Technology
Arts Sciences
TH Köln

Course Manual RM

Scanning Microscopy

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− General information

Long name	Scanning Microscopy
Approving CModule	RM_MaET
Responsible	Prof. Dr. Stefan Altmeyer Professor Fakultät IME
Valid from	winter semester 2020/21
Level	Master
Semester in the year	winter semester
Duration	Semester
Hours in self-study	114
ECTS	5
Professors	Prof. Dr. Stefan Altmeyer Professor Fakultät IME
Requirements	mathematics: differential- and integral calculus complex numbers vector calculus basics of differential geometry physics / optics: geometrical optics wave optics
Language	German
Separate final exam	Yes

Literature

- Reimer: Scanning Electron Microscopy (Springer)
- Meyer, Hug, Bennewitz: Scanning Probe Microscopy (Springer)
- Wilhelm, Gröbler, Gluch, Heinz: Die konfokale Laser Scanning Mikroskopie (Carl Zeiss)

Final exam

Details

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

To a small amount, the lowest competence level, knowledge, is checked. This could be e.g. the different types of cathodes in electron microscopes, which lead to different classes of instruments or it could be a question regarding the different building principles of confocal measurement setups.

The next competence level is related to skills.

	Examination could be done by showing the sketch of a setup and it has to be devided into different functional groups and the critical aspects in each group has to be identified. Another skill to be tested could be to start from the Lorenz force and show, why charged particles don't change their energy in magnetic fields. The highest competence level adressed is methodical expertise. It can be checked by the discussion of a real world task: More scientific tasks could be to give a justified explaination, if the construction of an electron microscope with a certain acceleration voltage needs relativistic calculation or not. Another question could be if quantum effects have to be taken into account or not when dealing with a certain type of cathode system. More practical oriented questions could regard a measurement task in 3D topography and it has to be explained, what measurement principle could be chosen for this task and which one not. A guided discussion is very well suited to find out, if the underlying principles are understood and can be applied correctly, if scientific transfer is possible and how much overview there is.
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
Knowledge	electron microscopy wave-particle dualism of electrons, De Brogli wavelength reletivistic mass increas resolution of electron optical systems depth of field in an electron microscope electron emission physics of electron emission thermoionic emission Schottky emission field emission technical construction of electron emitters brigthness as a conserving magnitude magentic deflection units focussing lens equations of motion for electrons in focussing lenses principles of aberration minimization scan system electron matter interaction primary electrons secondary electrons Auger electrons Bremsstrahlung characteristic x rays cathodo luminescence Everhart-Thornley detector electron contrast topography contrast material contrast lattice orientation contrast conductivity contrast applications and limitations tunneling microscope wave function definition continuity and continuous differentiable probability interpretation principle potential diagram Fermi level work function quantummechanical calculation of the tunneling probability biased tunneling barrier and WKB

Special requirements

none

Accompanying material	lecture notes as downloadable file
Separate exam	No

approximation
piezo motors
physical principles
nonlinearity, hysteresis, creep
principles of control theory in a tunneling microscope
preparation of tunneling tips
image as result of a measurement
convolution of object and tip
lattive resolution and atomic resolution
applications and limits

atomic force microscope
setup
types: contact mode, noncontact mode, tapping mode, magnetic mode,
applications and limits

confocal microscopy
principle of confocal apertures
principle of optical sectioning
lateral and axial resolution
pupil illumination and over-illumination in concofal laser scanning microscopes
problems of adjustment
Nipkow disc
freedom of adjustment
light budget and reflections
rotating microlens array
confocal dispersion sensor
applications and limits

Skills

electron micorscope
calculate classical and relativistic electron speeds
calculate wavelngths of electron
calculate resolution of electron optical systems
explain the different emission regimes
explain the different electron-matter interaction processes
sketch and explain the different types of electron lenses
sketch and explain an Everhart-Thornley detector
calculate the depth of field in an electron microscope

tunneling microscope
sketch and explain the potential over space diagram for tunneling
explain the Ansatz to calculate the tunneling probability
explain the difference between atomic- and lattice resolution

Expenditure classroom teaching

Type	Attendance (h/Wk.)
Lecture	0
Exercises (whole course)	0
Exercises (shared course)	0
Tutorial (voluntary)	0

– Practical training

Learning goals

Goal type	Description
Skills	Adjustment and use of electron microscopes tunneling microscopes atomic force microscopes confocal micorscopes perform a metrological task measurement of hights measurement of 3D topographies structural analysis finding ultimate resolution limits interpretation of metrological findings

Expenditure classroom teaching

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

Special requirements

none

Accompanying material	none
Separate exam	Yes

Separate exam

Exam Type	EN Projektaufgabe im Team bearbeiten (z.B. im Praktikum)
Details	Accopmpaning the execution of the metrological task Examination of the theoretical background regarding the underlying principles of the instrumentation and the application Examination of the results regarding the technical level of the experimental process and the scientific level of the analysis and interpretation.
Minimum standard	All experimentals tasks have been performed. In all experiments a level of understanding is achieved, that a use of the instrumention all alone is possible. At least 50 % of the images and measurement results would be, if given in an industrial or scientific context, regarded as sufficient and problem solved.