Università di Torino
Dipartimento di Fisica

Seminar

Technological applications of Silicon Carbide

<u>Tuesday, October 22nd h 9:30</u>
Aula Fubini – Dipartimento di Fisica

Research at the CNA on Silicon Carbide: from Materials to Devices

Prof. Javier Garcia Lopez
Dpto. de Física Atómica Molecular y Nuclear. Universidad de Sevilla
Centro Nacional de Aceleradores (CNA)

Engineering spin-based quantum technology

Prof. Cristian Bonato
School of Engineering & Physical Sciences, Institute of Photonics and Quantum Sciences
Herriott-Watt University, Edinburgh

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The physical and electronic properties of SiC make it one of the most prominent semiconductor materials for use under extreme radiation and temperature conditions and also mark it as a good candidate for spintronic applications. In this talk I will discuss different applications of the 3 MV Tandem accelerator from the National Accelerator Center to investigate different aspects of this material.
In the first part I will show how the magnetic properties of SiC single crystals can be modified by ion implantation and the usefulness of the Rutherford Backscattering Spectrometry technique in channeling geometry to explore the structural damage introduced during the implantation process. Then, I will comment some examples of the use of the Ion Beam Induced Charge technique to study state-of-the-art SiC detectors.

Javier García López is Professor of Nuclear Physics at the University of Seville. Following his undergraduate studies in Physics at theAutonomous University of Madrid, he earned a doctorate in the field of "High Temperature Superconductors" at the University Denis-Diderot (Paris). Subsequently, he obtained a postdoctoral position at the University of Twente (The Netherlands) to work on laser ablation. He joined the University of Seville in 1997 to participate in the commissioning of the first Spanish ion beam accelerator, the 3 MV Tandem accelerator of the Centro Nacional de Aceleradores, of which he is the Scientific Coordinator. His research interests have focused on the application of Ion Beam Analytical techniques and ion implantation in materials science and on the development and study of radiation detectors. He is co-author of more than 150 publications in these areas.

Engineering spin-based quantum technology

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School of Engineering & Physical Sciences, Institute of Photonics and Quantum Sciences
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Single spins are an excellent platform for the implementation of quantum memories/repeaters for secure quantum networks and nanoscale quantum sensors operating at the ultimate limits of spatial resolution. The deployment of these technologies into real applications requires engineering spin-based devices to make them reliable, robust and compatible with industrial-scale processing.
In this talk, I will discuss two aspects of our recent work on spin-based quantum technologies. In the first part of my talk, I will describe some of our recent results in engineering silicon carbide quantum spintronic devices for quantum networking [1]. Silicon carbide, as a semiconductor widely used in power electronics, offers a great opportunity in integrating spintronics, photonics and electronics on a single multi-functional platform. I will report the first observation of spin-dependent optical transitions (a key requirement for spin-photon interfaces) on single vanadium centres in SiC, which have recently attracted attention due to direct telecom-wavelength (O-band) emission and the availability of a coherent electron spin [2]. I will show that, by engineering the isotopic composition of the SiC matrix, we reduce the inhomogeneous spectral distribution of different emitters down to 100 MHz, significantly smaller than any other single quantum emitter [3]. This is important as the implementation of quantum networks requires all spin-photon

interfaces to operate at exactly the same frequency.
Further I will discuss our work on developing wafer-scale microphotonics structures, such as solid immersion lenses, in SiC [4], and our effort in creating spin defects, automatically registered in the centre of the micro-lens, by femtosecond laser writing. I will finally discuss our plans to create quantum opto-electronic devices in SiC for quantum networking.
In the second half of my talk, I will give an overview about our current directions in quantum sensing. We have recently installed the world's first commercial scanning NV magnetometer at low temperature (1.8K). I will describe its operation, and our preliminary work in mapping domains in a 2D anti-ferromagnet (CrSBr). I will finally briefly outline the vision and the goals of the recently-funded UK Hub about "Quantum Sensing for Healthcare", led by UCL.

[1] S.Ecker et al, "Quantum communication networks with defects in silicon carbide", arXiv:2403.03284 (2023)
[2] J. Hendriks et al, “Coherent spin dynamics of hyperfine-coupled vanadium impurities in silicon carbide”, arXiv:2210.09942 (2022)
[3] P. Cilibrizzi et al, “Ultra-narrow inhomogeneous spectral distribution of telecom-wavelength vanadium centres in isotopicallyenriched silicon carbide”, Nature Communications 14, 8448 (2023)
[4] C. Bekker et al., "Scalable fabrication of hemispherical solid immersion lenses in silicon carbide through grayscale hard-mask lithography", Appl Phys Lett. 112, 173507 (2023)

Cristian Bonato is a Professor at Heriot-Watt University, where he leads the "*Spin-based quantum technology*" theme within the Quantum Photonics Laboratory. He currently holds an EPSRC Early-Career fellowship (2019-2024) and is the Principal Investigator for Heriot-Watt's Nanoscale Quantum Sensing facility.
Born near Venice (Italy), he has been awarded a PhD in Electrical Engineering (2008), both from the University of Padova (Italy), for work on quantum communication and photonic entanglement. Before joining Heriot-Watt University as Assistant Professor in 2016, he has he has been a visiting researcher at Boston University, USA (2006-2008) and has worked as a post-doctoral researcher in the Netherlands on semiconductor cavity-QED (Leiden University) and on spin control with nitrogen vacancy centres in diamond (Technical University Delft).