Interferometers Technical Note

Guide

It is requested a lot of time and effort, even to experienced professionals, in order to make an optical laboratory system from assembling optical elements, holders and bases.
In addition, it is expected that people who use the optical system for the first time does not know well where and how to treat. And, it will cause trouble.
We offer interferometer and a unit of Schlieren optics which is a base not only to beginner but also for experienced ones who want to save time.

- General Interferometers … A interferometer unit used in the field of education or for teaching practice. Users can freely change component arrangement to assemble various interferometers. It can also be used for simple verification experiments, and is an indispensable item for optical training.
- Fluid Visibility Optics …… It is often confused with an interferometer, but we redesigned the schlieren optical system, which is used for quantitative observation of fluid. We used white light as the light source to enable observation of subtle contrast, and a configuration that allows loading of observed images into a PC.
- D-TOP Optics …………… An optical system that is one step more advanced than the general interferometer, and slightly closer to an optical instrument. It is useful for verifying both functionality and compactification. This optical system enables observation of minute samples that the general interferometer cannot check.

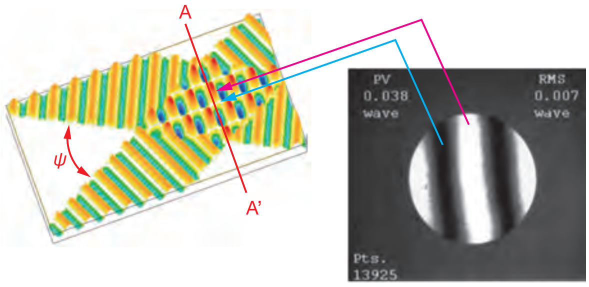
Features of Interferometers

Observation of dynamic phenomena of 1μm or less that are unrecognizable by human senses often uses interferometers. For example, all the basic principles such as surface accuracy measurement of optics, an end measuring machine used for precise measurement of distance or travel, equipment capable of measuring fast and minute changes such as speedometer or vibrometer utilize interference of light.
An interferometer provides high resolution, but the range that an optical system can measure is not so broad. This is because the periodicity of waves makes identification of a phase difference of an integral multiple of waves difficult.
Most of the commercially available interferometry devices consist of an optical system of interferometer and an analysis device for interference signals.
Advanced electronics used in the analysis device enable measurement both with high resolution and broad measurement range. This chapter introduces interferometers consisting of only an optical system, not fitted with an analysis device for interference signals. The range available for observation is therefore very limited. However these interferometers are sufficient for the purpose of basic interferometry experiments or theory testing. Interference is utilized for practical purposes in many fields. These fields can use the interferometers as basic experiment devices.

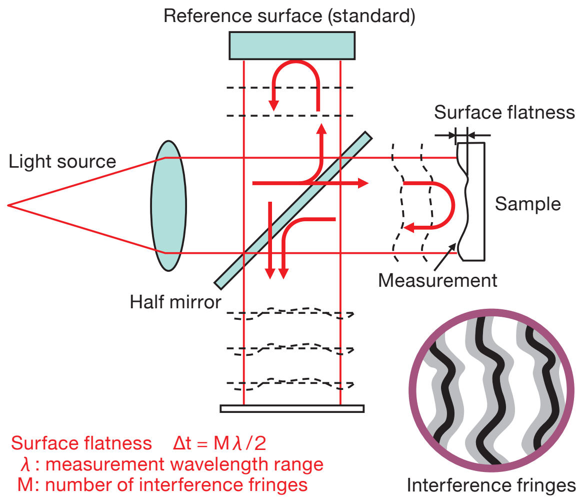
Principle of Interferometer

When you split a light wave having regular periods such as a laser beam into two waves and then recombine them, you can observe an interference phenomenon of light waves. When superimposing the two waves, the resultant wave has a part with amplified intensity and a part with diminished intensity alternately, making fringes of light and dark.
These interference fringes indicate the phase difference between the two optical path lengths, and one fringe is equivalent to the phase difference of the length of light source wavelength (half of the wavelength in the case of round-trip optical path).
Since it is impossible to identify components of phases different by an integral multiple of waves of interference fringes, what you can actually observe is limited to either variation of phases different by lower than an integral multiple of waves or continuous phase variation.
The wavelength of the light source is 632.8nm in the case of a He-Ne laser, therefore the one phase between fringes of an interferometer of round-trip optical path becomes very short, 0.3μm. This is why an interferometer is capable of measuring minute displacement or variation.
High sensitivity provides precise measured values however, at the same time detects influences of disturbance such as vibration or air turbulence. To prevent this, experiments need to be performed on a vibration isolator bench or the entire experiment system needs to be shut off from the outside with black-out curtains or the like.

- Interference is a superimposition of two waves.
- Interference fringes appear when waves have regular periods.



Simulation diagram of the two-beam interference

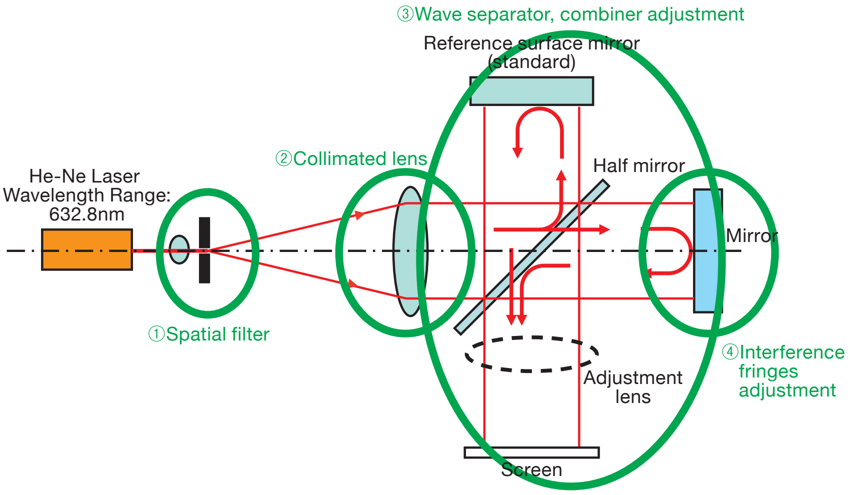


To measure surface accuracy with an interferometer, install a sample in one optical path, and superimpose the wavefront reflected by the measuring surface with the plane wave reflected by the reference surface. Interference fringes generated at this time are folded, reflecting the shape of the measuring surface.
The shape of the measuring surface can be found from the amount of fold of these fringes.

Points for Assembly

**It is easy to assemble an interferometer once you master the knack of it.
The following are some points that require attention during assembly.**

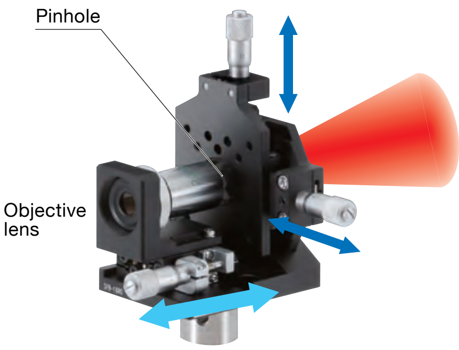
First of all, to align the optical axis of all components, adjust the height of holders using posts and post holders. To make the laser beam horizontal to the installation stand, adjust the angle of a He-Ne laser. Roughly arrange each component while keeping some space required for adjustment of the holders.
To enter light correctly into optics, adjust components in sequence starting from the laser light source.

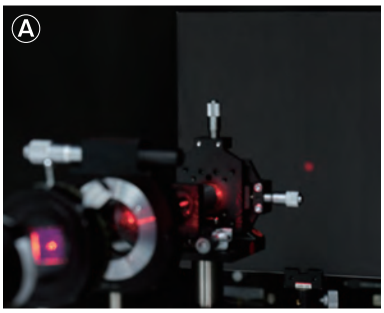


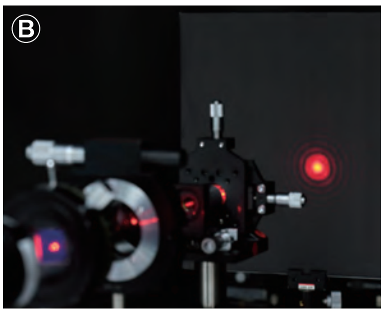
When installing components, firmly fasten various joints or clamps so that holders do not move. Such parts include the coarse/fine switching clamps for elevation and azimuth of a mirror holder, or clamp of a post holder, the on/off of the lever of a magnet base.
If joints or clamps are not fastened, vibrations tend to occur, making stable observation of interference fringes difficult.

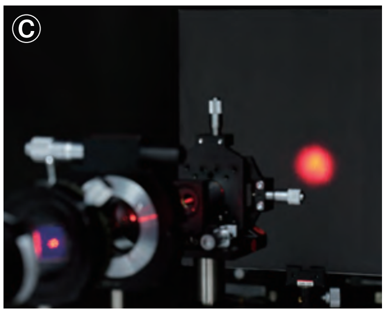
①Spatial Filter Holders

A spatial filter holder is a device consisting of an objective lens and a pinhole, and makes a diverging ray from a laser beam while at the same time eliminating distortion in beam wavefronts or diffraction rings caused by particles to convert it to a clean Gaussian distribution.
Adjust the position of the spatial filter component so that the laser beam can be perpendicular to the center point of the objective lens. Move the pinhole away from the objective lens using the micrometer of the objective lens stage, and find a weak light that passed the pinhole Ⓐ. Then move the vertical and horizontal axes of the pinhole, and find the position where the passed light becomes maximum Ⓑ. When gradually moving the objective lens closer to the pinhole, the light that passed the pinhole becomes bright, but if the objective lens keeps approaching toward the pinhole, the light becomes darker. When it gets darker, adjust the pinhole and find the position where the light becomes bright. Repeat this operation until the brightness reaches maximum and there are no diffraction rings Ⓒ.



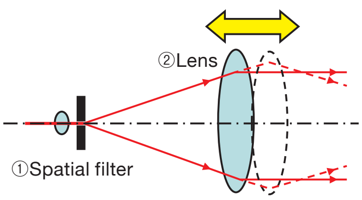


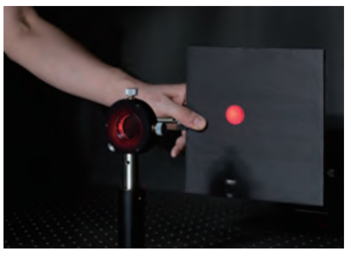




②Collimated Light

The lens component receives light diverging from the spatial filter component, and converts it to thick collimated light.
For collimation adjustment, place a screen at a distance, and adjust the lens position toward the direction of the optical axis so that the beam diameter projected to the screen is the same as the beam diameter immediately after the lens.





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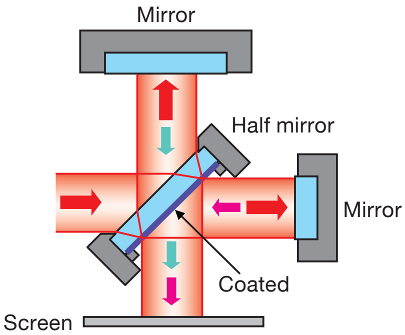
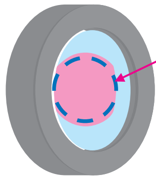
③Splitting of a Beam and Recombination





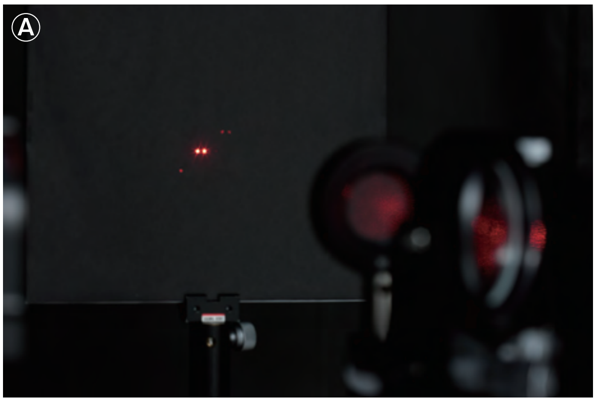
A collimated light is split and re-combined by using a half mirror. A half mirror is positioned so that a beam is flexed to a right angle, but a plate type half mirror causes shade on part of the beam because of its thickness and holder frame, limiting observation of interference fringes to a small area at the center of the half mirror. (It is especially noticeable in a Michelson interferometer.) To solve this problem, attach the half mirror in the reverse orientation (the coated surface faces the retaining ring side) and adjust the half mirror component so that the clear aperture of the transmitted beam is maximized.

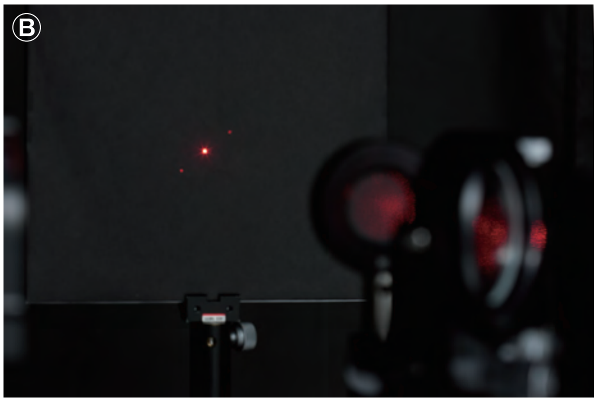
* A beamsplitter holder (BHAN) that will not cause shade on a beam even when the coated surface is facing the front is also available.
 WEB Reference Catalog Code W4011

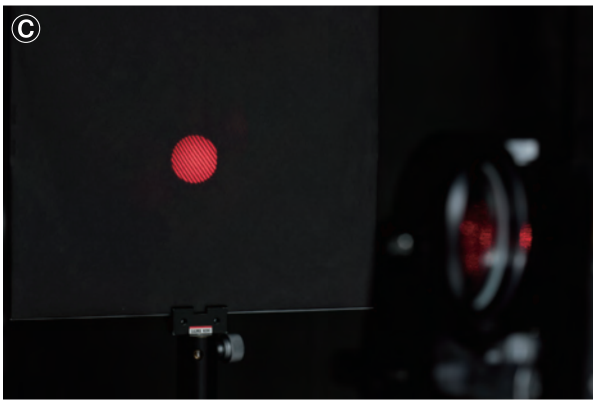
Install the mirror component so that the collimated beam fits in the clear aperture of the mirror, and adjust positioning of each holder so that the two beams are projected on the screen to be over lap at the same size.
When a wedged plate type half mirror is used, a transmitted beam is slightly refracted due to the refractive index of the half mirror. The two optical paths divided by the half mirror, therefore, are not at precisely 90 degrees, but it will not affect measurement or observation of interference fringes.

④Angle Adjustment of the Beam

Even if the two beams are perfectly superimposed by the adjustment in ③, interference fringes cannot be observed in most cases. To observe interference fringes, the parallelism of the two beams needs to be set to one minute or less. There are various adjustment methods, but here we introduce one method that uses an adjustment lens.
Prepare an adjustment lens that has a long focal length (adjustment lens component IFC2-AL Reference A052), insert it between the half mirror and the screen, and adjust the lens position so that the focal spots of the beams are on the screen. Picture Ⓐ
To completely superimpose the two spots, make fine adjustment by moving only the mirror of one optical path. Picture Ⓑ (To make the adjustment easier, make the spots as small as possible and somewhat diminish the brightness of the spots.)
You can observe fine interference fringes when you remove the adjustment lens. Picture Ⓒ (Repeat the aforementioned steps until fringes are visible.)
Next, while keeping the interference fringes visible, gradually increase the spacing between fringes by making fine adjustment on one side of the mirror holder. (At this time, if you adjust both mirror holders at the same time, the adjustment may become irreversible.)
Adjustment of the azimuth (θy) of the mirror holder increases or decreases the horizontal spacing between fringes, and adjustment of the elevation (θx) of the mirror holder increases or decreases the vertical spacing between fringes.
The interference pattern most suitable for observation is when the number of vertical or horizontal interference fringes is three or four. Picture Ⓓ







Experiment Method

**After assembling an interferometer, to understand the features of the interferometer, having a simple experiment before entering a full-scale experiment is suggested.
From which, you can acquire a lot of information that cannot be obtained from textbooks or math formulas. The following four experiment methods are simple and do not require any special tools.**

Fringe Control

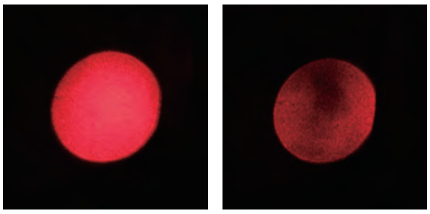
To change the direction of interference fringes, adjust the elevation and azimuth of a mirror. To increase spacing between fringes and make even brightness on the entire surface, further make ultra fine adjustment. The number of fringes indicates the crossing angle of the two beams. When the number of fringes is zero, the two beams are completely parallel.
Then, to increase the number of interference fringes, rotate the mirror. The crossing angle can be found from the number of interference fringes.

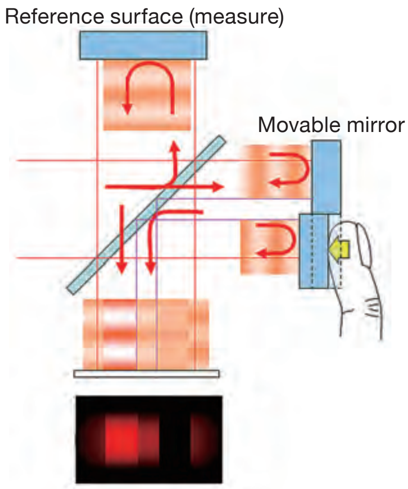
$$\sin\psi = \frac{N\lambda}{2D}$$

N: Number of interference fringes, D: Beam diameter, ψ: Crossing angle, λ: Wavelength

Phase Shift

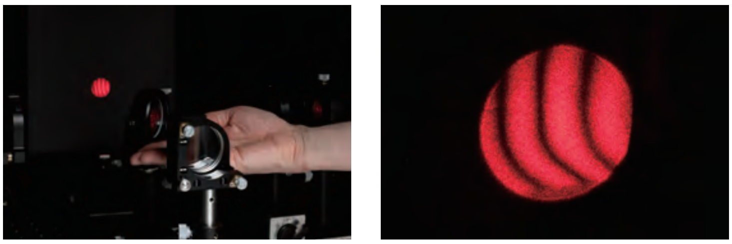
When no fringes are present, if you lightly touch (press) the mirror on one side toward the direction of the optical axis, the brightness of the interference fringes changes drastically. Brighter interference fringes indicate that the phases of two beams match, and darker fringes indicate that the two beams diminish each other because their phases are different by half the wavelength. When moving for half the wavelength, the brightness and darkness alternate.





Air Turbulence

If you slowly insert your hand from underneath one optical path of an interferometer, you can observe fringe deflection. This is because the air is warmed by the temperature of the palm, changing the refractive index of the air like a heat haze. Fringe deflection is greater near the palm due to heat dissipated from the palm.



Distortion of the Mirror

If you tighten and slightly loosen the mirror retaining screw (set bolt) that fixes the mirror on a mirror holder of an interferometer, you can observe changes in the shape of interference fringes. When the screw is strongly tightened, the mirror is distorted by the stress, resulting in distortion of the flat surface of the reflector. The distortion is too minute for humans to detect, but is observed as a drastic change in fringes in the interferometer.