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

Last modified: 22/06/2020

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

Degree: MASTER'S DEGREE IN PHOTONICS (Syllabus 2013). (Optional subject).
ERASMUS MUNDUS MASTER'S DEGREE IN PHOTONICS ENGINEERING, NANOPHOTONICS AND BIOPHOTONICS (Syllabus 2010). (Optional subject).

Academic year: 2020 **ECTS Credits:** 3.0 **Languages:** English

LECTURER

Coordinating lecturer: Mompart Penina, Jordi

Others: Ahufinger Breto, Verónica

PRIOR SKILLS

Basic knowledge on quantum physics and quantum optics

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CE5. (ENG) Màster en Fotònica:
Saber realizar y comprender experimentos básicos que demuestren los principales fenómenos de óptica y fotónica.

Transversal:
CT1. (ENG) Màster en Fotònica:
EMPRENDIMIENTO E INNOVACIÓN. Conocer y entender los mecanismos en que se basa la investigación científica, así como los mecanismos e instrumentos de transferencia de resultados entre los diferentes agentes socioeconómicos implicados en los procesos de I+D+i.
CT5. (ENG) Màster en Fotònica:
INGLÉS. Acreditar un nivel adecuado de este idioma, tanto de forma oral como por escrito, en consonancia con las necesidades que tendrán las tituladas y los titulados.
CT3. (ENG) Màster en Fotònica:
TRABAJO EN EQUIPO. Ser capaz de trabajar como miembro de un equipo interdisciplinar ya sea como un miembro más, o realizando tareas de dirección con la finalidad de contribuir a desarrollar proyectos con pragmatismo y sentido de la responsabilidad, asumiendo compromisos teniendo en cuenta los recursos disponibles
CT4. (ENG) Màster en Fotònica:
USO SOLVENTE DE LOS RECURSOS DE INFORMACIÓN. Gestionar la adquisición, la estructuración, el análisis y la visualización de datos e información en el ámbito de la especialidad y valorar de forma crítica los resultados de esta gestión.

TEACHING METHODOLOGY

- Lectures
- Resolution of exercises in the classroom

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 atom-light interactions.

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

Cooling, trapping of neutral atoms and linear atom optics

Description:
Light forces on atoms: dipolar force and radiation pressure force. Cooling: Laser cooling. Atomic traps: optical traps, magneto-optical traps, magnetic traps. Linear atom optics: focusing, atomic mirrors, atomic diffraction, atom interferometry.

Full-or-part-time: 6h
Theory classes: 6h

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 coherence and phase manipulation. Atom lasers. Matter-wave solitons. Atomic four-wave mixing. Superfluidity and vortices.

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

And more...

Description:
Disorder and Anderson localization. Tonks-Girardeau gas. Two-component Bose-Einstein condensates. Spinor condensates.

Full-or-part-time: 2h 30m
Theory classes: 2h 30m

GRADING SYSTEM

Two activities will be evaluated:
- Written exam (60%)
- Homework assessments (40%)
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:
- 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.
- 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: www.phys.ens.fr/~dalibard/publications/varenna98.pdf.
- Cohen-Tannoudji, C.; Guery-Odelin, D. Advances in atomic physics : an overview. Singapore: World Scientific, 2011. ISBN 9789812774972.

Complementary:
- 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/