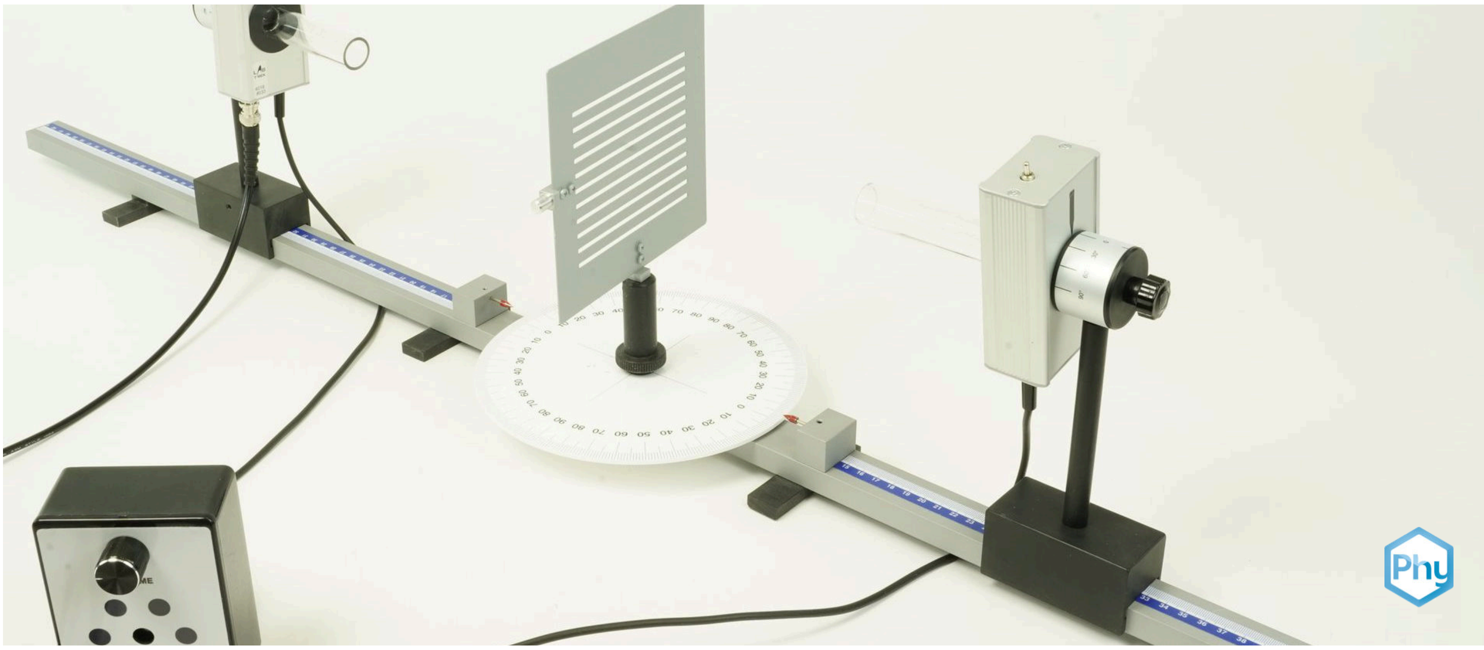
Polarization of Microwaves



Physics | Mechanics | Vibrations & waves

Difficulty level	Group size	Preparation time	Execution time
-	-	-	-

This content can also be found online at:

http://localhost:1337/c/6015365d38ab09000357db18

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General information

Application

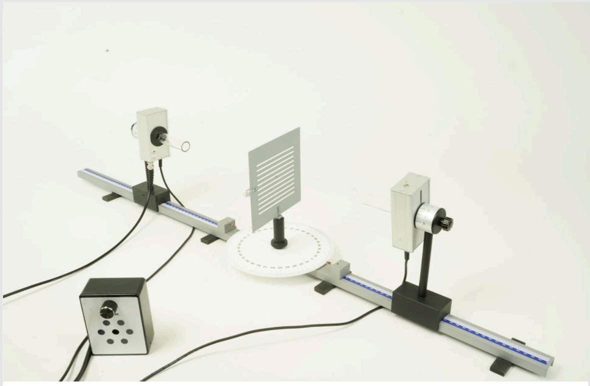

Fig.1: Experimental set-up

The polarization of microwaves is utilized in satellite communication to minimize interference between signals. Different polarizations can transmit on the same frequency band without disrupting each other. This allows for a more efficient use of available bandwidth. By choosing the appropriate polarization, signal quality can be enhanced. As a result, a more stable and clearer communication link is ensured.

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Other information (1/2)

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Prior knowledge

The prior knowlege required for this experiment is found in the theory section.

Main principle

Electromagnetic waves impinge on a grating whose transmissivity depends on the rotation plane of the waves.

Other information (2/2)

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Learning objektiv

The goal of this experiment is to investigate the polarisation of microwaves.

Tasks

Measure the intensity of the microwave radiation behind a polarisation grating as a function of the angle.

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Theory (1/3)

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Electromagnetic waves, i.e. also microwaves, can be described by an electric part, a magnetic part, and their respective directions of propagation, which are perpendicular to one another (see Fig. 2).The direction of propagation is described by the wave vector $\vec{k}$. The direction of the oscillation is known as the polarisation. A distinction is made between linear polarisation in which the oscillation planes do not change, and circulation polarisation in which the respective oscillation plane rotates.

When a polarised wave impinges on a grating, this grating is either transmissive, non-transmissive, or partially transmissive, depending on the direction of polarisation. Looking at the projection of the electric field vector in the direction of the grating (see Fig. 3), there is the transmitted part $E(\alpha)$, depending on the angle α under which the polarised waves impinge on the grating.

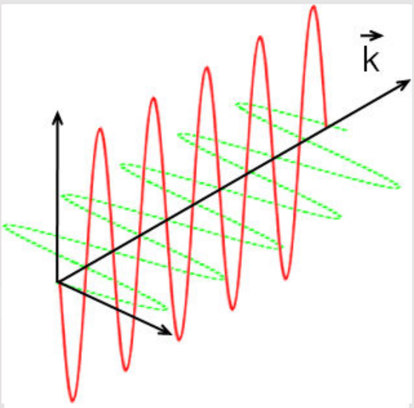

Fig. 2: Electromagnetic wave (schematic representation)

Theory (2/3)

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$E(\alpha) = E_0 \cdot \cos(\alpha)$ (1)

An object that is transmissive with regard to electromagnetic waves depending on the angular alignment, is referred to as a polariser. Actually, the diode that is used for the experiment acts as a second polariser, which means that a second projection in the direction of reception of the diode must also be taken into consideration.

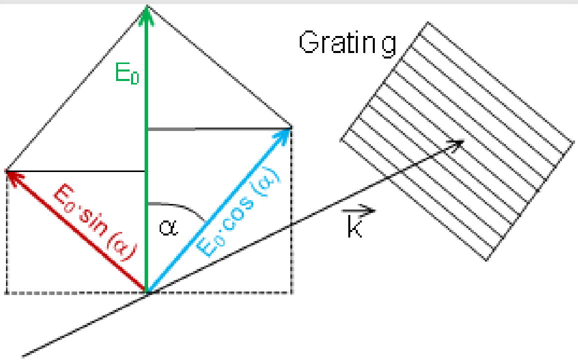

Fig. 3: Projections of the electric field vector

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Theory (3/3)

This is why the following applies to the measured intensity I(α):

$I(\alpha) = I_0 \cdot \cos^2$ (2)

This relationship is known as "Malus' law". (The amplitudes E_0 are incorporated in the intensity measurement in a square manner.)

For a better understanding, the following analogy from the field of mechanics should be taken into consideration: If a rope is fed through a grating and tensed, and if then one of the ends of the rope is caused to oscillate, the wave will either pass through the grating or be blocked, depending on the direction of excitation.

Please note: Polarisation exists solely for transverse waves (oscillation perpendicular to the direction of propagation). Longitudinal waves (oscillation parallel to the direction of propagation), e.g. like in the case of sound propagating in the air, cannot be polarised.

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Equipment

Position	Material	Item No.	Quantity
1	Microwave set II, 110...240 V	11743-99	1

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Setup and Procedure

Setup (1/2)

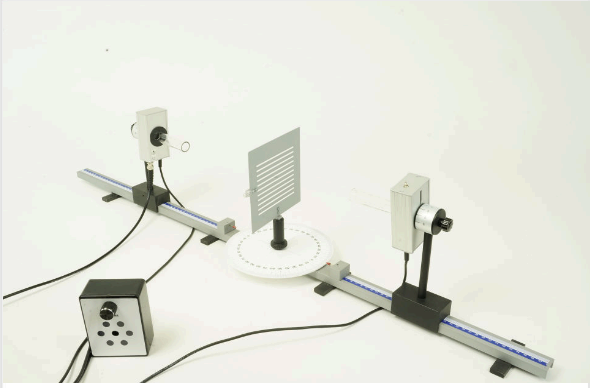

Fig. 4: Experimental set-up

- Set the experiment up as shown in Fig. 4.
- Install the grating in the centre of rotation of the angle scale (vertical alignment of the grating bars) and align the mark of the scale to 180°.
- Combine the angle scale and meter rule by way of the screw on the back of the angle scale and the recess in the meter rule.
- Turn the meter rule in order to align the reference mark (arrow) on the angle scale with the one of the meter rule so that they coincide. Position the set-up on your experiment surface so that you can read the scale of the meter rule without any parallax.

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Setup (2/2)

- Position the transmitter on the fixed rule of the angle scale at 285 mm (the opening of the housing is located at a distance of 15 cm).
- Position the receiver opposite the transmitter at approximately 190 mm so that the distance between the opening of the receiver and the grating is approximately 6.5 cm.

Procedure

Switch the microwave transmitter on by connecting the control unit to the mains power supply. Maximise the voltmeter reading by varying the amplitude of the transmitter (amplitude controller) and the position of the transmitter and receiver along the optical axis.
Rotate the transmitter completely around its axis in order to ensure that the measuring range is used to the fullest possible extent without exceeding it. Correct the amplitude if necessary. Vary the angle of the transmitter in steps of 10° and measure the receiver signal by way of the voltmeter. Use the angle scale of the set square for the angular adjustment by aiming the grating through the set square and by using the corresponding angle mark for the perpendicular alignment.

Return the transmitters to its normal operating position (no rotation). Remove the polarisation grating from its holder and turn it manually in the beam. Observe the voltmeter while doing so. You can switch on the internal modulation and internal loudspeaker for better demonstration. Remove the grating completely from the beam path. Then, turn the transmitter and afterwards the receiver. Observe the reading of the voltmeter as a function of the relative alignment of the transmitter and receiver with regard to one another.

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Evaluation

Results (1/4)

Demonstrate the dependence of the intensity on the angle α of the polarisation grating by plotting the voltage U (which is proportional to the intensity) as a function of the angle α (see Fig. 6). Correct the angle α by 90° so that all of the angles are stated with regard to the vertical axis. Verify Malus' law by plotting the voltage U as a function of $\cos^2(\alpha)$ so that a linear relationship results.

The dependence of the intensity on the angle at which the radiation impinges on the grating is confirmed within the scope of the measurement accuracy (Malus' law). The dependence of the intensity on the relative alignment of the transmitter and receiver has also been demonstrated.

The deviations from the expected dependence in accordance with Malus are due to the inaccuracy of the angular adjustment (parallax), but they may also be due to a non-ideal diode characteristic of the receiver. A potential invalidation of the measurement due to reflections in the environment should also be taken into consideration as a source of error in addition to voltmeter reading errors.

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Results (2/4)

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α [°]	$\alpha_{corrected}$ [°]	U [V]	$\cos^2(\alpha)$
0	-90	0.3	0.000
10	-80	0.65	0.030
20	-70	1.1	0.117
30	-60	1.5	0.250
40	-50	1.975	0.413
50	-40	2.175	0.587
60	-30	2.425	0.750
70	-20	2.525	0.883
80	-10	2.75	0.970
90	0	2.8	1.000

α [°]	$\alpha_{corrected}$ [°]	U [V]	$\cos^2(\alpha)$
100	10	2.75	0.970
110	20	2.6	0.883
120	30	2.2	0.750
130	40	1.8	0.587
140	50	1.5	0.413
150	60	1.05	0.250
160	70	0.6	0.117
170	80	0.35	0.030
180	90	0.275	0.000
190	100	0.55	0.030

Results (3/4)

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α [°]	$\alpha_{corrected}$ [°]	U [V]	$\cos^2(\alpha)$
200	110	1.1	0.117
210	120	1.7	0.250
220	130	2.025	0.413
230	140	2.3	0.587
240	150	2.55	0.750
250	160	2.725	0.883
260	170	2.85	0.970
270	180	2.9	1.000
280	190	2.825	0.970
290	200	2.6	0.883

α [°]	$\alpha_{corrected}$ [°]	U [V]	$\cos^2(\alpha)$
300	210	2.3	0.750
310	220	1.825	0.587
320	230	1.4	0.413
330	240	0.9	0.250
340	250	0.55	0.117
350	260	0.325	0.030
360	270	0.3	0.000

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Results (4/4)

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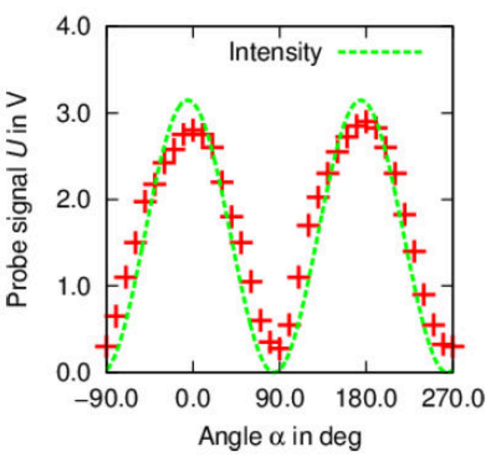

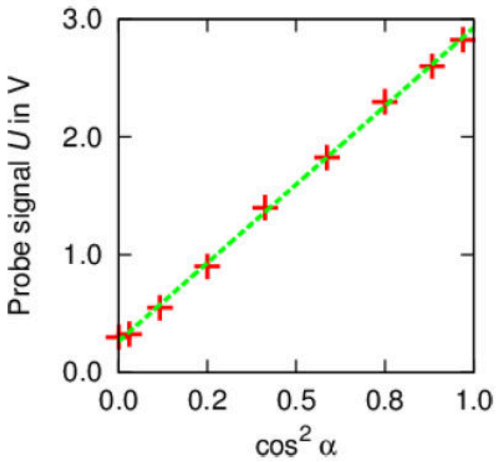

Fig. 6: The intensity as a function of the (corrected) angle and Malus' law

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