DOCTORAL STUDIES COURSE UNIT DESCRIPTION

Name of subject	Scientific Field	Center	Department
Solid State Physics (10 ECTS credits)	Physics N 002	Center for Physical Sciences and Technology	Optoelectronics Department
Student’s workload	Hours	Student’s workload	Hours
Lectures	40	Consultations	
Individual study	200	Seminars	10

Course annotation
The course aims at presenting an integral and systematic scheme of a description of physical phenomena in solids on the doctoral-studies level. The course is focused on semiconductor and metal physics and, to reveal microscopic mechanisms of physical phenomena in solids, it analyzes the elementary excitations of quantum mechanical states, their origins and character, their interaction, dynamics, and kinetics. The main topics of the course (and their approximate content): Crystallographic description of the atomic structure of solids (symmetry and groups, classification scheme of crystals, Fourier transform of atomic structure). Crystallophysics (tensors of physical quantities, Neumann principle, stress and strains, crystaloptics). X-ray, electron, and neutron diffraction (classical and quantum-mechanical descriptions, research techniques). Features of interatomic interaction (chemical bonds, techniques of lattice-sum calculations). Microscopic model of solids (adiabatic and single-particle quantum-mechanical approximations, exchange and correlation effects). Jellium model and electron gas (Drude–Sommerfeld theory, Lindhard screening scheme, Wigner crystallization). Band structure of electron spectrum (Bloch theorem, band structure analysis techniques, pseudopotentials, Kane model, Luttinger Hamiltonian). Methods of a description of electron dynamics (WKB, effective mass, and Wannier techniques). Semiconductors (impurities and point deffects, charge carrier statistics). Electric field induced effects (polarization, Wannier spectrum, Franz–Keldysh effect). Magnetic field effects (magnetization, de Haas – van Alphen oscillations, cyclotron resonance, Landau spectrum). Solid state optics (features of optical transitions in dielectrics, semiconductors, and metals, excitons, plasmons and EELS, photoemission spectroscopy). Phonons (normal modes and quantum mechanical description, micro- and macroscopic descriptions of acoustic vibrations, self-focusing of phonons). Experimental techniques of phonon spectrum investigations (IR spectroscopy, neutron spectroscopy, Raman and Brillouin scatterings). Anharmonic effects (Grüneisen theory, phonon-phonon interaction, the second sound). Electron-phonon interaction (mechanisms of electron-phonon scattering in metals and semiconductors, strong interaction – polarons). Kinetics of charge carriers (Drude–Lorentz kinetic model, Boltzmann kinetic equation, relaxation characteristics of the test particle). Kinetic phenomena (electric and thermal conductivities, magnetoelectric and thermoelectric effects, hot electrons). Junctions (surface effects, surface reconstruction, *p-n* and hetero- junctions). Nonequilibrium charge carriers (lifetime, cascade capture, theory of multiphonon capture).
List of literature
1. N. W. Ashcroft and N. D. Mermin, *Solid State Physics* (Holt, Rinehart, and Winston, 1976) 2. P. Y. Yu and M. Cardona, *Fundamentals of Semiconductors* (Springer, 2002) 3. U. Mizutani, *Introduction to the Electron Theory of Metals* (Cambridge University Press, 2001)

4. H. Haug and S. W. Koch, *Quantum Theory of the Optical and Electronic Properties of Semiconductors* (World Scientific, 2004)
5. A. O. E. Animalu, *Intermediate Quantum Theory of Crystalline Solids* (Prentice-Hall, Inc., 1977)
6. V. Karpus, *Solid State Physics* (lecture notes, 2021)

Consulting teachers	Scientific degree	Pedagogical Name	Main scientific works published in a scientific field in last 5 year period
Vytautas Karpus	Dr.		1. V. Karpus, S. Tumėnas, A. Eikevičius, H. Arwin, Interband optical transitions of Zn, *Phys. Status Solidi B* 253(3), 419–428 (2016). 2. R. Butkutė, G. Niaura, E. Pozingytė, B. Čechavičius, A. Selskis, M. Skapas, V. Karpus, A. Krotkus, Bismuth quantum dots in annealed GaAsBi/AlAs quantum wells, *Nanoscale Res. Lett*. 12, 436 (2017). 3. V. Karpus, R. Norkus, R. Butkutė, S. Stanionytė, B. Čechavičius, A. Krotkus, THz-excitation spectroscopy technique for band-offset determination, *Optics Express* 26, 33807–33817 (2018). 4. V. Pačebutas, R. Norkus, V. Karpus, A. Geižutis, V. Strazdienė, S. Stanionytė, A. Krotkus, Band-offsets of GaInAsBi-InP heterojunctions, *Infrared Physics and Technology* 109, 103400 (2020). 5. T. Paulauskas, B. Čechavičius, V. Karpus, L. Jočionis, S. Tumėnas, J. Devenson, V. Pačebutas, S. Stanionytė, V. Strazdienė, A. Geižutis, M. Čaplovičová, V. Vretenár, M. Walls, A. Krotkus, Polarization dependent photoluminescence and optical anisotropy in CuPtB-ordered dilute $GaAs_{1-x}Bi_x$ alloys, *J. Appl. Phys*. 128, 195106 (2020).

Certified during Doctoral Committee session 02/02/2022, protocol No. (7.17 E) 15600-KT-32

Committee Chairman prof. S. Juršėnas