シラバス参照

Japanese

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Course Schedule Information

Course Code／時間割コード	290370
Semester／開講区分(開講学期)	Spring and Summer Term
Day and Period／曜日・時間	Mon3
Course Name (Japanese)／開講科目名	汎分光
Room／教室	School of Engineering Science/Lecture Room G215-221
Course Name／開講科目名(英)	Solid State Spectroscopy
Capacity／定員	999
Course Numbering Code／ナンバリング	29MAPH5F401,29FRMS5F401,29ELOS5F401
Credits／単位数	2.0
Student Year／年次	1,2
Instructor／担当教員	SEKIYAMA Akira,KISU Takayuki

List of Instructor(s)

Detailed Syllabus Information

Course Name／講義題目

Language of the Course／開講言語: English

Type of Class／授業形態: Lecture Subject

Course Objective／授業の目的と概要

In this course, candidates will learn fundamental principles and properties of lights and interactions between a light and a matter, of which solid state spectroscopy consists, on the basis of classical and quantum physics.

At first, candidates will learn principles and properties of synchrotron radiation, which is a kind of application of advanced classical electromagnetism.
Here the synchrotron radiation is introduced since nowadays it is recognized as an excellent tunable light source in vacuum ultraviolet and x-ray regions and hence employed in the fields of materials (and biological) science and engineering including industrial fields.
Candidates will then learn monochromatization by using crystal and grating monochromators and focusing of the light by a mirror as practical techniques.

Then candidates will learn
• interactions between a light and a matter (charged particle) in the regions from infrared to x-ray based on classical and semi-classical theories,
• fundamental quantum theory of interactions between a light and an electron after introduction of a quantization of light,
which are important for understanding phenomena related to lights.
Furthermore, as an application of the above quantum theory,
• x-ray absorption and photoemission spectroscopy for both non-interacting and interacting electron systems,
• x-ray spectroscopic techniques other than photoemission
will be learned. Here, candidates will learn how the spectroscpoic results are directly related to the electronic structure of solids.

Learning Goals／学習目標

Candidates will be able to
• explain the phenomena of synchrotron radiation on the basis of a knowledge of classical electromagnetism
• obtain the monochromator conditions by calculations for crystal and grating monochromatizations on the basis of a knowledge of primal diffraction theories
• explain the wavelength (photon energy) dependence of complex difraction index for several typical crystalline solids on the basis of a knowledge of interactions between lights and matters within the classical and semi-classical theories
• derive the selection rules for the dipole transitions in one-photon optical process from the calculations on the basis of knowledge of a quantum theory for interactions between lights and electrons
• explain the origins of peak structures in the photoemission spectra on the basis of fundamental understanding of photoemission spectroscopy for interacting electron systems

Requirement / Prerequisite／履修条件・受講条件

In this course, it is assumed that candidates have already learn
• classical mechanics including analytical mechanics,
• electromagnetism [for instance, contents covered by "Introduction to electrodynamics" (up to Chap. 9) wirtten by D. J. Griffiths],
• quantum mechanics (time-dependent Schrödinger equation, eigenvalues and eigenfunctions, perturbation theory),
• solid state physics (reciprocal space, phonons, free electron Fermi gas, energy bands, thermal properties, Fermi surface covered by "Introduction to solid state physics" written by C. Kittel).

Class Plan／授業計画

The course is planned to be listed below, but is subjected to change.

1st Title:Overview of this courese, electromagnetic waves in vacuum,

	methods for light emissions After brief overview of this course, properties of lights as electromagnetic waves, methods for light emissions are discussed. Black-body ratiation as a mechanism of light emission from a globar lamp is also introduced. Instructor : Akira Sekiyama
2nd	Title:Physics of synchrotron radiation based on the classical electromagnetism Synchrotron radiation, a unique and useful artificial light source in a wide wavelength (photon energy) region from infrared to gamma ray, is discussed by using retarded potentials and Lienart-Wiechert potentials as an application of the classical electromagnetic theory including special relativity. Homework (report) will be assigned. Instructor : Akira Sekiyama
3rd	Title:Characteristics of synchrotron radiations Characteristics of synchrotron radiations (pulse, collimation, polarization, continuous spectrum from infrared to gamma rays) from a bending magnet and from an insertion device called as undulator or wiggler are discussed based on the classical electromagnetism and a relativistic eauation of motion for an electron. Instructor : Akira Sekiyama
4th	Title:Monochromatization of hard and soft x-rays, X-ray focusing by using mirrors Method of hard x-ray monochromatization by using cryltal monochromators utilizing a Bragg reflection, and that of soft x-ray (and ultraviolet) monochromatization by using grating monochromators are discussed. The latter is explained based on geometrical optics where the most important is the Fermat's principle. After those, the physics of x-ray focusing by using mirrors is also learned. Homework (report) will be assinged. Instructor : Akira Sekiyama
5th	Title:Optical properties of solids within the classical and semi-classical theories pt.I After introduction of complex refraction index, the relation between the complex refraction index and dielectric function, the Kramers-Kronig relations are discussed. Dielectric function (charge susceptibility) for free-electron gas based on the Drude model is also discussed. Instructor : Akira Sekiyama
6th	Title:Optical properties of solids within the classical and semi-classical theories pt.II After discussion of the dielectric function for lattices (harmonic oscillators) based on the Lorentz model, photo-absorption by inner-core electrons and its contributions to the charge susceptibility will be discussed based on the semi-classical theory, where the electrons (lights) are treated by the quantum (classical) theory. Then, a high-energy (short-wavelength) limit of the dielectric function is also discussed. Homework (report) will be assinged. Instructor : Akira Sekiyama
7th	Title:Interaction of lights with electrons in a quantum theory, X-ray absorption After introductions of the Hamiltonian for electrons in an electromagnetic field and quantization of lights, one-photon process is discussed (two-photon process leading to a phenomenon of diffraction is out of focus in this course), where the Fermi's golden rule and selection rules in photo-absorption processes are derived. As applications of the one-photon process, x-ray absorption of gasses, that of solids, its linear dichroism (LD-XAS), and magnetic circular dichroism in x-ray absorption spectra (MCD-XAS) are also discussed. Instructor : Akira Sekiyama
8th	Title:Photoemission spectroscopy of solids: Threel-step model and valence-band photoemission Photoemission spectroscopy of solids is discussed. After introduction of photoelectric effects and brief explanation of photoemission spectroscopy based on the energy conservation law, the three-step model (creation of a photoelectron, its travel to a surface, and emission into vacuum), which is highly practical to learn the photoemission process, is discussed. Both angle-integrated and angle-resolved valence-band photoemission spectrscopies for non-interacting electron systems are also explained. Homework (report) will be assigned.

	Instructor : Akira Sekiyama
9th	Title:Formulation of core-level photoemission spectra for interacting systems pt.I: Coulomb and exchange interactions leading to the core-level shifts After description of many-body electron systems in solids, the formulation of photoemission spectra is discussed using the nomenclature of second quantization for interacting systems where the Coulomb interactions between electrons are switched on. Formulation of core-level photoemission and such "intra-site" effects seen in the core-level spectra as spin-orbit splitting, asymmetric peak structure for metals, and exchange splitting are also discussed. Instructor : Akira Sekiyama
10th	Title:Formulation of core-level photoemission spectra for interacting systems pt.II: Multiplets Multiplet structure of the electron energy levels originating from the anisotropy of the Coulomb and exchange interactions of electrons, which provides the original meaning of "electron correlation", is discussed. Then the multiplet structure of the core-level photoemission is explained. Finally, the recently discovered linear dichroism of the multiplet structure in (angle-resolved) core-level photoemission probing the outer strongly correleted electronic structure is introduced. Instructor : Akira Sekiyama
11th	Title:Formulation of valence-band photoemission spectra for interacting systems: Green's function Formulation of valence-band photoemission for interacting systems will be discussed after introducing the retarded Green's fuction in the quantum field theory based on the Heisenberg representation, where candidate will learn that the angle-resolved photoemission (ARPES) spectra are essentially equivalent to the retarded Green's function as a function of one-electron momentum and energy if the transition matrix-element effects could be neglected. Homework (report) will be assigned. Instructor : Akira Sekiyama
12th	Title:Actual photoemission experiment pt.I Based on previous lecture of Angle integrated/resolved photoemission spectroscopy, several actual photoemission researches will be introduced, especially on the quasi pariticle of ARPE spectra and its self energy extraction to know the one electron Green's function. Instructor : Takayuki Kiss
13th	Title:Actual photoemission experiment pt.II Remarkable progresses of photoemission spectroscopy in this decade are introduced. Owing to these progresses, photoemission spectroscopy plays quite important roles in the field of solid state physics. Instructor : Takayuki Kiss
14th	Title:Reserved Instructor : Takayuki Kiss
15th	Title:Recent topics related to x-ray spectroscopy using synchrotron radiation As unique techniques by using synchrotron radiation, resonance photoemission and polarization-dependent photoemission are discussed. After introducing some techniques for x-ray (absorption) detections, topical synchrotron radiation-based x-ray spectroscopy such as EXAFS (extended x-ray absorption fine structure), PEEM (photoemission electron microscopy), and inelastic x-ray scattering will be discussed. Optional homework (report) will be assinged. Instructor : Akira Sekiyama

Independent Study Outside of Class／授業外における学習	Review of each lecture, and study for assigned homework (reports), and view of the lecture and related movie files indicated by the instructors.
Textbooks／教科書・教材	Summary of lecture in each lecture will be uploaded on the CLE system in advance.
Reference／参考文献	1. For learning of synchrotron radiations as a application of advanced classical electromagnetism, • V. D. Berger and M. G. Olsson, "Classical Electricity and Magnetism: A Contemporary Perspective" (Allyn and Bacon Inc.) or • W. K. H. Panofsky and M. Phillips, "Classical Electricity and Magnetism" (2nd edition, Dover) 2. For learning of properties and applications of synchrotron radiations, • D. Attwood, "Soft X-Rays and Extreme Ultraviolet Radiation: Principles and Applications" (Cambridge University Press)

	3. For learning of basis of crystal monochromatization, • B. E. Warren, "X-ray diffraction" (Dover) 4. For learning of interactions between a light and electrons using quantum theory, • R. Schankar, "Principles of Quantum Mechanics" (Springer), or L. I. Schiff, "Quantum Mechanics" (McGraw-Hill) • H. Ibach and H. Lueth, "Solid-State Physics: An Introduction to Principles of Materials Science" (Springer) , or • G. Grosso and G. P. Parravicini, "Solid State Physics" (Elsevier Academic Press), or • N. W. Ashcroft and N. D. Mermin, "Solid State Physics" (Thomson Learning) 5. For learning of electron spectroscopy of solids including photoemission, • S. Huefner, "Photoelectron Spectroscopy" (Springer) • S. Suga and A. Sekiyama, "Photoelectron Spectroscopy: Bulk and Surface Electronic Structures" (Springer)
Grading Policy／成績評価	Attitude to learning evaluated by the quizzes (about 25%), reports (homeworks) on subjects assigned in this course (about 75%)
Other Remarks／コメント	Every lectures will be given by e-learning with the on-demand lecture movie files and quizzes (short test), which are prepared in the CLE system in advance. The candidates are required to learn each lecture within the designated period. Details are separately announced.
Special Note／特記事項	When students with disabilities take this course and request reasonable accommodation, please contact the Graduate Students Section or the instructor in advance and discuss the concerns.
Office Hour／オフィスアワー	15:10-16:40 on Friday (A. Sekiyama) 15:10-16:40 on Monday (T. Kiss)
Keywords／キーワード	
Messages to Prospective Students／受講生へのメッセージ	By learning this course, candidates will get enough knowledge of solid state spectroscopy, which is very useful to study electronic structure in solids, and is one of the main subjects in the field of materials physics.

Instructor(s)

Instructor Name／教員氏名	Name (hiragana)／ふりがな	Affiliation, Title, Course／所属・職名・講座名	Office／居室	Extension／内線	E-mail／e-mail
Sekiyama, Akira	せきやま　あきら	Division of Materials Physics, Professor	D410	6420	sekiyama@mp.es.osaka-u.ac.jp
Kiss, Takayuki	きす　たかゆき	Division of Materials Physics, Associate Professor	D250	6417	

Cautions for Students