UNIVERSITÀ
degli STUDI
di CATANIA

**DIPARTIMENTO DI FISICA E ASTRONOMIA**

**DOTTORATO DI RICERCA IN FISICA**

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# Selected topics in Quantum Technologies

3 CFU


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**Program of the course**:
Quantum Tecnologies (QT) is an interdisciplinary subject where physics, computer science and chemistry merge. In the last decade interest has grown both for the conceptual importance of methods, requiring a deeper understanding of quantum mechanics, and for the enormous potential in applications. QTs aim at exploiting exquisite quantum behavior to perform tasks which are tackled inefficiently by that present day technologies. For instance quantum computation relies on superpositions and entanglement to achieve exponential speedup of certain algorithms, which in a standard digital computer take a time growing exponentially with the input. The course presents selected topical concepts, techniques and physical systems of interest in the field of QT.

1) Quantum circuits with superconductors [1] (4 ore)
2) Cavity QED [2] and circuit QED [1] (4 ore)
3) Ultrastrong light-matter coupling [3] (2 ore)
4) Optimal control Theory for quantum systems [4] (2 ore)
5) Quantum simulators. [5] (2 ore)
6) Elements of advanced numerical methods: partial differential equations (7 ore)

**Bibliography**:

[1] Uri Vool and Michel Devoret, Introduction to quantum electromagnetic circuits, Int. J. Circ. Theor. Appl. 2017; 45:897–934
[2] S. Haroche and J.M. Raimond, Exploring the Quantum : Atoms, Cavities and Photons, Oxford, 2006.
[3] Anton Frisk Kockum, Adam Miranowicz, Simone De Liberato, Salvatore Savasta and Franco Nori, Ultrastrong coupling between light and matter, Nature Review Physics 1, 19 (2019); P. Forn-Díaz, L. Lamata, E. Rico, J. Kono, and E. Solano}, Rev. Mod. Phys., (2019), arXiv:1804.09275.
[4] J Werschnik and E K U Gross, Quantum optimal control theory, Journal of Physics B: Atomic, Molecular and Optical Physics 40, R175-R211( 2007); D. D'Alessandro, Introduction to Quantum Control and Dynamics, CRC Press, Boca Raton, FL, 2007.
[5] M. Nielsen and I. Chuang. Quantum Computation and Quantum Information. Cambridge University Press, Cambridge, 2010.