Interference of microwaves

Related topics
Wavelength, standing wave, reflection, transmission, Michelson interferometer.

Principle and task
A microwave beam, after reflection from a metal screen or glass plate, interferes with the primary waves. The wavelength is determined from the resultant standing waves.

Equipment

Microwave transmitter w. klystron	11740.01	1
Microwave receiver	11740.02	1
Microwave receiving dipole	11740.03	1
Microwave power supply, 220 VAC	11740.93	1
Protractor scale with pointer	08218.00	1
Glass plate, 200×300×4 mm	08204.00	2
Screen, metal, 300×300 mm	08062.00	2
Plate holder	02062.00	3
G-clamp	02014.00	2
Meter scale, demo, l = 1000 mm	03001.00	2
Tripod base -PASS-	02002.55	1
Barrel base -PASS-	02006.55	4
Support rod -PASS-, square, l 250 mm	02025.55	1
Right angle clamp -PASS-	02040.55	1
Multirange meter with amplifier	07034.00	1
Adapter, BNC-plug/socket 4 mm	07542.26	1
Connecting cord, 750 mm, red	07362.01	1
Connecting cord, 750 mm, blue	07362.04	1

Problems
Measurement of the wavelength of microwaves through the production of standing waves with

1. reflection at the metal screen,
2. plane-parallel plate,
3. the Michelson interferometer.

Set-up and procedure
The experimental set up for reflection at the metal screen is shown in Fig. 1 (above). The microwave receiving dipole is used for field-strength measurement. Fig. 3 shows the set up for interference at plane-parallel plates. D_1 and D_2 denote the directional receivers for measuring reflection and transmission respectively. The Michelson interferometer is shwon in Fig. 1 and in Fig. 5.

For detection, the microwaves (9.45 GHz) are amplitude-modulated, either internally with a frequency of 50 Hz or externally with any desired (LF) frequency. With constant modulation (Frequency and amplitude), the signal demodulated with a receiving diode (e. g. 50 Hz) is proportional to the field strength and is measured directly with the digital multimeter.

Through superimposition (interference) of the microwaves (RF), e. g. through reflection, standing waves are produced, so that the LF signal measured with the receiving diode reflects the interference structure and can thus be used to measure

Fig.1a: Experimental set up for the interference of microwaves in the Michelson interferometer (beneath).
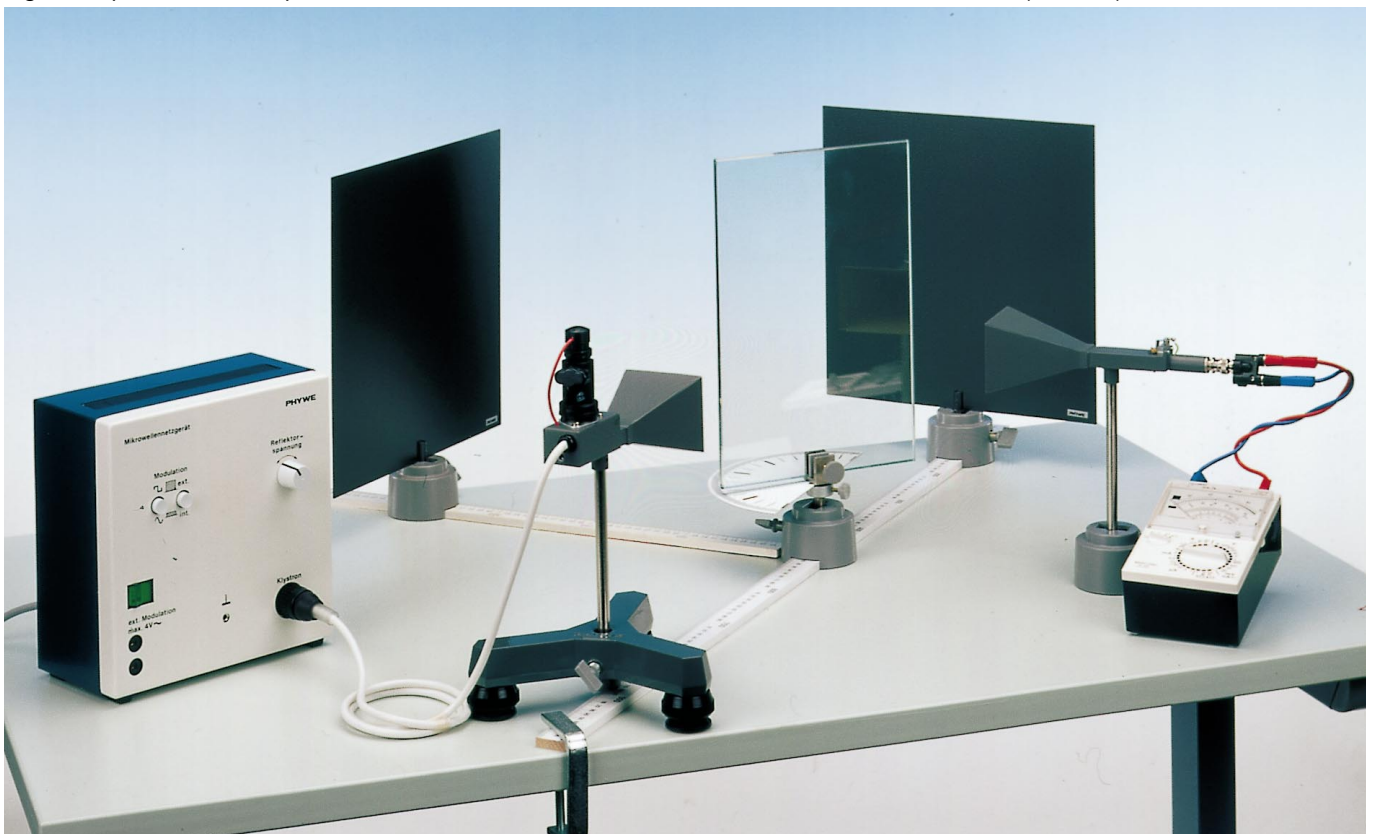
Interference of microwaves

Fig.1b: Experimentel set up for interference of microwaves with a plane parallel plate.

the wavelength. Since the incident and reflected waves from the screen are generally of different internsities, total extinction should not be expected (Fig. 2).

Theroy and evaluation

If a plane wave approaches along the *x*-axis and is reflected at a surface which is perpendicular to the *x*-axis, the incident and reflected waves interfere with each other:

$$E = A \sin \omega \left(t - \frac{x}{c}\right) - A \cos \omega \left(t + \frac{x}{c}\right)$$

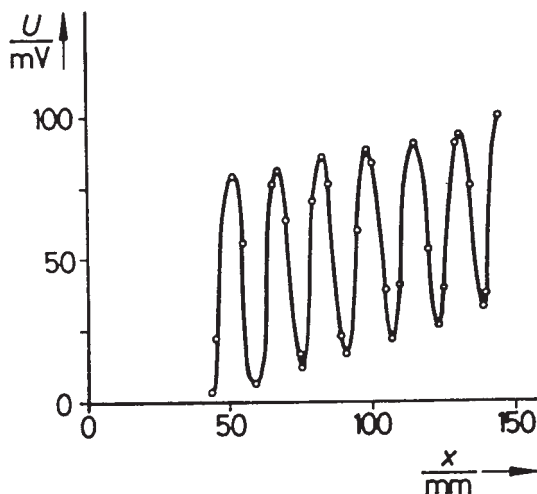$$E = 2 A \sin \omega t \; sin \; \frac{\omega x}{c}$$

Fig. 2: Intensity distribution on the reflection of microwaves, as a function of the distance from the screen.

where ω is the angular frequency and *c* is the speed of propagation of the wave. *E* thus disappears for

$$x = n \cdot \frac{\lambda}{2} \, ,$$

where

$$n = 0, 1, 2, \dots$$

From the distance between the maxima in Fig. 2, the wavelength is obtained as the mean value

$$\lambda = 3.18 \text{ cm.}$$

If a microwave falls on the surface of a glass plate, part of the wave is reflected and the remainder enters the glass. At the rear surface, partial reflection and transmission again occur. If two glass plates are placed parallel to each other and perpendicular to the microwave beam, interference occurs as with reflection at the screen. If a receiver is set up behind the two glass plates (see Fig. 3), the interference spectrum is obtained as a function of the spacing *x* of the glass plates.
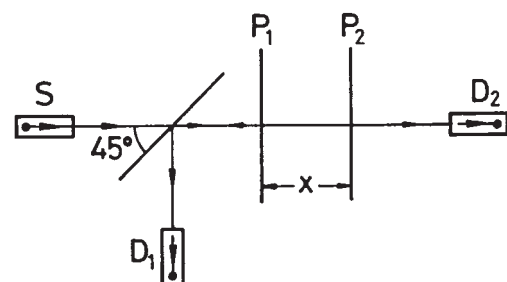

Fig. 3: Interference at plane-parallel plates in transmission.

Fig. 4: Intensity distribution in the diffraction of microwaves as a function of the plate spacing with interference at plane-parallel plates in transmission.
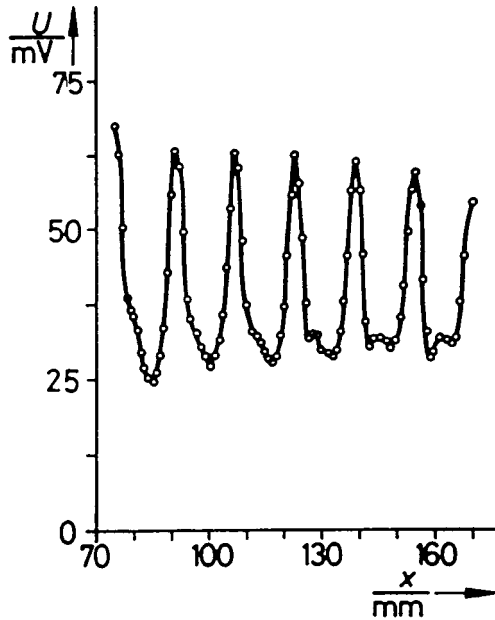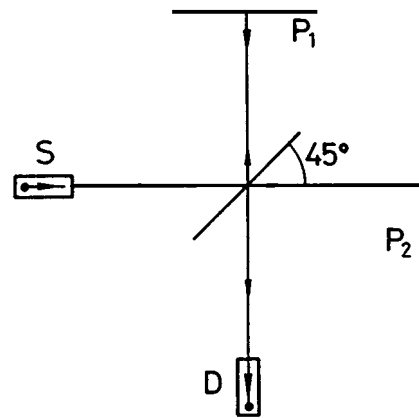

Fig. 5: Michelson arrangement for the interference of microwaves.

The mean value of the wavelength is obtained from the distances between the maxima as

$$\lambda = 3.18 \text{ cm.}$$

The small intermediate maxima in Fig. 4 are interference maxima between the outer surfaces of the glass plates (plate thickness 0.4 cm), while the principal maxima belong to the interferences at the opposing faces of the two plates.

If the experimental set up is altered so that the observations are made in reflection instead of transmission, the maxima and minima are interchanged, because of the phase change at reflection.

If an incident microwave is divided into two coherent waves and if the partial waves are brought of interference through reflection at metal plates (Michelson interferometer: see Figs. 1 and 5), intensity maxima and minima are formed as a function of the position of the screens.
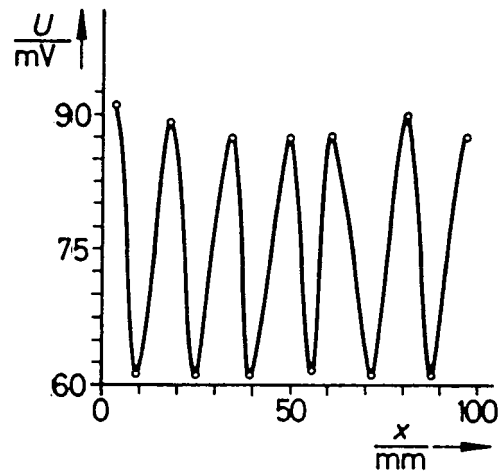

Fig. 6: Intensity distribution during interference of microwaves in the Michelson arrangement, as a function of the position of the reflection screens.