# Technology Arts Sciences TH Köln

# Course HO - Holography

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# <u>General information</u>

Long name	Holography
Approving CModule	HO BaET
Responsible	Prof. Dr. Stefan Altmeyer Professor Fakultät IME
Level	Bachelor
Semester in the year	summer semester
Duration	Semester
Hours in self-study	78
ECTS	5
Professors	Prof. Dr. Stefan Altmeyer Professor Fakultät IME
Requirements	mathematics: - vector calculus - complex numbers - Fourier transform physics / optics - paraxial optics - wave optics
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Separate final exam

Yes

Final exam

As long as the number of participants is not too high, an oral examination is preferred over written exams.

Lowest competence level checked is knowledge. Questions could adress the definition of thick and thin gratings, the formulation of the grating equation for thick gratings for different angular situations, the numbers of achievable diffraction efficiency in amplitude- and phase holograms.

The next competence level is related to skills. Examination could be done by the task to find out the position of the different diffraction orders when a holographics setup is given, the diffraction efficiency of the different diffraction orders of a thin phase hologram are calculated, the requirements on temporal coherence in a holographic setup is used to find the maximum allowed linewidth of the laser in use, or to explain, what details have to be considered, when a holographic setup has to be built.

The highest competence level adressed is methodical expertise. It can be checked by a real world task: E.g. the design of a holographic setup to record digital holograms for a technical 3D contour measurement, the draft of an algorithm to calculate a digital hologram, the design of a procedure to copy holohrams, so that they can be reconstructed with white light instead of lasers. In a guided discussion or guided calculation it can be found out easily, if the underlying principles are understood and can be applied proactively, if intellectual transfer is made and if there is sufficient overview.

#### Minimum standard

Correct answer of at least 50 % of the questions

#### Exam Type

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### <u>Lecture</u>

### Learning goals

#### Knowledge

Characterisitcs of a hologram, difference to photos, stereograms, 3D cinema etc.

thin gratings grating equation exposure of gratings influence of angles influence of polarization diffraction efficiency of thin gratings amplitude gratings phase gratings Holographic imaging equations recording of a hologram reconstruction of a hologram interpretation of the different diffraction orders location of the diffraction orders inline and side band holograms

#### zone plates

inline zone plates interference of spherical and plane wave focal points as real and virtual images white light reconstruction, dispersion, orthoscopic and pseudoscopic image interpretation as angular grating with variable perio off axis zone plates interference of spherical and plane wave shift of spherical wave: shift of zone plate tilt of plane wave: ellipitical deformation increase in spatial frequencies separation of real and virtual image applications: measurement of particles, injection system design, respirable sprays

basic properties of holograms transition from elementary holograms to complex holograms dispersion in holograms reconstruction with different wavelengths reconstruction with white light blurring in non image plane hologra,s viewbox in dependence on the image depth recording with high aperture objectives diffusors for aperture stretching in near image plane holography image plane holography and dispersion coherence requirements of reconstruction light source extension and lateral image precision spectral pureness and axial image precision

copying holograms contact copy copy with image plane shift coherence requirements in copy processes

thick gratings definiton Bragg condition efficiency

classificaion of holograms interferogram of two point sources locations of equal phase and euqality in distance difference classification thick and thin holograms on- and off-axis holograms transmission and refixion holograms Fourier holograms white light holograms Benton's white light holograms thin white light hologram reduction of perspective to one dimension methods for recording and reconstruction print copying application: EC card, ID card, product labelling Denisjuk holograms thick white light hologram Lippmann's color photography principle of spectral filtering depth of field, spectral properties, luminosity rennisance due to new materials: photopolymer RGB Denisjuks applications: head-up display, sensor holograms, autostereoscopic displays

multiplexing of holograms angular multiplexing wavelength multiplexing share of index modulation applications: low content displays, RGB Denisjuk holograms

digital holograms phase conserving interference of spherical waves restriction to amplitude or phase due to recording materials phase freedon of image points Gerchberg Saxton algorithms, iterative Fourier transform algorithms calculation of digital stereograms phas shifting spatial light modulators: LCoS displays applications: Diffractice Optical Elements, holographic ruler, flexible digital optics, cinematic holography and displays

if there is enough time in the semester:

coupled wave theory of Kogelnik to calculate the diffraction efficiency of thick holograms.

### Skills

Judge advantages and drawbacks of different technical 3D technologies

Calculate efficiencies of thin gratings

Calculate types and positions of different diffraction orders in off axis holograms

Apply the principles to spatially move and tune the efficieny of the different diffraction orders

Calculate the depth of field in holograms an find required parameters for the light sources

Classify holograms and choose the right application specific one

Choose the right copy process for each application

Design holographic setups application specific

# Expenditure classroom teaching

Туре	Attendance (h/Wk.)
Lecture	2
Tutorial (voluntary)	0
Separate exam	
none	

# • <u>Practical training</u>

# Learning goals

Skills
align laser to optical axis
setup spherical and plane waves
plan foldes beam paths
align complex optical setups
balance optical paths in asymmetric setups
make and use a setup for Denisjuk holograms
make and use a setup for zone plates
make and use a setup for gratings
make and use a setup for off axis holograms
make and use a setup for rainbow copies
make and use a setup for digital holography with an LCoS display

# Expenditure classroom teaching

Туре

Practical training	2
Tutorial (voluntary)	0

## Separate exam

### Exam Type

working on projects assignment with your team e.g. in a lab)

### Details

 Written examination questions and complex calculations, which require to find a suitable Ansatz, related to the experiment have to be prepared at home.

2) The homework is discussed with all participants at the beginning of the laboratory. The underlying ideas of the experiments have to be explained at the beginning of the laboratory and are discussed extensively.

3) Make the experiment alone in a team of two.

- Build up and adjust your own setup
- record and reconstruct holograms with this setup

#### Minimum standard

All written tasks must have been delt with.

The basic ideas of the experiment must have been understood.

All experiments must have been performed.

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