretical results!
5. Measure the voltage difference of the piezo for two adjacent peaks of the same laser mode and determine the piezo expansion rate \([\text{nm/V}]\) using Eq. (1). Compare with the theoretical value (obtained from maximum stroke and maximum voltage amplitude of the piezo actuator).

6. Determine the dependence of the modes on the polarization. Take screen shots of three different angular positions (do not forget to write down the positions!), documenting the extremal settings (both modes visible, only one mode (each) visible).

5.2 Characterization of a confocal and concentric setup with \(r = 100\) mm

1. Build up and align the Fabry-Perot interferometer with the confocal setup with \(r = 100\) mm using a mirror distance of \(d = r\) and \(d = 2r\). Measure the actual distance \(d\) of the mirrors.

2. Determine for both cases the time distance \(\delta \tau\) between two adjacent peaks of the same laser mode and measure the FWHM of both peaks (take the mean value!).

3. Calculate for both cases the finesse \(F\), the free spectral range \(\delta \nu\) and the spectral resolution \(\Delta \nu\). Use the relation \(\frac{\delta \tau}{\Delta \tau} = \frac{\delta \nu}{\Delta \nu}\).

4. Using the mirror reflectivity \(R\) and \(d = r\) as well as \(d = 2r\), respectively, calculate for both cases the theoretical values for \(F_R\), \(\delta \nu\) and \(\Delta \nu\). Compare experimental and theoretical results!

5.3 Characterization of the plane mirror setup

1. Setup and align the plane mirror resonator. Use a mirror distance of \(d = 20\ldots30\) mm. Add the camera to the setup in order to observe the Haidinger rings. Use the polarizer and record an image for each mode.

2. Use an appropriate software (e.g. Matlab) and extract a cross section (horizontal or vertical) through the center of the rings from the recorded image in order to reveal the position of the rings. Measure for each mode the diameter \(D_p\) in (mm) for three to five rings and plot \(D_p^2\) over the ring number \(p\). Using a linear fit (for each mode) you can determine the excess \(\varepsilon\) and the slope \(\tan \gamma\). Now you can calculate the mirror distance \(d\). Compare with your measured value!

3. Calculate the number of interfering wavelengths \(m\) in this setup.

4. Calculate the free spectral range \(\delta \nu\) of this setup.

5. Calculate the wavelength separation of the two modes. Use the relation \(\tan \gamma \propto \lambda/d\).
6. Determine the visibility as a function of the radius $I(r)$ for one mode using the intensity cross section of the rings from 2. Plot your result.

5.4 Investigation of the stability criterion

1. Calculate the stability criterion for all used combinations of mirrors and distances $(r=75\text{mm}: d=r; r=100\text{mm}: d=r$ and $d=2r; r=\text{inf}: d=20\ldots30\text{mm})$ used in the experiment.

2. Display the stability plot (Fig. 7) in your report and mark the corresponding points for the combinations used.

3. Additional task (not mandatory): Investigate the stability of a resonator with the mirror combination $r_1 = 75\text{ mm}$ and $r_2 = 100\text{ mm}$ with $d = (r_1 + r_2)/2$ and $d = (r_1 + r_2)$. Setup and align the resonator and verify its stability. Do not forget to measure the actual mirror distance $d$. Calculate also the stability criterion.

A Preliminary questions

- What is multiple-beam interference and how does a Fabry-Perot interferometer work?
- Why is the surface roughness of the mirrors limiting the finesse of the Fabry-Perot interferometer?
- What are Haidinger interference rings?
- In the plane mirror setup, what is the influence of the mirror distance $d$ on the spectral resolution and ring diameter?
- Why is the distance $d = r$ of the spherical mirrors used in the confocal setup (stability criterion)? Are other configurations possible?
- What is the influence of the beam diameter in the confocal setup on the finesse?
- How can you expand the beam using a convex and a concave lens?
- Why is a polarizer needed in the experiments?

B Final questions

(To be answered within either the theory or discussion part.)

- What is the advantage of a Fabry-Perot Interferometer in comparison to a Michelson or a Mach-Zehnder interferometer?
• What is the meaning of the FSR?

• Compare the performance (Finesse, FSR, spectral resolution, stability) of the different resonator setups!

• Derive the functional dependence of the Visibility $V$ on the finesse $F$ step by step using Eq. (5) and (11).

References

