TERAPOL

TERahertz Axion POLaritons

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July 13, 2020

OBJECTIVE

Investigate AF-TIs materials (e.g. $Mn_xBi_yTe_z$) which might host axion quasiparticles by means of a terahertz time domain spectroscopy apparatus (THz-TDS)

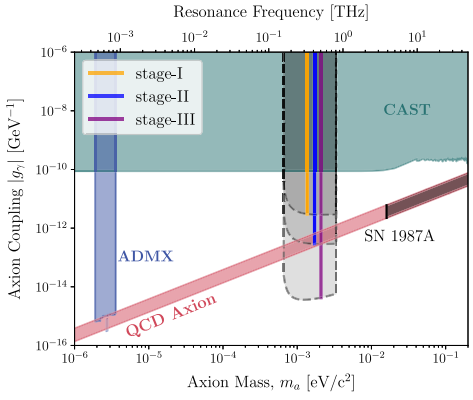
PHYSICAL REVIEW LETTERS **123,** 121601 (2019)

Proposal to Detect Dark Matter using Axionic Topological Antiferromagnets

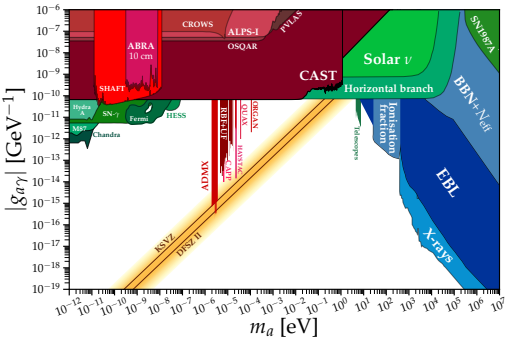
David J. E. Marsh[1,*] Kin Chung Fong,[2] Erik W. Lentz,[1] Libor Šmejkal,[3,4,5] and Mazhar N. Ali[6]

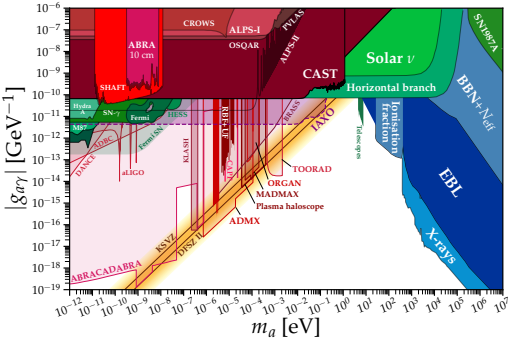
F-TIs materials can host quasiparticles which are resonantly driven in the presence of axions and emit THz photons which can be detected using a single photon detector

- $0.7 < m_a < 3.5\,\text{meV}$, axion mass interval currently inaccessible to other DM experiments or proposals
- $V_s \lesssim 1\,\text{cm}^3$ (stage I); x100 (stage II)
- tunability of the resonance with applied magnetic field



EXCLUSION PLOTS: CURRENT LIMITS AND PROJECTED SENSITIVITY





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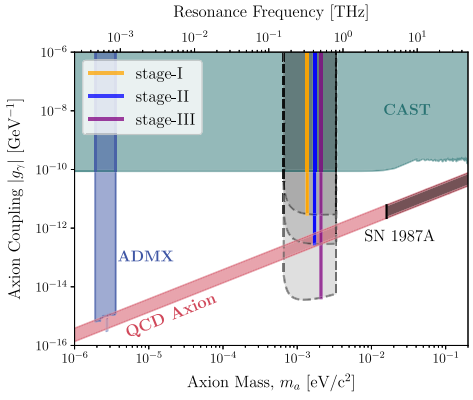
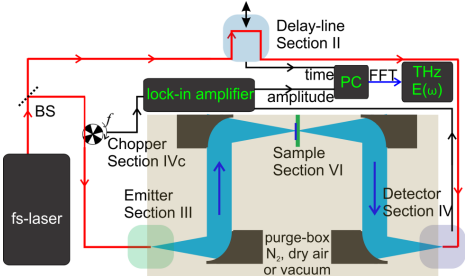


TERAHERTZ TIME DOMAIN SPECTROSCOPY (1)

Spectral range $0.1 - 1$ THz
$\rightarrow$ region of interest for vibrational spectroscopy of liquids, low frequency modes of molecular crystals, drugs, explosives…
$\rightarrow$ suited to measure the dynamics of mobile charge carriers since they reflect and absorb terahertz radiation

in 2012 we tested high speed semiconductors within the INFN MIR experiment (gr2)

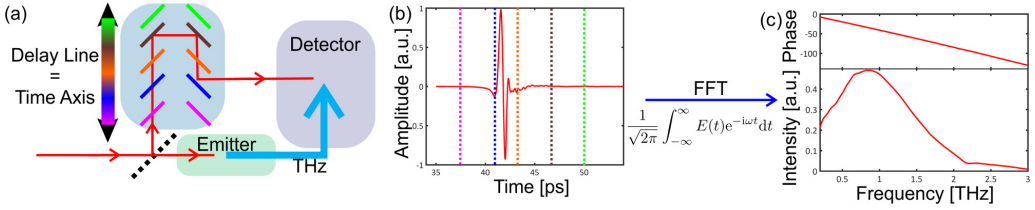
- femtosecond laser (mode-locked Ti:Sa)
- two beam paths, one with delay
- photoconductive antennas
- lock-in techniques



TERAHERTZ TIME DOMAIN SPECTROSCOPY (2)

In the transmission spectrum we search for a resonance whose frequency and width coincide with the relevant polariton parameters necessary to use AF-TIs as axion dark matter detectors.

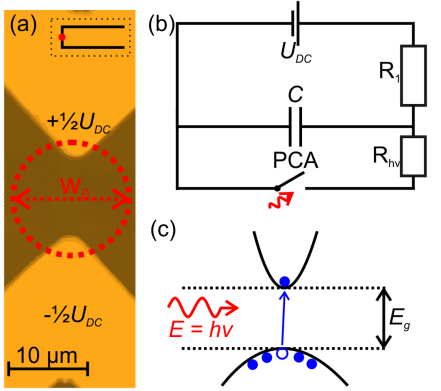
How **time domain** measurements can provide **spectral information**:

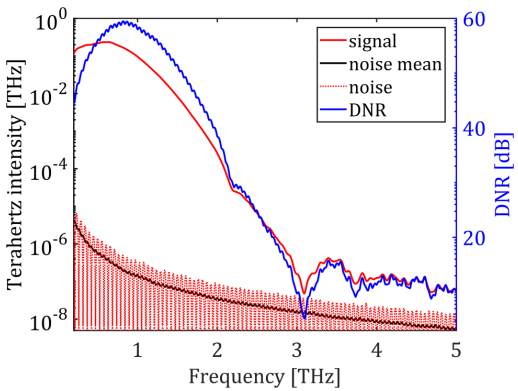


1. different colours → different delay-line positions, corresponding to different time points in (b)
2. measured THz time-domain signal (amplitude of the THz field at the detector antenna)
3. the FFT of the signal in (b) is used to infer system dynamic range

METHODOLOGY SNR AND DYNAMIC RANGE (DNR) (2)

The THz-TDS will be characterised in terms of dynamic range (DNR) and its resolution will be improved

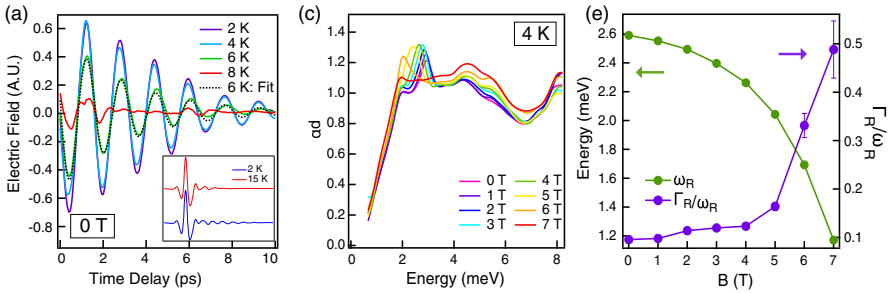




METHODOLOGY (2)

The measurements will be performed at a series of cryogenic temperatures and large magnetic fields

Example:
α-$RuCl_3$



1. narrow peak in the spectrum of the THz pulse transmitted through the sample for $T < 10\,\mathrm{K}$ (c)
2. the final plot with report A (amplitude of oscillations), Γ (decay rate of the oscillations) and frequency ω_R vs temperature
3. confirm AFMR with magnetic field variation

TERAPOL (**TER**AHERTZ **A**XION **POL**ARITON)

- Sezioni: **Padova**, **Pavia**
- Responsabile Nazionale: C. Braggio
- FTE PD: 1.4
  C Braggio (50%), F. Borghesani (60%), E. Conti (15%), P. Marchetti (15 %),
- FTE PV: 1.2
  F. Pirzio (60%), A. Agnesi (60%)
- Richieste finanziarie 60 keu (2021), 25 keu (2022)
- Richieste sezione PD: 2 MU O.M., 3 MU O.E.