OPTI 380A
Intermediate Optics Lab 10: Applications of the Michelson Interferometer

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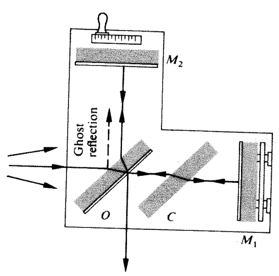
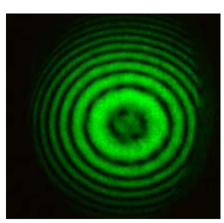
Michelson Interferometer Construction

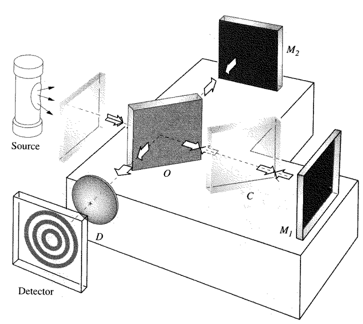


Division of amplitude

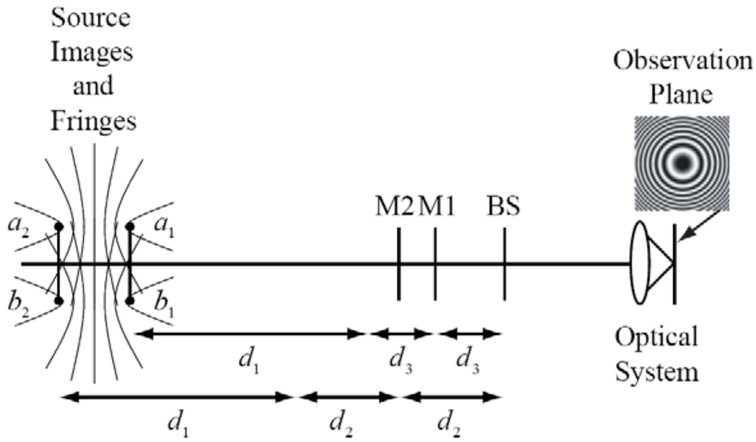
Compensator plate: equal path length and wavelength dispersion

Source: Extended, incoherent, quasimonochromatic (not a laser)

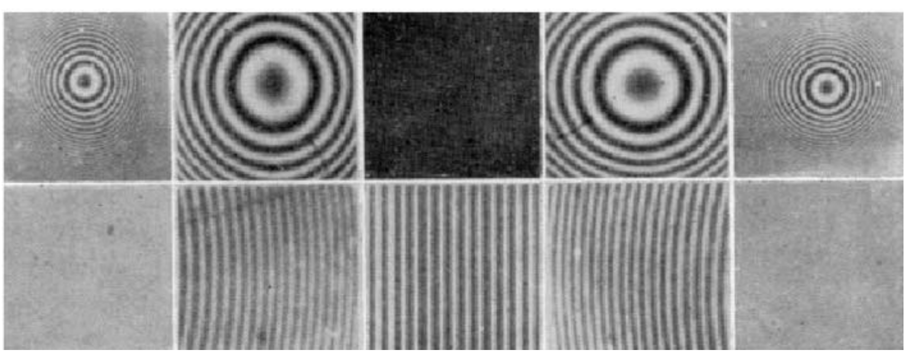




Michelson Interferometer from the Observer's Perspective



Michelson Interferometer Fringes



- ← **0** → +

M1 M2 OPD

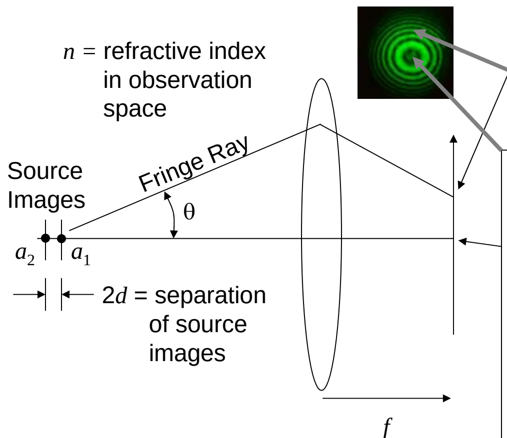
Top Row: | | Haidinger's Fringes

Bottom Row: \ / Fringes of Equal Thickness

Haidinger's Fringes

Observation of the On-Axis Fringe

(Haidinger's Fringes are also called *Fringes of Equal Inclination*.)



$\text{OPD} = 2nd\cos\theta$

$= m\lambda$ for bright fringe center.

On axis, OPD = $2d$ for $n = 1$, because $\theta = 0$. $2d = m\lambda$ for a bright fringe.

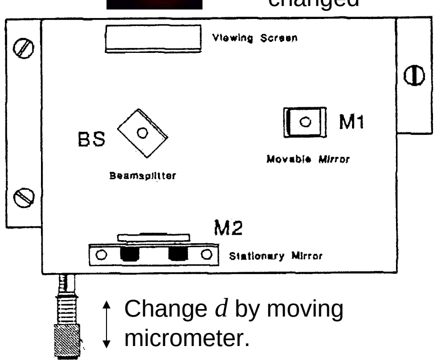
We can observe multiple oscillations of the on-axis fringe by changing the micrometer setting for mirror separation d.

m is typically very large, and it is difficult to know precisely. Changes in m are much easier to measure.

Michelson Interferometer Labs

- Calibration of micrometer using a HeNe laser (632.8 nm, max. drift ~0.01A)

On-axis fringe oscillates as d is changed



Change d by moving micrometer.

fringe formation

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

$$m\lambda = 2d \quad for \quad n = 1, \theta = 0$$

Change d and observe number of fringes ($m_2 - m_1$) that oscillate on axis.

$$d_2 - d_1 = \frac{(m_2 - m_1)\lambda}{2}$$

Beating of two wavelengths

Two sodium lines

$$I_1 = 2I\left[1+\cos\left(\frac{2\pi}{\lambda_1}2d\right)\right] \qquad I_2 = 2I\left[1+\cos\left(\frac{2\pi}{\lambda_2}2d\right)\right]$$

assume $\lambda_1 + \lambda_2 = 2\lambda \quad and \quad \lambda_1\lambda_2 = \lambda^2$

Normal fringe oscillation term

Total intensity is

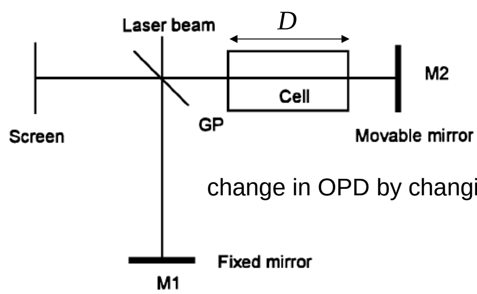
$$I_{total} = I_1 + I_2 = 4I\left[1+\cos\left(\frac{4\pi d}{\lambda}\right)\cos\left(\frac{2\pi\Delta\lambda}{\lambda^2}d\right)\right]$$

"Beat" term washes out fringes at periodic d

We see successive minimum to minimum visibility with mirror separation given by:

$$\Delta d = \frac{\lambda^2}{2\Delta\lambda}$$

Measurement of air refractive index



change in OPD by changing n

Air = 78% N_2, 20.9% O_2, 0.93% Ar, 0.03% CO_2

refractive index depends on mixture, humidity, pressure, temperature

- Table of refractive index

Material	Absolute Refractive Index
Air	1.0008
Water	1.330
Glass, soda-lime	1.510
Diamond	2.417
Ruby	1.760

Pressure dependence

- Refractive index varies linearly with density of gas.
- Higher pressure (P) air has higher refractive index.
- Assume linear relationship and vacuum index is 1.
- D is the cell length, observe on axis.

$$2n_2D - 2n_1D = m_2\lambda - m_1\lambda$$

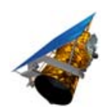
refractive indices at two different pressures

order numbers of two different fringes

- measure slope

$$SLOPE = \frac{\Delta n}{\Delta P} = \frac{n_2 - n_1}{P_2 - P_1} = \frac{(m_2 - m_1)\lambda}{2D(P_2 - P_1)}$$

Pressure Effects

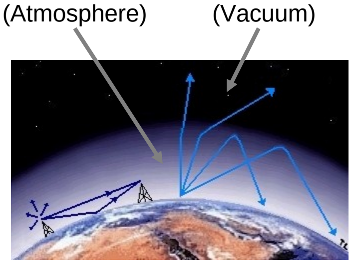


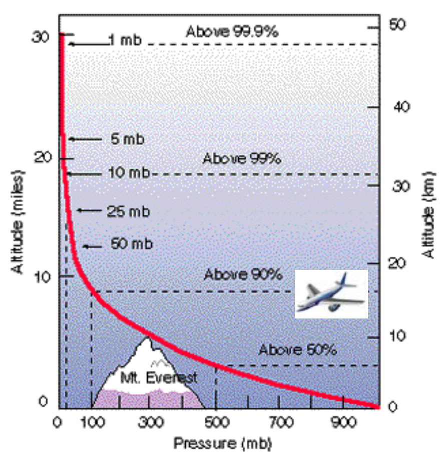
"GEOEYE-1" Satellite
(Altitude: 425 Miles)

Total Internal Reflection

Higher Index
(Atmosphere)

Lower Index
(Vacuum)

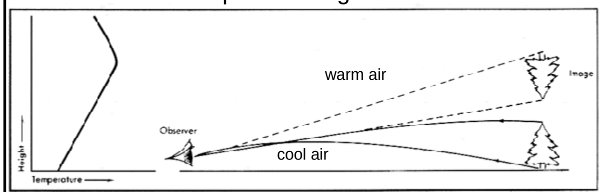




Temperature effects

refractive index decrease with increasing temperature

superior mirage



inferior mirage