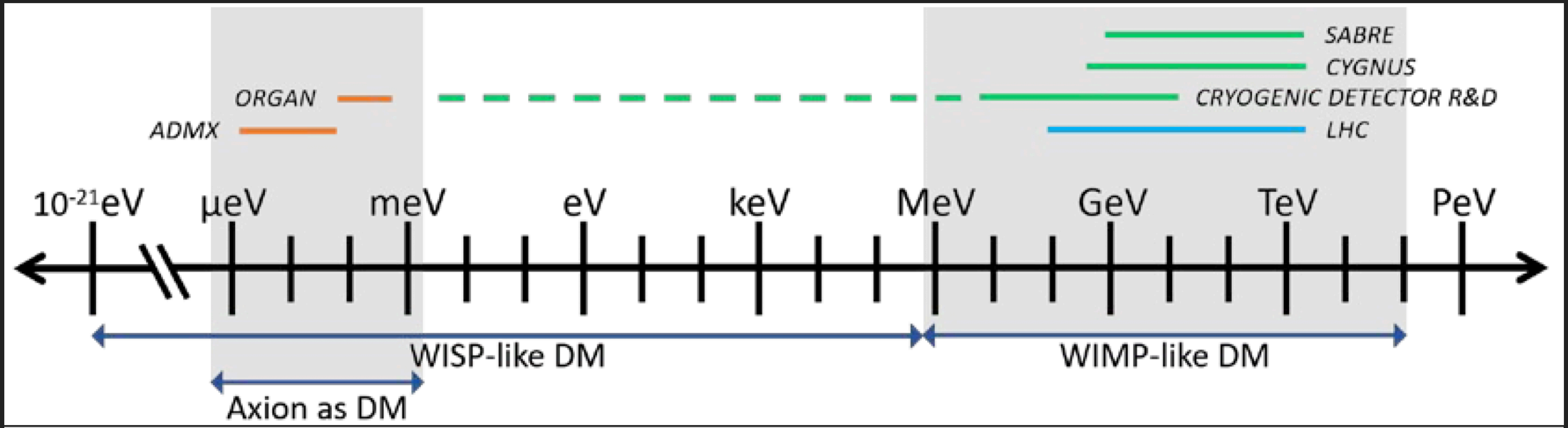
ARC CENTRE OF EXCELLENCE FOR DARK MATTER

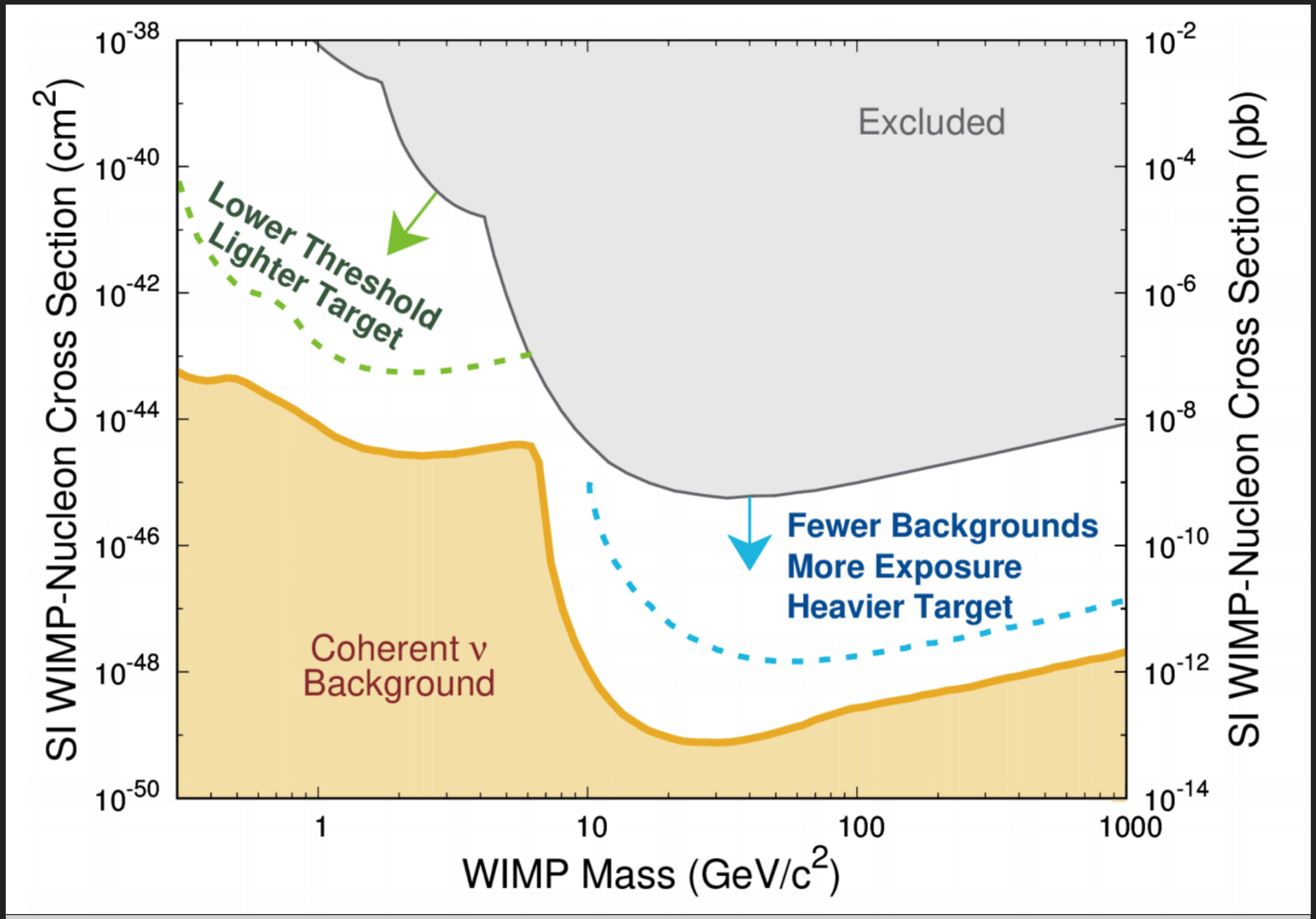
QUANTUM TECHNOLOGIES AND DARK MATTER LAB

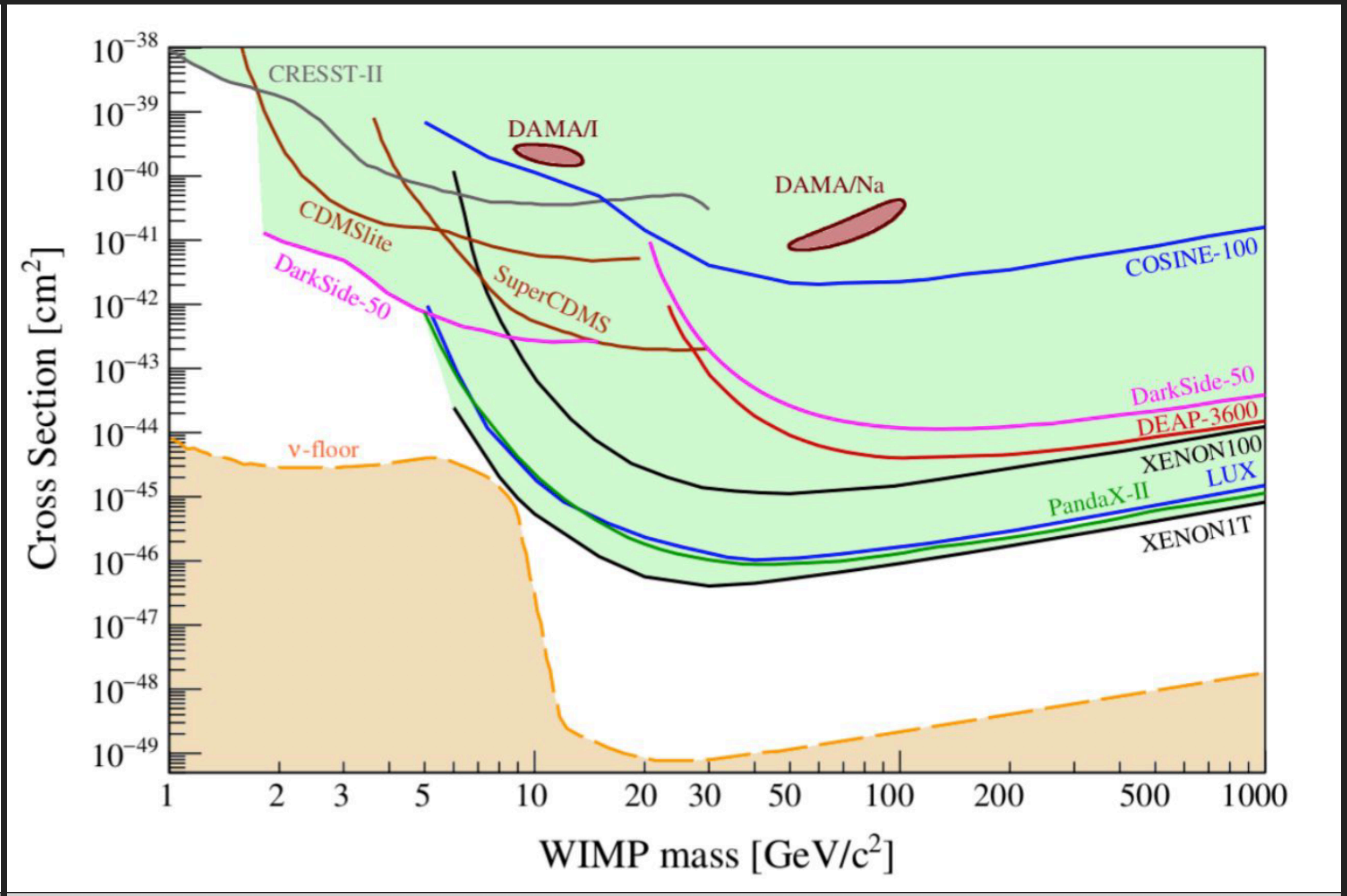
CRYOGENIC DIRECT DETECTION R&D

Dark Matter Landscape



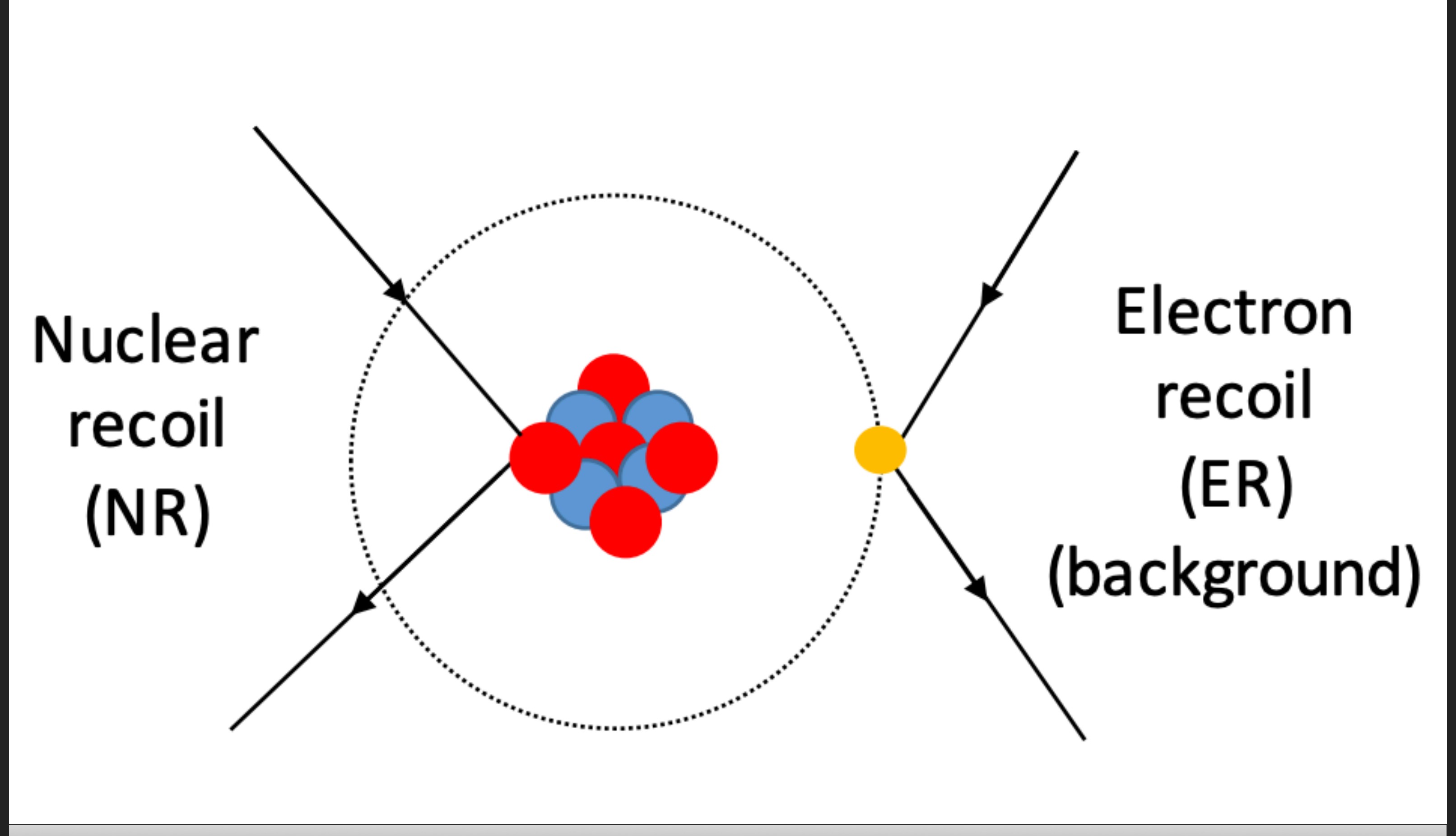
Current State



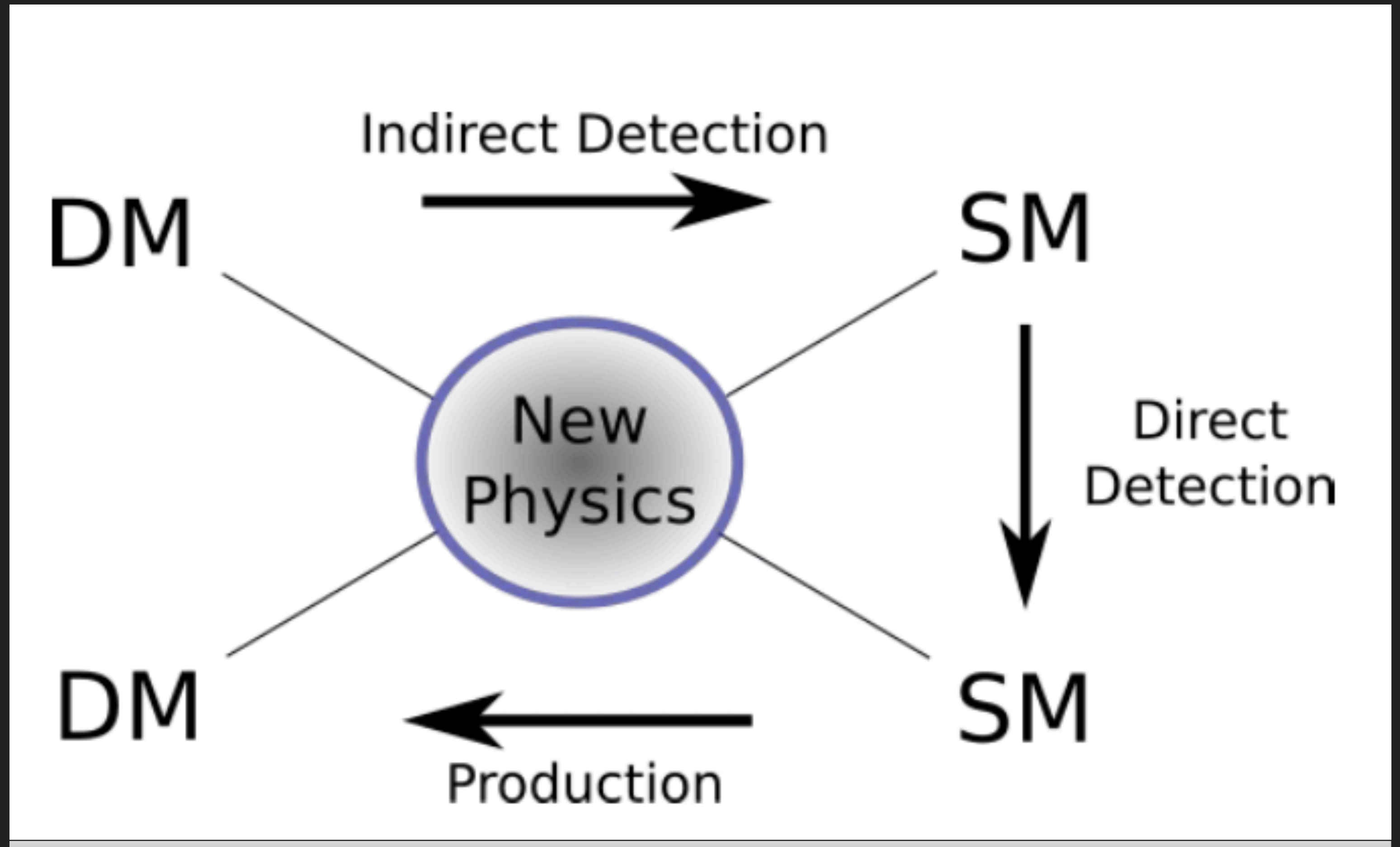


WIMPs Detection

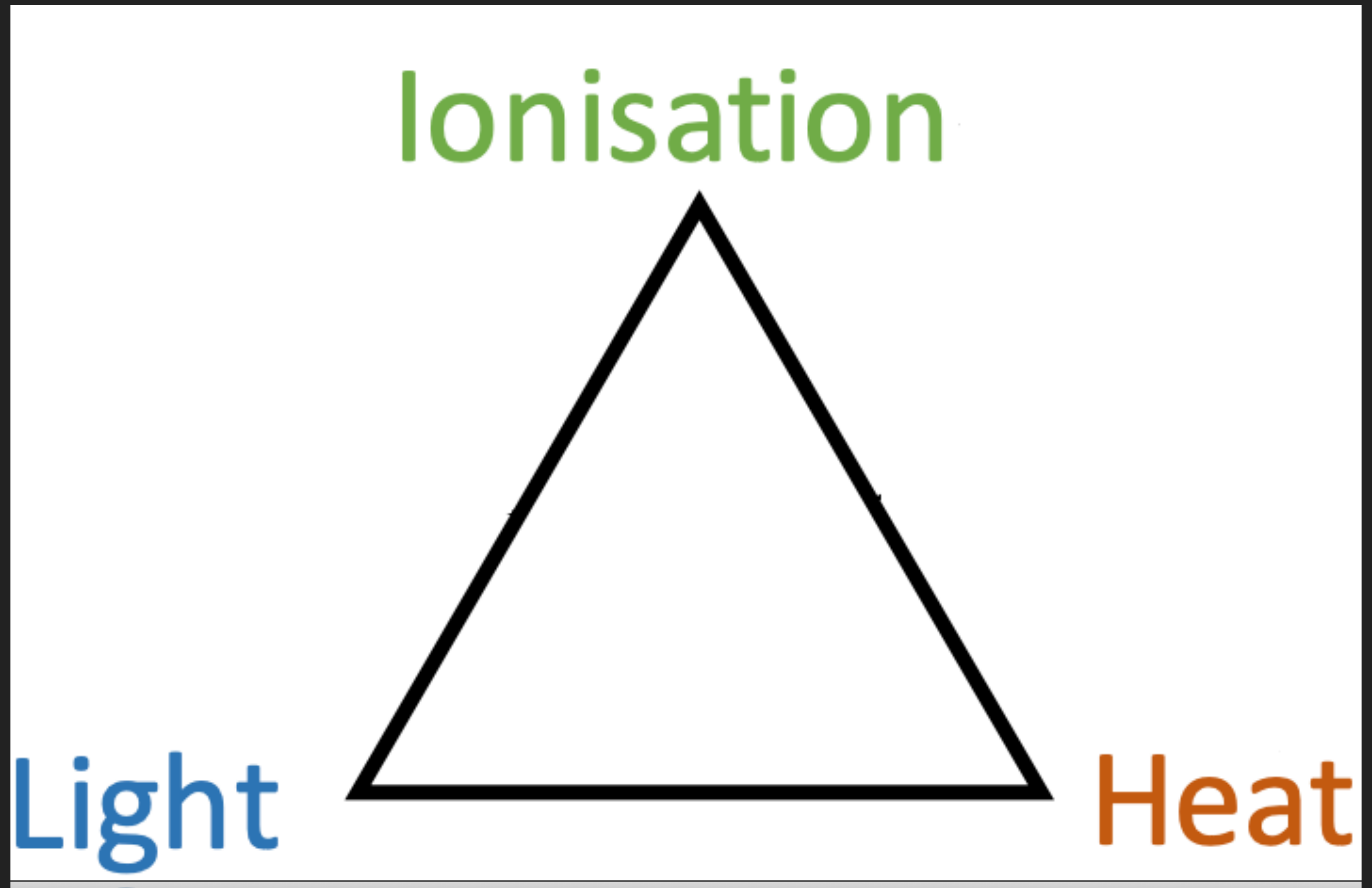
Recoil Event



Direct Detection

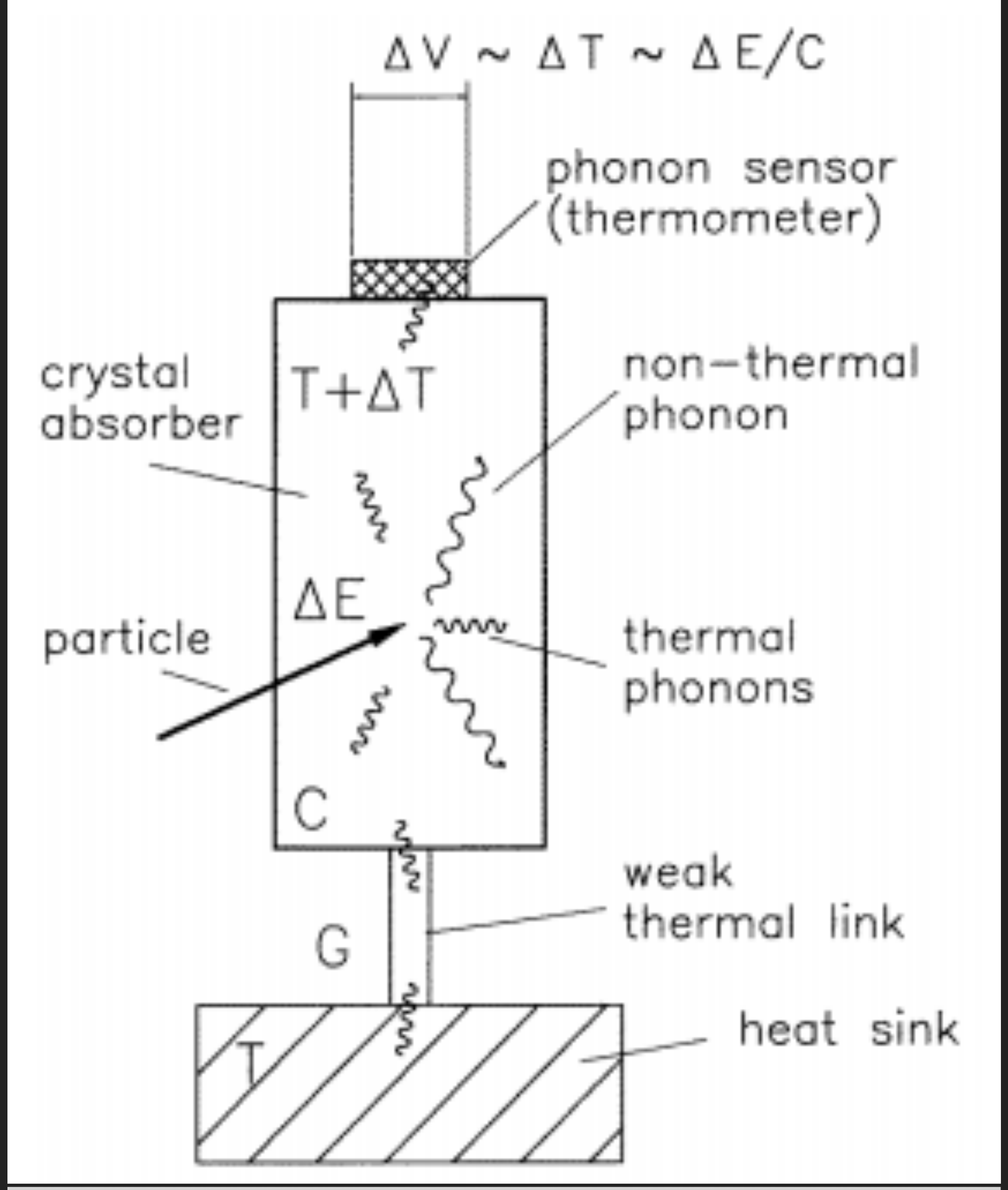


Complementary approaches to recoil detection



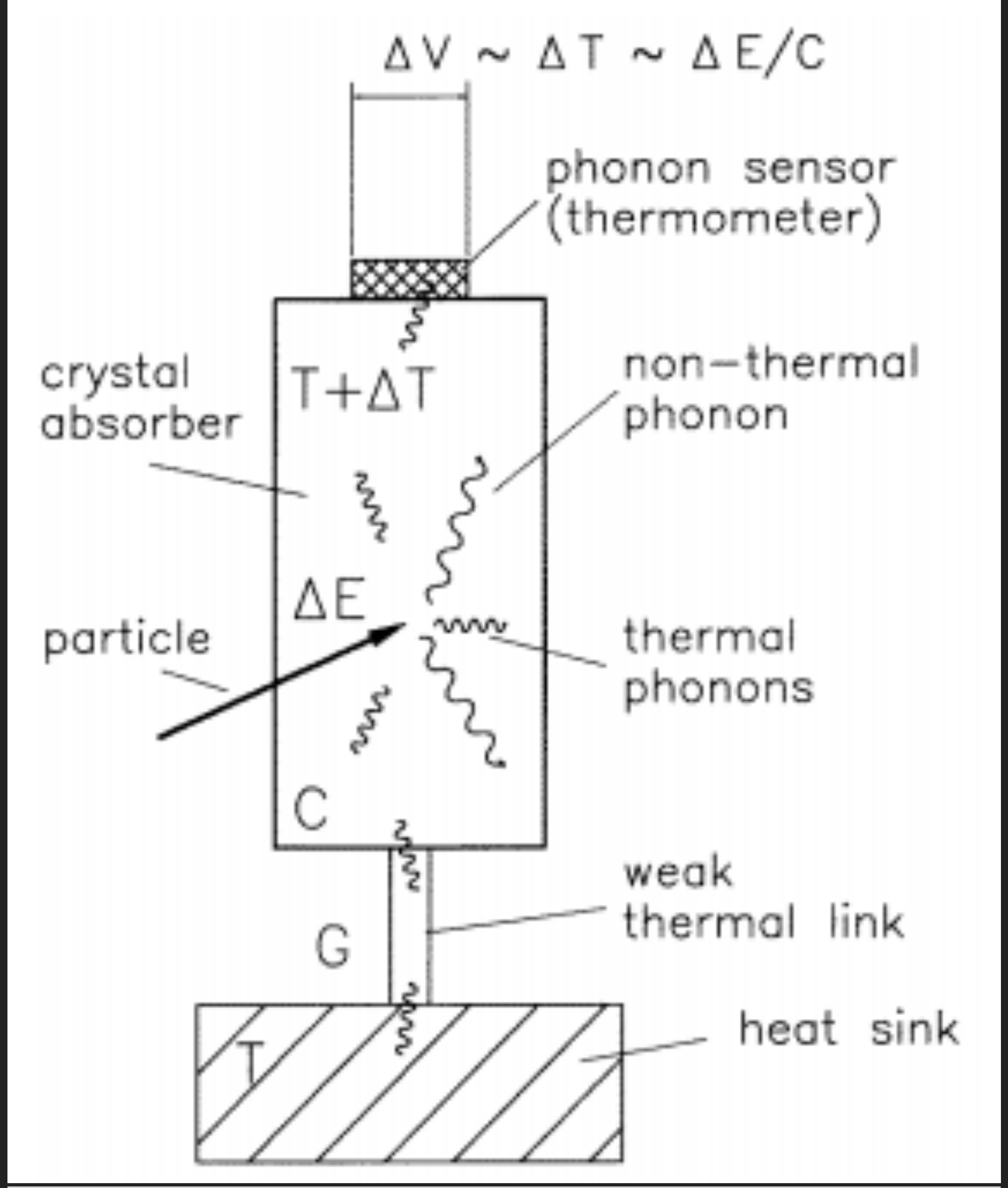
Detection Approaches

Phonons

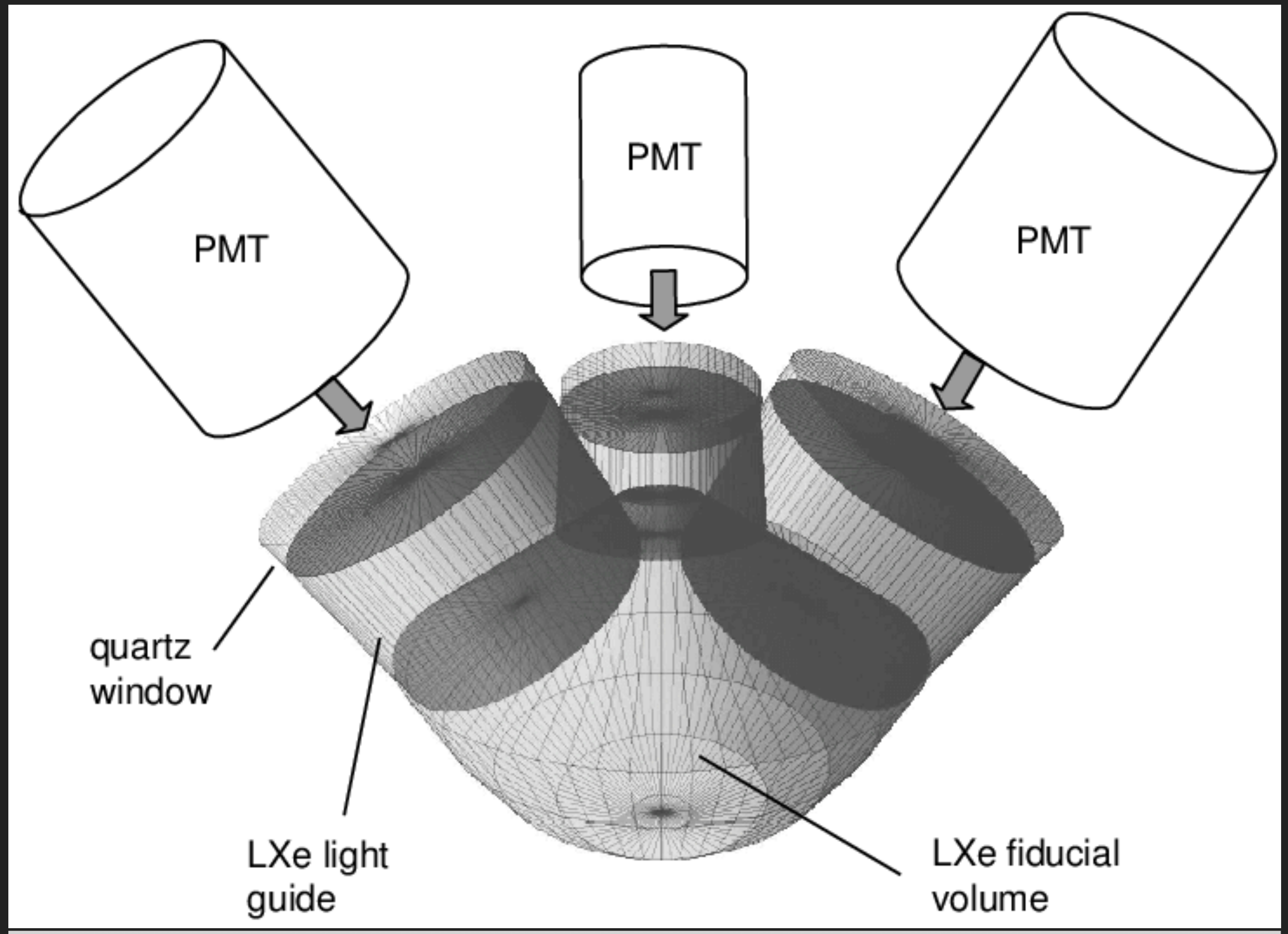


Detection Approaches

Phonons

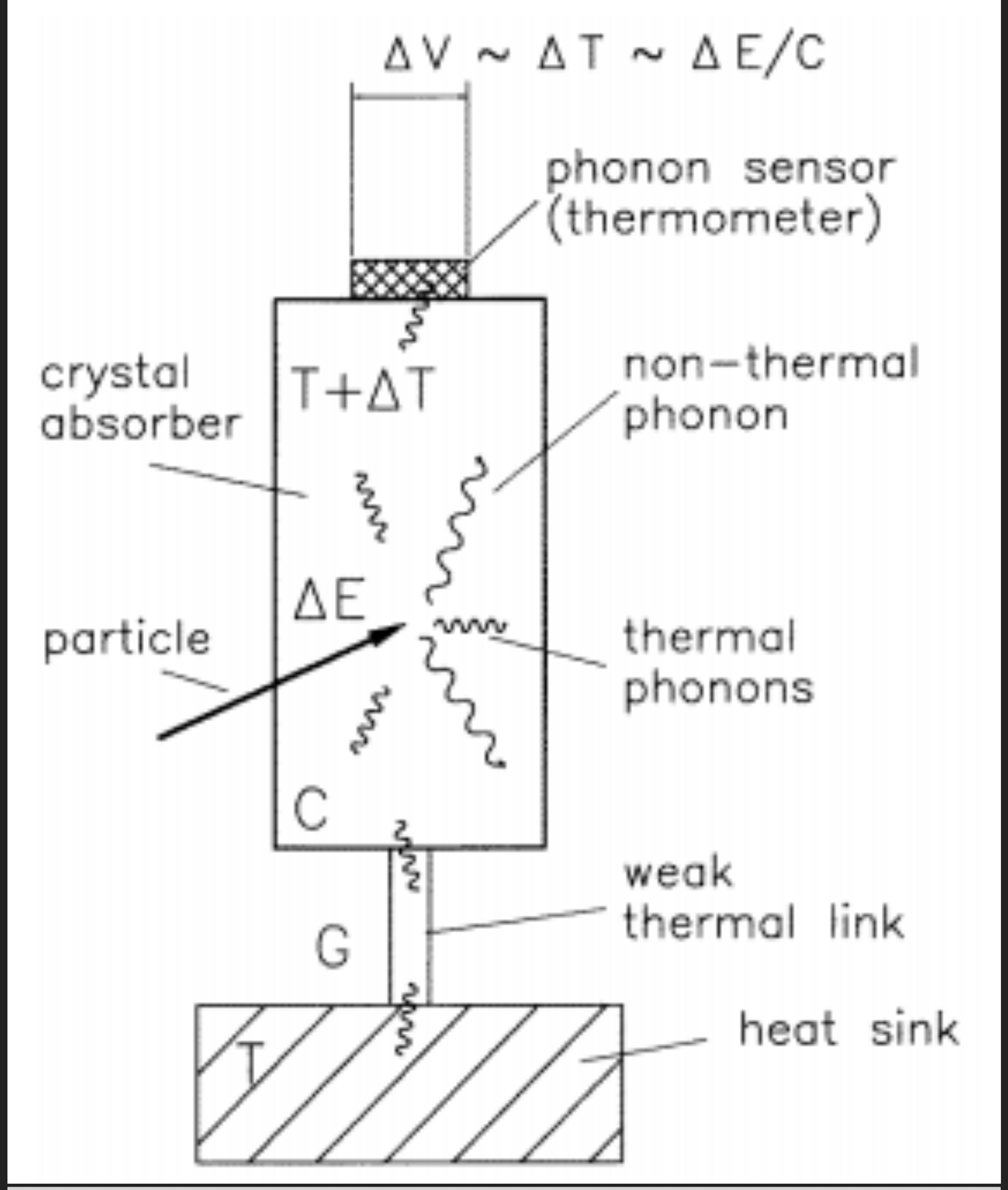


Photons

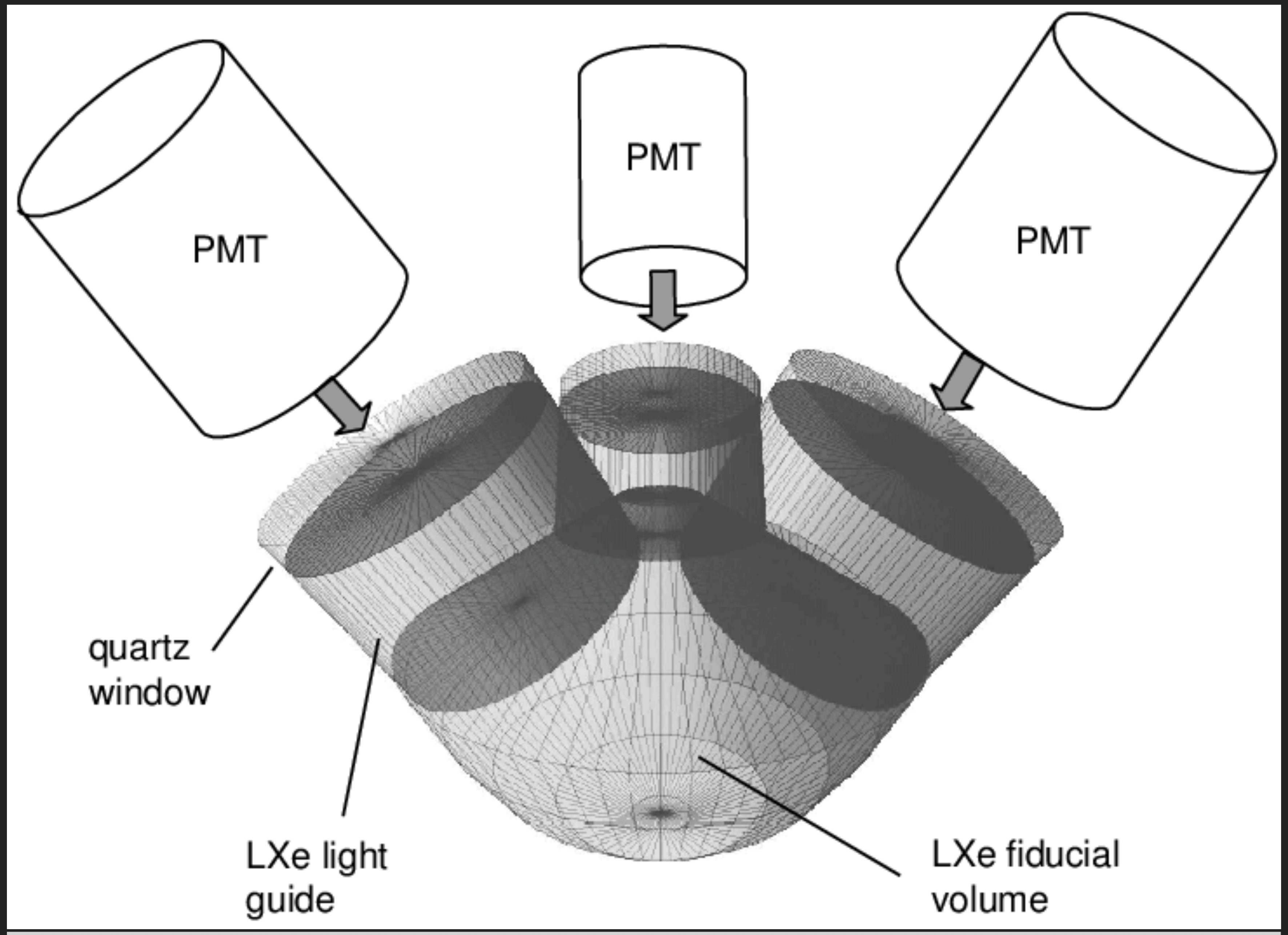


Detection Approaches

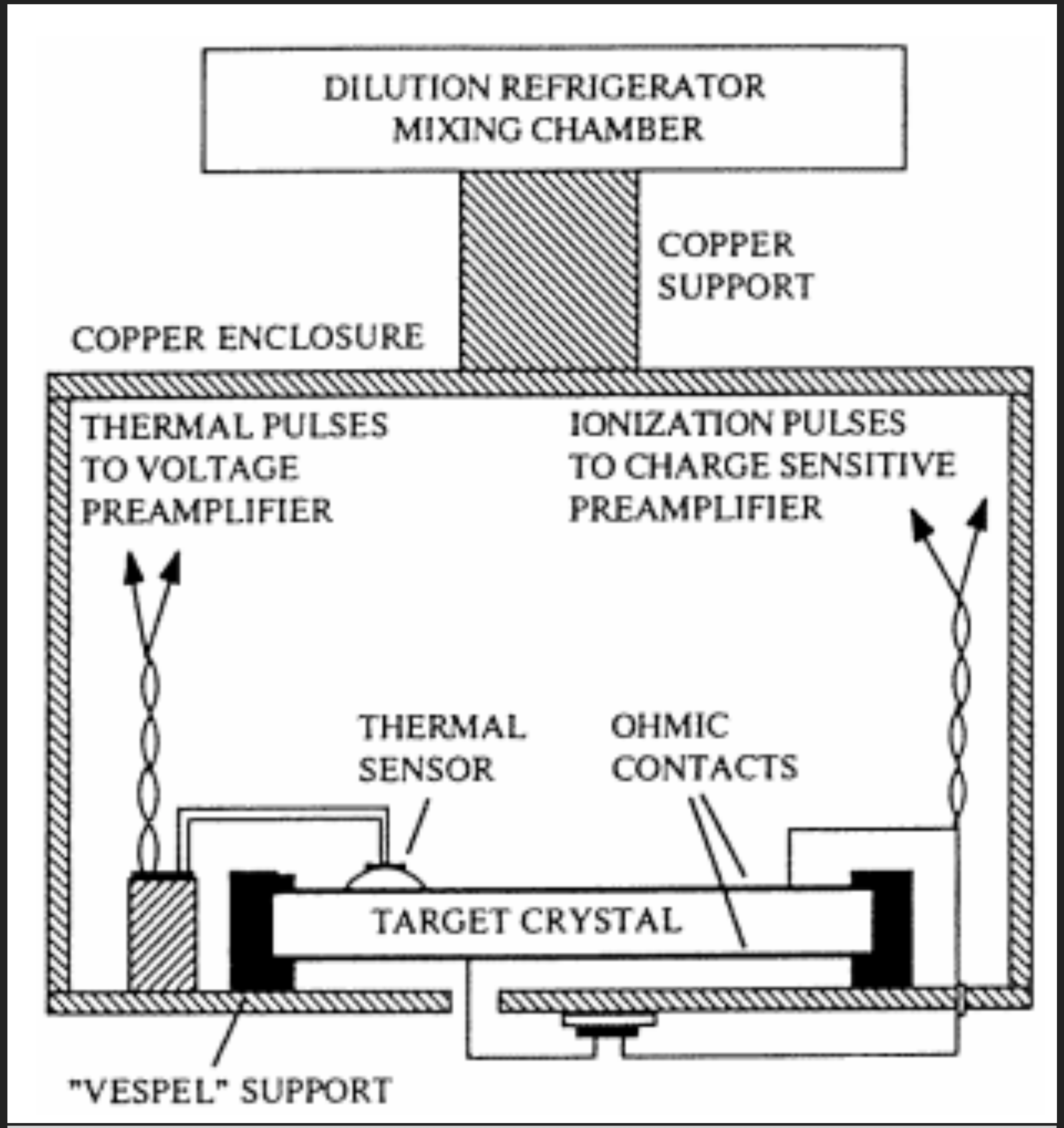
Phonons



Photons



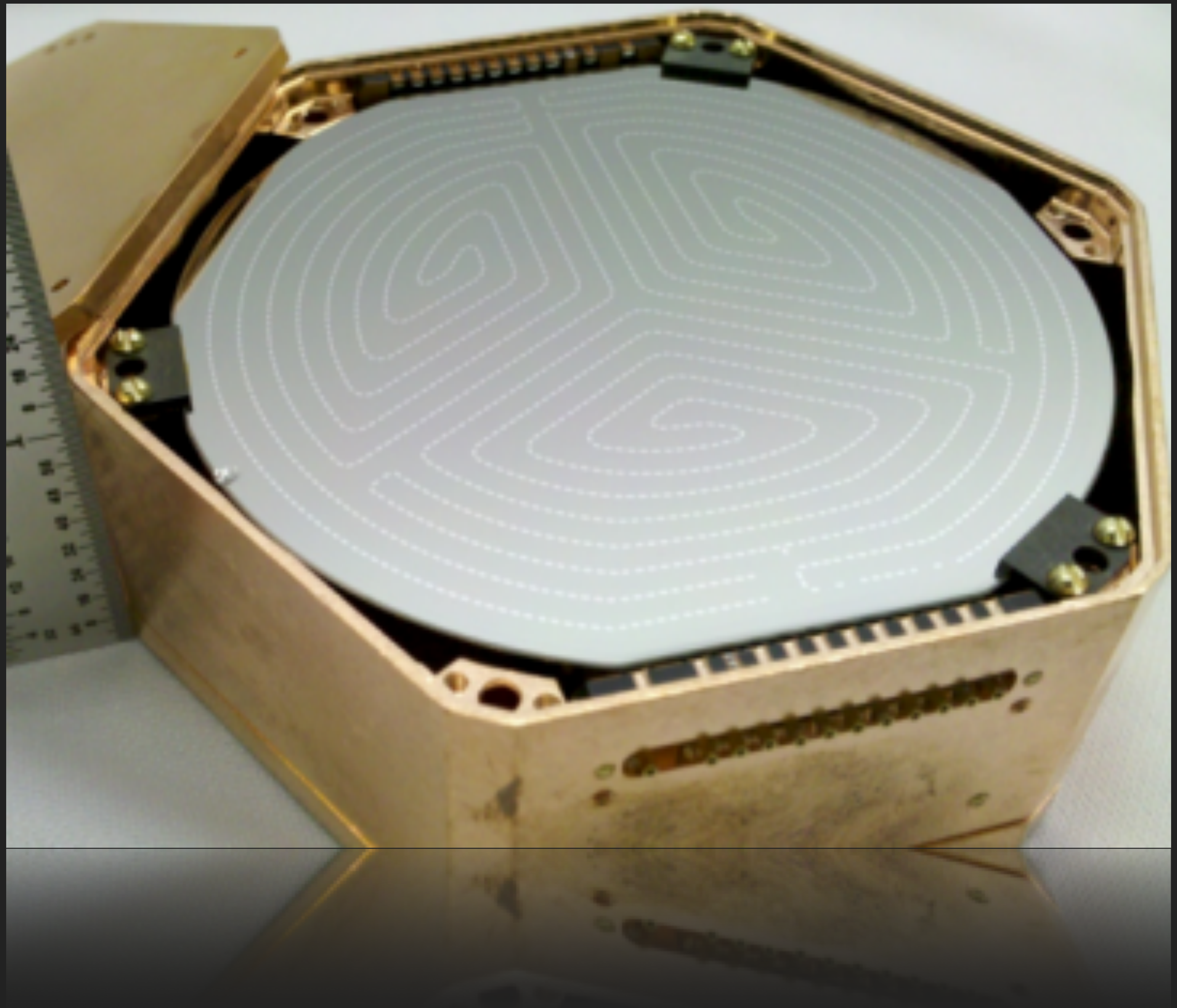
Ions



Research Directions

NEW TARGETS

TRADITIONALLY : GE, NAI AND SI



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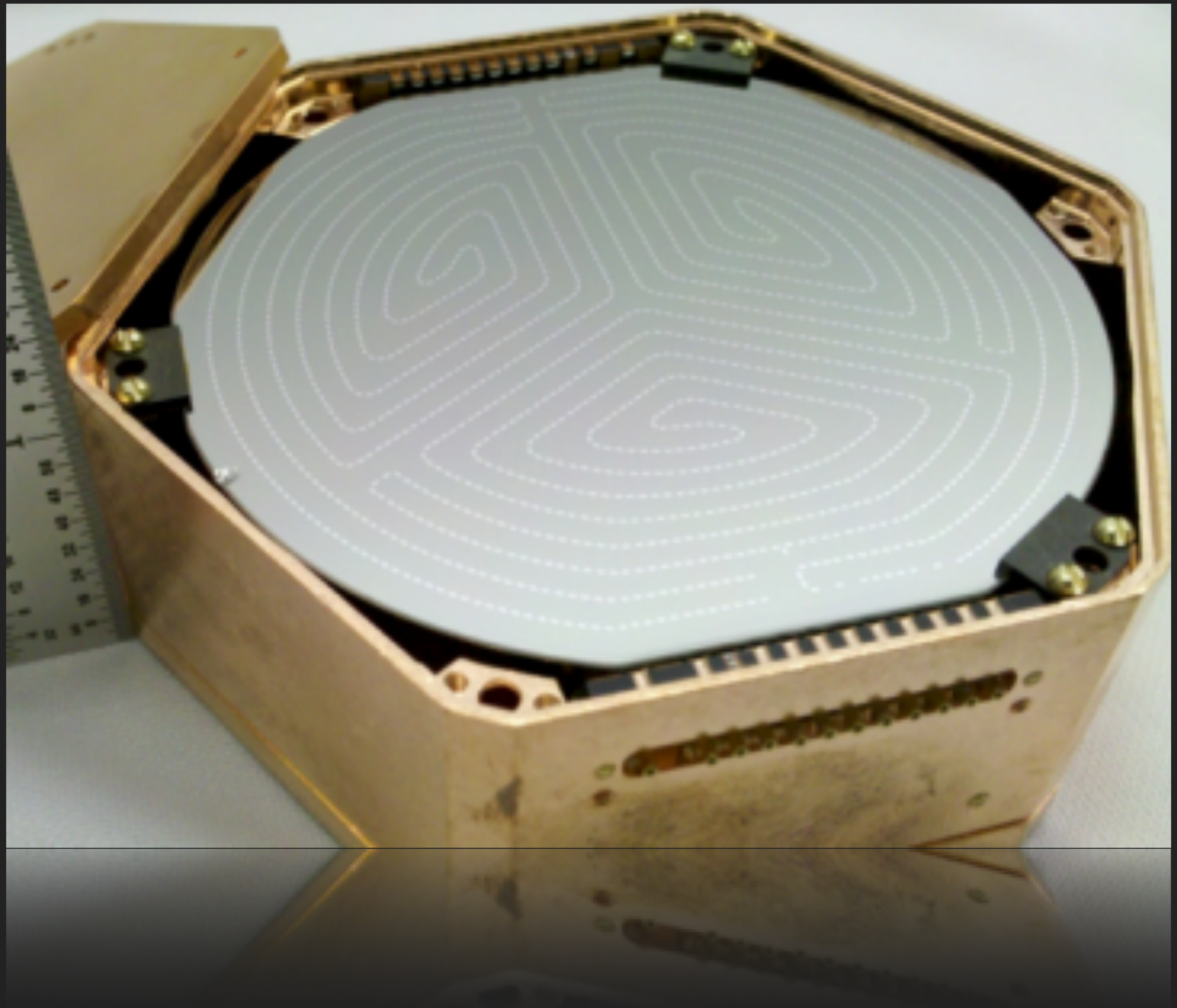
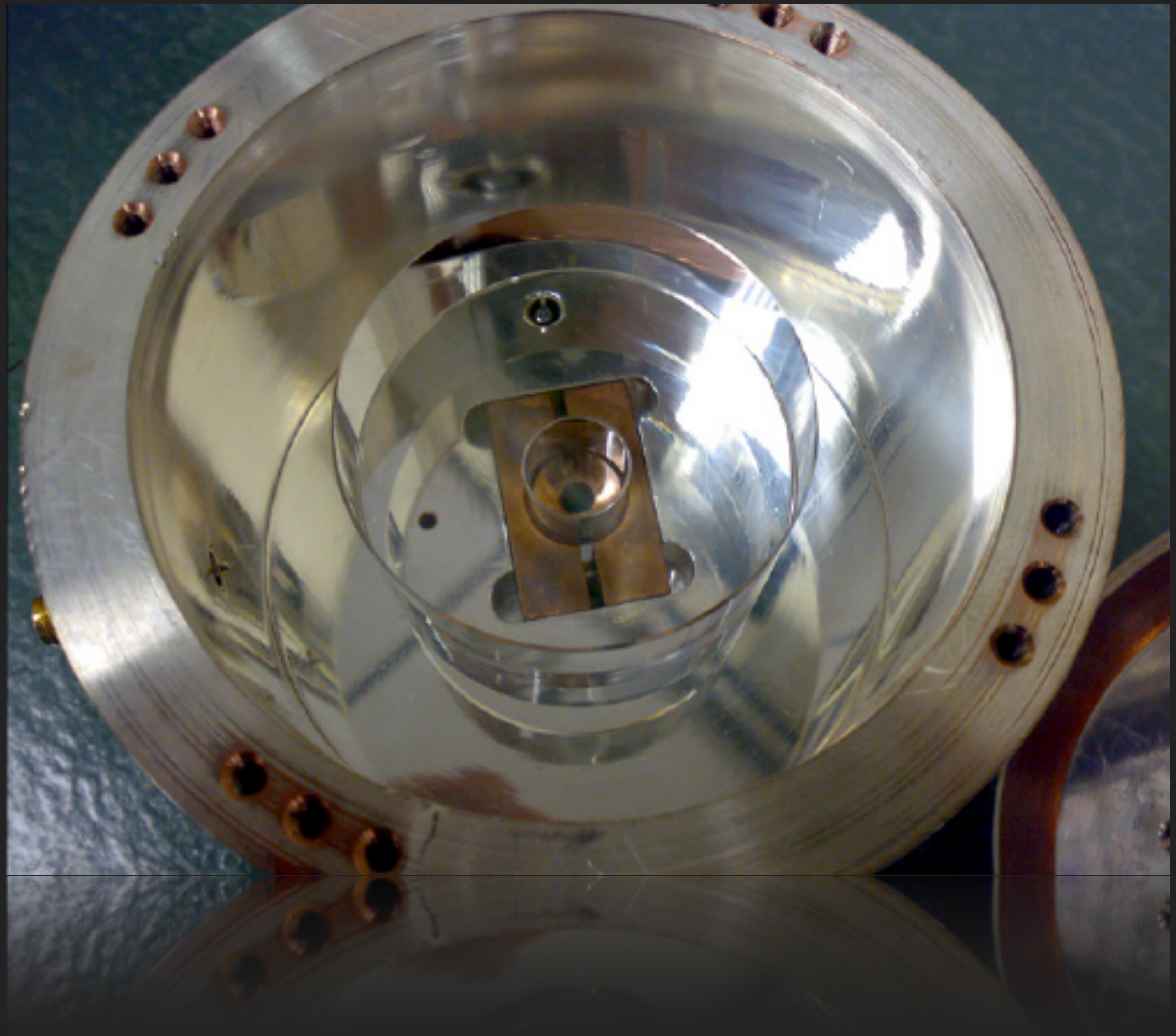
Research Directions

NEW TARGETS

TRADITIONALLY : GE, SI, NAI



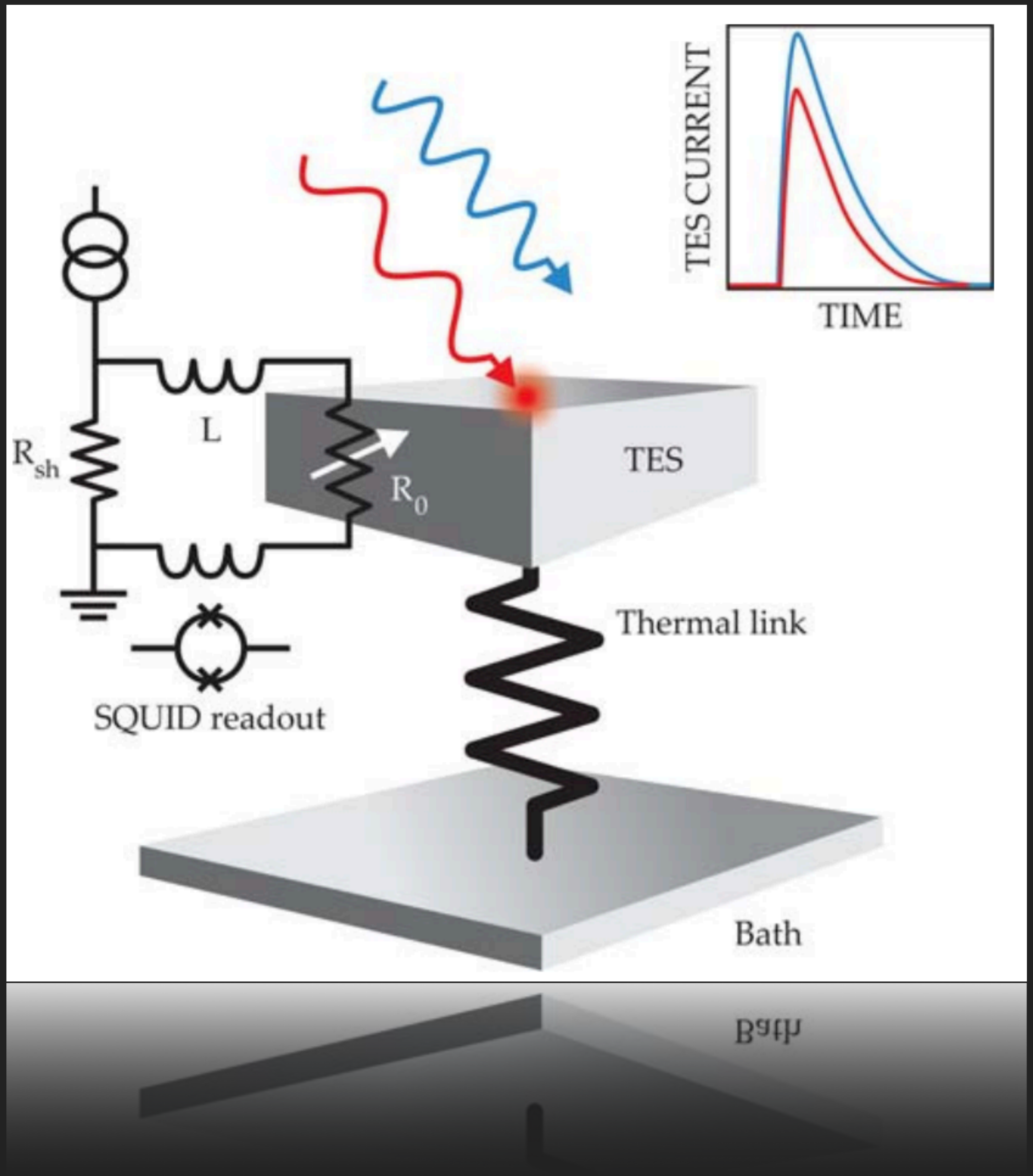
NEW: SAPPHIRE, LIF, GAAS, QUARTZ, $CAWO_4$



Research Directions

NEW TECHNIQUES

TRADITIONALLY: TES

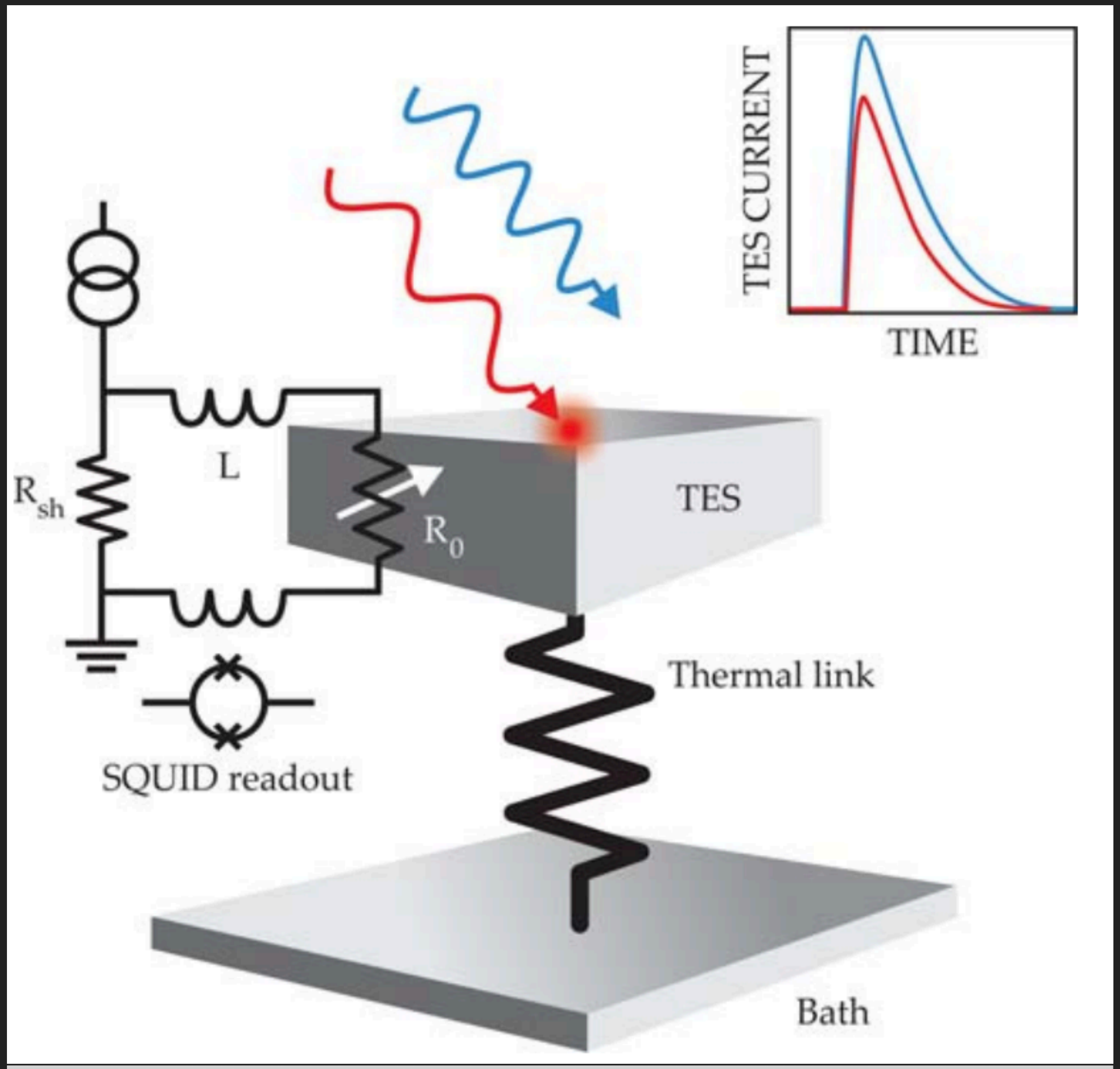


ARC CENTRE OF EXCELLENCE FOR DARK MATTER

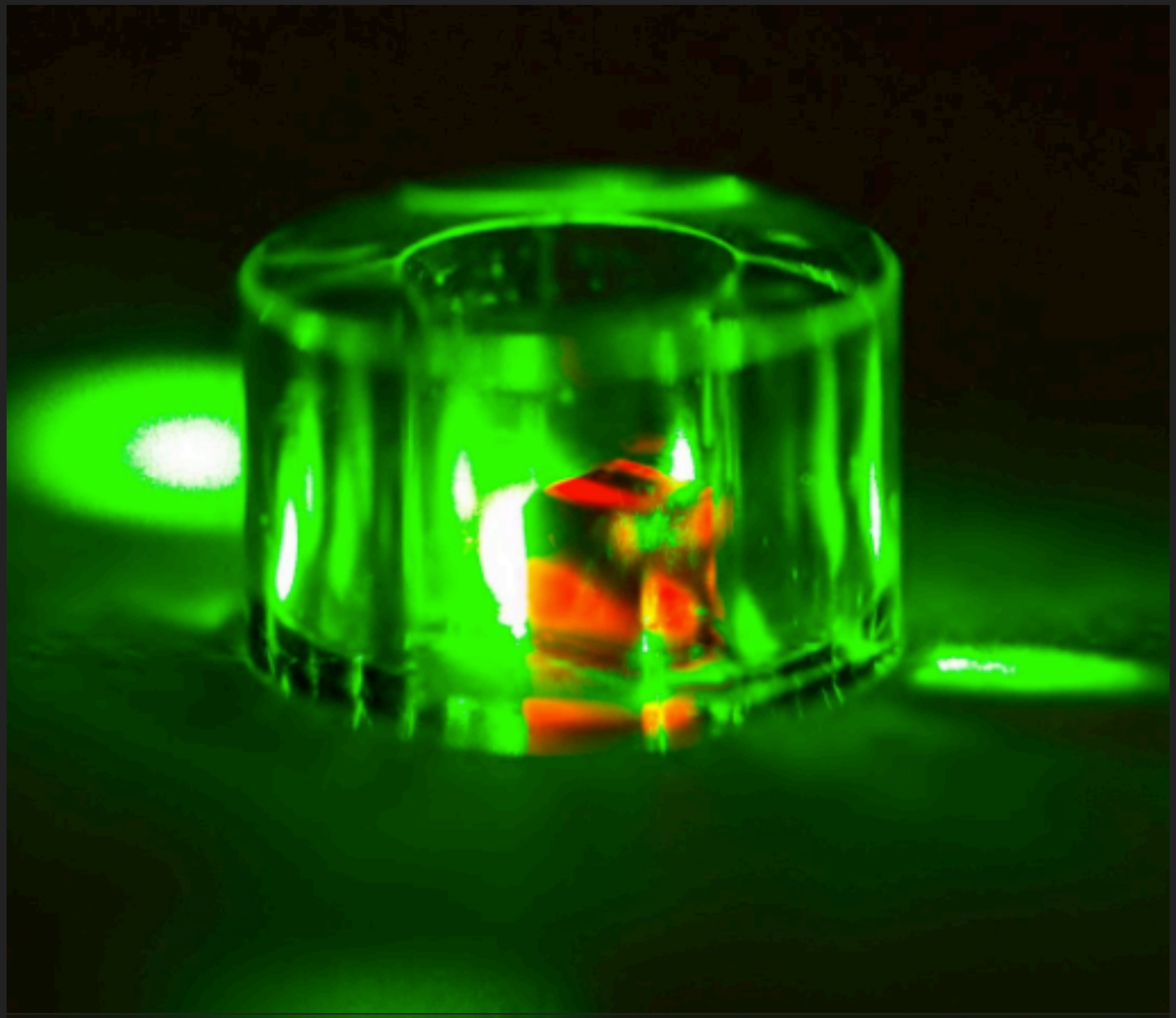
Research Directions

NEW TECHNIQUES

TRADITIONALLY: TES



SPIN ENSEMBLES, MASERS, CLOCKS



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Spin Ensembles

MAGNETIC BOLOMETER

ERBIUM DOPED YAG

A Magnetic Bolometer for Single-Particle Detection.

M. BÜHLER and E. UMLAUF

Walther Meissner Institut für Tieftemperaturforschung der Bayerischen Akademie des Wissenschaften - D-8046 Garching, FRG

(received 9 October 1987; accepted in final form 30 November 1987)

PACS. 29.40 – Radiation detectors.
PACS. 07.20M – Cryogenics.

Abstract. – We report on the first experiments with a composite magnetic bolometer whose mass is 7.5 grams. The thermal pulses produced by single 5.5 MeV α-particles have been measured with a SQUID yielding a pulse height of 165 mV at a noise level of 2 mV. Thus, the energy resolution is 65 keV and the resolution related to the mass of the detector $\Delta E/m$ is 8.7 keV/g. This last number is three orders of magnitude better than with other bolometers. Further developments for detecting neutrinos are pointed out.

Evidence of dilute ferromagnetism in rare-earth doped yttrium aluminium garnet

Warrick G. Farr,[1] Maxim Goryachev,[1] Jean-Michel le Floch,[1] Pavel Bushev,[2] and Michael E. Tobar[1]
[1]*ARC Centre of Excellence for Engineered Quantum Systems, University of Western Australia, 35 Stirling Highway, Crawley, Western Australia 6009, Australia*
[2]*Experimentalphysik, Universität des Saarlandes, D-66123 Saarbrücken, Germany*

(Received 9 July 2015; accepted 6 September 2015; published online 21 September 2015)

This work demonstrates strong coupling regime between an erbium ion spin ensemble and microwave hybrid cavity-whispering gallery modes in a yttrium aluminium garnet dielectric crystal. Coupling strengths of 220 MHz and mode quality factors in excess of 10^6 are demonstrated. Moreover, the magnetic response of high-Q modes demonstrates behaviour which is unusual for paramagnetic systems. This behaviour includes hysteresis and memory effects. Such qualitative change of the system's magnetic field response is interpreted as a phase transition of rare earth ion impurities. This phenomenon is similar to the phenomenon of dilute ferromagnetism in semiconductors. The clear temperature dependence of the phenomenon is demonstrated. *© 2015 AIP Publishing LLC.*

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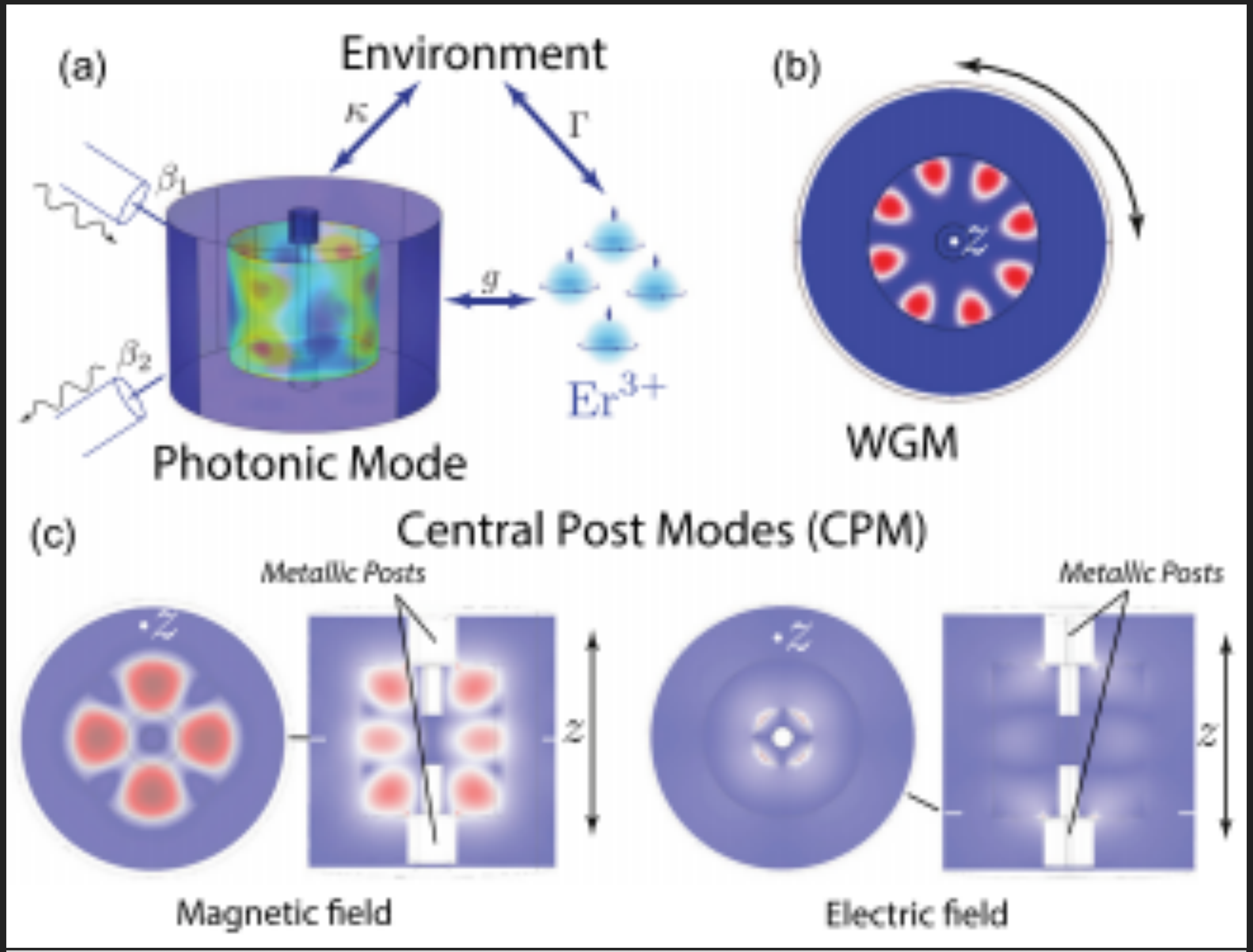
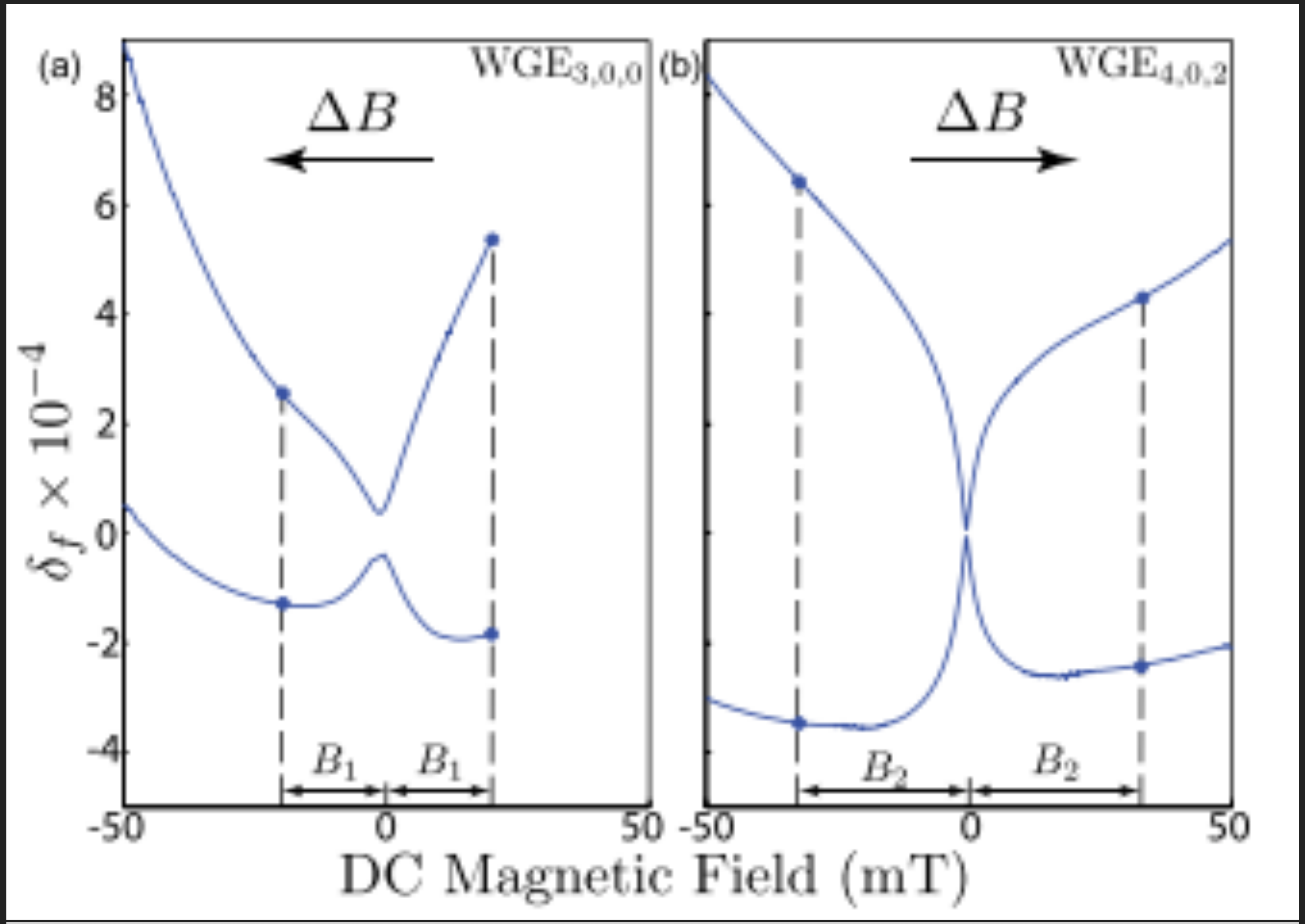
Spin Ensembles

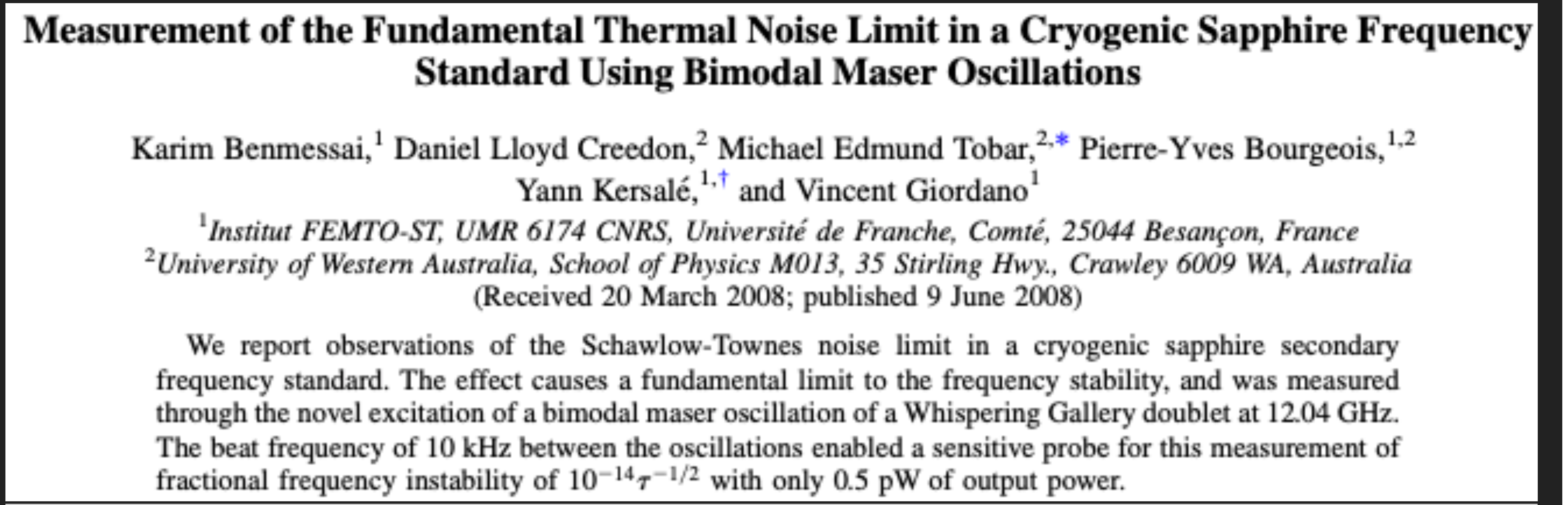
MAGNETIC BOLOMETER

ERBIUM DOPED YAG





Masers



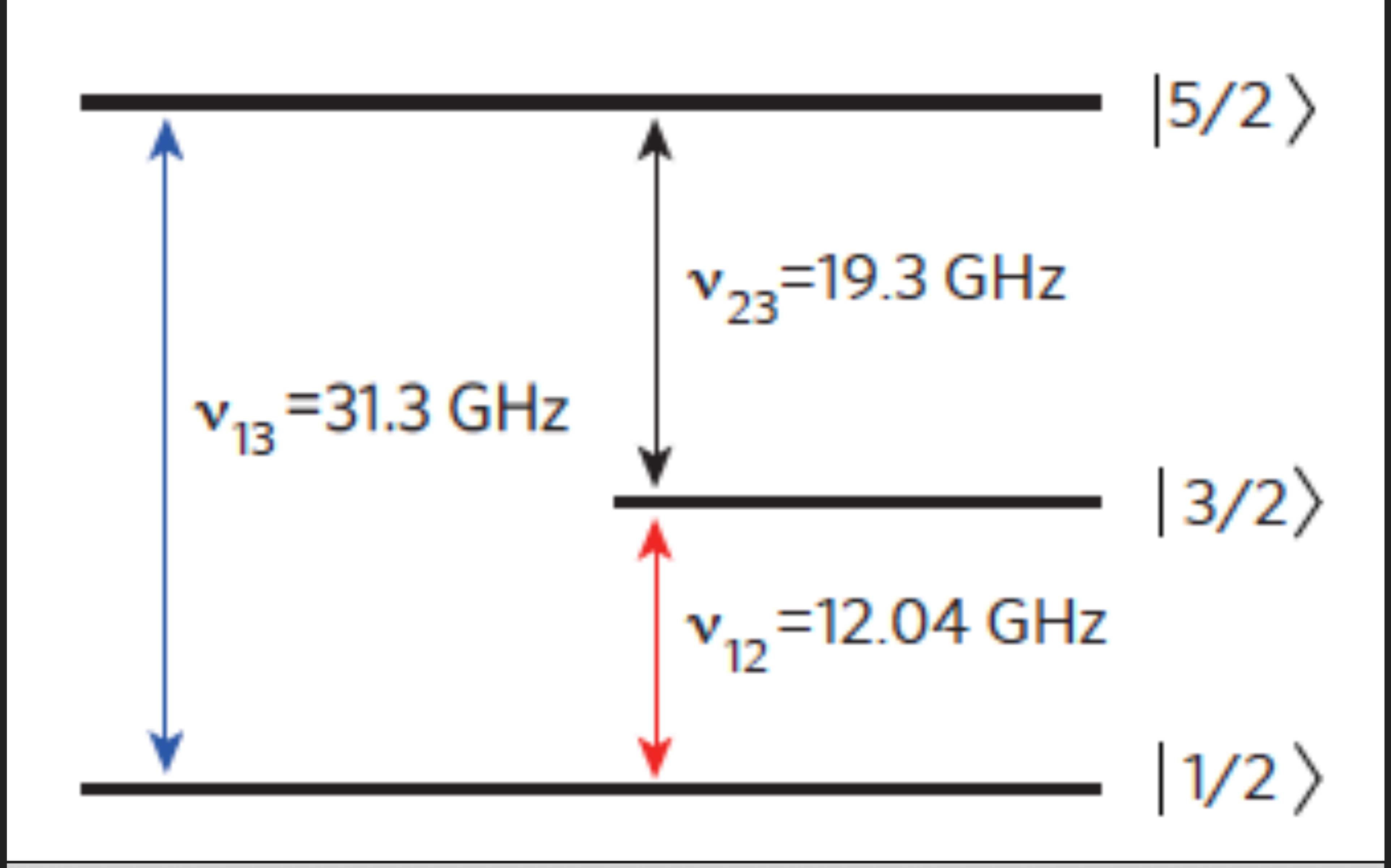
Measurement of the Fundamental Thermal Noise Limit in a Cryogenic Sapphire Frequency Standard Using Bimodal Maser Oscillations

Karim Benmessai,[1] Daniel Lloyd Creedon,[2] Michael Edmund Tobar,[2,*] Pierre-Yves Bourgeois,[1,2] Yann Kersalé,[1,†] and Vincent Giordano[1]

[1]*Institut FEMTO-ST, UMR 6174 CNRS, Université de Franche, Comté, 25044 Besançon, France*
[2]*University of Western Australia, School of Physics M013, 35 Stirling Hwy., Crawley 6009 WA, Australia*
(Received 20 March 2008; published 9 June 2008)

We report observations of the Schawlow-Townes noise limit in a cryogenic sapphire secondary frequency standard. The effect causes a fundamental limit to the frequency stability, and was measured through the novel excitation of a bimodal maser oscillation of a Whispering Gallery doublet at 12.04 GHz. The beat frequency of 10 kHz between the oscillations enabled a sensitive probe for this measurement of fractional frequency instability of $10^{-14}\tau^{-1/2}$ with only 0.5 pW of output power.

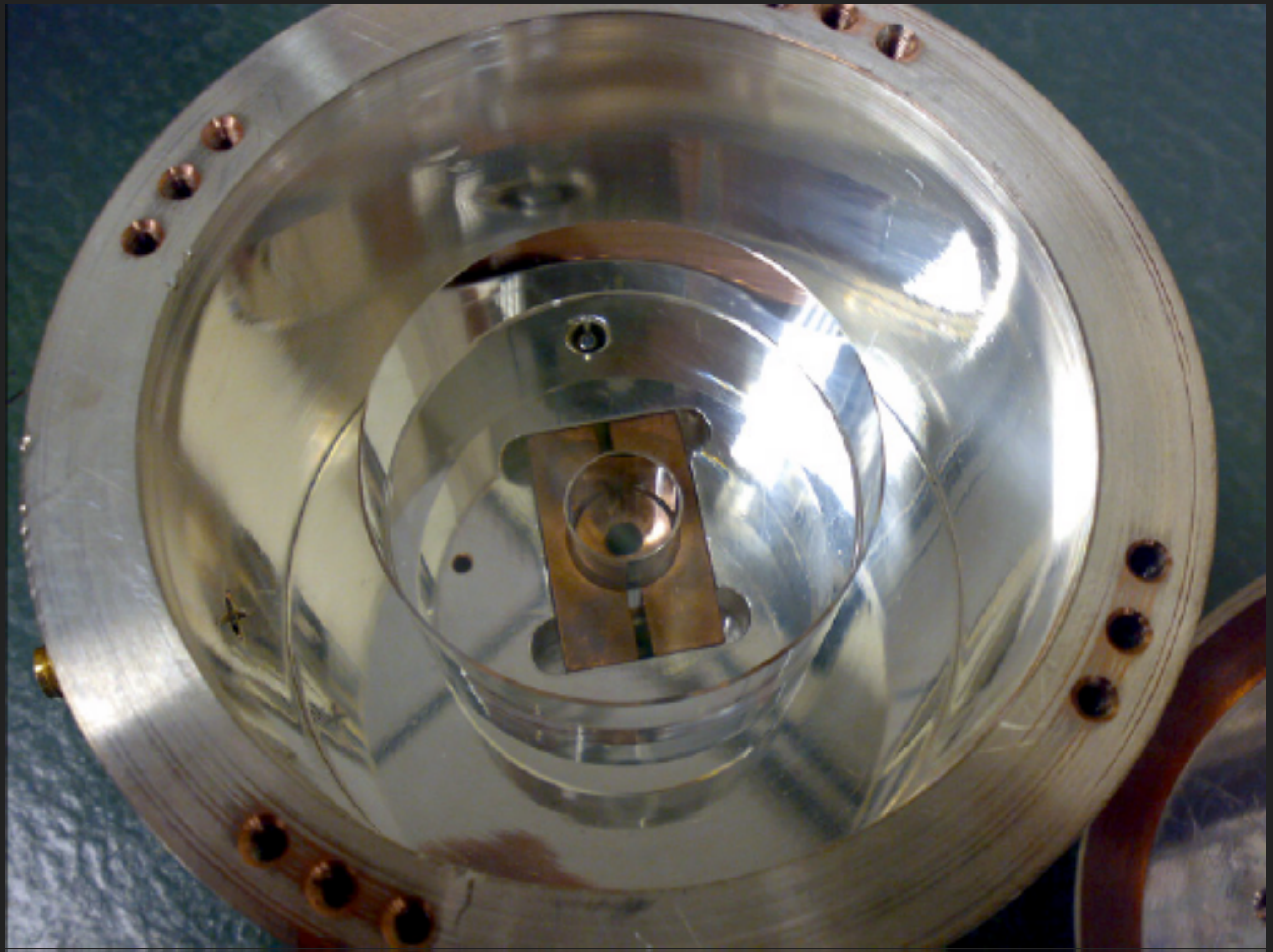
$Fe^{3+}:Al_2O_3$

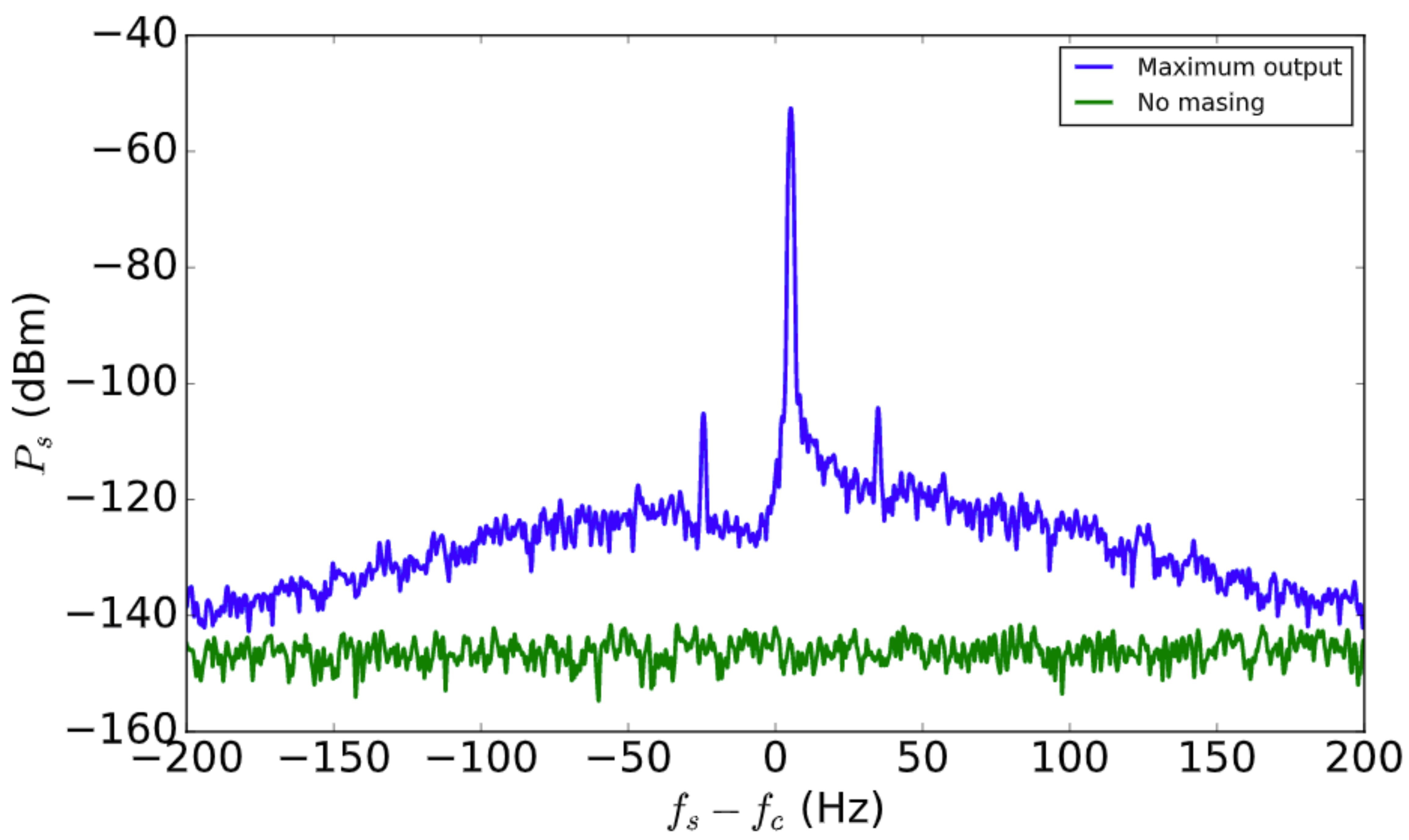


Masers

TRANSITION EDGE MASER DETECTOR

$FE^{3+}:AL_2O_3$





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Nonlinear ‘Clocks’

TRANSITION EDGE CLOCK DETECTOR

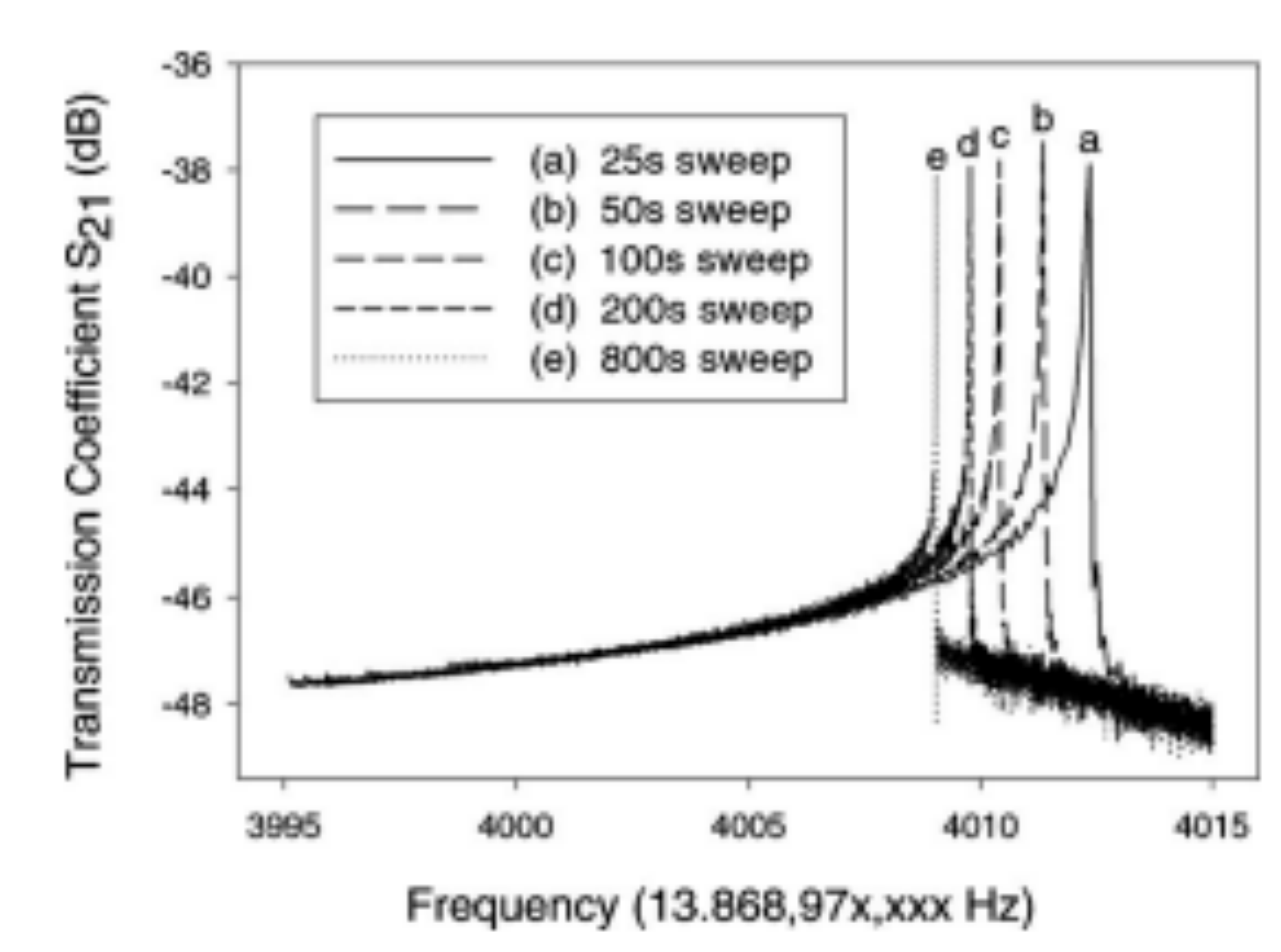
THERMAL INSTABILITIES

Single-crystal sapphire resonator at millikelvin temperatures: Observation of thermal bistability in high-Q factor whispering gallery modes

Daniel L. Creedon,* Michael E. Tobar, and Jean-Michel Le Floch
School of Physics (M013), University of Western Australia, 35 Stirling Hwy, Crawley, Western Australia 6009, Australia

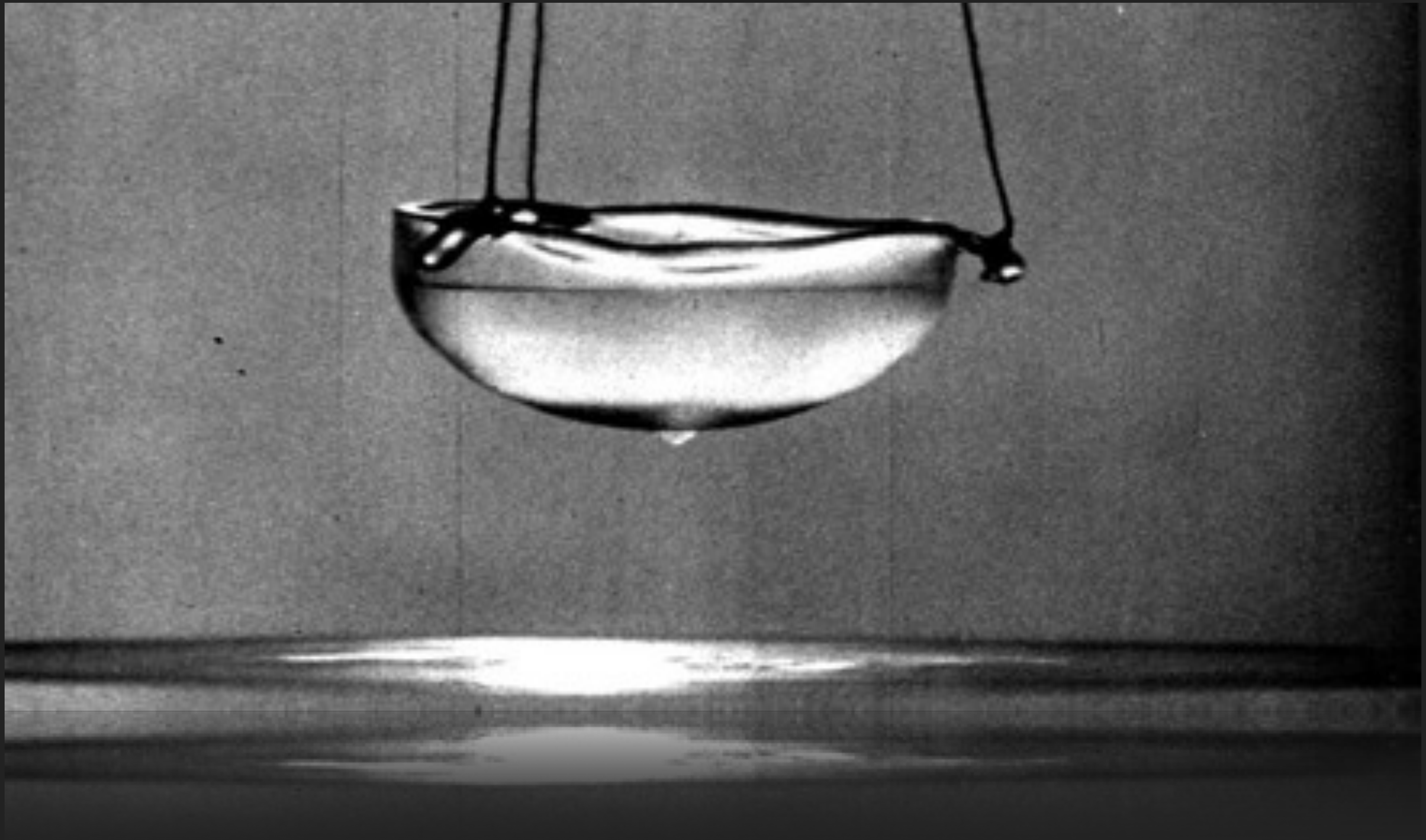
Yarema Reshitnyk and Timothy Duty
School of Mathematics & Physics, University of Queensland, St. Lucia, Queensland 4072, Australia
(Received 3 September 2010; published 27 September 2010)

Resonance modes in single crystal sapphire (α-Al_2O_3) exhibit extremely high electrical and mechanical Q factors ($\approx 10^9$ at 4 K), which are important characteristics for electromechanical experiments at the quantum limit. We report the cool down of a bulk sapphire sample below superfluid liquid-helium temperature (1.6 K) to as low as 25 mK. The electromagnetic properties were characterized at microwave frequencies, and we report the observation of electromagnetically induced thermal bistability in whispering gallery modes due to the material T^3 dependence on thermal conductivity and the ultralow dielectric loss tangent. We identify “magic temperatures” between 80 and 2100 mK, the lowest ever measured, at which the onset of bistability is suppressed and the frequency-temperature dependence is annulled. These phenomena at low temperatures make sapphire suitable for quantum metrology and ultrastable clock applications, including the possible realization of the quantum-limited sapphire clock.



New Hope

SUPERFLUIDS



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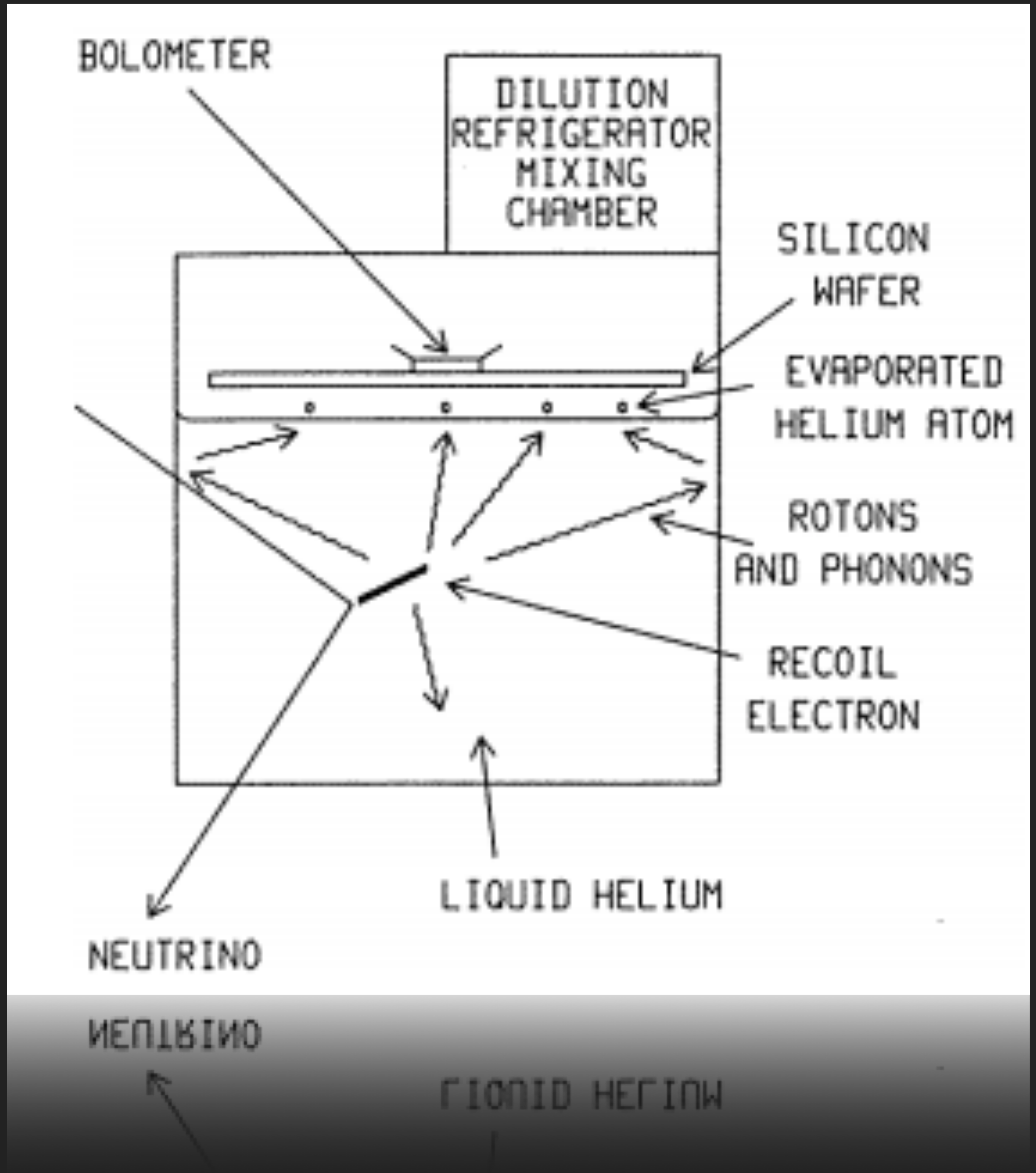
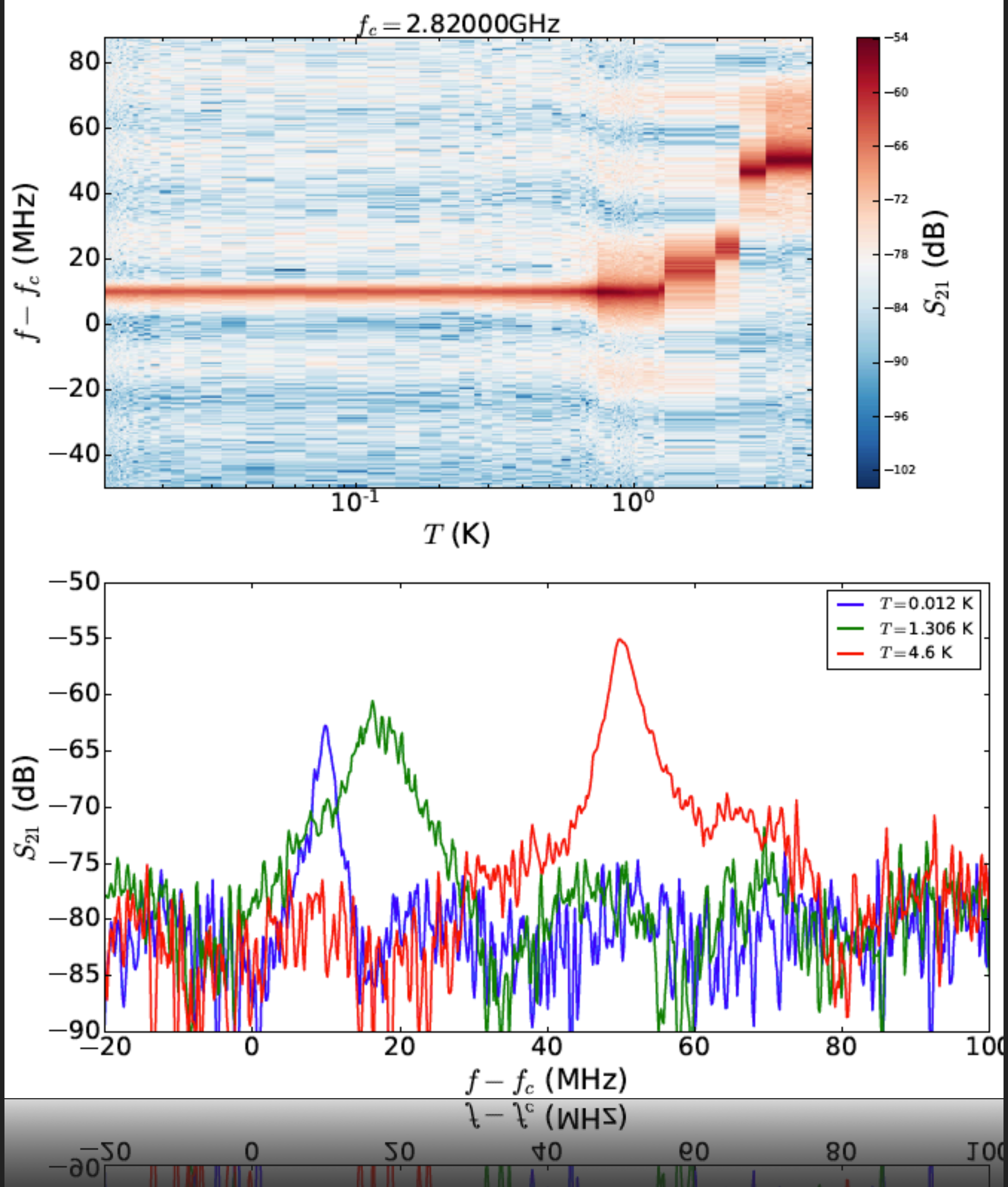
Superfluid Helium



Superfluid Helium @ UWA



Hydrogen ?

Windowless thin solid-hydrogen target: CHyMENE

A. Gillibert[1,a], A. Corsi[1], F. Flavigny[1], C. Louchart[1], L. Nalpas[1], A. Obertelli[1], E.C. Pollacco[1], G. Authelet[2], J.-M. Gheller[2], D. Guillaume[3], V. Méot[4], O. Roig[4], I. Vinyar[5], and A. Lukin[5]

[1] CEA, Centre de Saclay, IRFU/SPhN, 91191 Gif-sur-Yvette, France
[2] CEA, Centre de Saclay, IRFU/SACM, 91191 Gif-sur-Yvette, France
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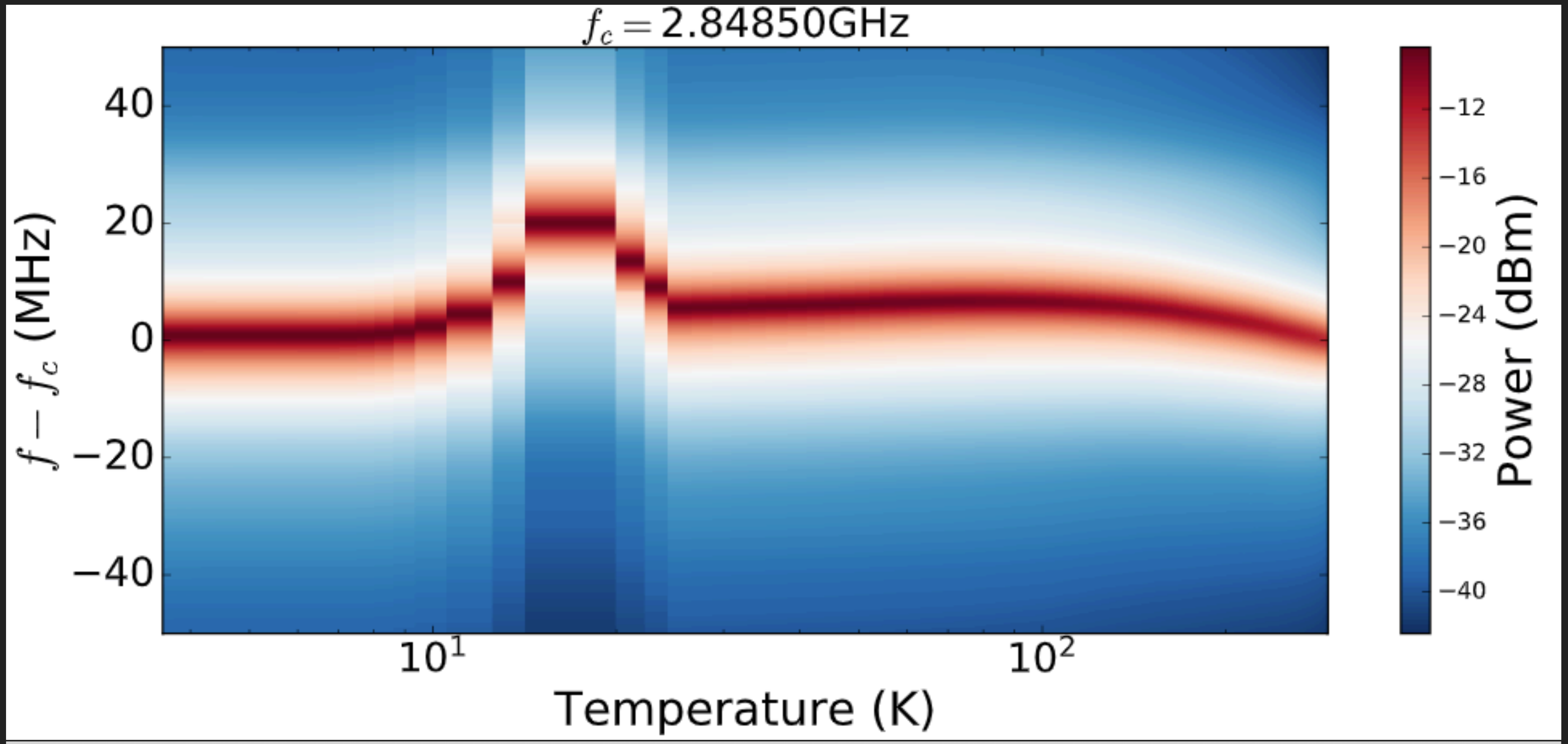
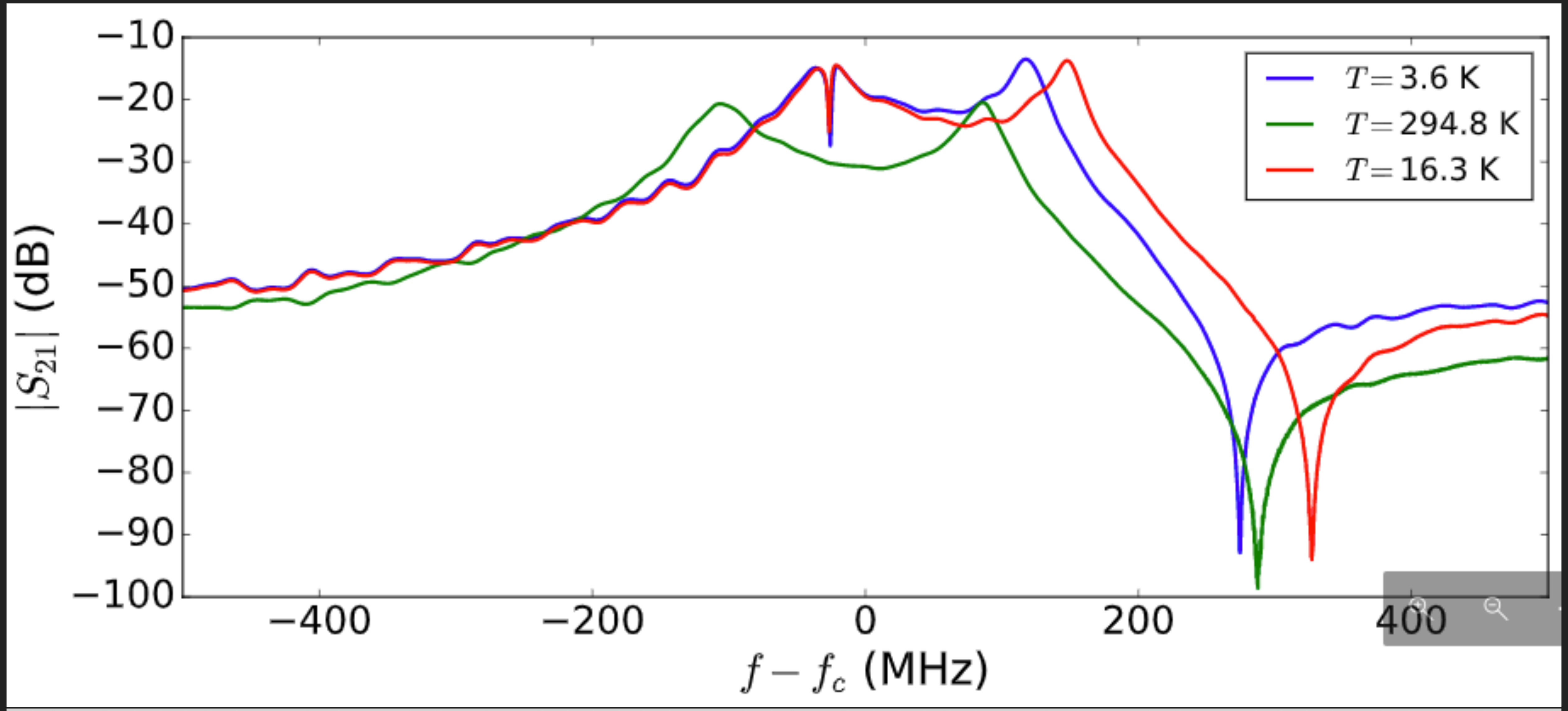
[5] PELIN Laboratory, 27A, Gzhatskaya, Saint-Petersburg, 195220, Russia

Received: 7 October 2013 / Revised: 26 November 2013
Published online: 18 December 2013 –
Communicated by N. Alamanos

Abstract. We report on the production of a windowless pure hydrogen H^2 film. The thickness is within the range 50–200 μm, in order to be used as a target for nuclear reactions in inverse kinematics with radioactive beams at low incident energy (2–15 MeV/nucleon). We give details about the production conditions and a first in-beam test in order to measure the thickness and the homogeneity with a 3 MeV proton beam.

Solid Hydrogen @ UWA





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Acoustic Detector

Energetic cosmic rays observed by the resonant gravitational wave detector NAUTILUS

P. Astone [a], M. Bassan [b], P. Bonifazi [c], P. Carelli [d], E. Coccia [b], S. D'Antonio [e], V. Fafone [f], G. Federici [a], A. Marini [f], G. Mazzitelli [f], Y. Minenkov [b], I. Modena [b], G. Modestino [f], A. Moleti [b], G.V. Pallottino [e], V. Pampaloni [f], G. Pizzella [g], L. Quintieri [f] … L. Votano [c]

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https://doi.org/10.1016/S0370-2693(01)00026-0

Abstract

Cosmic-ray showers interacting with the resonant mass gravitational wave antenna NAUTILUS have been detected. The experimental results show large signals at a rate much greater than expected. The largest signal corresponds to an energy release in NAUTILUS of 87 TeV. We note that a resonant mass gravitational wave detector used as particle detector has characteristics different from the usual particle detectors, and it could detect new features of cosmic rays.

Gravitational wave detection with high frequency phonon trapping acoustic cavities

Maxim Goryachev and Michael E. Tobar

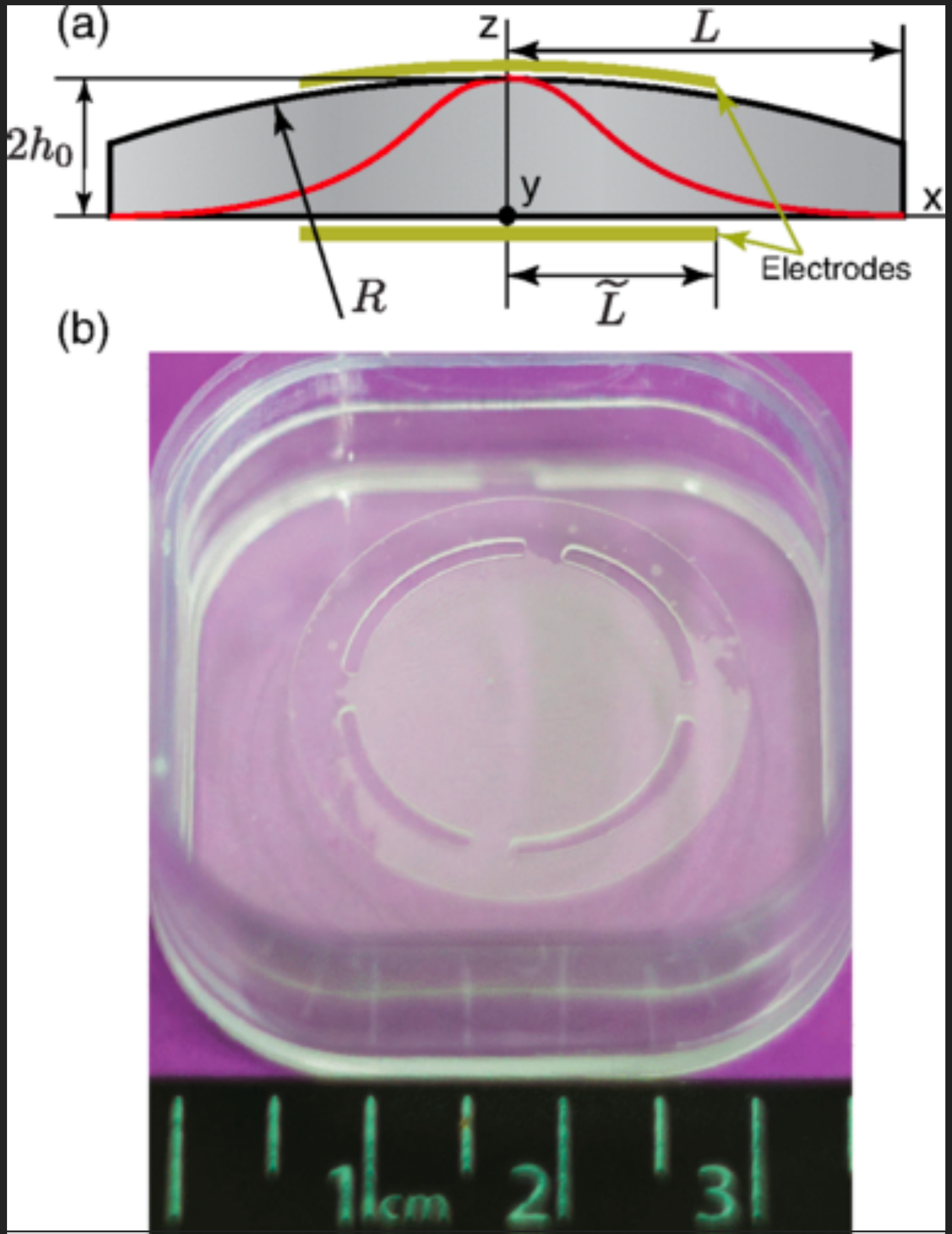
Phys. Rev. D **90**, 102005 – Published 24 November 2014

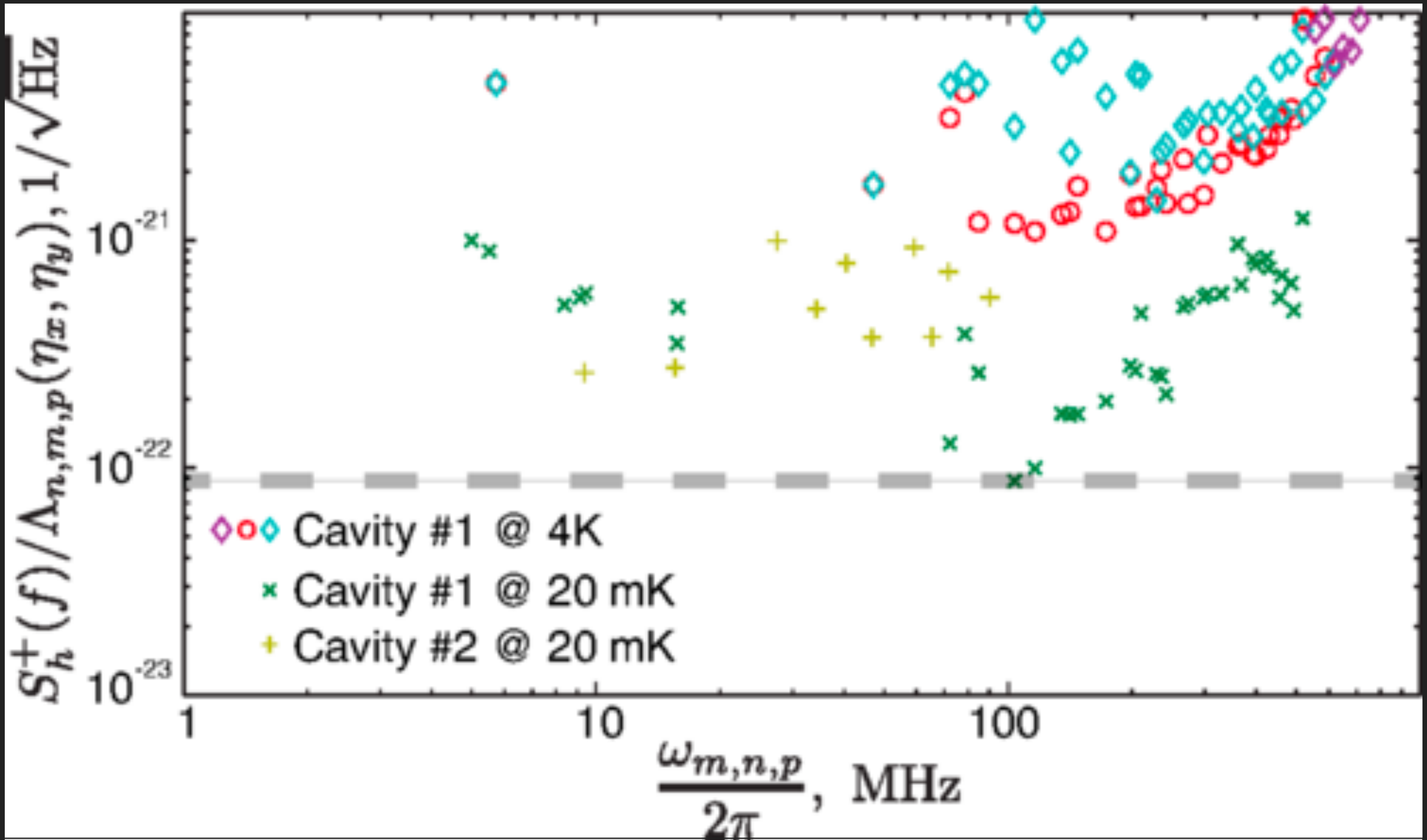
Article | References | Citing Articles (34) | PDF | HTML | Export Citation

ABSTRACT

There are a number of theoretical predictions for astrophysical and cosmological objects, which emit high frequency ($10^6 - 10^9$ Hz) gravitation waves (GW) or contribute somehow to the stochastic high frequency GW background. Here we propose a new sensitive detector in this frequency band, which is based on existing cryogenic ultrahigh quality factor quartz bulk acoustic wave cavity technology, coupled to near-quantum-limited SQUID amplifiers at 20 mK. We show that spectral strain sensitivities reaching 10^{-22} per $\sqrt{\mathrm{Hz}}$ per mode is possible, which in principle can cover the frequency range with multiple (> 100) modes with quality factors varying between 10^6 and 10^{10} allowing wide bandwidth detection. Due to its compactness and well-established manufacturing process, the system is easily scalable into arrays and distributed networks that can also impact the overall sensitivity and introduce coincidence analysis to ensure no false detections.

Acoustic Detector





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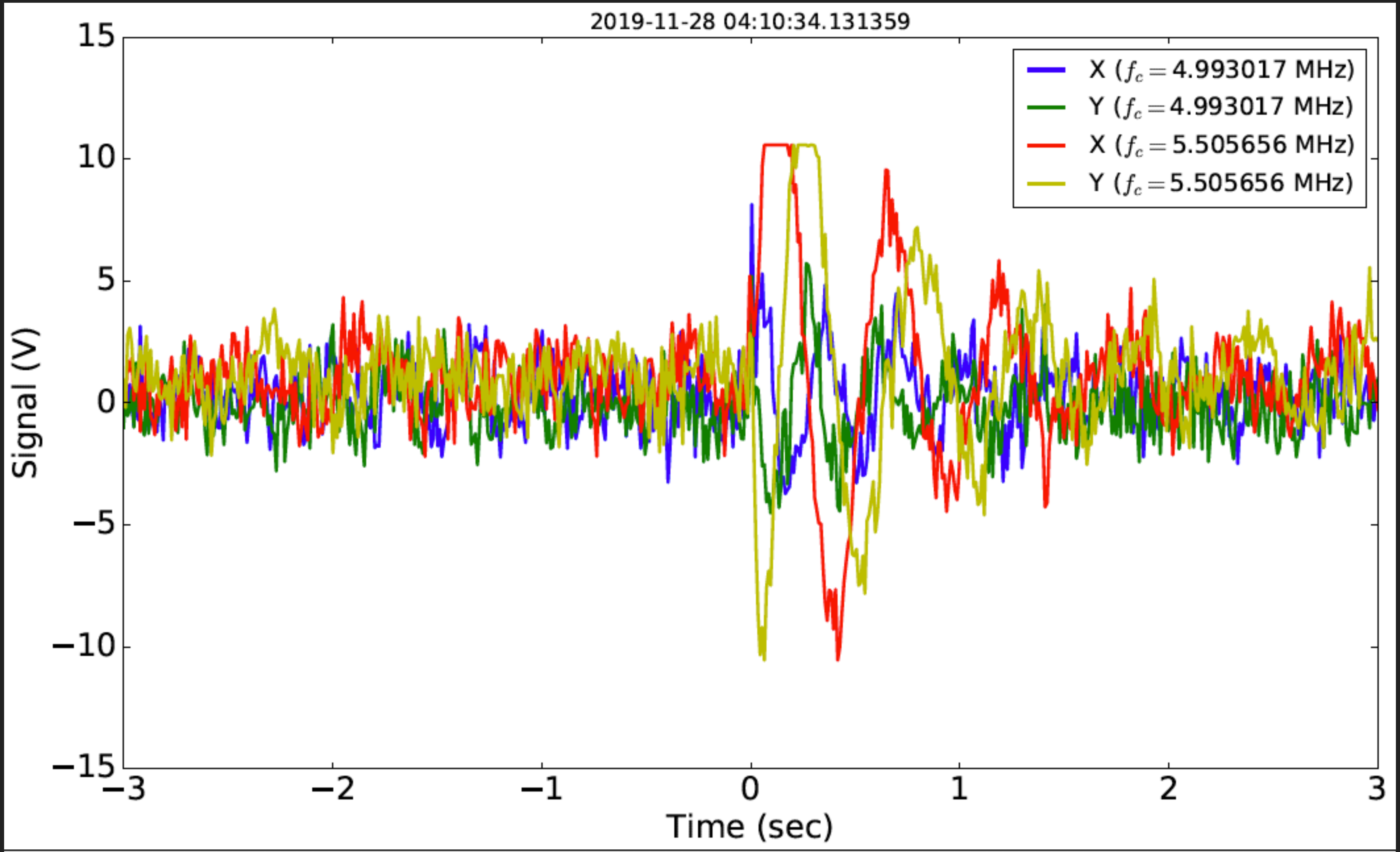
Acoustic Detector



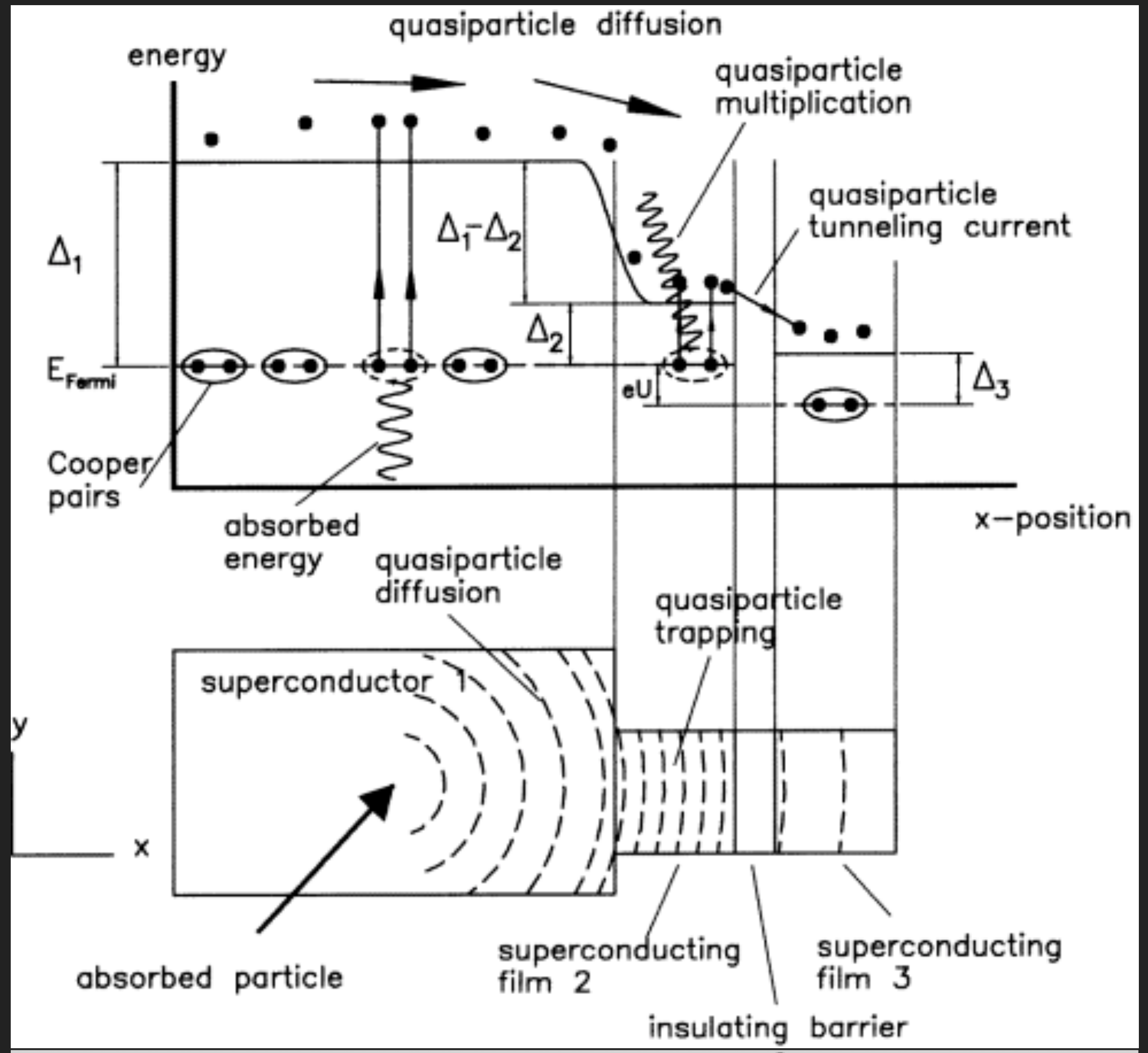
Other Novel Detection Approaches

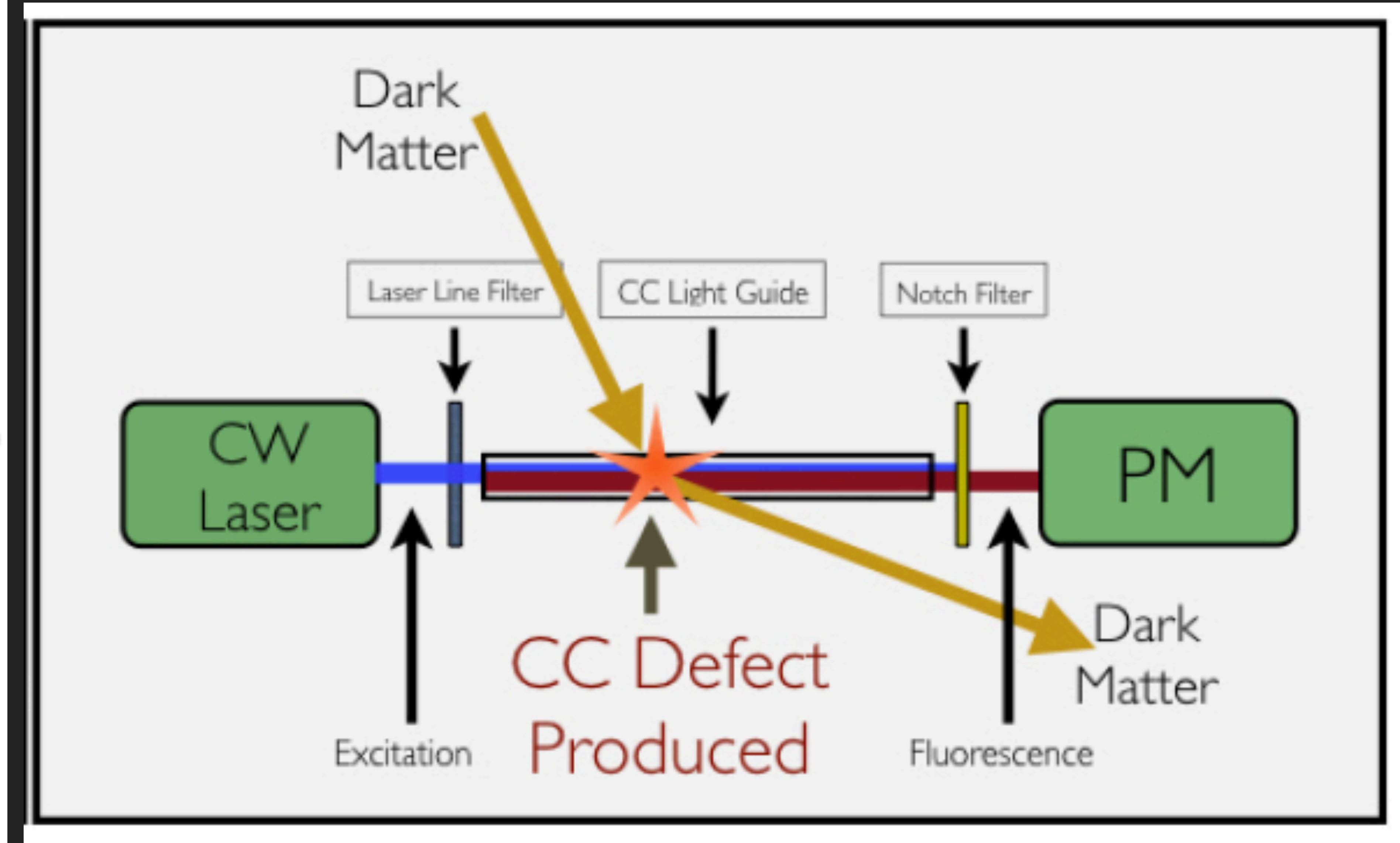
NEW APPROACHES

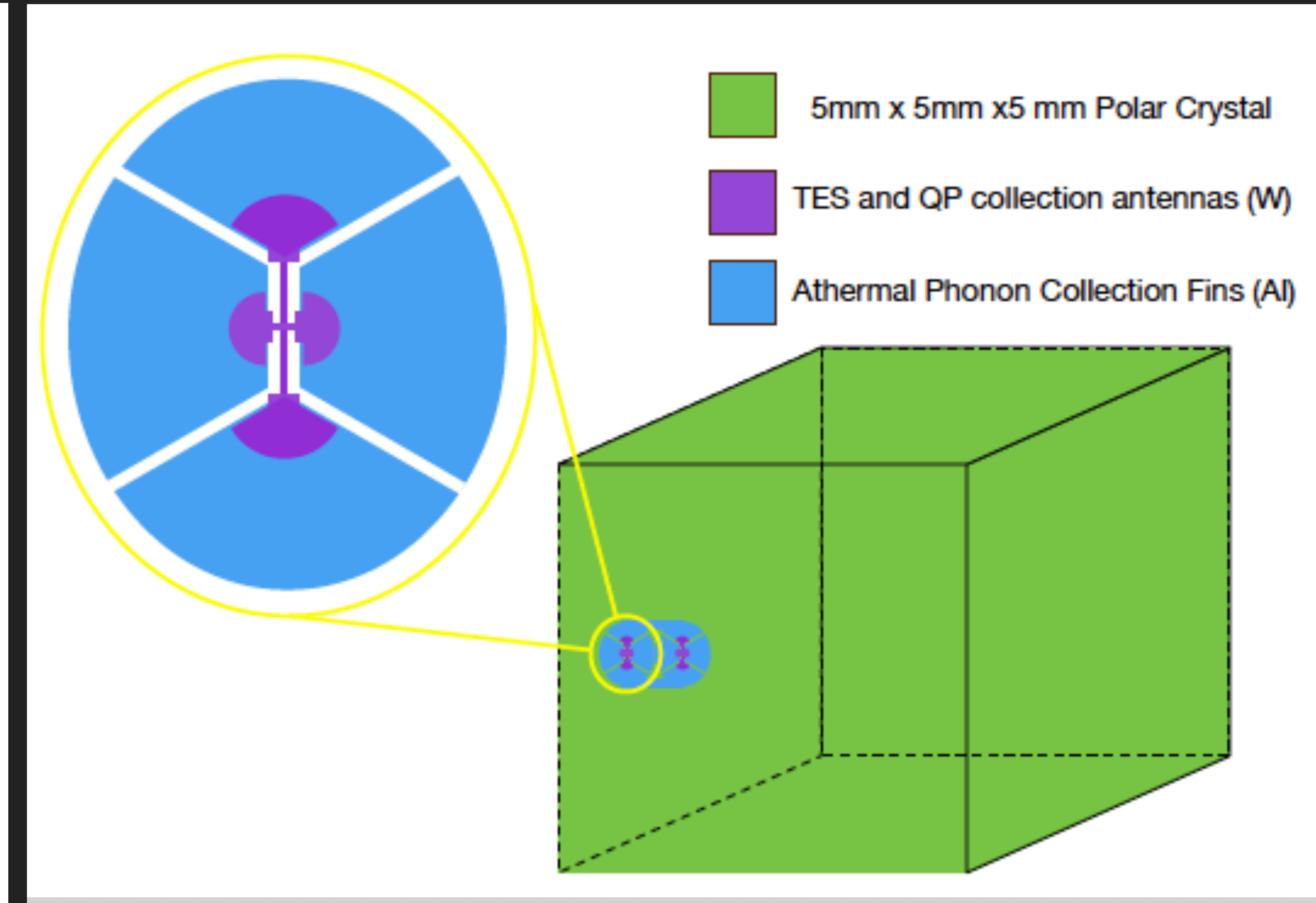
QUASIPARTICLES IN SC

DEFECTS IN CRYSTALS

OPTICAL PHONONS, MAGNONS



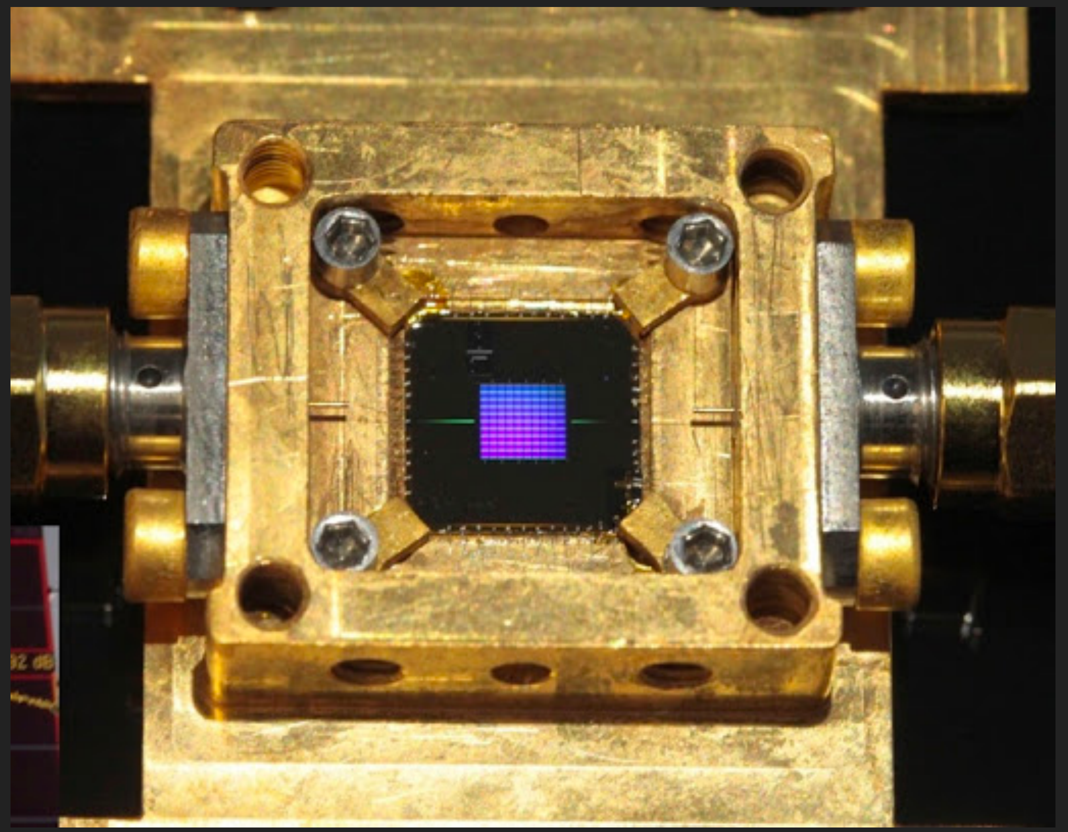


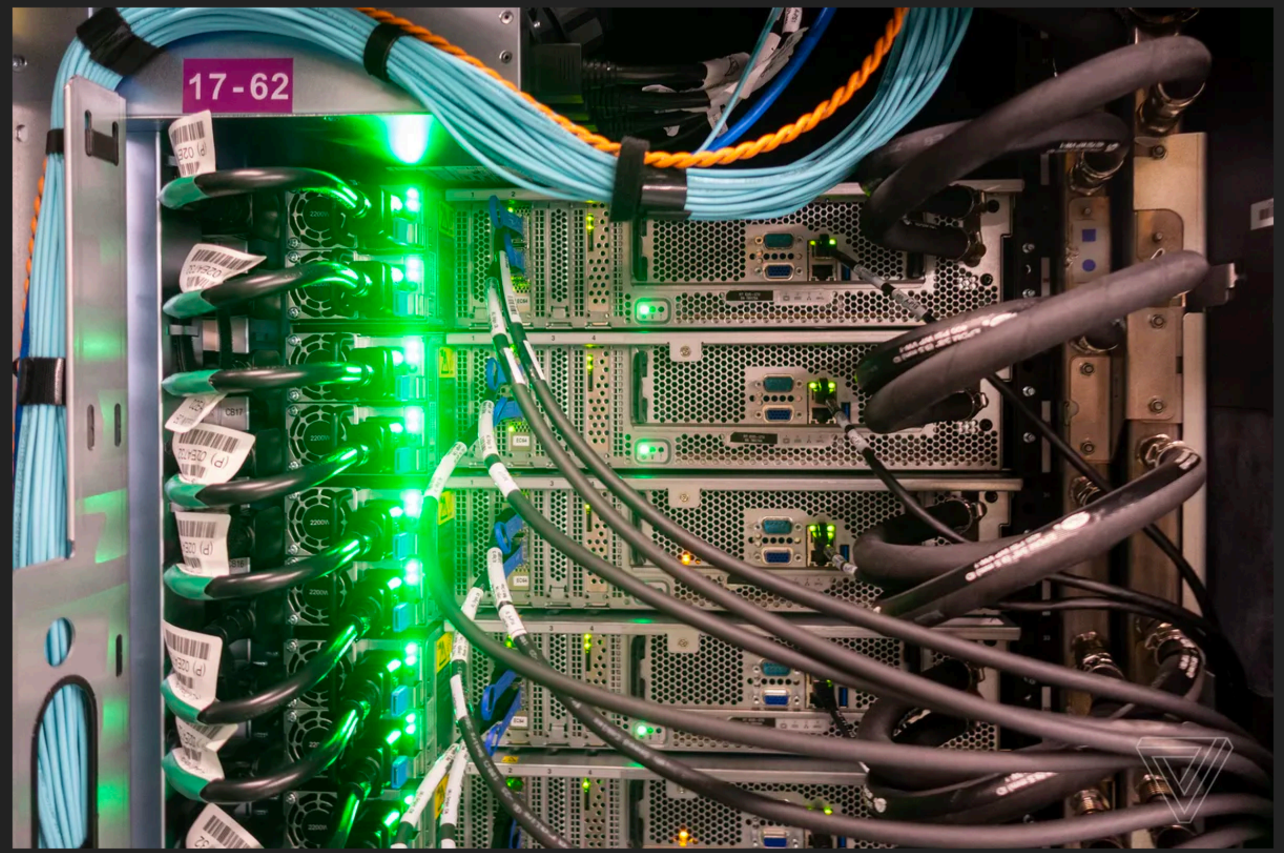


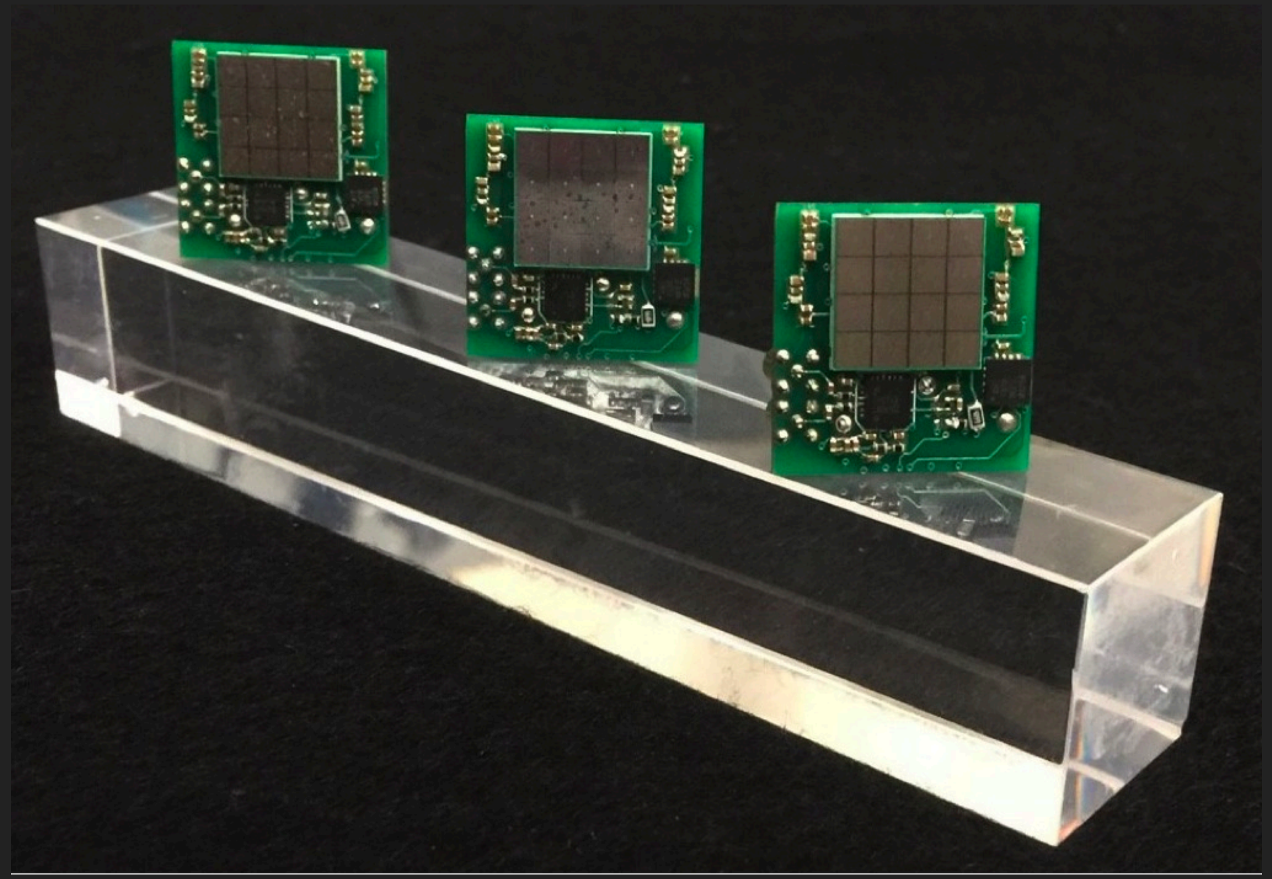
Research Directions

NEW TECHNOLOGIES

- FAST DATA ACQUISITION
- FAST SIGNAL PROCESSING
- DATA PROCESSING
- MICROWAVE ELECTRONICS
- LOW TEMPERATURE PHYSICS
- CONDENSED MATTER
- HIGH PURITY MATERIAL
- LOW RADIATION BACKGROUND
- HIGH QUALITY CRYSTALS





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