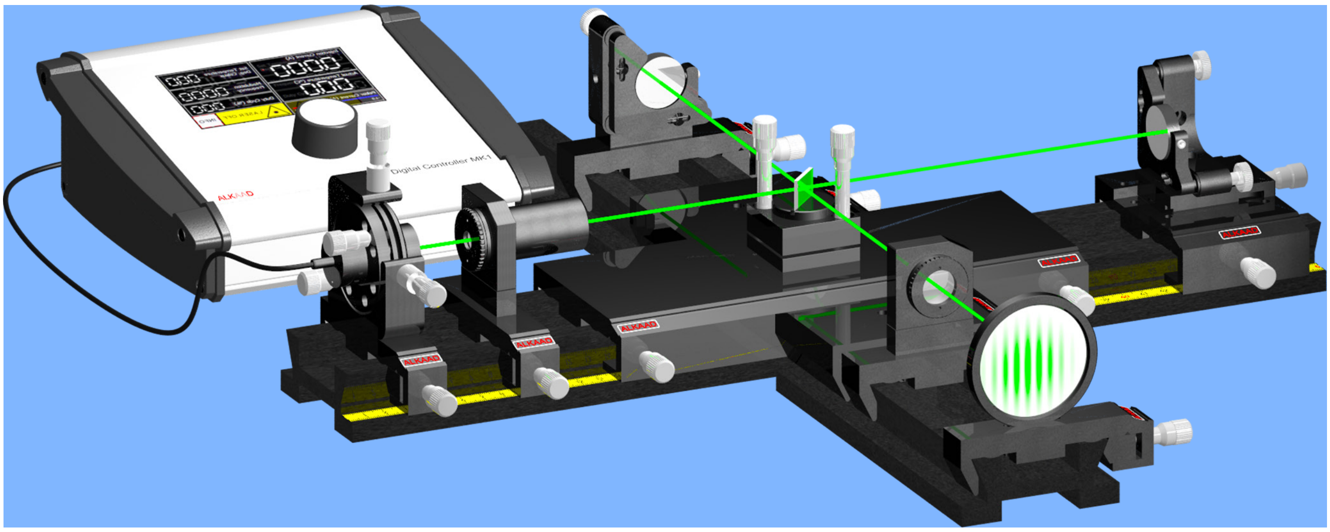
Laser Application

LM-0100 Michelson Interferometer



Keywords

DPSSL as coherent source
Fringe contrast
Spherical and plane waves
Properties of laser radiation
Coherence length
Two mode HeNe laser
Two beam interference
Fringe detection

Introduction

In 1881 A. A. Michelson constructed an interferometer, which later on also got his name, to counter prove successfully the theory of an universal ether assumed to be existing at that time. Later on he determined with this set-up the length of the basic meter in units of light wavelengths. Still, the promising use of interferometers in performing technical length measurements only reached significance after the discovery of the laser as a coherent light source. Today this contact less working high precision length measuring instruments have become an important tool for many areas of the machine building, industry like adjustment, final control, incremental displacement measurement for CNC machines, the control of machine tools and for calibration procedures. With the latest laser interferometers resolutions up to the nanometre range can be realised. The arrangement of the optical components has changed with regard to the original Michelson interferometer by the use of lasers as light sources. But with some exceptions, generally the two beam arrangements of Michelson is used. Within the frame of this experiment first the classical interferometer is setup and the interference pattern are observed on a screen. To understand the observed interference pattern the properties of Gaussian beams, wave fronts, radii of curvature and the superimposition of waves are discussed in the theoretical part of the manual. Starting with a simple model of monochromatic radiation, the spectral bandwidth of a light source will be considered and the influence on the contrast of the interferometer discussed. The coherence length is introduced, defined and measured.
The applied HeNe-Laser emits two orthogonally polarised modes with a coherence length of about 18 cm. In a second step the Michelson setup is upgraded to an technical interferometer.

How it works

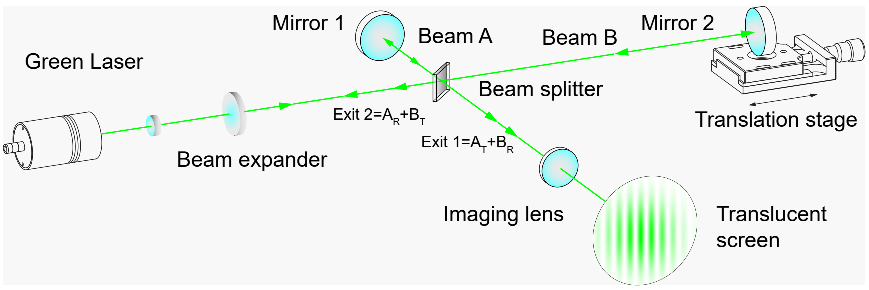


Fig. 2.1: The classical Michelson interferometer setup

The classical Michelson setup consists of the beam splitter, the mirror 1 and the mirror 2. The incident beam from a green laser 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 or circular pattern.

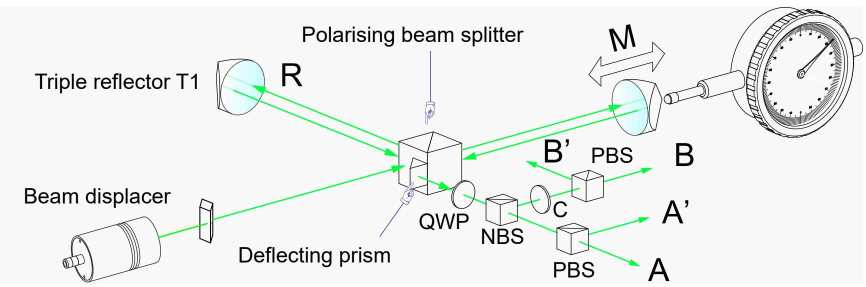
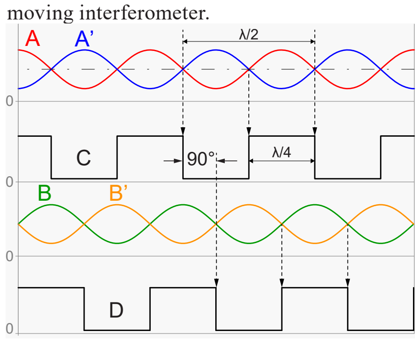


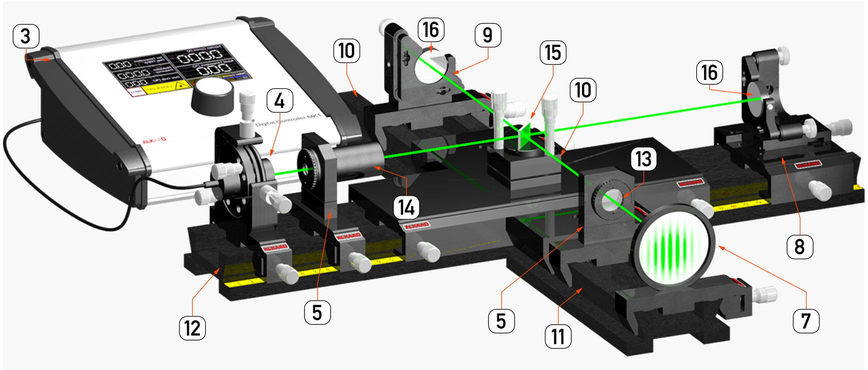
Fig. 2.2: The technical laser interferometer for length measurement

The technical interferometer is a refinement of the Michelson interferometer. To avoid any undesired back reflection into the laser source, triple reflectors are used instead of flat mirror. Furthermore the technical interferometer needs a mechanism for reliable counting of the fringes, even if the movement direction (M) is reversed. For this purpose optical quadrature signals are required. The superimposed waves of the reference arm (R) and (M) are leaving the interferometer at the deflecting prism. Both orthogonal linear polarised waves are converted into opposite circular polarisation by the quarter wave plate (QWP). In a next step the intensity is split into two equal parts, whereby one part travels to the channel (A) and the other to channel (B). In channel B a quartz polarizer turns the polarisation of channel B by 90° to channel A. In this way the required phase shift of 90° for the quadrature encoding is achieved. In addition, a polarizing beam splitter in each channel provides a 180° phase shift which is used to become independent of varying contrast of the moving interferometer.



A comparator converts the A, A' and the B,B' into the quadrature signal C and D which are counted by a quadrature counter.

Description of the components

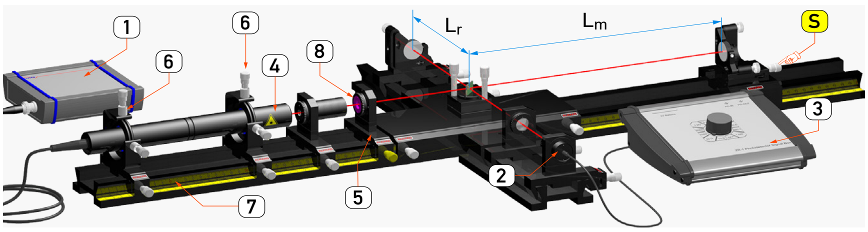


The Michelson interferometer is formed by the two mirrors (16) which are mounted into adjustable mounts (9). One mirror is mounted to a translation stage (8) attached to a carrier. The adjustable (10) beam splitter (15) divides and combines the beam of the green laser source (4) into two equal parts. The superimposed beams pass through the expansion lens (13) and are imaged onto the translucent screen (7) from which the pattern can be photographed by a simple digital camera. The light source is connected to the digital controller to provide the necessary current and temperature control. By means of the beam expander (14) the radius of curvature of the wave fronts can be changed from plane to spherical to create either stripes or circular interference pattern. From this interference pattern a photo can be taken by ordinary digital cameras of a smart phone and inserted into the student's report.
When moving the translation stage (8) the interference pattern changes accordingly. Real measurements can be carried out with in combination with the technical extension (38). For the measurement of the index of a gas like air we recommend the "PE-0600 Optical Interferometer" on 75.

LM-0100 Michelson Laser Interferometer consisting of:

Item	*Code*	*Qty.*	*Description*	*Details page*
1	CA-0080	1	Optics cleaning set	127 (12)
2	CA-0450	1	BNC connection cable 1 m	130 (28)
3	DC-0040	1	Diode laser controller MK1	121 (4)
4	LQ-0040	1	Green (532 nm) stabilized Laser, 40 mW	119 (3)
5	MM-0020	2	Mounting plate C25 on carrier MG20	93 (1)
6	MM-0100	1	Target Cross in C25 Mount	94 (9)
7	MM-0110	1	Translucent screen on carrier MG20	94 (10)
8	MM-0444	1	Kinematic mount 1", translation stage on MG65	96 (26)
9	MM-0440	1	Kinematic mount C30 on MG20	96 (25)
10	MP-0050	1	Cross-piece MG-65 with kinematic mount ø 25mm	92 (1)
11	MP-0130	2	Optical Bench MG-65, 300 mm	93 (7)
12	MP-0150	1	Optical Bench MG-65, 500 mm	93 (8)
13	OC-0010	1	Biconcave lens f=-10 mm, C25 mount	98 (2)
14	OC-0380	1	Beam expander x8 in ø 25 mm housing	100 (18)
15	OC-0500	1	Beam splitter plate ø 25 mount	101 (29)
16	OC-1200	2	Laser mirror C30, ROC flat, HR @ 632 nm	107 (80)
17	UM-LM01	1	Manual Michelson Interferometer	
	Option (order separately)			
18	CA-0200	1	Oscilloscope 100 MHz digital, two channel	128 (19)
19	LM-0110	1	Two mode HeNe laser extension	see below

Two mode HeNe laser extension



Based on the mode spacing of the two mode HeNe laser (4) the coherence length is 20 cm and can be determined by measuring the contrast as function of the path difference of the reference arm L_r and measuring arm L_m. By using a polarisation filter (8), one mode can be suppressed resulting in a single mode laser with much longer coherence length. The measurement starts with equal length of L_r and L_m .The path difference is increased in 1 cm steps and at each position the adjustment screw (S) is slightly turned back and forth while observing the oscilloscope which shows the signal of the photodetector (2). A more or less pure sine curve with varying amplitude and offset is observed (Fig. 2.3 and Fig. 2.4). The coherence length is reached at the position where the contrast reaches its minimum.

Measuring the contrast function and coherence length

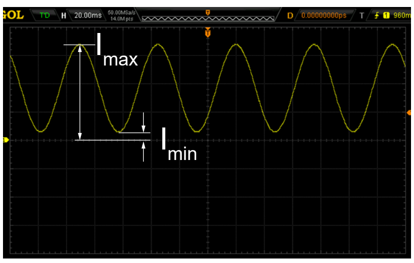


Fig. 2.3: Good contrast

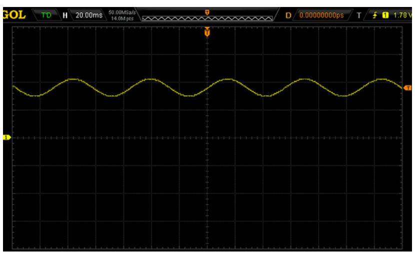
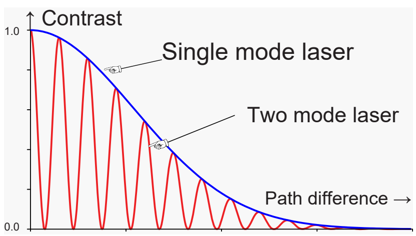


Fig. 2.4: Low contrast



Contrast function

LM-0110 Two mode HeNe laser extension consisting of:

Item	*Code*	*Qty.*	*Description*	*Details page*
1	DC-0062	1	High voltage supply 5 mA	122 (7)
2	DC-0120	1	Si-PIN Photodetector, BPX61 with connection leads	123 (14)
3	DC-0380	1	Photodetector Junction Box ZB1	125 (30)
4	LQ-0300	1	Two mode HeNe laser Ø30 housing, 632 nm	120 (14)
5	MM-0024	1	Rotary mount on carrier MG20	93 (2)
6	MM-0470	2	XY mount, soft ring 30 mm, on MG20	97 (30)
7	MP-0150	1	Optical Bench MG-65, 500 mm	93 (8)
8	OC-0710	1	Polarizer in C25 mount	102 (34)