Technology
Arts Sciences
TH Köln

# Course
# RM - Scanning Microscopy

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## General information

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

### 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

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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.

## Lecture / Exercises

### Learning goals

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#### 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 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

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### 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 |

## Separate exam

none

## Practical training

## Learning goals

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### 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 |

## Separate exam

### Exam Type

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

### 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.