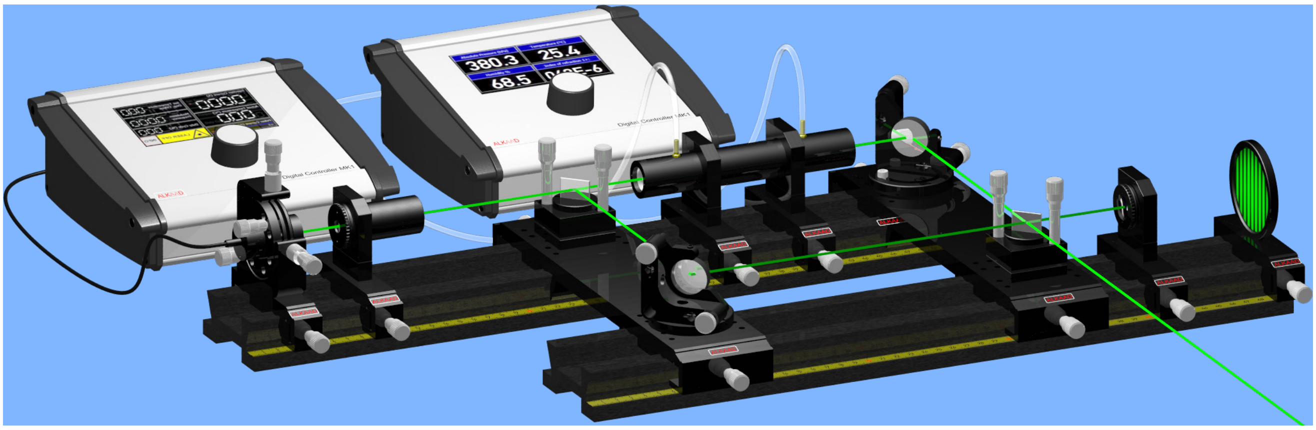
PE-0600 Optical Interferometer



Michelson Interferometer
Evacuable Cell
Interference
Beam Expander
White Light Interference
Index of Refraction
Coherence
Beam Splitter
Mach-Zehnder Interferometer
Edlen Formula
Wavelength of Light
Translucent Image Screen

In 1881 Albert Michelson used an interferometer to successfully disprove the theory of a universal ether that existed till then. Later on, he determined the length of the basic meter in units of light wavelengths with this set-up. Still, the use of interferometers in performing technical length measurements only reached significance after the discovery of the laser as a coherent light source. Today, high precision length measuring instruments have become an important tool for many areas of the machine building industry. The Michelson interferometer commonly uses one moveable mirror which is attached to the object for which a path length measurement on nm scale is performed. The Mach-Zehnder interferometer has no moving parts and the operation is based on the retardation of one beam with respect to the other by changes of the index of refraction of the probe medium. This experiment provides both, a Michelson and a Mach-Zehnder interferometer. The Michelson interferometer is used to demonstrate the classical interference patterns. For the Mach-Zehnder interferometer an evacuable tube is inserted into one of the beam paths and the interference pattern visualizes the changes of the index of refraction. The measurement of the index of refraction of air as a function of the pressure is made by using the vacuum pump.

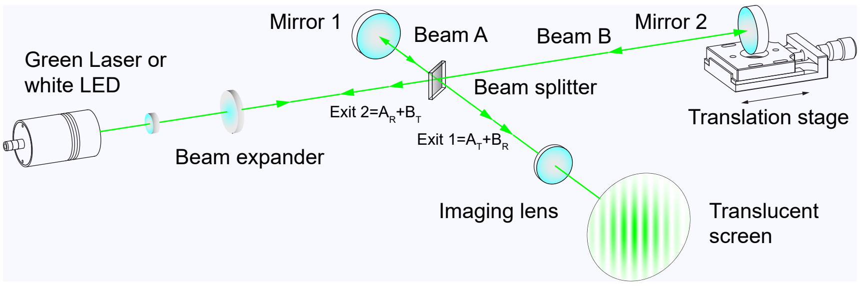


Fig. 4.29: Michelson Interferometer

The classical Michelson setup consists of the beam splitter, the mirror 1 and the mirror 2. The incident beam from either a green laser or a white light LED is split into two beams at the beam splitter. The returning beams from mirror 1 and 2 are imaged by means of a diverging lens onto a translucent screen. Mirror 2 is mounted on a translation stage for precise change of the related optical path, particularly for white light interference. The beam expander provides an enlarged beam with plane wave fronts resulting in a fringe pattern with a parallel structure. Circular rings are obtained, when the beam expander is aligned for curved wave fronts.

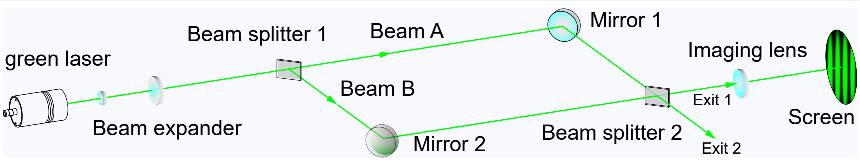


Fig. 4.30: Mach-Zehnder Interferometer

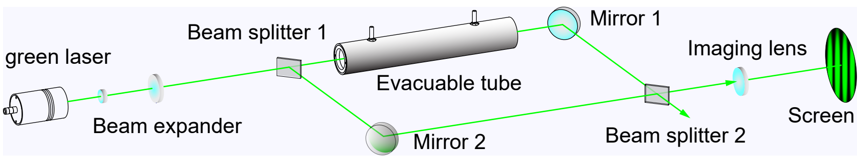


Fig. 4.31: Measuring the index of refraction as function of the pressure

The great advantage of a Mach-Zehnder interferometer lies in the fact that there are no back reflections from the interferometer mirror into the light source as it is the case with a Michelson interferometer. The back reflections create undesired fluctuations and frequency hopping of the laser. That is one of the reasons why the Mach-Zehnder Interferometer found much more application than the Michelson setup. The beam of the green laser is enlarged by a beam expander. At beam splitter (1) the expanded beam is split into two beams (A, B) with same intensity. One propagates to the mirror (1) and the other one is deflected by 90° and travels to the mirror (2). Both beams are combined again at beam splitter (2). 50% of each beam is transmitted and reflected. The interference pattern on the screen is created by the reflected part of A_R and the transmitted part of B_T at exit (1). At exit (2) a combination of A_T and B_R is available, however not used here. The bright to dark transitions of the interference pattern are proportional to the path or phase difference of beam A and B. In case of the Michelson, the path difference can be created by moving one of the mirrors, which is not possible with the Mach-Zehnder setup. Another way to introduce such a phase shift is to insert an optical transparent material in one arm of the interferometer and to change its index of refraction. Within this experiment a tube is used, which is filled by the surrounding air and can be evacuated. By counting the number ΔN of moved fringes for an pressure interval ΔP provides the information to calculate the index of refraction of air as function of the pressure. Additional sensors for temperature and humidity enables the comparison of the measured value for the index of refraction of air n with the results of the Edlen formula $n(P,T,H)$, whereby P is the pressure, T the temperature and H the relative humidity.

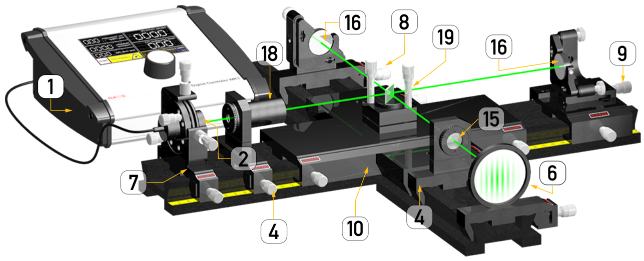


Fig. 4.32: Michelson Interferometer

A selected green laser (2) with high coherence is mounted into the adjustment holder (7). A beam expander (18) is used to enlarge the beam diameter as well as to provide plane waves. The adjustable beam splitter unit (19) splits the beam into two beams. After being reflected from the mirror (16) they are recombined by the same beam splitter. By means of the imaging lens (15) the interference pattern is imaged onto the translucent white screen (6) photographs can be taken by a standard smartphone camera. Both mirrors are mounted into precise adjustment holder to align the beams for best contrast. One mirror is mounted onto a translation stage (9). One turn of the screw moves the mirror 250 micro metre accordingly resulting in the shift of the interference pattern.

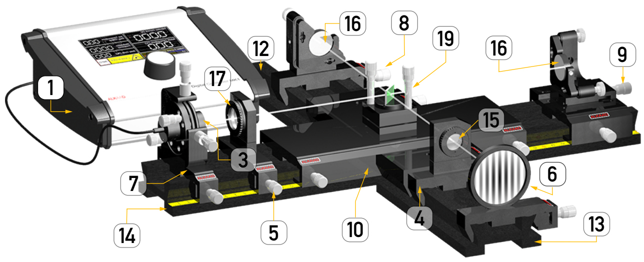


Fig. 4.33: White Light Interferometer

White light interference takes place only if the optical length of both interferometer arms have precisely the same optical length. To demonstrate this phenomenon, a white LED (3) is used. The light of the LED is collimated by an achromat (17) inserted into the mounting plate (5). By using a ruler the initial equal distance of the mirror is aligned. For the fine tuning the translation stage (9) is used. The translation stage has a travel range of 5 mm. However, to find and hold the proper position requires patience and experience. To find the right position in an easier way the optional photodetector (22) and the audio fringe detector (23) are recommended. The fringe detector contains an AC amplifier connected to a speaker. The input is the photodetector signal. In case interference occurs a burst of tones become audible. Turning back and forth of the adjustment screw of the translation stage and listening to the bursts the proper setting can be found. In the event of such a burst interference fringes appear and a fine tuning for best contrast may then be started.

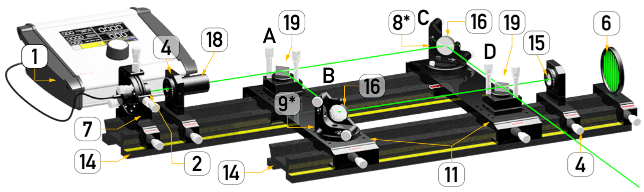


Fig. 4.34: Mach-Zehnder Interferometer

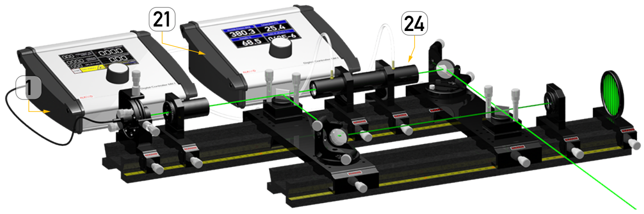


Fig. 4.35: Mach-Zehnder Interferometer with evacuable cell

Most parts of the Michelson interferometer are reused. Two bridge carrier (11) interlink two optical rails (14). The beam of the green laser (2) passes a beam expander (18) to increase the beam diameter and to provide plane waves. Subsequently the beam is split with the first adjustable beam splitter (19, A) into two beams. Mainly the reflected beam can be adjusted whereby the transmitted beam remains unaffected. The direction of the transmitted beam will be aligned by means of the 4 axes adjustment holder (7) in such a way that the beam hits the centre of mirror (16, C). The reflected beam is aligned in such a way that it hits the centre of the mirror (16, B). By means of the mirror adjustment holder (8* and 9*) both mirrors are aligned such, that the beams hit the centre of the beam splitter plate (D). The transmitted beam shows up on the translucent white screen (6) whereby the reflected beam is aligned by the fine pitch screws of its adjustment holder (19, C). The goal of the alignment is to achieve the collinearly propagation of both beams, which is indicated by the appearance of a rich contrast interference pattern. Also here, the photograph of the interference pattern can be taken from the rear of the translucent screen by any digital camera. After perfectly aligning the Mach-Zehnder interferometer, the evacuable cell (24, option) is placed onto the rail as shown in Fig. 4.35. It is recommended to operate the cell using the vacuum controller (22, option). The controller contains a precise pressure sensor with an operating range of 300 - 1100 hPa with an accuracy of ±0.1 hPa, a temperature sensor with an accuracy of ±0.1 °C and a humidity sensor with an accuracy of ±1%. The cell is connected via two flexible hoses to the vacuum controller (21). One hose is connected to the integrated vacuum pump and the other one via a valve to the rear of the controller, where either the surrounding air or another provided gas streams into the cell. The pressure inside is set by this valve and displayed on the controller. In addition, the temperature and humidity of the air or gas is displayed. Changing the pressure changes the index of refraction inside the cell and causes a shift of the interference fringes which needs to be counted visually. The measurement of the number of fringes as function of the pressure difference is recorded and transferred into a graph. From this, the index of refraction of air as a function of the pressure is derived and compared with the Edlen formula.

PE-0600 Optical Interferometer consisting of:

Item	*Code*	*Qty.*	*Description*	*Details page*
1	DC-0020	1	LED and Photodiode Controller	121 (2)
2	LQ-0020	1	Green (532 nm) DPSSL in ø25 housing	118 (1)
3	LQ-0200	1	White LED in ø 25 Housing	119 (6)
4	MM-0020	2	Mounting plate C25 on carrier MG20	93 (1)
5	MM-0030	1	Mounting plate C30 on carrier MG20	93 (4)
6	MM-0110	1	Translucent screen on carrier MG20	94 (10)
7	MM-0420	1	Four axes kinematic mount on carrier MG20	96 (24)
8	MM-0440	1	Kinematic mount ø25.4 mm on MG20	96 (25)
9	MM-0444	1	Kinematic mount 1”, translation stage on MG65	96 (26)
10	MP-0065	1	Carrier cross piece MG-65	92 (2)
11	MP-0082	2	Bridge connector for two rails plus riser plate	92 (3)
12	MP-0120	1	Optical bench MG-65, 200 mm	92 (6)
13	MP-0130	1	Optical Bench MG-65, 300 mm	93 (7)
14	MP-0150	2	Optical Bench MG-65, 500 mm	93 (8)
15	OC-0010	1	Biconcave lens f=-10 mm, C25 mount	98 (2)
16	OC-0100	2	Front face mirror in C25 mount	99 (7)
17	OC-0140	1	Achromat f=40 mm in C30 mount	99 (9)
18	OC-0320	1	Beam expander x2.7 in ø25 housing	100 (16)
19	OM-0010	2	Adjustable beam splitter	110 (2)
20	UM-PE06	1	Manual “Optical Interferometer”	
	Option (order separately)			
21	DC-0110	1	Vacuum Controller	123 (13)
22	DC-0120	1	Si-PIN Photodetector, BPX61 with connection leads	123 (14)
23	DC-0260	1	Audio fringe detector	124 (24)
24	OM-0820	1	Gas cuvette assembly	116 (42)

Highlights

Basic / advanced experiment

Intended institutions and users:

- Physics Laboratory
- Engineering department
- Electronic department
- Biophotonics department
- Physics education in Medicine