**CONTRATOS PREDOCTORALES 2021 SEVERO OCHOA**

**PROJECT TITLE / JOB POSITION TITLE:**

**Quantum sensors for ultralight dark matter searches**

**RESEARCH PROJECT / RESEARCH GROUP DESCRIPTION:**
**(2.000 characters – including spaces)**

The main goal of the project is the development of quantum sensors based on thin film superconductors, which operate at extremely low temperatures (T<<1K), to detect ultralight dark matter.
Cosmological evidence indicates that 85% of the matter in our Universe is dark matter (DM). The favorite DM candidate has been the weakly interacting massive particle (WIMP) whose mass is expected to lie somewhere between the proton mass and a mass one thousand times larger. But after decades of searching, no evidence for WIMP existence has been obtained. Alternatively, the existence of sub-GeV DM particles with mass between 1 keV and the mass of the proton has gained a lot of attention.
The direct detection of sub-GeV DM particles poses major experimental challenges. In the past two years, several theoretical ideas have been proposed as detection channels for light and ultralight DM search. Among them, special interest deserves the excitation of optical phonons in polar or Dirac materials via electron scattering. The use of such excitations would imply daily modulation in the signal, when using an anisotropic target; and this would provide further evidence for sub-GeV DM.
Experimentally, the detection of optical phonons requires extremely sensitive detectors, such as cryogenic detectors based on Transition Edge Sensors (TES) working at 10-20mK. These detection schemes require the development of high quality superconducting thin films of selected materials, for phonon collection, detection and wiring. The properties of these films need to be finely tuned in order to optimize their functionality. Afterwards, prototype sensors must be designed, fabricated and tested. The present thesis proposal focuses on this work, done as an interdisciplinary project funded by the Next Generation Europe funds within the CSIC PTI+ on Quantum Technologies and involves researchers from ICMAB, IFCA, IMB and INMA.

**JOB POSITION DESCRIPTION:**
**(2.000 characters – including spaces)**
*Include all the relevant information about the position, role, responsibilities and skills required within the project/group*

The thesis will focus on the so-called quasiparticle-trap-assisted TES (QETs), coupled to a polar target. A QET is a phonon detector constituted by a TES connected to a superconducting film with higher $T_c$ and larger area, called fin. The fin collects the phonons generated in the target after the DM interaction, which diffuse to the surface; in the fin, these phonons generate quasiparticles, which diffuse towards the end where the TES lies, where they are detected.


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The separation of phonon collection and detection allows decoupling the large area required for high detection efficiency from the low TES volume required to optimize detector sensitivity.
The performances of the detector depend on the phonon downconversion and diffusion in the target, and on the sensitivity of the QET which, in turn, depends on the quasiparticle diffusion length in the fin, on the performances of the TES, and on the specific design of them both.
The thesis work will focus on the development (fabrication and characterization) of superconducting films, the detailed study and tuning of the relevant parameters for the different components of the detectors, including the design of suitable test structures; special attention will be paid to the impact of relevant detector design parameters, such as critical temperatures, dimensions, and overlap between components. Finally, it is expected that the student will contribute, within the interdisciplinary collaboration, to the design of detector.

We look for a student interested in interdisciplinary, collaborative projects, with a background on solid state physics and materials science. He/she will work in a environment with experts in materials science, nanotechnology and particle physics, and should benefit from tight interaction with them all. Film and device fabrication and characterization will be performed at ICMAB and IMB. Cryogenic characterization in dilution refrigerators will be at INMA. Simulation tools (COMSOL, GEANT4) will also be used.

**GROUP LEADER:**

**Title: Dr.**
**Full name: Lourdes Fàbrega Sánchez** (Researcher ID: L-5090-2014)
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**Research project / Research Group website:** *under construction (recently awarded project). For details see additional links provided*

**RELATED LINKS TO THE POSITION (optional)**
**URL:** https://newscenter.lbl.gov/2019/06/10/small-dark-matter-experiments-broaden-hunt/
**Tittle link:** "What if Dark Matter is Lighter? Report Calls for Small Experiments to Broaden the Hunt"

**URL:** https://www.sciencedirect.com/science/article/pii/S0370269318306816
**Tittle link:** "Detection of light dark matter with optical phonons in polar materials"

**URL:** https://www.annualreviews.org/doi/pdf/10.1146/annurev-nucl-101916-123130
**Tittle link:** "Advances in bolometer technology for fundamental physics" (Review on prospects of cryogenic detectors for Fundamental Physics)

**URL:** https://icmab.es/extremely-sensitive-radiation-detectors-to-explore-the-universe-in-the-forthcoming-esa-space-missions
**Tittle link:** "Extremely sensitive radiation detectors to explore the Universe"



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