Modulbezeichnung:	**X-ray quantum optics (PW XrayQO)** (X-ray quantum optics)	**5 ECTS**
Modulverantwortliche/r:	Adriana Palffy-Buß	
Lehrende:	Adriana Palffy-Buß	

Startsemester: WS 2020/2021	Dauer: 1 Semester	Turnus: unregelmäßig
Präsenzzeit: 60 Std.	Eigenstudium: 90 Std.	Sprache: Englisch

Lehrveranstaltungen:

Tutorial for X-ray Quantum Optics (WS 2020/2021, Übung, 2 SWS, Adriana Palffy-Buß)
X-ray Quantum Optics (WS 2020/2021, Hauptseminar, 2 SWS, Adriana Palffy-Buß)

Inhalt:

Content:

- X-ray sources
- X-ray imaging, scattering and diffraction
- Light-matter interactions
- Resonant atomic and nuclear interactions
- Introduction to quantum optics
- Coherence and interference effects
- Nuclear quantum optics
- X-ray quantum control

The course combines concepts of Quantum Optics and Coherent X-ray Optics. The study of the interaction of optical light with resonant electronic transitions in atoms has led to the development of many high-impact quantum-based devices, such as lasers, atomic clocks or miniature sensing, and in parallel to new quantum technologies such as quantum cryptography and computing. However, in the near future, harnessing the interaction between atoms and hard x-ray photons with a far larger energy than optical photons may be advantageous. X-ray photons are much easier to detect, can penetrate deeper into materials, can be focused to much smaller spot sizes, and should in principle support faster information processing. Ongoing efforts in the understanding and exploiting quantum dynamics with x-rays are supported by the recent commissioning of novel high-frequency light sources that render x-ray quantum optics possible. The lecture will follow the recent progress made in this direction introducing the related theoretical concepts of quantum optics, atomic physics, and light-matter interaction, together with an overview of present applications such as imaging at the x-ray free electron laser.

Lernziele und Kompetenzen:

- explain the relevant topics of the lecture
- apply the methods to specific examples

Literatur:

Bibliography and recommended further reading:

Part I: Generation of x-rays, x-ray properties, interaction with matter

- High-Intensity X-rays-Interaction with Matter by Stefan P. Hau-Riege (Wiley-Vch, Weinheim, 2011)
- Elements of Modern X-ray Physics by Jens Als-Nielsen and Des McMorrow (John Wiley & Sons, Chichester, 2001)
- Potential for biomolecular imaging with femtosecond X-ray pulses, R. Neutze, R. Wouts, D. van der Spoel, E. Weckert and J. Hajdu, Nature 406, 752 (2000)
- Single mimivirus particles intercepted and imaged with an X-ray laser, M. M. Seibert et al., Nature 470, 78 (2011)
- X-ray Free Electron Lasers and Their Applications chapter by Sebastien Boutet and Makina Yabashi in X-ray Free Electron Lasers by S. Boutet, P. Fromme and M. Hunter (editors) Springer, Cham (2018). https://doi.org/10.1007/978-3-030-00551-1_1

Part II: Introduction to quantum optics

- Quantum Optics by Marlan O. Scully and Zuhail M. Zubairy (Cambridge University Press, 1997)

- The quantum theory of light by Rodney Loudon, (Oxford University Press, 2003)
- Quantum jumps of light recording the birth and death of a photon in a cavity, S. Gleyzes et al., Nature 446, 297 (2007)
- Dark-State Polaritons in Electromagnetically Induced Transparency, M. Fleischhauer and M. D. Lukin, Physical Review Letter 84, 5094 (2000)

Part III: Nuclear quantum optics

- X-ray quantum optics by B. W. Adams et al., Journal of Modern Optics 60, 2 (2013)
- Nuclear Condensed Matter Physics with Synchrotron Radiation by Ralf Röhlsberger (Springer Berlin Heidelberg, 2004)
- Electromagnetically Induced Transparency with Resonant Nuclei in a Cavity, R. Röhlsberger, H.-C. Wille, K. Schlage and B. Sahoo, Nature 482, 199 (2012)
- Rabi oscillations of x-ray radiation between two nuclear ensembles, J. Haber et al., Nature Photonics 11, 720 (2017)
- Coherent Control of Nuclei and X-rays by Wen-Te Liao (Springer Theses Series, 2014)

Verwendbarkeit des Moduls / Einpassung in den Musterstudienplan:

Das Modul ist im Kontext der folgenden Studienfächer/Vertiefungsrichtungen verwendbar:

[1] **Physik (Bachelor of Science)**

(Po-Vers. 2020w | NatFak | Physik (Bachelor of Science) | Gesamtkonto | Physikalische Wahlfächer | X-ray quantum optics)

Dieses Modul ist daneben auch in den Studienfächern "Materials Physics (Master of Science)", "Physics (Master of Science)", "Physik (Master of Science)", "Physik mit integriertem Doktorandenkolleg (Bachelor of Science)", "Physik mit integriertem Doktorandenkolleg (Master of Science)" verwendbar.

Studien-/Prüfungsleistungen:

X-ray quantum optics (Prüfungsnummer: 71971)

Prüfungsleistung, mündliche Prüfung, Dauer (in Minuten): 30

Anteil an der Berechnung der Modulnote: 100% Prüfungssprache: Englisch

Erstablegung: WS 2020/2021, 1. Wdh.: WS 2020/2021 (nur für Wiederholer)

1. Prüfer: Adriana Palffy-Buß
