Course Title (in English) | Physics of semiconductor bulk crystals and nanostructures
---|---
Course Title (in Russian) | Физика полупроводников и полупроводниковых наноструктур
Lead Instructor(s) | Vladimir Kulakovskii

Status of this Syllabus | The syllabus is a work in progress (draft)
Contact Person | Vladimir Kulakovskii
Contact Person’s E-mail | tsir@elch.chem.msu.ru

1. Annotation

**Course Description**

The course focuses on the presentation of foundations of the modern physics of semiconductors. Along with the traditional branches (band theory, phenomena in the contacts, single particle excitations and interparticle interactions) developed for bulk semiconductors, the course includes the problems of composite quasiparticles and collective excitations in low dimensional semiconductor nanostructures (quantum wells, quantum wires and quantum dots) and microcavities. The basic principles and features of semiconductor lasers are also addressed.

**Course Prerequisites**

Solid state physics in frames of the course of general physics.

2. Structure and Content

**Course Academic Level**

Master-level course suitable for PhD students

**Number of ECTS credits**

3

<table>
<thead>
<tr>
<th>Topic</th>
<th>Summary of Topic</th>
<th>Lectures (# of hours)</th>
<th>Seminars (# of hours)</th>
<th>Labs (# of hours)</th>
</tr>
</thead>
</table>


2. Semiconductors in external fields. The mean values of the velocity and acceleration of the electron.

3. Effective mass method. The energy spectrum of electrons and holes in magnetic and constant electric field (quantum theory), shallow impurity levels, donors in multivalley semiconductors.

4. Statistics of electrons and holes in semiconductors. Fermi-Dirac and Boltzmann distributions, the effective density of states in the bands, the carrier concentration in the degenerate and nondegenerate semiconductors, the concentration of electrons and holes at the local levels. Fermi level in intrinsic and doped semiconductors.

5. Phenomena in the contacts. Potential barriers, the current density, the Einstein relation, the conditions of equilibrium, thermonic work function, the contact potential difference.

6. The distribution of the electron density and potential in space-charge layer, the screening length, enriched and depleted layers. Rectification in metal – semiconductor contact, p-n-junction.


8. The problems of justification of the band theory. The adiabatic approximation, the approximation of small oscillations, the method of self-consistent field.


10. Band-to-band and excitonic absorption and emission in direct and indirect semiconductors.

11 Exciton polaritons in bulk semiconductors.

Basics of semiconductor physics.


2. Quantum Hall effect.

3. Excited states in quantum wells and dots: Excitons, trions, biexcitons, multiexciton states.

4. Semiconductor lasers.


7. Multistability of resonantly excited microcavity polaritons.

Low dimensional structures.

3. Assignments
4. Grading

Type of Assessment  | Graded
---|---

**Grade Structure**

<table>
<thead>
<tr>
<th>Activity Type</th>
<th>Activity weight, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homework Assignments</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>30</td>
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</table>

**Grading Scale**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Activity weight, %</th>
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<tbody>
<tr>
<td>A</td>
<td>80</td>
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<tr>
<td>B</td>
<td>65</td>
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<tr>
<td>C</td>
<td>55</td>
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<tr>
<td>D</td>
<td>45</td>
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<tr>
<td>E</td>
<td>35</td>
</tr>
<tr>
<td>F</td>
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</table>

5. Basic Information

**Attendance Requirements**  | Mandatory
---|---

**Maximum Number of Students**

<table>
<thead>
<tr>
<th>Maximum Number of Students</th>
<th>Overall: 15</th>
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</thead>
<tbody>
<tr>
<td>Per Group (for seminars and labs):</td>
<td>15</td>
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</table>

**Course Delivery Frequency**  | Every year
---|---

**Students of Which Programs do You Recommend to Consider this Course as an Elective?**

<table>
<thead>
<tr>
<th>Masters Programs</th>
<th>PhD Programs</th>
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</thead>
<tbody>
<tr>
<td>Materials Science</td>
<td>Materials Science and Engineering</td>
</tr>
<tr>
<td>Photonics and Quantum Materials</td>
<td>Physics</td>
</tr>
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</table>

**Course Tags**  | Physics
---|---

6. Textbooks and Internet Resources

**Required Textbooks**

<table>
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<th></th>
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<tbody>
<tr>
<td>VL Bonch-Bruevich S.G.Kalashnikov Физика полупроводников, Moscow, Nauka, 1977 9785020140325</td>
</tr>
<tr>
<td>Оптическая спектроскопия объемных полупроводников и наноструктур. Учебное пособие. Тимофеев В. 2015. Лань</td>
</tr>
</tbody>
</table>
### Recommended Textbooks

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<tr>
<th></th>
<th></th>
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<tbody>
<tr>
<td>5020249270</td>
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</tbody>
</table>

### Web-resources (links) | Description
--- | ---
http://www.studmed.ru/download/07b1e16e503/ | Оптические явления в полупроводниковых квантово-размерных структурах. Под ред. Е. Л. Ивченко и Л. Е. Воробьева.

### 7. Facilities

### Software

Matlab

### 8. Learning Outcomes

#### Knowledge

Knowledge of the basics of modern semiconductor physics.

#### Skill

Ability to solve quantitative problems related to bulk and low-dimensional semiconductors, as well as to semiconductor-based heterostructures.

#### Experience

Experience of reading and analysis of scientific literature in the area of semiconductors physics and corresponding high-tech devices.

### 9. Assessment Criteria

#### Select Assignment 1 Type

Homework

#### Input Example(s) of Assignment 1 (preferable)

Consider current-voltage curve for superconductor-based heterostructure proposed by the Instructor. Calculate the parameters of this structure. Predict the behavior of the curve when these parameters are changed.

#### Assessment Criteria for Assignment 1

Quantitatively correct values of parameters, realistic prediction.

#### Select Assignment 2 Type

Homework
Consider the luminescence spectrum of certain quantum dots proposed by the Instructor. Calculate the mean size of dots and estimate their size distribution.

**Assessment Criteria for Assignment 2**

Quantitatively correct value of the mean size, reasonable comments to the estimates of the shape and width of size distributions.

**Select Assignment 3 Type**

Homework

**Input Example(s) of Assignment 3 (preferable)**

Consider semiconductor device proposed by the Instructor. Comment on possible functional characteristics of this device and on the possibility of their improvement.

**Assessment Criteria for Assignment 3**

Correct answer about key device characteristics, correct choice of the literature data for analysis of the proposed device.

10. Additional Notes

**Free Style Comments (if any)**

The course will be presented in the Institute of Solid State Physics (Chernogolovka), magnetic corp, room 115. Fridays, 13.30, starting from Nov 2, 2018.

**Upload a File (if needs to be)**

https://ucarecdn.com/b9bcb8ef-a6b8-49d2-93ef-a9b8e1fd1a32/

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