# PH 301

# ENGINEERING OPTICS

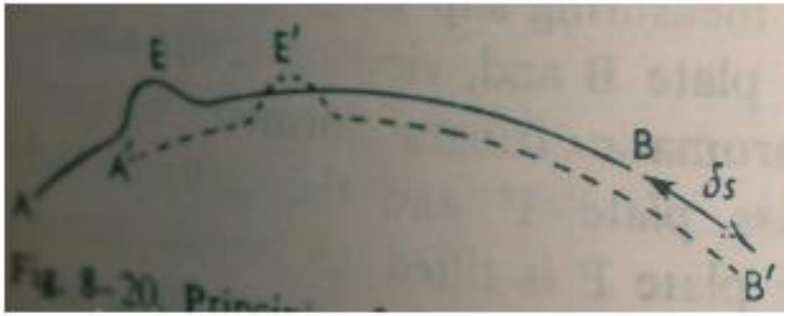
## Lecture_Interferometers_15

# Wavefront Shearing Interferometer

- In TGI, wavefront under test is compared with a reference wavefront &, to produce the latter, it is necessary to employ a dividing mirror & comparison mirror which are highly corrected over an aperture equal to that of optical system under test.

- This may become an insuperable difficulty when it is desired to test very large aperture astronomical telescope objectives.

- In wavefront shearing interferometer, this difficulty is overcome. When one part of a wavefront is under test, a different part of the same wavefront acts as reference wavefront.




**Principle of wavefront shearing interferometer**

- **AB represents a wavefront which should be spherical but in fact exhibits a local error at E.**

- **A'E'B' is an identical wavefront which is displaced circumferentially a distance *δs*.**

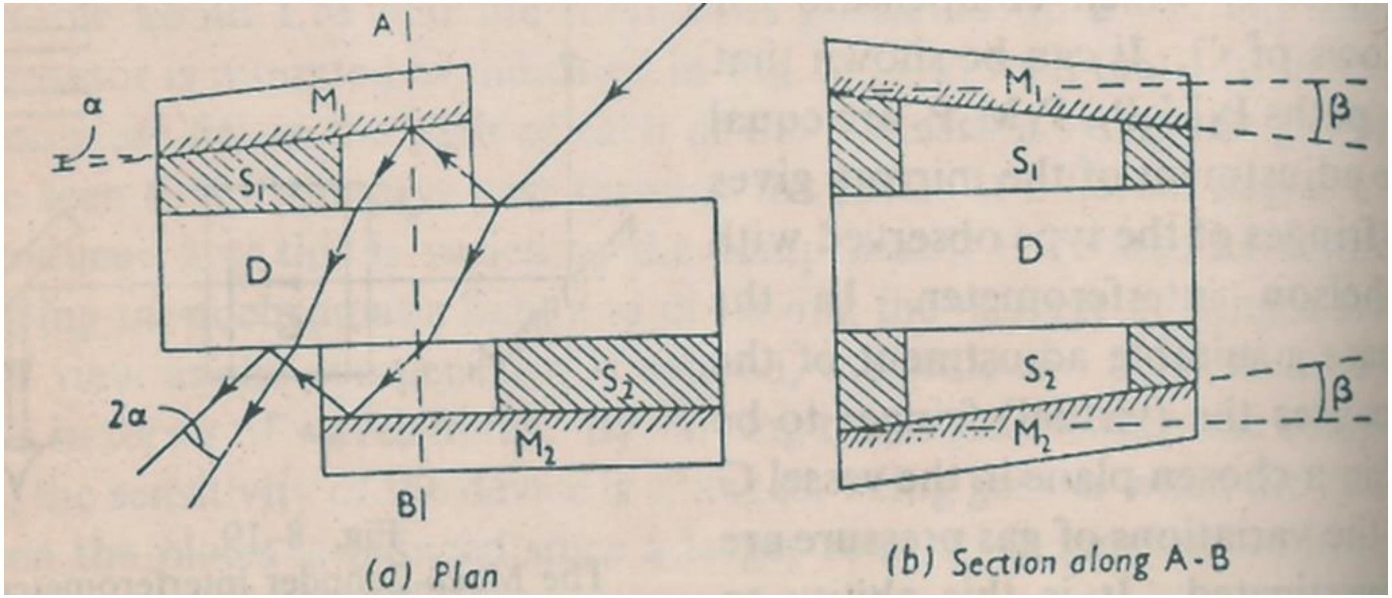
- **If wavefronts are coherent, they will interfere & in the region of E & E' will give patterns similar to those observed in TGI.**

- **If wavefronts are tilted through equal & opposite small angles about the chord AB, eye viewing the waves will see a series of fringes parallel to AB, fringes being distorted in the region of E & E'.**

- **As in TGI, measurement of these fringes enables the nature of error E to be calculated.**

- **In wavefront shearing interferometer, interfering wavefronts are obtained by amplitude division of wave emerging from optical system under test.**

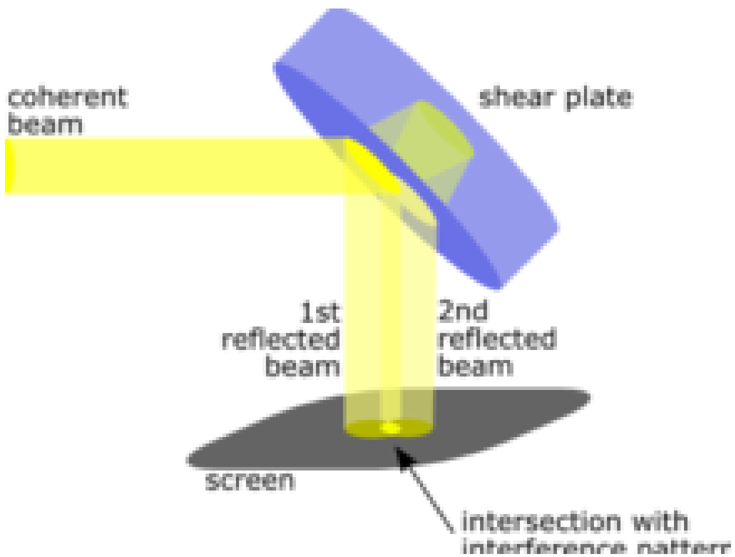
- **Components are recombined in such a way that one is sheared a distance *δs* relative to other.**




**Interferometer with fixed shear & tilt**

# Wavefront Shearing Interferometer

**It is an extremely simple means to observe interference & use this to test collimation of light beams, especially from laser sources which have a coherence length which is usually a lot larger than thickness of shear plate so that basic condition of interference is fulfilled.**



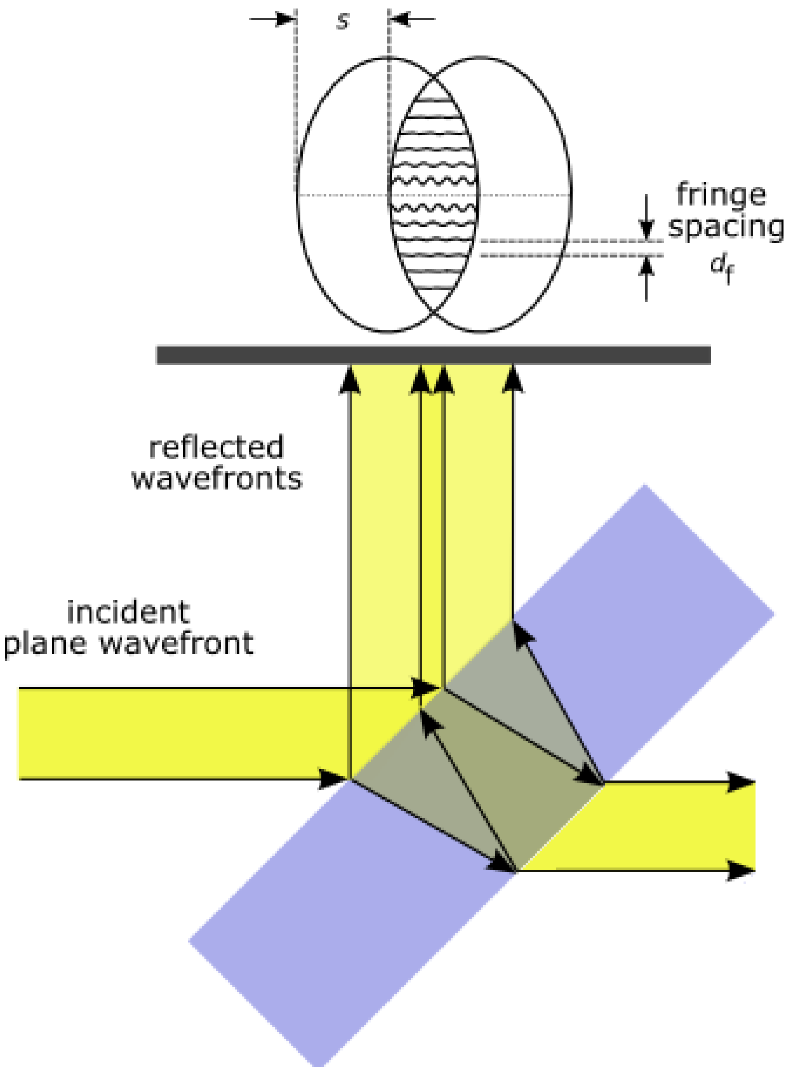

**Principle of shearing interferometer**

- **Testing device consists of a high-quality optical glass, like N-BK7, with extremely flat optical surfaces that are usually at a slight angle to each other.**

- **When a plane wave is incident at 45°, which gives maximum sensitivity, it is reflected two times. Two reflections are laterally separated due to finite thickness of plate & by the wedge. This separation is referred to as the *shear* & has given the instrument its name. The shear can also be produced by gratings.**

- **Parallel-sided shear plates are sometimes used, but interpretation of interference fringes of wedged plates is relatively easy & straightforward.**

- **Wedged shear plates produce a graded path difference between front & back surface reflections; as a consequence, a parallel beam of light produces a linear fringe pattern within the overlap.**




**Side view of shear plate & resulting interference pattern, seen on a screen. To minimize ghost reflections, shear plate is left bare, without any sort of mirror coating.**

❖ **With a plane wavefront incident, overlap of two reflected beams shows interference fringes with a spacing of,**

$$d_f = \frac{\lambda}{2n\theta}$$

***λ*** **= wavelength of beam,** ***n*** **= refractive index,** ***θ*** **= wedge angle. Fringes are equally spaced & will be exactly perpendicular to wedge orientation & parallel to a usually present wire cursor aligned along the beam axis in shearing interferometer.**

❖ **Orientation of fringes varies when beam is not perfectly collimated.**

❖ **In case of a noncollimated beam incident on a wedged shear plate, path difference between two reflected wavefronts is increased or decreased from the case of perfect collimation depending on sign of curvature. Pattern is then rotated & beam's wavefront radius of curvature** ***R,***

$$R = \frac{s.d_f}{\lambda \sin \gamma}$$

***s*** **= shear distance,** ***γ*** **= angular deviation of the fringe alignment from that of perfect collimation.**

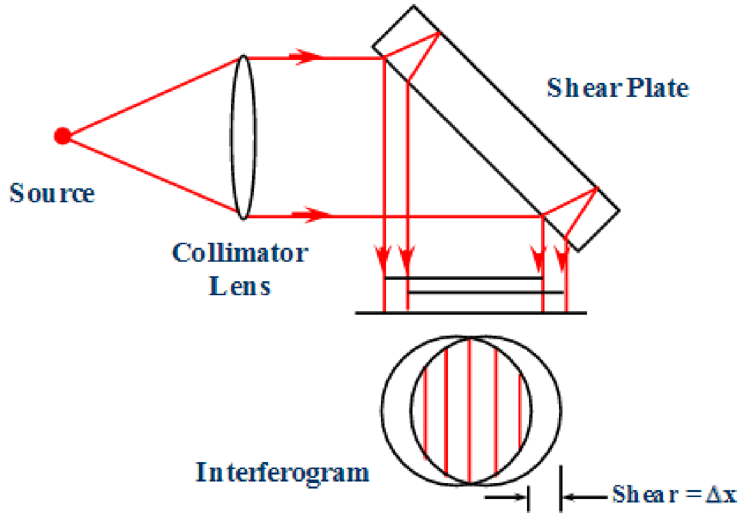
- **Wavefront shearing interferometers belong to the class known as common path interferometers, in which both test & reference beams pass through the system under examination.**

**Applications**:

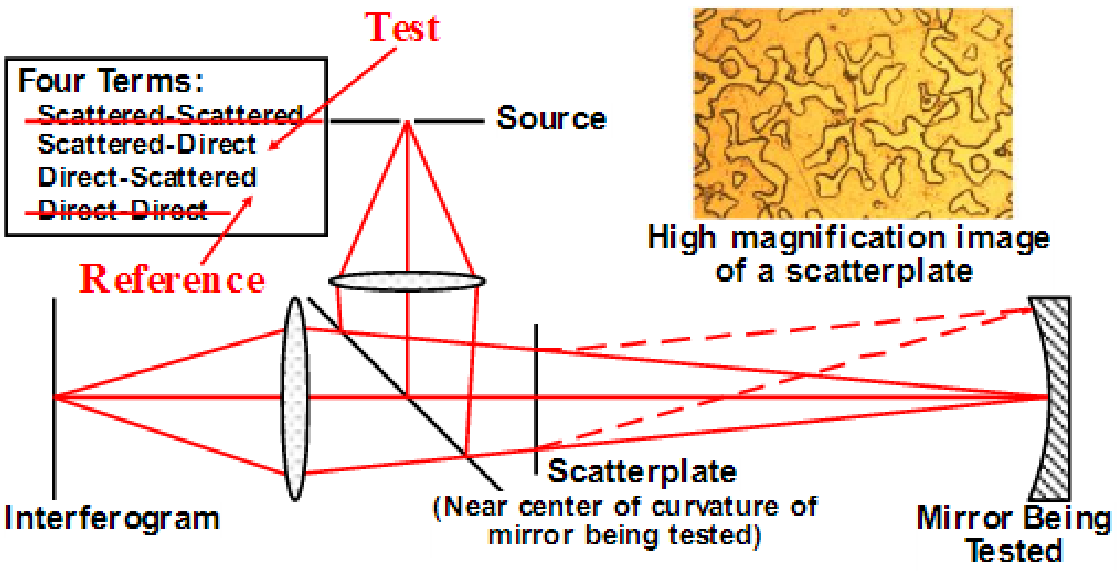
- **Astronomical wavefront sensing**
- **Lens testing**
- **Collimation testing**
- **Testing large aperture optical systems**

# Lateral shear interferometry

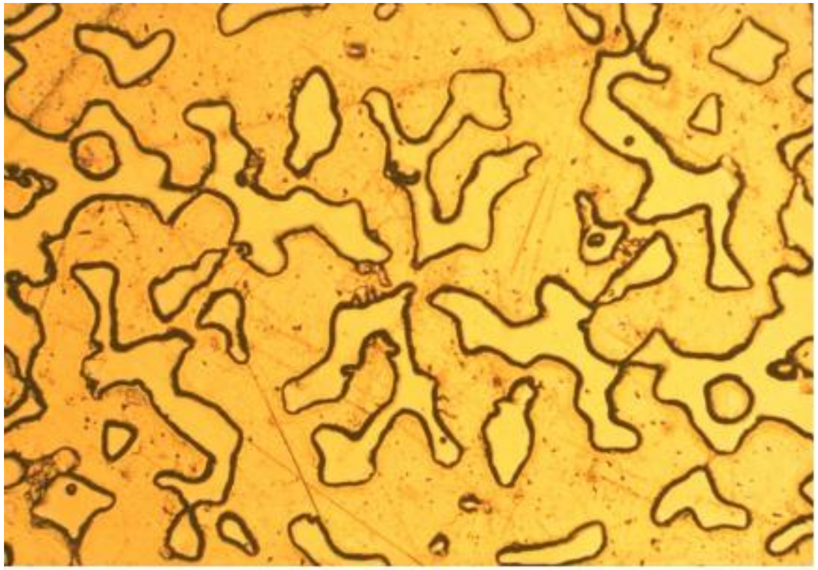
## Measures wavefront slope



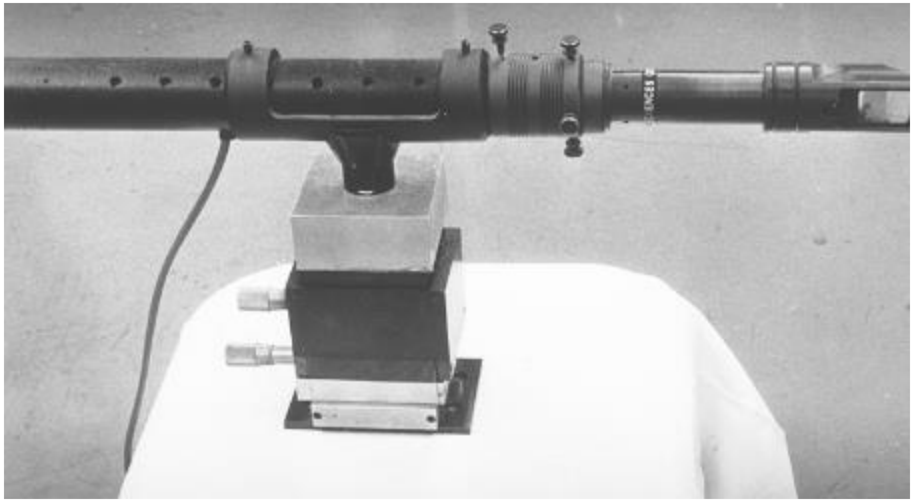
# Scatterplate Interferometer



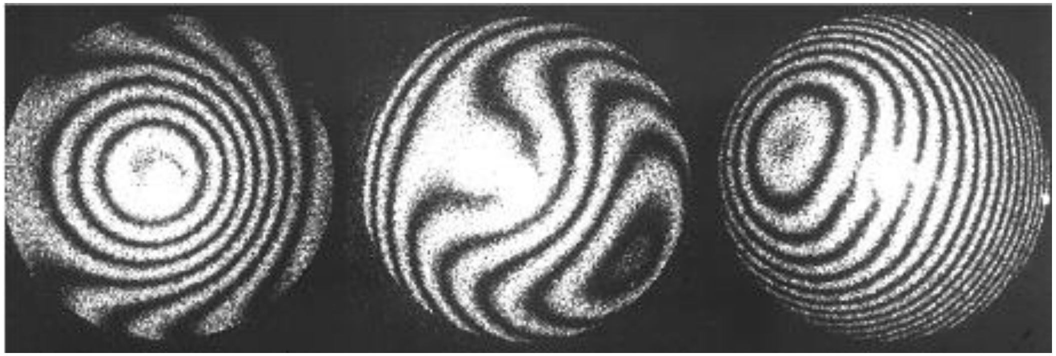

- Scatter plate has inversion symmetry.
- Scatter plate is located at center of curvature of test mirror.
- Direct scattered & scattered-direct beams produce fringes.



Microscopic image of scatterplate.



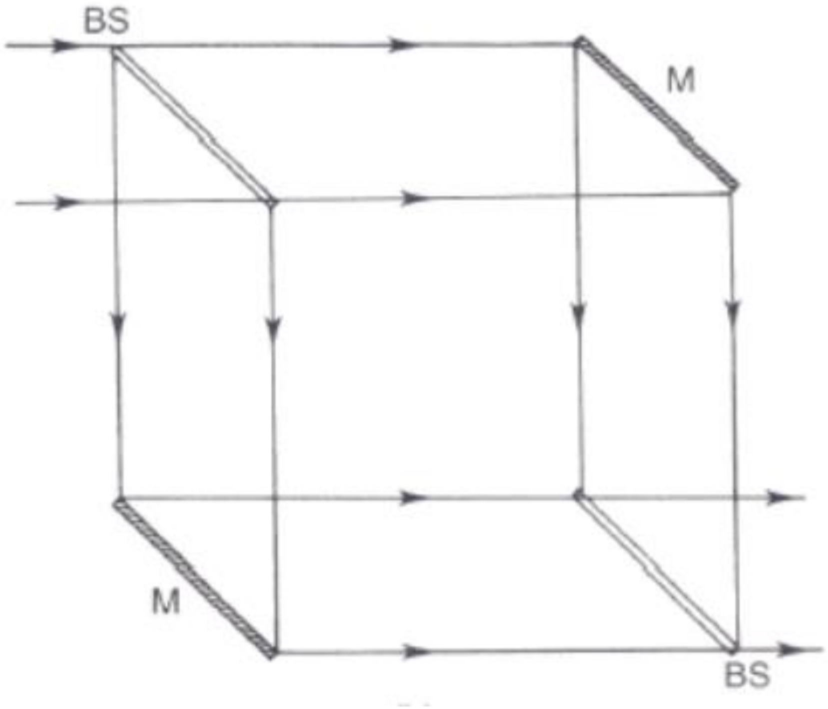
Scatterplate interferometer

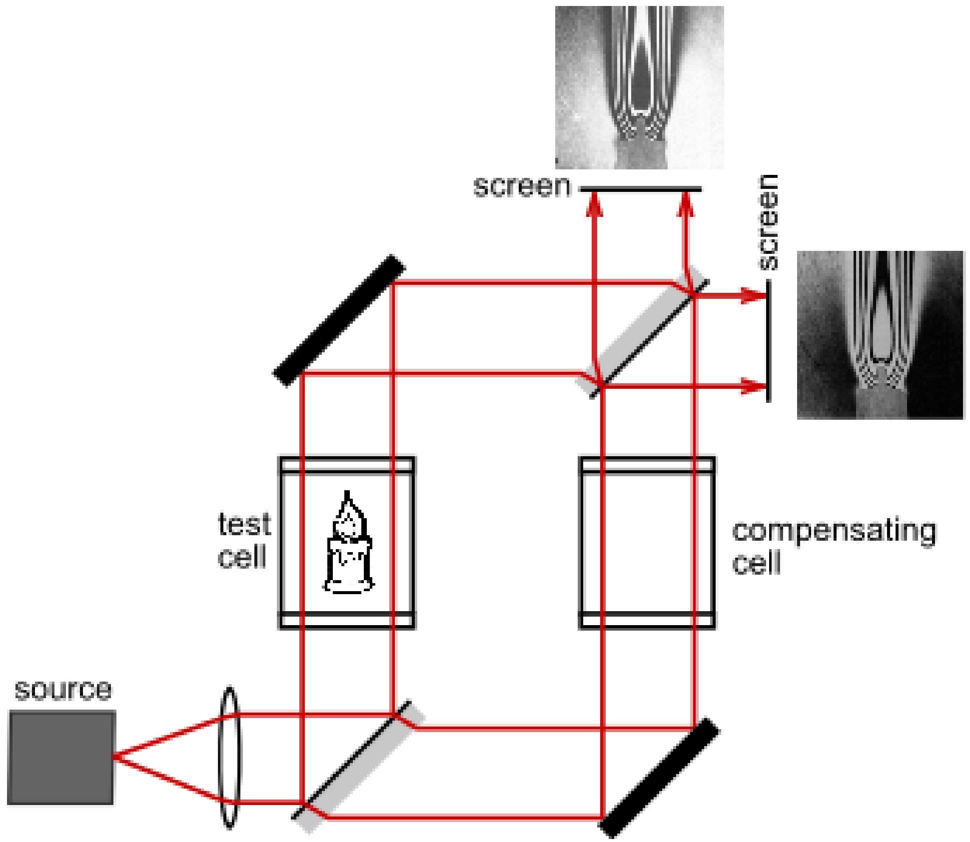


**Scatterplate interferograms**

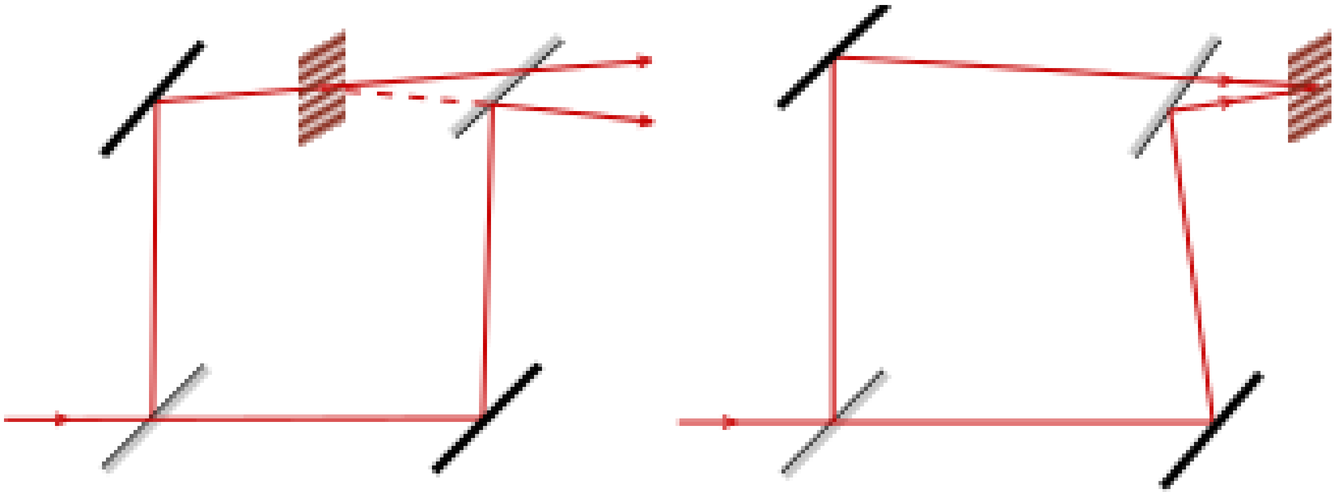
# Mach-Zehnder Interferometer

**Ludwig Mach & Ludwig Zehnder, 1891**

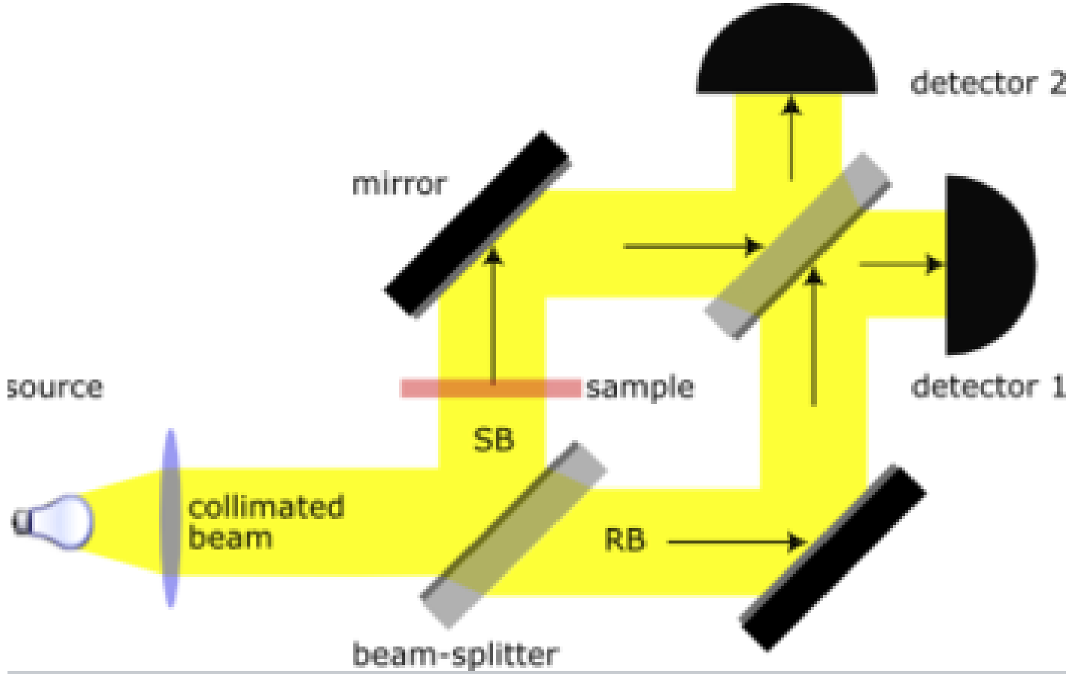




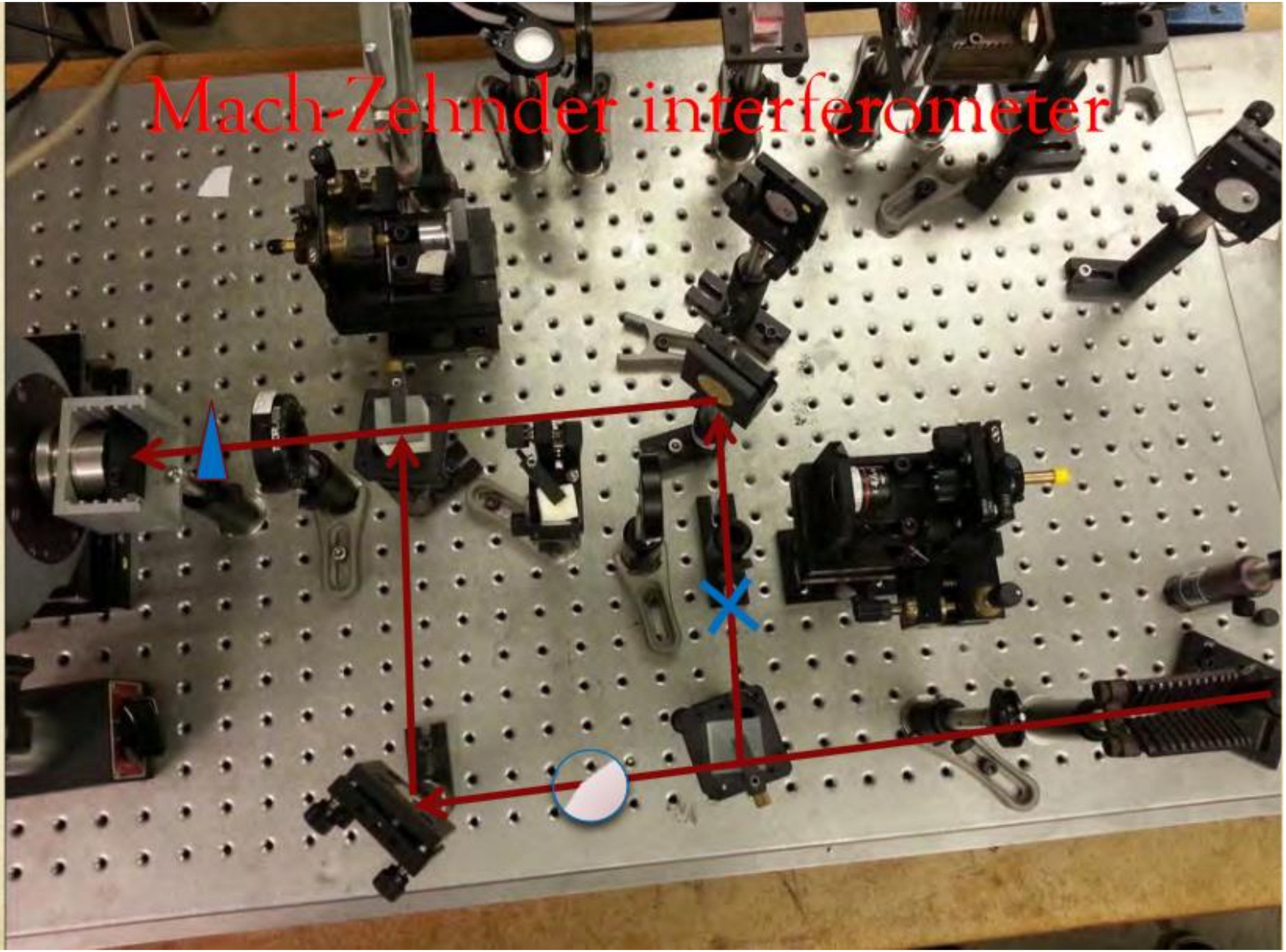

**Mach-Zehnder interferometer is used in the fields of aerodynamics, plasma physics & heat transfer to measure pressure, density, & temperature changes in gases. Analyzing a candle flame. Either output image may be monitored.**



**Localized fringes result when an extended source is used in a Mach-Zehnder interferometer. By appropriately adjusting mirrors & beam splitters, fringes can be localized in any desired plane.**

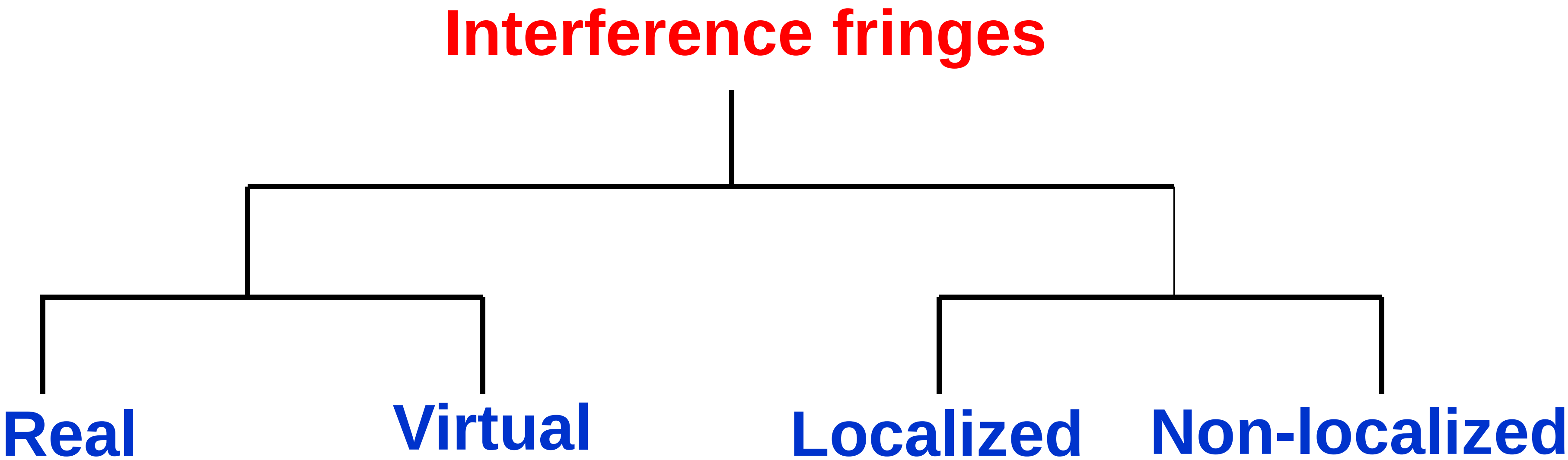



**Effect of a sample on phase of the output beams in a Mach-Zehnder interferometer.**


Mach-Zehnder interferometer

## Applications of MZI:

- ❖ **Due to versatile configuration (rectangular, parallelogram) & flexibility in fringe localization it is used in fundamental research topics (counterfactual definiteness, quantum computation, quantum entanglement, quantum logic, quantum cryptography, quantum electronics, neutron diffraction, optical encryption).**
- ❖ **Used to study transparent objects.**
- ❖ **Analyzing wind tunnel gas dynamics.**
- ❖ **Multipurpose sensing applications.**


Interference fringes
Real
Virtual
Localized
Non-localized

# Real fringe

- Can be intercepted on a screen placed anywhere in the vicinity of the interferometer without a condensing lens system.

# Virtual fringe

- Cannot be projected onto a screen without a condensing focusing system. In this case, rays do not converge.

# Non-localized fringe

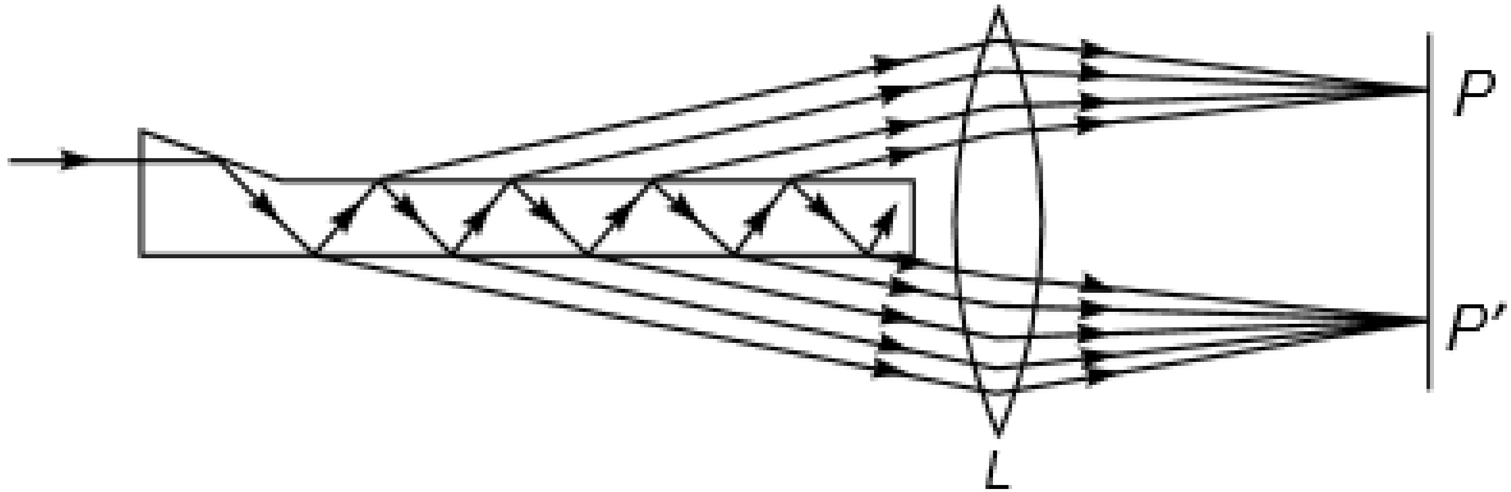
- Exists everywhere
- Result of point/line source

# Localized fringe

- Observed over particular surface

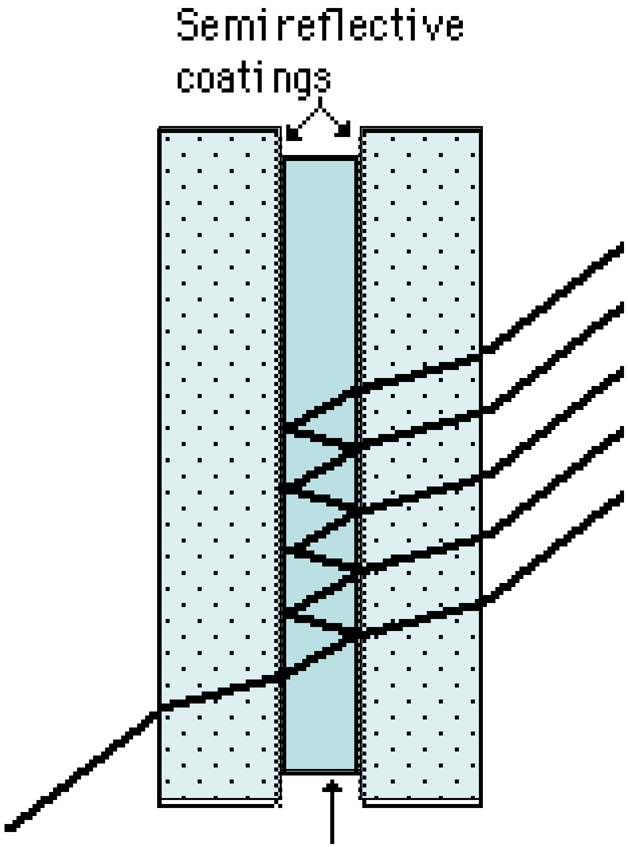
- Result of extended source

# Lummer–Gehrcke plate




- Unlike in Fabry-Perot interferometer, space between reflecting surfaces is a dispersive medium.
- No. of reflections is also not very large as in the case of Fabry-Perot interferometer; the no. of reflections depends on length of plate & angle $\theta$. Thus, RP of instrument depends on length of plate.
- Earlier, Lummer-Gehrcke plates were used in high resolution spectroscopy. However, they have been replaced by more flexible Fabry-Perot interferometer.

# Interference Filter




**An interference filter is designed for normal incidence of 488 nm light. The refractive index of the spacer is 1.35. What should be the thickness of the spacer for normal incidence of light?**

$$2n_2 d \cos\theta_2 = m\lambda$$

$$2n_2 d = \lambda$$

$$d = 180.74 \quad \text{nm}$$

**It will pass different wavelengths if angle of incidence is not 90$^o$.**

# *LIGO* - Laser Interferometer Gravitational Wave Observatory

**To detect gravitational waves, one of the predictions of Einstein's general theory of relativity**

**Hanford Nuclear Reservation, Washington, Livingston, Louisiana**

**Arm length: 4 km, Displacement sensitivity: $10^{-16}$ cm**

**When gravitational waves pass through interferometer they will displace mirrors!**