

Course Manual LT

Laser Physics and Technology

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– General information

Long name Laser Physics and Technology

Approving CModule [LT_BaET](#), [LT_BaOPT](#)

Responsible Prof. Dr. Stefan Altmeyer
Professor Fakultät IME

Valid from winter semester
2022/23

Level Bachelor

Semester in the year winter semester

Duration Semester

Hours in self-study 78

ECTS 5

Professors Prof. Dr. Stefan Altmeyer
Professor Fakultät IME

Requirements mathematics:
matrices
differential calculus
integral calculus

physics / optics:
basics of geometrical optics
basics of wave optics

Language German

Separate final exam Yes

Literature

Eichler, Eichler: Laser - Bauformen, Strahlführung, Anwendungen (Springer)

Poprawe: Lasertechnik (Copy-Shop AC-UNI-COPY)

Pedrotti, Pedrotti, Bausch, Schmidt: Optik für Ingenieure. Grundlagen (Springer)

Final exam

Details

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

Lowest competence level checked is knowledge. This could be e.g. structural components that are present in every laser, the definition of physical quantities like beam quality, beam quality factor, beam parameter product, or it could be wavelenths, typical power and fields of application of the mmost important industrialy lasers.

The next competence level is related to skills. Examination could be done by a beam calculation of a gaussian beam along an optical path with lenses, the calculation of the potential optical stability of a resonator, or by a rough calculation of the expected number of longitudianl modes of a laser with a given laser medium and given resonator parameters.

The highest competence level adressed is methodical expertise. It can be checked by the discussion of a real world task: E.g.: What are the basic parameters required for a welding process, semiconductor lithography or an medical operation of the eye. Give sound explainaitions and describe further procedure for parametrization and choice of laser source and optical equipment.

Include economical and safety considerations. In a guided discussion 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 EN mündliche Prüfung, strukturierte Befragung

– Lecture / Exercises

Learning goals

Goal type	Description
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Special requirements

none

Accompanying material	lecture notes as downloadable file
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Separate exam	No
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Knowledge

Types of lasers and their fields of application
gas lasers
CO₂ laser
excimer laser
argon ion laser
dye laser
solid state laser
diode laser
optical pump
telecommunication
laser material processing

laser principle
absorption, spontaneous emission, stimulated emission
Maxwell-Boltzmann distribution
inversion
3- and 4 level systems
rate equations

transversal modes
Fresnel number
optical regimes: geometrical optics, Fresnel diffraction and Fraunhofer diffraction
diffraction operator, Eigenvalues and Eigenfunctions
Laguerre-Gauss modes and Hermite-Gauss modes
mathematics of Laguerre-Gauss modes
transversal monomode lasers

axial modes
resonator and standing waves
comb of modes and amplification bandwidth
Fabry-Perot interferometer, Etalon
frequency bandwidth of an axial mode
quality factor and finesse
axially monomode laser
temporal coherence, coherence length

properties of the gaussian beam
complete definition with one single parameter: beam radius or Rayleigh length
Beam quality and beam quality factor
diffraction limited beam as consequence of Heisenberg's uncertainty relation

propagation of gaussian beams
beam transfer matrices
ABCD law of beam propagation
Rayleigh length as location of strongest wavefront bending
types of - and reasons for -

deviations of Gaussian beam
propagation from geometrical
optics

resonator design
g parameter
stability of resonators as a
eigenvalue problem
stability diagram
stability and mode volume

If sufficient time in the semester left:

Ultra short pulse lasers
laser materials with high
amplification bandwidth
dispersion compensation
mode coupling and Kerr effect
hard and soft aperture mode
coupling
starting mechanisms for mode
coupling
orders of magnitude of physical
properties of ultra short pulse
lasers
average power
pulse peak power
intensity
light pressure
strength of the electrical field
energy transferred to electrons
light-matter interaction
warming and melting
vaporizing and subliming
photo disruption
electron-phonon coupling time
Coulomb explosion
generation of hard x-rays
cold material processing and its
applications

Skills

classify laser materials
differentiate and classify transverse modes
calculate quality factor and finesse of a Fabry-Perot interferometer
calculates the propagation of Gaussian beams
calculate the stability of a resonator
calculate the most important optical parameters of a laser
choose a suitable laser and optical system for a given application

All acquired knowledge is not meant to be fact based knowledge but should be interconnected within by a deeper understanding of the underlying physical principles and intellectual transfer should be possible:

- physics of laser light generation and physical properties of laser light
- physics of light-matter interaction
- diffraction theory

Expenditure classroom teaching

Type	Attendance (h/Wk.)
Lecture	2
Tutorial (voluntary)	0

– Practical training

Learning goals

Goal type	Description
Skills	<ul style="list-style-type: none">- build a laser, align and start it- build a setup of measuring tranverse modes, measure traverse modes and calculate beam quality- measure axial modes, find out the free spectral range, the spectral bandwidth of a single mode, the amplification bandwidth of a laser, the coherence length of a laser- build a diode pumped solid state laser- build a unit for frequency doubling and use it in combination with a diode pumped solid state laser.- write scientific report<ul style="list-style-type: none">describe the taskdescrib the idea of the solutionexplain the experimental setupexplain the data processingmake error analysispresent the results and make a critical discussion

Expenditure classroom teaching

Type	Attendance (h/Wk.)
Practical training	2
Tutorial (voluntary)	0

Special requirements

none

Accompanying material

Instrcutions for the experiments as downloadable files.

Operating manuals for complex equipment as downloadable files.

Separate exam

Yes

Separate exam

Exam Type

EN Projektaufgabe im Team bearbeiten (z.B. im Praktikum)

Details

1) Written examination questions related to the experiment have to be prepared at home and shown at the beginning of the laboratory.

2) The underlying ideas of the experiment have to be explained at the beginning of the laboratory.

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

- Build up and adjust your own setup
- Acquire / measure data with this setup

4) Write a documentation on the experiment. It will be checked with regard to

- completeness
- scientific and precise language
- correctness
- understanding of the interrelations and interpretation of the results

Minimum standard

All written tasks must have been dealt with.

The basic ideas of the experiment must have been understood.

All experiments must have been performed.

The reports must be free of systematical errors.