Istituto Nazionale di Fisica Nucleare

Proposal Grant Giovani CSN5 - Year 2025

UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA

ANECDOTE:
An NTL-Enhanced Cryogenic Detector with Optically Transparent Electrodes

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Goal of the project

The **ANECDOTE** project aims to develop a new, versatile, semiconductor-based cryogenic detector featuring Neganov-Trofimov-Luke amplification, achieved through an innovative electrode design.

Semiconductor substrate
Si, Ge, narrow-gap

+

Transparent conductive oxide coating
ITO, AZO, used for solar cells

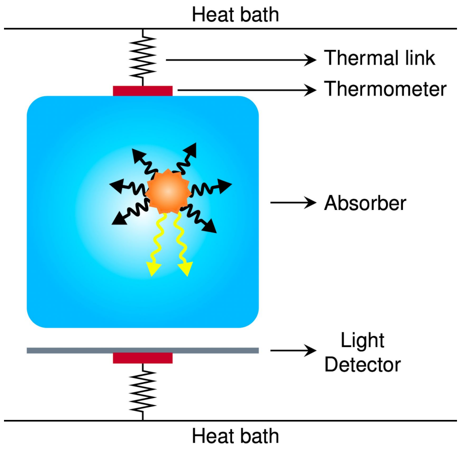
⇒

NTL-amplified cryogenic detector

→ Highly sensitive light detector
rare event searches

→ High-resolution, large-area particle detector
X-ray and low-energy electron spectroscopy

State of the art



- many INFN CSN2 experiments (CUPID, CRESST, COSINUS, RES-NOVA) plan to use semiconductor-based cryogenic devices as ancillary detectors to measure scintillation/Cherenkov light

- goal: particle ID and pile-up discrimination

- high signal-to-noise ratio needed for sensitivity to very rare events
  → NTL effect: $A \propto E_{dep} + \eta q V N_{eh}$

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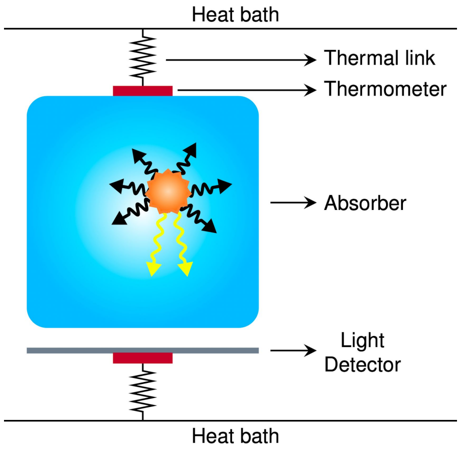

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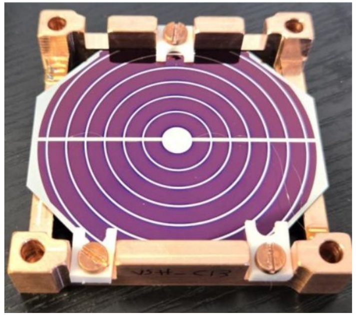
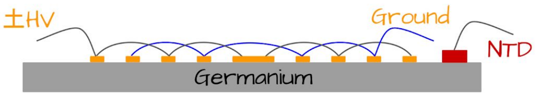




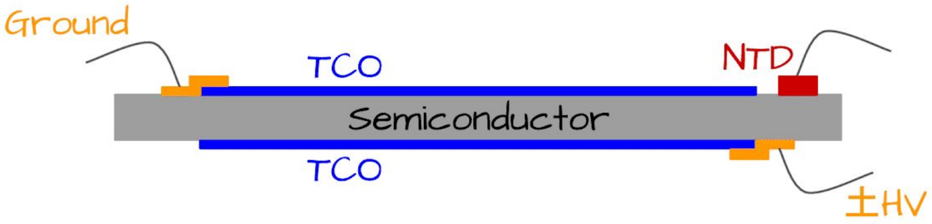
Example of CUPID light detectors:

- Germanium wafer
- drift mostly // to surface
- hold V > 100 V

Limitations:

- long path to reach electrodes
  → trapping probability
- surface quality matters
- asymmetric amplification
- no amplification for particles
- cost (~1k€ per device)

The ANECDOTE idea



- **Semiconductor** substrate (Si, Ge, ...)
- thin film of **Transparent Conductive Oxide** (TCO) deposited through sputtering on both sides
- **NTL bias** directly connected to TCO layers (bonding wires + indium)
- signal read with an **NTD**

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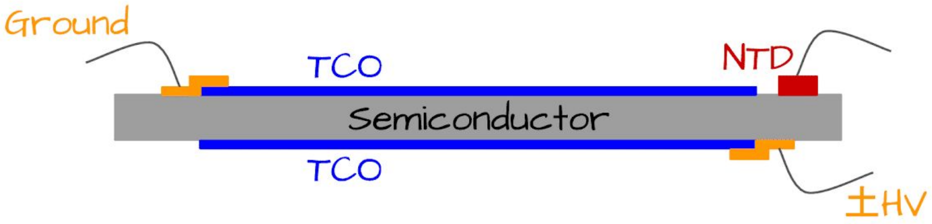

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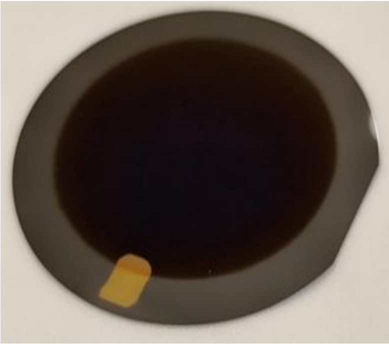
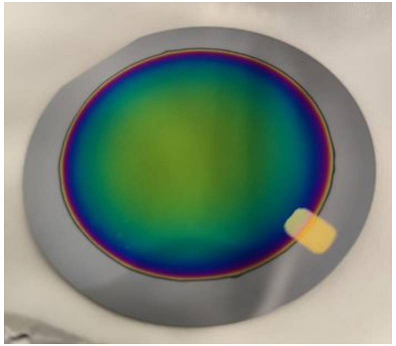
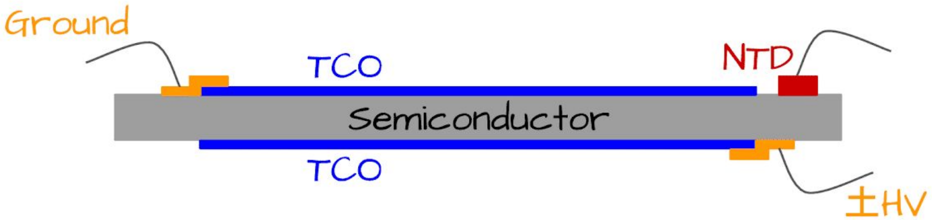
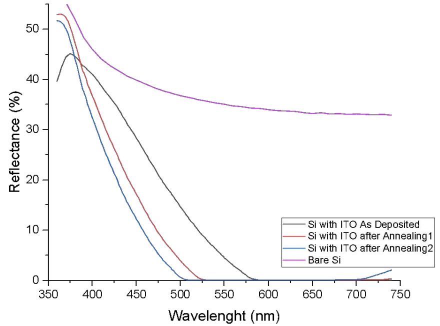



Devices produced @ Legnaro

The ANECDOTE idea



- TCOs are transparent to optical light in a given range (dependent on thickness) → used for photovoltaic cells



- drift ⊥ to surface:
  - short path → low trapping probability
  - less dependent on surface quality
  - symmetric gain

- electrode geometry allows for uniform electric field → amplification for particles achievable

- Cheaper and easier fabrication process than currently used light detectors

A phased approach

Phase I

- production of several Si-based devices with Indium-Tin-Oxide (ITO) coating
  - different ITO thicknesses
  - different ITO coverages
  - different Si thicknesses

@ Legnaro

- characterization @10mK at Bicocca cryostat
  - optical fiber + pulsed LED
  - radioactive sources

Deliverable: device capable of holding >100 V → light detector for next-gen CSN2 experiments

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Phase II

- production of devices with different:
  - TCOs → AZO, FTO…
  - substrate → Ge, narrow-gap semiconductors

@ Legnaro

- characterization @10mK at Bicocca cryostat
  - optical fiber + pulsed LED
  - radioactive sources

Deliverable: versatile detector for high S/N light and particle measurements

Semi-TCO versatility

Narrow-gap semiconductors (InSb…) hardly used as particle detectors due to high leakage current
→ O(10 mK) temperatures + NTL amplification can be exploited to approach Fano limit

X-ray and low energy β detector

- resolution of ~20-25 eV could be achievable with a large-area device
- applications in X-ray searches (lab and space), precise β spectroscopy

Optical photon detector

- increased signal due to small bandgap
- applications as scintillation/Cherenkov light detectors with even higher S/N

Infrared photon detector

- sensitivity down to few infrared photons achievable due to O(0.1 eV) gap
- possible applications in quantum computing

ANECDOTE's workflow