# The project 2-SPaCE: 2-dimensional materials for Single Photon CountErs

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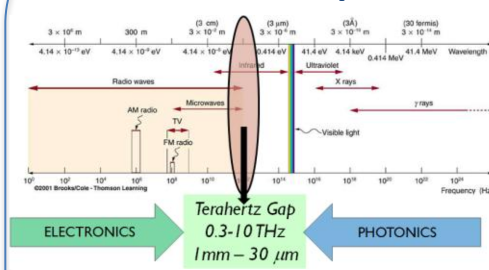
## THz Gap

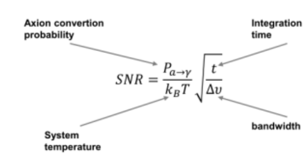



## Introduction

•absence of sensitive detectors is the **main technological bottleneck** for applications (spectroscopy, security, …)

•for certain applications an ultimately high sensitivity reaching a **photon-counting level is indispensable;** however, in THz range photon energies are far smaller (E< 124 meV, $\lambda$> 10 $\mu$m) and the single-photon detection is no longer trivial, in marked contrast to the visible and near-infrared regions

**Single Photon Counters for dark-matter applications:** theory predicts *very weak quasi-monochromatic signals* (*few photons level*) in strong magnetic fields, produced via axions resonant conversions in a region of the parameters space difficult to reach with different techniques (microwaves, sub-THz and THz)



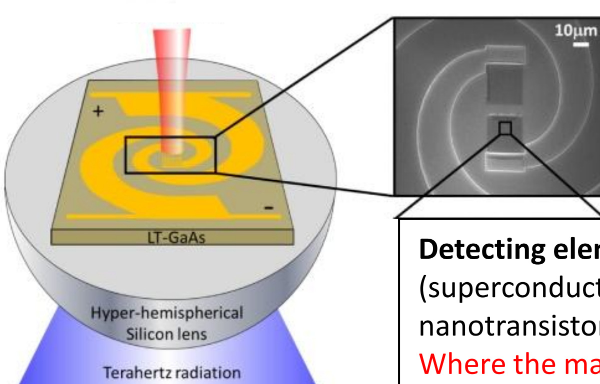

*With the available detector technologies, attainable sensitivities are currently far below the level of single-photon detection at THz frequencies!*

## Project Key Concepts

**R&D Goals:** New approaches and devices based on **interaction between THz radiation and the novel technologically important 2D materials** ( like graphene and $MoS_2$), to be employed as single photon counters in the sub-THz and THz regions.

•Among several novel detection schemes proposed in the last decade, only quantum devices based on nanostructured semiconductors have demonstrated single-photon detection

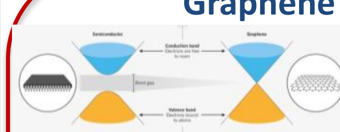
Best Detector Scheme for free-space THz beams: *quasi optical approach* (common to bolometers, phototransistor, Schottky diodes, etc..)




**Quasi Optical Detectors**
The THz beam is collected and converted by the antenna, to confine a THz current in a sub-wavelength region (antenna feed)

**Detecting element**
(superconducting nanowire, nanotransistors,..
Where the main efforts are focused!

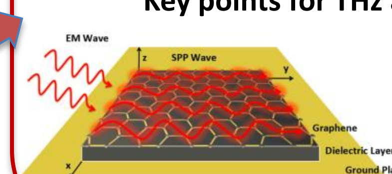
### Graphene and 2D materials



Carriers in 2D system are massless dirac

2D-materials detectos
•Low Noise, Broadband absorption, high-mobility, flexible
•Challenge: responsivity and large area fabrication

**Key points for THz applications**



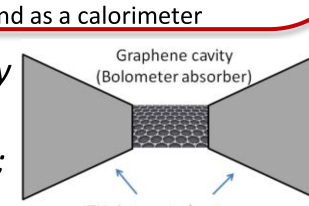

•strong light-matter interaction and collective effects (plasma waves )
•Transport dominated by Hot-Carrier: potential for very high sensitivity as both a bolometer and as a calorimeter

### Cryogenic detectors

•*General advantages : noise reduction, noise thermometry possible*

•***Graphene-based cryogenic detectors:*** *weak coupling with the substrate, low heat capacity (fast response and high E resolving power needed for single photon detection)*

•*Device design: Superconducting junctions for thermal isolation within the graphene cavity; impedance tunability via field effect gating*




## Potential Impact

•Device Technology: fabrication solutions, integration of the 2D materials in the current detector technologies

•Materials Science: 2D materials beyond graphene ($MoS_2$), topological insulators; synthesis and manipulation methods

With the aim of fabricating 2D-based detectors using, we will propose and develop novel solutions for the microfabrication of future electronic devices, contributing to the advancement of 2D materials science and device technology, whose foreseen applications will be not only in field of dark matter studies. *The focus will be the study of the properties that could make 2D materials usable in detectors, but the results are expected to be relevant for the knowledge on 2D materials in general.*