PREPARATORY SCHOOL TO THE

Winter College on Optics 2019

Applications of Optics and Photonics
in Food Science

OUTLINE OF THE EXPERIMENTS in the DIFFRACTION LABORATORY

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EXPERIMENTS on

1 - MICHELSON INTERFEROMETER

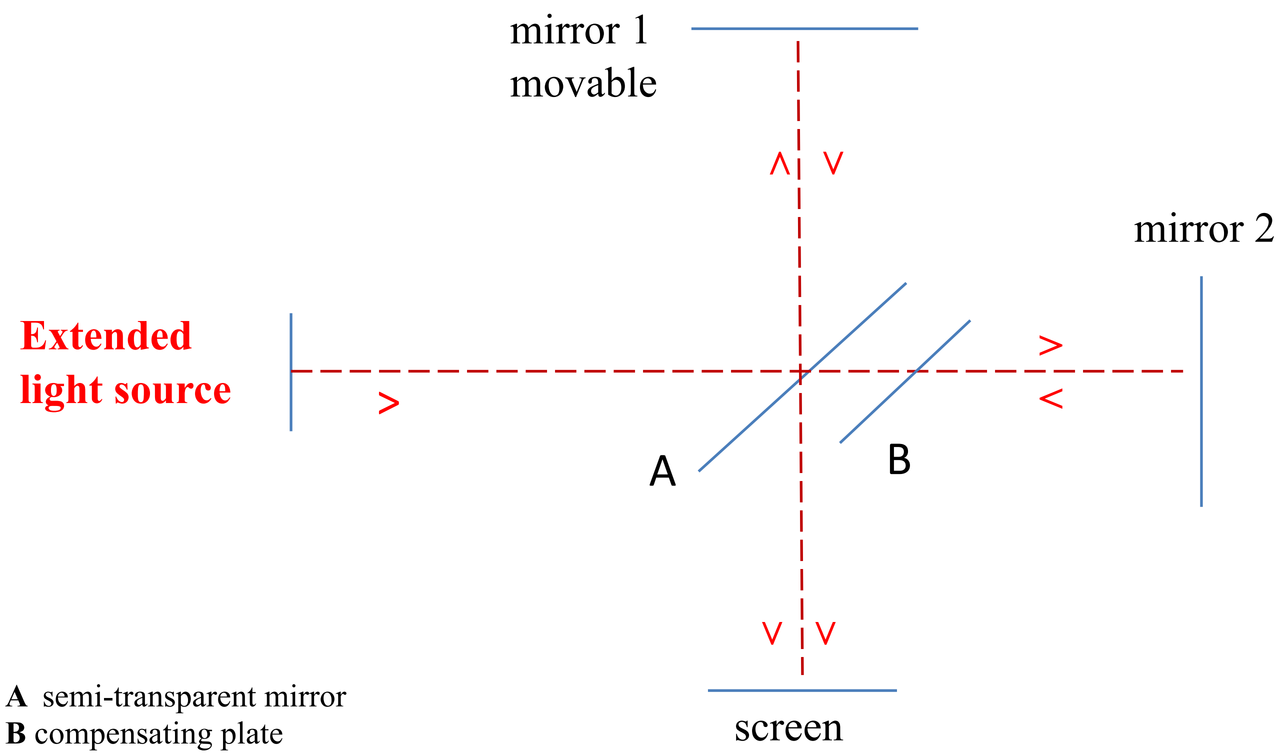
2 - BASIC of SPECTROSCOPY

3 - DIFFRACTION and FOURIER TRANSFORMS

Important note: here we deal with field phenomena, that is amplitude and phase. Our eyes are sensitive to energy, therefore we will never see the "field", but

we see: intensity, that is amplitude square

Simple scheme of a MICHELSON interferometer



An extended beam of light, from a coherent source (e.g. a laser beam) on the left side, travels toward a semitransparent mirror, where it is split in two beams, one reflected towards mirror 1 and another transmitted towards mirror 2. The beam reflected from mirror 1 is transmitted towards the receiver. The beam reflected from mirror 2 is reflected from the semitransparent mirror towards the receiver. The two beams interfere and give rise to a pattern in the receiver plane. One mirror, here mirror 1can be moved back and forward or rotated.

SHAPE OF THE FRINGES OF THE MICHELSON INTERFEROMETER

The shape of the fringes is the result of the interference between the two beams and depends on the the phase difference φ of the two beams on the receiver plane.

A - TILTED MIRRORS, that is **inclined beams and their wave fronts**. In these case the fringes have an hyperbolic shape, that can be approximated as linear in the center. Depending on the situation, the curvature of the hyperbolas can be on one side or another with respect to the symmetry center (or line).

B - PARALLEL BEAMS, **that is parallel mirrors**: if the two beams arrive parallel on the receiver plane, the two **wavefronts are parallel** and the interference figure depends on the phase difference between the two beams:

- in **general** the fringes of two perfectly parallel beams are circular ones. There are two particular cases:
    - if the two parallel beams are **in phase**, phase difference $\varphi = 0$, the receiver plane is uniformly illuminated, because the two beams interfere positively at each point,
    - if the two beams arrive **out of phase** $\varphi = \pi$, the receiver plane is completely black due to negative interference at each point.

EXPERIMENT IN THE LABORATORY ON ALIGNING A MICHELSON INTERFEROMETER

The shapes of the fringes can help aligning the interferometer.

In the laboratory we will learn to work with a Michelson interferometer

INTERFEROMETER OF MICHELSON: EXPERIMENTS

by Dr. Miltcho Danailov

- **setting up and alignment** of a Michelson Interferometer,
- **fringe observation**, and
- **change of the relative phase** of the two beams by a wedge pair in one arm. Wedge pairs are often used in ultrashort pulse setups for controlling and stabilizing the Carrier-to-Envelope phase of ultrafast lasers.

Main components: **Diode or Diode-pumped laser, Telescope, Negative lens, Beamsplitter, HR mirrors, Fused Silica wedges**

Description of the procedure to perform the three experiments is described in the next two slides.

- INTERFEROMETER ALIGNMENT AND FRINGE OBSERVATION IN SLIGHTLY TILTED WAVEFRONT GEOMETRY

a. Insert the telescope in-front of the laser and achieve a good beam collimation

b. Setup the Michelson interferometer by inserting the beam splitter and placing the HR mirrors appropriately

c. Position the white screen in a position where fringes can be observed and align the beams reflected by the mirrors to coincide on the screen

d. Find out how different fringe spacing can be obtained and explain it

- INTERFEROMETER ALIGNMENT IN PARALLEL WAVEFRONT GEOMETRY

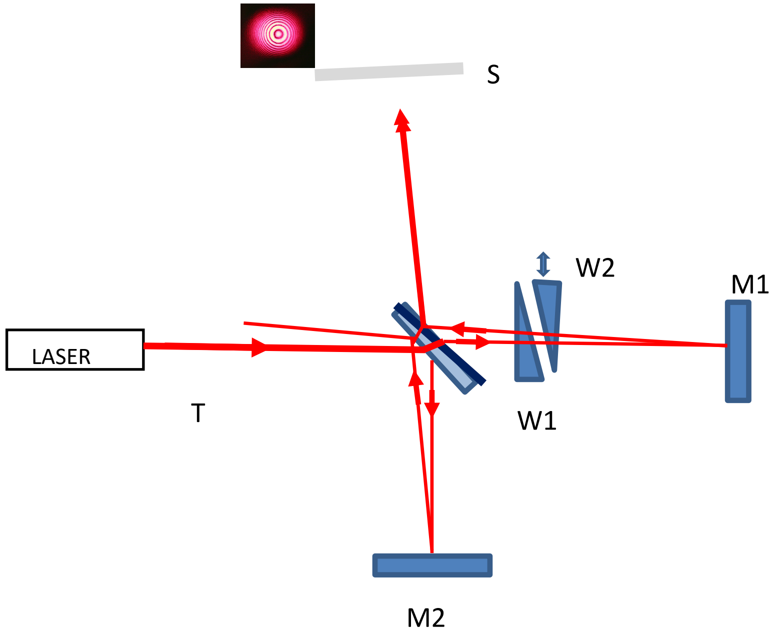
- Insert the negative lens for easy fringe observation
- Align the interferometer for observing circular fringes
- How the number of fringes in this geometry can be reduced? Tray to get few fringes or even a single fringe

- INTERFEROMETER MEASUREMENT OF PHASE CHANGES BY A WEDGE PAIR

- Insert and align the two wedges in one of the interferometer arms in antiparallel configuration
- Using the micrometer change the insertion of the wedge and measure the relation between wedge movement and fringe changes,
- on the basis of the above measurement estimate the wedge angle, given that the wedge material is fused silica (use the refractive index of fused silica for the laser wavelength)

- **OBSERVATION OF THE BEHAVIOUR OF FRINGE VISIBILITY WHEN RELATIVE ARM LENGTH IS CHANGED**
  - Using the translator for the end mirror position installed in one arm, scan the arm length over several mm, adjusting the pointing to keep a constant number of fringes
  - Monitor the change of fringe pattern visibility and try to explain the observed periodic modulation: it is related to the longitudinal mode structure of the laser

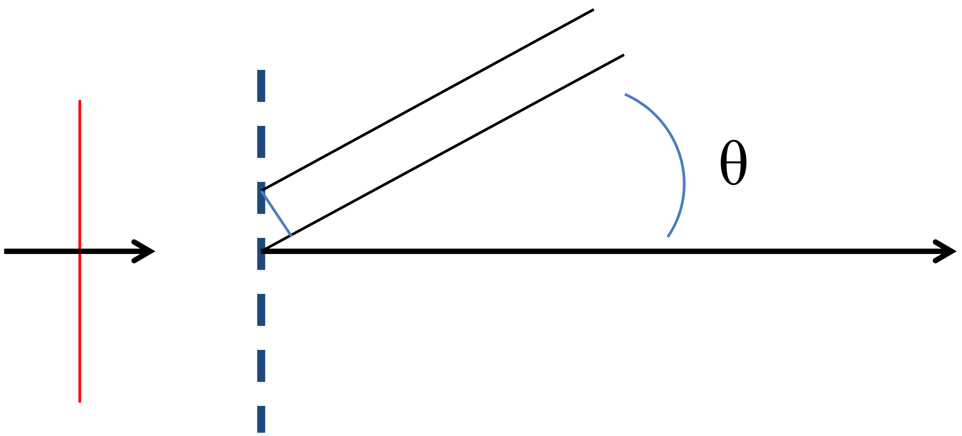
EXPERIMENTAL SETUP:
LASER: diode or diode-pumped laser
T: magnifying telescope or negative lens
BS: Beam splitter (semitransparent mirror)
M1,M2: High-reflectivity mirrors,
M2 mounted on a precision translation stage
S- white screen



2 - BASIC OF SPECTROSCOPY: DECOMPOSITION OF LIGHT BY DIFFRACTION GRATINGS

- Spectroscopy is separation of light from a source in its frequency components. The basic element allowing it is the diffraction grating.

d period



Impinging Light

$$d \sin\theta = m\lambda$$, constructive interference

Laser beams of different frequencies are sent on a low frequency diffraction grating and diffraction orders of the different lasers are produced.

By let them impinge on a screen the different wavelenght relations are measured, by using the relationship:

$$d \sin \theta_1 = m \lambda_1$$
$$d \sin \theta_2 = m \lambda_2$$

and the wavelenghts also obtained.

EXPERIMENTS

By use of **linear gratings of different periods** (100, 300, and 600 and 1000 lines/mm) decomposition will be shown of radiation from different sources including lasers and leds. A number of orders will be seen.

In particular cases the relationship between the wavelengths of two laser, green and red, will be checked by measuring the diffraction angles.

Examples will be also seen of spectra produced by a **two-dimensional grating**.

EXPERIMENTS on DIFFRACTION and FOURIER TRANSFORM

We will experience diffraction of HeNe laser radiation, wavelength 632,8 nm, by:

a - wires,

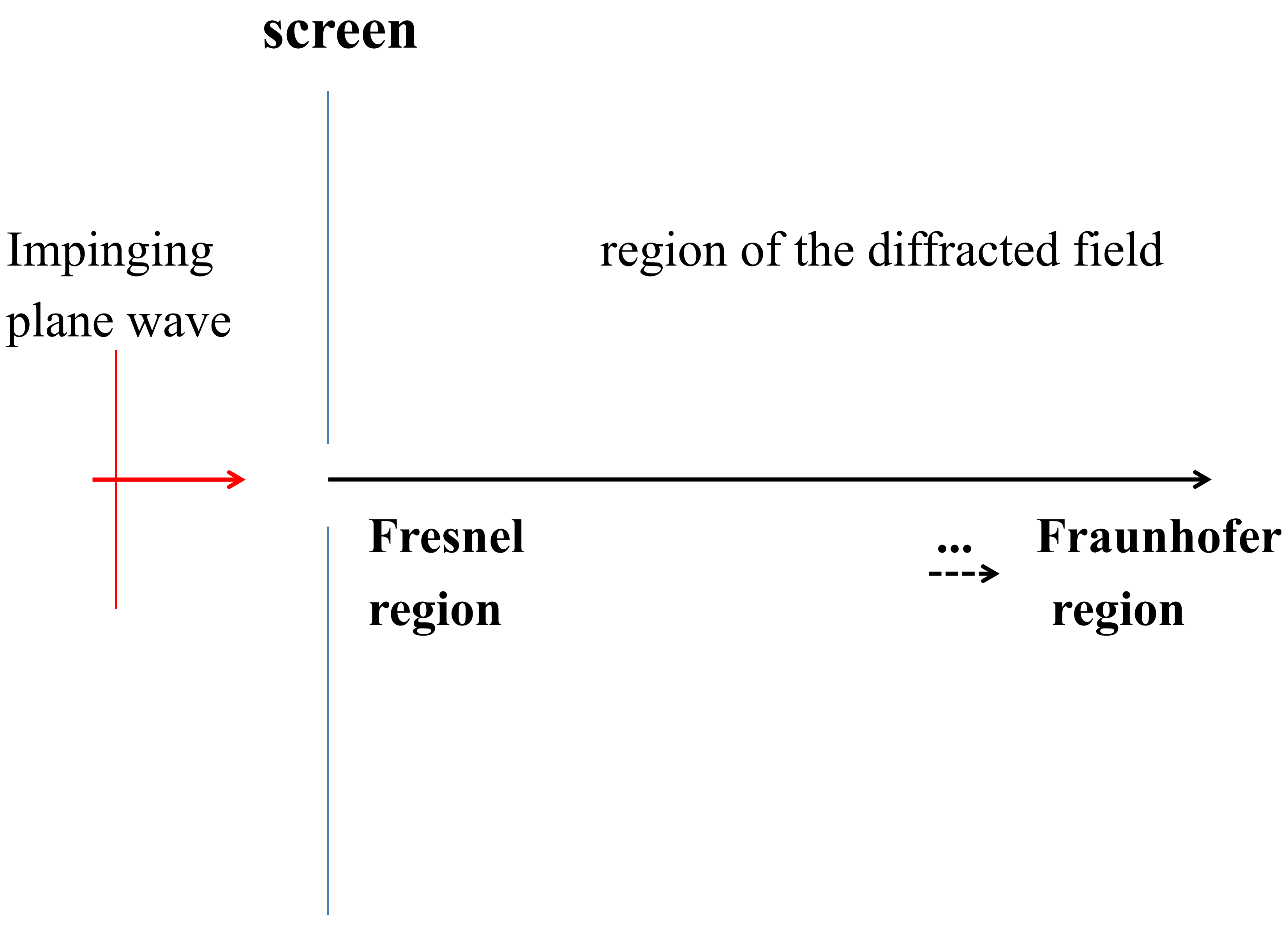
b - slits of different width and

c - circular apertures of different radius

and will make measurements to check the dependence on the aperture radius

We will give interpretation of diffraction in terms of Fourier transform

Diffraction by an aperture on a screen



DIFFRACTION GIVES RISE TO:

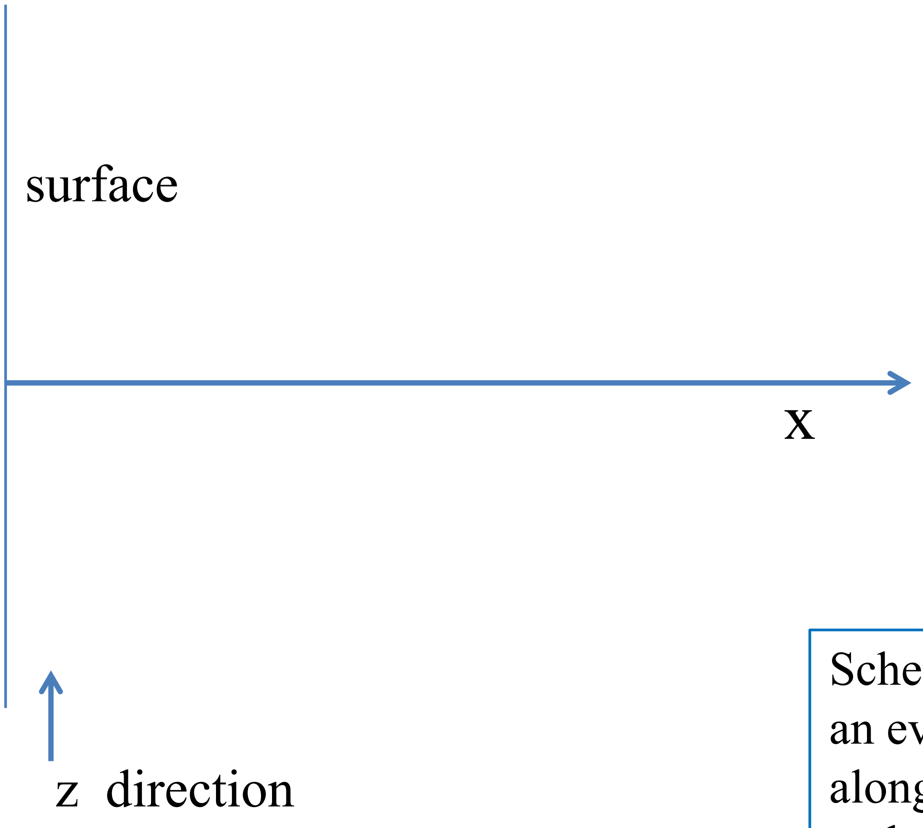
1 - (real) waves propagating in the space after the screen.

On a screen at some distance they give rise to an illumination patterns depending on the distance. Interest here is on a screen very far, Fraunhofer region.

2 - evanescent waves propagating along the screen.

They are also called surface waves. Their amplitude decreases in few wavelengths from the screen and do not propagate in the space. They carry information that is lost and set the diffraction limit to the resolving power of optics instruments

GEOMETRY OF EVANESCENT WAVES



Scheme for the description of an evanescent wave flowing along a surface in z direction and evanescing normally to it.

$$v(P,t) = A \exp(-k\, \alpha_i\, x)\, \exp[i(k\, \gamma_r\, z - \omega t)]$$

DIFFRACTION EXPERIMENTS

- We will follow the pattern development from Fresnel to Fraunhofer region

- We will check the angular dependence on the aperture width by measuring the width of the intensity patterns in the Fraunhofer region in different cases.

- For the circular opening: considerations on the resolving power of instruments, such as the Telescope, will be made,

the microscope deserves some more attention, Abbe formula, and is not considered here.

FOURIER TRANSFORM

Diffraction operates the Fourier Transform:

the field at infinity is the transform of the field on the aperture

We will check that

FUNCTION	TRANSFORM
1 - **Rect**	**Sinc** = [sin(arg)] /arg
2 - **Circ**	**Airy Function** = [Bessel J_1(arg)] /arg

Remember: **we see the square**.

If the aperture is the border of a converging lens, the transform goes in the focal plane. In the **focal plane** the lens operates the **Fourier Transform of the field on its aperture**. This is the basis of the optical elaboration of images, which utilizes the Convolution theorem in the focal plane.

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