Course guide
230579 - FCTBEC - From Cooling and Trapping of Neutral Atoms to Bose-Einstein Condensates

Last modified: 14/12/2023

Unit in charge: Barcelona School of Telecommunications Engineering
Teaching unit: 1022 - UAB - (ANG) pendent.

Degree: MASTER'S DEGREE IN PHOTONICS (Syllabus 2013). (Optional subject).

Academic year: 2023 **ECTS Credits:** 3.0 **Languages:** English

LECTURER

Coordinating lecturer: Consultar aquí / See here: https://telecos.upc.edu/ca/estudis/curs-actual/professorat-responsables-coordinadors/responsables-assignatura

Others: Consultar aquí / See here: https://telecos.upc.edu/ca/estudis/curs-actual/professorat-responsables-coordinadors/professorat-assignat-idioma

PRIOR SKILLS

Basic knowledge on quantum physics and quantum optics

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CE5. Know how to perform and understand basic experiments that demonstrate the main phenomena of optics and photonics.

Transversal:
CT1. ENTREPRENEURSHIP AND INNOVATION. Knowing and understanding the mechanisms on which scientific research is based, as well as the mechanisms and instruments for transferring results between the different socioeconomic agents involved in R&D&I processes.
CT5. ENGLISH. Accredit an adequate level of this language, both orally and in writing, in line with the needs that the graduates will have.
CT3. TEAMWORK. Be able to work as a member of an interdisciplinary team, either as another member, or performing management tasks in order to contribute to developing projects with pragmatism and a sense of responsibility, assuming commitments taking into account the available resources.
CT4. SOLVENT USE OF INFORMATION RESOURCES. Manage the acquisition, structuring, analysis and visualization of data and information in the field of the specialty and critically assess the results of this management.

TEACHING METHODOLOGY

- Lectures
- Resolution of exercises in the classroom or at home

LEARNING OBJECTIVES OF THE SUBJECT

The main objective of this course is to provide an introduction into the recent developments in the field of atom optics which exploits the particle-wave duality of atoms. This field emerged with the cooling and trapping of neutral atoms to very low temperatures. At these temperatures, it is possible to implement mirrors, beam splitters, diffraction gratings and interferometers for atoms, in close analogy to standard optics. Moreover, the achievement of Bose-Einstein condensation in 1995 opened the possibility to develop a coherent source of atoms, in analogy with light sources of coherent radiation. The phenomena of condensation offers, however, much more possibilities and a much richer dynamics that will be discussed along the course.

STUDY LOAD

Type	Hours	Percentage
Self study	51,0	68.00
Hours large group	24,0	32.00

Total learning time: 75 h

CONTENTS

Introduction

Description:
Basic atomic physics. Atomic structure, levels degeneracy, and symmetries. Fine and hyperfine levels. Interaction with external fields: Zeeman effect, AC-Stark shift. Basic processes of light-matter interaction. Low energy atomic collisions.

Full-or-part-time: 2h
Theory classes: 2h

Cooling, trapping, imaging of neutral atoms and linear atom optics

Description:
Light forces on atoms: dipole and radiation pressure forces. Cooling: Laser cooling. Atomic traps: optical traps, magneto-optical traps, magnetic traps. Detection methods of quantum gases. Linear atom optics: atomic diffraction and atom interferometry.

Full-or-part-time: 8h
Theory classes: 8h

Bose-Einstein Condensation

Description:
The ideal gas of bosons. Weakly interacting bosons. Mean field approach: The Gross-Pitaevskii equation, Bogoliubov de Gennes equations, hydrodynamic theory. One and two dimensional bosonic trapped gases.

Full-or-part-time: 8h
Theory classes: 8h

Nonlinear and quantum atom optics

Description:
Matter-wave solitons. Superfluidity and vortices.

Full-or-part-time: 4h
Theory classes: 4h

And more...

Description:
Strongly correlated regime: Bose-Hubbard model and Tonks-Girardeau gas. Quantum degenerate Fermi gases. Two-component Bose-Einstein condensates and spinor condensates.

Full-or-part-time: 2h
Theory classes: 2h

GRADING SYSTEM

Two activities will be evaluated:
- Written exam (40%)
- Homework assessments (60%)
In addition, there will be an oral recovery exam for those students who have not passed the subject once the written exam and the delivery of problems have been evaluated.

BIBLIOGRAPHY

Basic:
- Dalibard, J. "Collisional dynamics of ultra-cold atomic gases". Proceedings of the International School of Physics Enrico Fermi, Course CXL [on line]. 1998 [Consultation: 28/04/2017]. Available on: http://www.phys.ens.fr/~dalibard/publications/varenna98.pdf.- Foot, C.J. Atomic physics. 2005. ISBN 0198506953.
- Pitaevskii, L.P.; Stringari, S. Bose Einstein condensation. Oxford University Press: Clarendon Press, 2003. ISBN 0198507194.
- Pethick, C.J; Smith, H. Bose-Einstein condensation in dilute gases. 2nd ed. Cambridge ; New York: Cambridge University Press, 2008. ISBN 9780521846516.
- Fox, M. Quantum optics : an introduction. 2006. ISBN 0198566727.
- Metcalf, H.J.; Van der Straten, P. Laser cooling and trapping. New York: Springer, 1999. ISBN 0387987479.
- Cohen-Tannoudji, C.; Guery-Odelin, D. Advances in atomic physics : an overview. Singapore: World Scientific, 2011. ISBN 9789812774972.

Complementary:
- Barengui, Carlo; Parker, Nick G. A primer on quantum fluids [on line]. Springer, 2016 [Consultation: 21/06/2023]. Available on: https://arxiv.org/pdf/1605.09580. ISBN 978-3319424743.
- Bongs, K.; Sengstock, K. "Physics with coherent matter waves". Reports on progress in physics [on line]. 2004, v. 67 , núm. 6, p. 907-963 [Consultation: 17/07/2017]. Available on: https://arxiv.org/abs/cond-mat/0403128v1.- Legget, A.J. "Bose-Einstein condensation in the alkali gases: Some fundamental concepts". Reviews of modern physics [on line]. 2001, vol. 73, núm 2, pag 307-356 (April 2001) [Consultation: 17/07/2017]. Available on: https://www.researchgate.net/publication/239443683_Bose-Einstein_condensation_in_the_alkali_gases_Some_fundamental_concepts.- Ketterle, W.; Durfee, D.S.; Stamper-Kurn, D.M. "Making, probing and understanding Bose-Einstein condensates". International School of Physics "Enrico Fermi". (1998: Varenna, Itàlia) [on line]. 1999, vol 40 (p.67-166) [Consultation: 17/07/2017]. Available on: https://arxiv.org/abs/cond-mat/9904034v2.- Dalfovo, F.; Giorgini, S.; Pitaevskii, L.P.; Stringari, S. "Theory of Bose-Einstein condensation in trapped gases". Reviews of modern physics [on line]. 71, 463 (1 April 1999) [Consultation: 17/07/2017]. Available on: https://arxiv.org/abs/cond-mat/9806038.

RESOURCES

Hyperlink:
- Lectures du College de France by C. Cohen-Tannoudji. courses 1998-1999, 1999-2000.. http://www.phys.ens.fr/cours/college-de-france/