Msc. Microsystems Engineering - Introduction to the programme
Prof. Dr. Moritz Diehl, Dean of Studies

11 October 2017
The technology
A macrosystem

The Airbus A380

- Approximately 1 Million single parts!
  - One Wing: 32,000 parts
- Costs: $ 275 Millions
  - Average per single part $ 275
- High effort for single part fabrication

Can you imagine such a system with 2 Million parts?
A microsystem

The DMD
- Digital Micro-mirror Device
- 1.6 cm x 1.6 cm
- 508,800 mirrors 17 µm x 24 µm
- ~ 2.2 million parts
- Price: ~ € 2 000
- Price / part: < 0.1 Cent
- Mass fabrications

Microsystems
- Many functions
- Small volume
Microsystems are small

Small

A hair, on the same scale. Diameter: \(~ 50 \, \mu\text{m}\)

Smaller

Tiny
A huge variety in microsystems
Microsystems are everywhere

- **Medicine**
  - Minimally-invasive surgery
  - Diagnostics

- **Communications**
  - Fiber optics
  - Mobile phones

- **Consumer**
  - Autonomous networks
  - Sensors

- **Industry**
  - Process management
  - Instrumentation

- **Automobile**
  - Rotatio rate sensors
  - Airbags
The career
Studies: technical skills

- Educational goal:
  - To graduate students who can go from idea to product

- The required skills:
  - Problem definition
  - Solutions & evaluation

- Design & development
  - Fabrication
  - Characterization & optimization
  - Packaging
  - System testing & qualification
  - Transfer to production
  - Marketing

The challenge starts now
Studies: Non-technical skills

- Technical excellence is a given...

- ... but graduates also need:
  - Ability to work in a team
  - Social competence
  - Creativity
  - Openness to new ideas
  - Self-confidence
  - Communication skills
  - Entrepreneurial thinking
  - Ability to motivate, oneself and others
  - Leadership capabilities
Where do I go with my degree?

- Microsystems engineers become:
  - Entrepreneurs, technicians, engineers, group leaders, managers, CEOs, astronauts,…

- Potential employers:
  - Large & small companies of all types
  - Startups and spin-offs

- What do employers want?
  - Potential for development
  - Ability to learn
  - Communications ability (in English and German!)
  - Experience, experience, experience
  - Particular skills? Not so much…

13.10.2017
The department
Faculty of Engineering

- Faculty in operation since 1995
- Department of Computer Science (IIF)
  - 17 professors / ~ 760 students
- Department of Microsystems Engineering (IMTEK)
  - 21 professors / ~ 800 students
- Department of Sustainable Systems Engineering (INATECH)
  - 5 professors / ~ 80 students
22 Laboratories at IMTEK

- MEMS Applications
  Prof. Dr. Roland Zengerle
- Assembly and Packaging Technology
  Prof. Dr. Jürgen Wilde
- Bio- and Nano-Photonics
  Prof. Dr. Alexander Rohrbach
- Biomedical Microtechnology
  Prof. Dr. Thomas Stieglitz
- Biomicrotechnology
  Prof. Dr. Ulrich Egert
- Chemistry and Physics of Interfaces
  Prof. Dr. Jürgen Ruhe
- Design of Microsystems
  Prof. Dr. Peter Woias
- Electrical Instrumentation
  Prof. Dr. Leonhard Michael Reindl
- Gas Sensors
  Prof. Dr. Juergen Woellenstein
- Materials Process Technology
  Prof. Dr. Thomas Hanemann
- Micro- and Material Mechanics
  Prof. Dr. Christoph Eberl
- Microactuators
  Prof. Dr. Ulrike Wallrabe
- Microelectronics
  Prof. Dr. Yiannos Manoli
- Micro-optics
  Prof. Dr. Hans Zappe
- Microsystems Materials
  Prof. Dr. Oliver Paul
- Nanotechnology
  Prof. Dr. Margit Zacharias
- Optical Systems
  Prof. Dr. Carsten Buse
- Sensors
  Prof. Dr. Gerald Urban
- Simulation
  Prof. Dr. Lars Pastewka
- Smart Systems Integration
  Prof. Dr. Alfons Dehé
- Systems Theory
  Prof. Dr. Moritz Diehl
Our foci in research and teaching

- Circuits and Systems
- Design and Simulation
- Biomedical engineering
- Lab-on-a-chip
- Materials
- Process Engineering
- Sensors and Actuators

Chip integrated fuel cell
Optical gas sensor
Electrode array for the brain
The curriculum
General principles:

- **Interdisciplinary basic education** in electrical engineering, physics, chemistry, materials science, technology

- **Hands-on education**
  lab classes in the clean room, electronics and chemistry lab classes, system design project...

- **Systems and application oriented**
  education with a broad, encompassing view

- **Fit for business - non-technical education:**
  project management, IP, business plans, company financing...
Structural principles of all study programs at the faculty

- 30 ECTS per semester
- 30 hours work load per credit point
- All programs are organized in modules
- A module can consist of one or several courses
- Performance evaluation after the semester
Modules in the study program

- **Module Components**
  - Lectures – German: Vorlesung (V)
  - Exercises – German: Übung (Ü)
  - Laboratories – German: Praktische Übung (P)

- **Study performances ("Studienleistungen")**
  - Exercises, reports, mid-term exams…
  - Are not part of your final grade, but may be a pre-requisite for sitting the final exam
  - Are not always graded (only “pass” or “fail”)

- **Exams ("Prüfungsleistungen")**
  - Written or oral exams, reports, …
  - Are always graded
MSc. program in Microsystems

Scope of MSE
- Feasible in 4 semesters (average duration 5 semesters)
- 120 ECTS

Components
- Core courses
- Concentrations are elective modules
- MSc thesis

Educational goals
- Research qualification
- Laboratory techniques
- Presentation & reporting capability
## MSE – Mandatory modules

<table>
<thead>
<tr>
<th>Module</th>
<th>Semester</th>
<th>Type</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Microsystems Engineering</td>
<td>All modules to be completed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microelectronics</td>
<td>1</td>
<td>VÜ</td>
<td>5</td>
</tr>
<tr>
<td>Micro-mechanics</td>
<td>1</td>
<td>VÜ</td>
<td>5</td>
</tr>
<tr>
<td>MST Design Lab I</td>
<td>1</td>
<td>P</td>
<td>3</td>
</tr>
<tr>
<td>Micro-optics</td>
<td>1</td>
<td>VÜ</td>
<td>5</td>
</tr>
<tr>
<td>Sensors</td>
<td>1</td>
<td>V+P</td>
<td>5</td>
</tr>
<tr>
<td>MST Technologies and Processes</td>
<td>1</td>
<td>VÜ</td>
<td>5</td>
</tr>
<tr>
<td>Signal Processing</td>
<td>2</td>
<td>VÜ</td>
<td>5</td>
</tr>
<tr>
<td>Assembly and Packaging Tech.</td>
<td>2</td>
<td>VÜ</td>
<td>5</td>
</tr>
<tr>
<td>Biomedical Microsystems</td>
<td>2</td>
<td>VÜ</td>
<td>5</td>
</tr>
<tr>
<td>Dynamics of MEMS</td>
<td>2</td>
<td>VÜ</td>
<td>5</td>
</tr>
<tr>
<td>Micro-actuators</td>
<td>2</td>
<td>VÜ</td>
<td>5</td>
</tr>
<tr>
<td>Micro-fluidics</td>
<td>2</td>
<td>VÜ</td>
<td>5</td>
</tr>
<tr>
<td>MST Design Lab II</td>
<td>2</td>
<td>P</td>
<td>3</td>
</tr>
<tr>
<td><strong>Mathematics</strong></td>
<td><strong>This module to be completed</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Probability and Statistics</td>
<td>1</td>
<td>VÜ</td>
<td>5</td>
</tr>
</tbody>
</table>
### MSE – Elective modules

<table>
<thead>
<tr>
<th>Module</th>
<th>Semester</th>
<th>Type</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 concentration areas to be chosen. At least 9 ECTS in each of them. Total ECTS required 24</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circuits and Systems</td>
<td>2-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design and Simulation</td>
<td>2-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Life Sciences: Biomedical Engineering</td>
<td>2-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Life Sciences: Lab-on-a-chip</td>
<td>2-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials</td>
<td>2-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MEMS Processing</td>
<td>2-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Photonics</td>
<td>2-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensors and Actuators</td>
<td>2-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal Profile</td>
<td>2-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Master's thesis (mandatory)</td>
<td>3-4</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>Total</td>
<td>1-4</td>
<td></td>
<td>120</td>
</tr>
</tbody>
</table>
**MSE and MST joint concentrations**

Examples of courses offered in the concentration areas (may vary from year to year)

<table>
<thead>
<tr>
<th>Module</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Circuits and systems</strong></td>
<td></td>
</tr>
<tr>
<td>Analog CMOS circuit design</td>
<td>3</td>
</tr>
<tr>
<td>Autonomous Microsystems</td>
<td>3</td>
</tr>
<tr>
<td>Circuit design for sensors and actuators</td>
<td>3</td>
</tr>
<tr>
<td>Innovative energy systems</td>
<td>3</td>
</tr>
<tr>
<td>Integrated Microsystems</td>
<td>3</td>
</tr>
<tr>
<td>Optical Microsystems</td>
<td>3</td>
</tr>
<tr>
<td>VLSI system design</td>
<td>3</td>
</tr>
<tr>
<td>Wireless technologies</td>
<td>3</td>
</tr>
<tr>
<td>Dynamics of MEMS</td>
<td>3</td>
</tr>
<tr>
<td><strong>Design and simulation</strong></td>
<td></td>
</tr>
<tr>
<td>CAD</td>
<td>3</td>
</tr>
<tr>
<td>Control of embedded systems</td>
<td>3</td>
</tr>
<tr>
<td>Design of large-scale MST systems</td>
<td>3</td>
</tr>
<tr>
<td>FEM simulation</td>
<td>3</td>
</tr>
<tr>
<td>Multi-scale simulation</td>
<td>3</td>
</tr>
<tr>
<td>Quantum mechanics for MEMS</td>
<td>3</td>
</tr>
<tr>
<td>Reliability</td>
<td>3</td>
</tr>
<tr>
<td>Systems theory II</td>
<td>3</td>
</tr>
<tr>
<td><strong>Materials</strong></td>
<td></td>
</tr>
<tr>
<td>Atomic force microscopy</td>
<td>3</td>
</tr>
<tr>
<td>Biomaterials</td>
<td>3</td>
</tr>
<tr>
<td>Ceramics for MST</td>
<td>3</td>
</tr>
<tr>
<td>Materials testing and analysis</td>
<td>3</td>
</tr>
<tr>
<td>Nanostructured optical surfaces</td>
<td>3</td>
</tr>
<tr>
<td>Nanotechnology</td>
<td>3</td>
</tr>
<tr>
<td>Polymers for MST</td>
<td>3</td>
</tr>
<tr>
<td><strong>MEMS processing</strong></td>
<td></td>
</tr>
<tr>
<td>Advanced silicon technology</td>
<td>3</td>
</tr>
<tr>
<td>Applications of LIGA</td>
<td>3</td>
</tr>
<tr>
<td>Ceramics laboratory</td>
<td>3</td>
</tr>
<tr>
<td>Lithography</td>
<td>3</td>
</tr>
<tr>
<td>Low-cost micromachining</td>
<td>3</td>
</tr>
<tr>
<td>Microstructured polymer components</td>
<td>3</td>
</tr>
<tr>
<td>Thermal Microsystems</td>
<td>3</td>
</tr>
</tbody>
</table>
### Life sciences: Biomedical engineering

- Biomedical engineering I (electrical signals) 3
- Biomedical engineering II (non-electrical signals) 3
- Biomedical measurements and instrumentation lab 3
- Biomedical microtechnology 3
- Biotelemetry and health telematics 3
- Fundamentals of electrical stimulation 3
- Implant fabrication technology 3
- MST in medicine 3

### Life sciences: Lab-on-a-chip

- Analytics with microsystems 3
- Bio-MEMS 3
- Computational fluid dynamics 3
- DNA analytics 3
- Micro process engineering 3
- Microfluidic platforms 3
- Molecular simulation 3

### Personal Profile

Courses from any of the concentration areas 3

### Sensors and actuators

- Applications of micro-actuators 3
- Bionic sensors 3
- Lasers 3
- Micro-acoustics 3
- Micro-mechanical sensors 3
- Optical micro-sensors 3
- Position sensors 3
- Sensors laboratory 3

### Photonics

- Basic Optics Laboratory 3
- Basic and Advanced Optics Laboratory 3
- Advanced topics in Micro-Optics 3
- Micro-optics Laboratory I and II 3
- Modern Optics I and II 3
- Nonlinear optical materials 3
- Optical Materials 3
- Optical Trapping and Particle Tracking 3
- Optical measurement techniques 3
- Optoelectronic Devices 3
- Photonic imaging 3
- Wave and Fourier Optics 3
## MSE courses, first semester

<table>
<thead>
<tr>
<th>Mon</th>
<th>Tue</th>
<th>Wed</th>
<th>Thu</th>
<th>Fri</th>
</tr>
</thead>
<tbody>
<tr>
<td>08:00 - 10:00</td>
<td>Probability and Statistics lecture Room 101 00 026</td>
<td>08:00-10:00 Probability and Statistics, tutorial Room 101 00 026</td>
<td>8:00 – 10:00 Microelectronics tutorial Room 101 00 036</td>
<td>10:00-12:00 Microoptics tutorial Room 051 00 006, 051 00 031, 051 00 034</td>
</tr>
<tr>
<td>10:00 – 12:00</td>
<td>Sensors lecture Room 101 01 009/013</td>
<td>10:00-12:00 Microelectronics lecture Room 101 00 036</td>
<td>10:00 - 12:00 Microoptics lecture Room 101 00 036</td>
<td>12:00 - 14:00 MST Design Lab I Room 082 00 006</td>
</tr>
<tr>
<td>12:00 - 14:00</td>
<td>Micromechanics lecture Room 101 00-036</td>
<td>12:00 – 13:00 MST Technologies and Processes Room 101 00 010/014</td>
<td>12:00-14:00 Micromechanics tutorial Room 101 00 036</td>
<td>12:00 - 14:00 MST Design Lab I Room 082 00 006</td>
</tr>
<tr>
<td>14:00 – 16:00</td>
<td>MST Technologies and Processes, Room 101 01-009/013</td>
<td>14:00 – 15:00 Sensors lecture Room 101 01 009/013</td>
<td>14:00 – 16:00 Sensors Lab, group 2 Room 078 00 035</td>
<td>14:00 – 16:00 Sensors Lab, group 3 Room 078 00 035</td>
</tr>
</tbody>
</table>
| 16:00 – 18:00| MST Design Lab I Lecture Room 082 00 006 | 16:00 – 18:00 Sensors Lab, group 1 Room 078 00 035 | 16:00 – 18:00 Sensors Lab, group 3 Room 078 00 035 | 18:00 – 20:00 Sensors Lab, group 4 Room 078 00 035

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Plagiarism

- Plagiarism is:
  - Using someone else’s texts, pictures, reports, data, solutions, whatever….
  - ... without giving the source

- Sources include:
  - Books, the internet, colleagues, …

- To make it clear:
  - Plagiarism is illegal

- The simple „if…then“ loops:
  - If you plagiarize…(once)
  - ... then you fail
  - If you plagiarize repeatedly (=twice)
  - ... then your academic career is over.
Some thoughts to share…

- **A Master’s program in Germany**
  - You have to organize your courses and your life
  - You have to register for your courses on your own
  - We challenge you from the first day on to assess given knowledge…
  - …and to transfer given knowledge from one course to another
  - We will show you many aspects of microsystems related disciplines and applications to broaden your knowledge and increase the opportunities for an exciting career.

- **That means for you…**
  - YOU have to take the initiative to ASK, ASK and read until you understand
  - WE give you the overview, YOU have to learn the details
Enjoy being a student!

- It is helpful to
- Structure your day
- Have unstructured free time
- Meet colleagues
- Keep up with your work
- Turn off on occasion

Don‘t forget

- Family
- Friends
- Sports
- Culture
- Autumn leaves…
Moreover...

- Buy textbooks
- Contact your mentor
- Form study groups
- Poke around in the laboratories
- Find an MSc thesis advisor early
- Stay registered
- Get enough sleep
  - But not in my class, please
Mentoring

- Every student has a faculty mentor
  - A professor as a contact person
  - Assigned by the Dean of Studies
- Student’s contact for:
  - Problems, questions, clarifications, job searches, recommendations, or just general advising
After graduation
Apply for a job

- **In Industry**
  - Find out what you like during your MSc program
  - Use job portals and company websites to monitor the market
  - Visit career workshops to gather tips how to apply
  - Go to recruiting fairs
Phd. as research assistant

- Perform a research project (on your own)
- Look for an open position
- Apply
- Get paid for the PhD project
- Overtake responsibility as project assistant
- Support your professor with respect to educational tasks
- Duration: 3-5 years
Contact persons I

- **Dean of studies:** Prof. Moritz Diehl
  - Moritz.diehl@imtek.de
  - 203 67852

- **Program coordinator:** Ursula Epe
  - studienkoordination@tf.uni-freiburg.de
  - 203 8340

- **Student advisers:**
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    - 203 67479
  - Dr. Oswald Prucker
    - 203 7164
    - studienberatung@imtek.de
Contact persons II

- Examination office
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    - pruefungsamt@tf.uni-freiburg.de
    - 203 8083
  - Susanne Storck
    - pruefungsamt@tf.uni-freiburg.de
    - 203 8083
Thank you very much for your attention!