Activities in HIM (Germany) & PKU (China)

—— Atomic Magnetometry and Related Applications in Exotic Physics——

The 1st International Workshop on Global Network of Cavities to Search for Gravitational Waves (GravNet)

Prof. Dr. Teng Wu

Institute of Quantum Electronics, School of Electronics, Peking University

email: wuteng@pku.edu.cn

Budker AG

2015.03 - 2015.06 : PhD candidate, 3-months' visit, ***Nitrogen Vacancy Centers in Diamond***

[Peking University] Ask for Short-term Visiting Student's Position (**Self-Funded**)

Dmitry Budker <dbudker@gmail.com>
to me

Nov 16, 2014, 4:24 AM

Nov. 16, 2014, 4:24 AM

English > Chinese (Traditional) Translate message   Turn off for: English

Dear Teng Wu:

I think it would be very good if you could come to our laboratory as a visiting student. I am not sure if you know this, our group is now in two geographical locations, one at Berkeley, and another at the new Helmholtz institute and the Johannes Gutenberg University at Mainz, Germany. It is our German operations that are rapidly expanding at the moment, and where I think it would be best for you to visit. Would this be of interest?

To proceed, please ask Prof. Hong Guo to e-mail me a (possibly brief) recommendation letter for you; also, please let me know what will be needed on my side to support your application for the scholarship. Let me know also if you would like to speak with me via SKYPE (I am dmitrybudker).

Budker AG

2015.03 - 2015.06 : PhD candidate, 3-months' visit, *Nitrogen Vacancy Centers in Diamond*

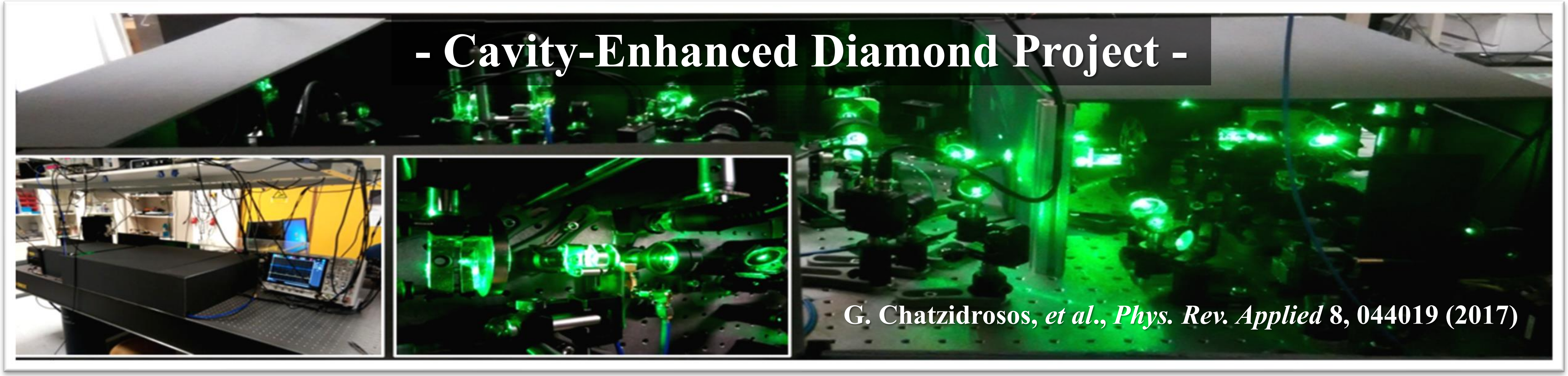
Dr. Nathan Leefer

Dr. Lykourgos Bougas

Dr. Arne Wickenbrock

Dr. Georgios Chatzidrosos

Prof. Dr. Yannick Dumeige



Helmholtz Institüt Mainz (2015)

Budker AG

2015

Married
PhD degree
Baby

2016

2015.03 - 2015.06 **PhD candidate**, 3-months' visit, Nitrogen Vacancy Centers in Diamond


Dr. Nathan Leefer


Dr.Lykourgos Bougas


Dr. Arne Wickenbrock


Georgios Chatzidrosos


Prof. Dr. Yannick Dumeige

2016.09 - 2019.09 **Postdoc**, 3 years, Zero- to Ultralow-Field Nuclear Magnetic Resonance, CASPEr


Dr. John Blanchard


Dr. Min Jiang/Billion


Antoine Garcon


Román Picazo Frutos

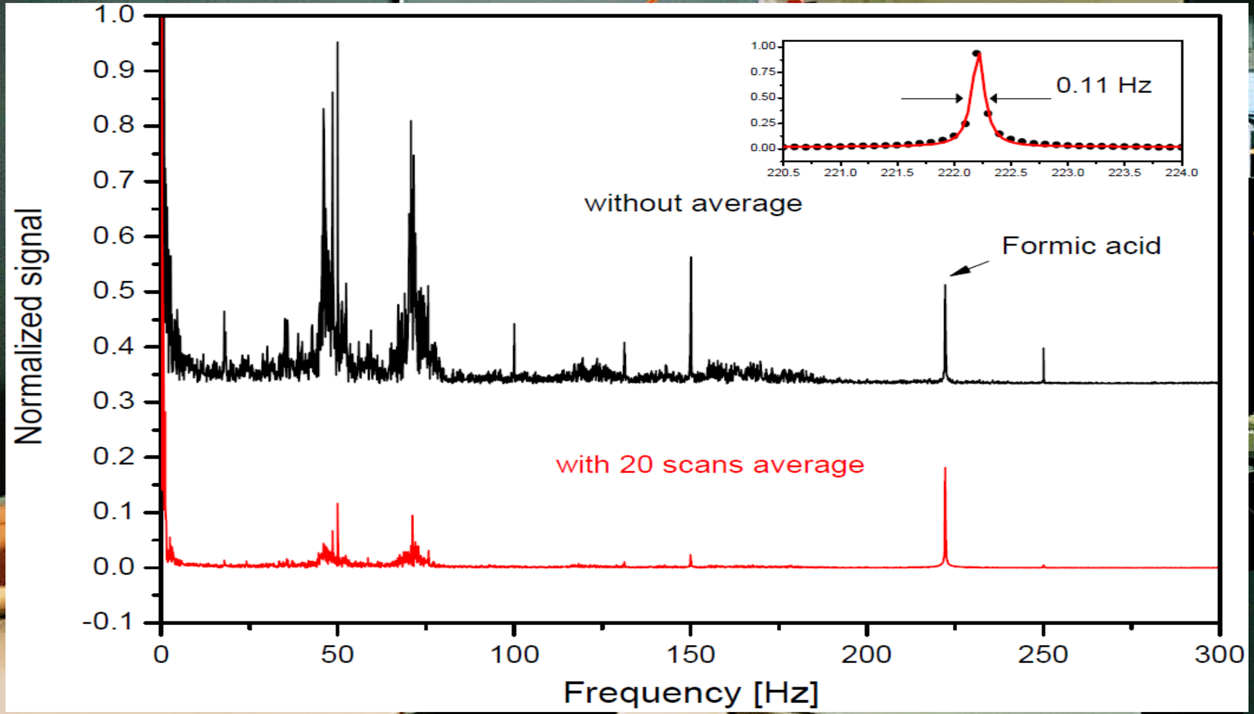

Dr. James Eills


Dr. Kirill Sheberstov

CASPEr Group: **Arne, Nate, Gary, Hector, Marina, Martin, Prof. Derek J. Kimball, Yevgeny…**

Zero- to Ultralow-Field (ZULF) Nuclear Magnetic Resonance

(photo taken date: Jan. 2017)

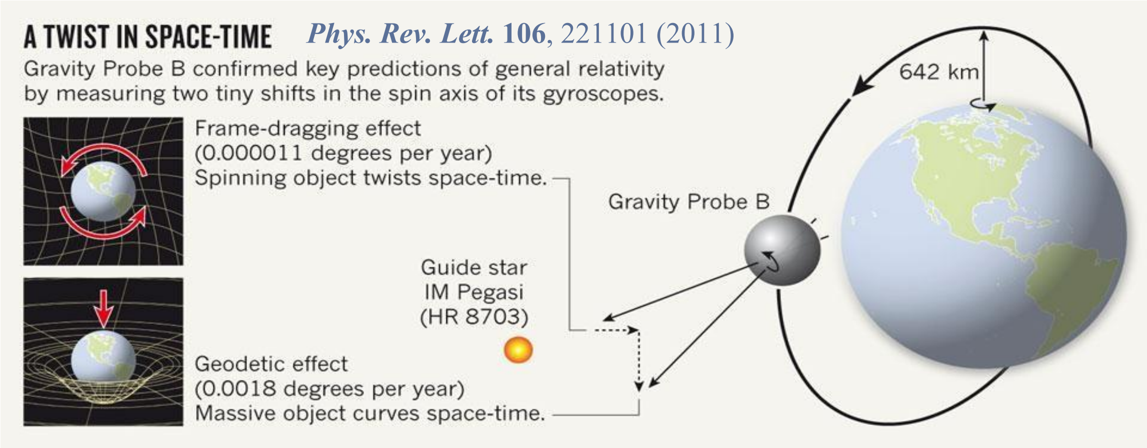


First ZULF NMR signal @ Mainz: *Formic Acid* (Dec. 2016)

Q: Why to measure the *Gravitation Induced Spin Precession* Signal?

I. Check whether *Spin* experiences the *Same* Geodetic and Frame-Dragging effects as a *Classical Gyroscope*

Phys. Rev. Lett. **106**, 221101 (2011)



?

Phys. Rev. D **103**, 044056 (2021)

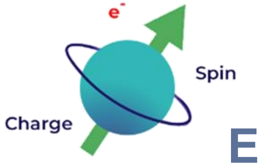
Gravity Probe Spin: Prospects for measuring general-relativistic precession of intrinsic spin using a ferromagnetic gyroscope

Pavel Fadeev,[1,*] Tao Wang,[2] Y. B. Band,[3] Dmitry Budker,[1,4] Peter W. Graham,[5] Alexander O. Sushkov,[6] and Derek F. Jackson Kimball[7,†]

[1]*Helmholtz Institute Mainz, Johannes Gutenberg University, 55099 Mainz, Germany*
[2]*Department of Physics, Princeton University, Princeton, New Jersey 08544, USA*
[3]*Department of Chemistry, Department of Physics, Department of Electro-Optics, and the Ilse Katz Center for Nano-Science, Ben-Gurion University, Beer-Sheva 84105, Israel*
[4]*Department of Physics, University of California at Berkeley, Berkeley, California 94720-7300, USA*
[5]*Department of Physics, Stanford Institute for Theoretical Physics, Stanford University, California 94305, USA*
[6]*Department of Physics, Boston University, Boston, Massachusetts 02215, USA*
[7]*Department of Physics, California State University—East Bay, Hayward, California 94542-3084, USA*

II. Check whether the *Extension* of General Relativity is Possible (*Pseudoscalar Coupling, Long-range Spin-dependent Potential*)

Rev. Mod. Phys. **48**, 393 (1976) *Phys. Rev. D* **18**, 2739 (1978) *Phys. Rev. D* **30**, 130 (1984) *Rev. Mod. Phys*. **90**, 025008 (2018)



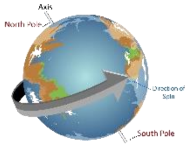
Spins
Electron, Nucleus

Hypothetical bosonic fields

?

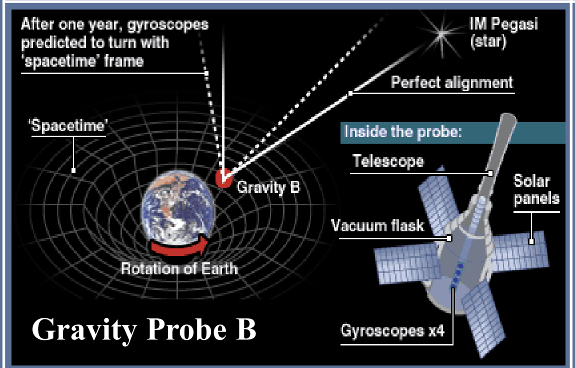
Extension of General Relativity based on Rieman-Cartan Space-Time

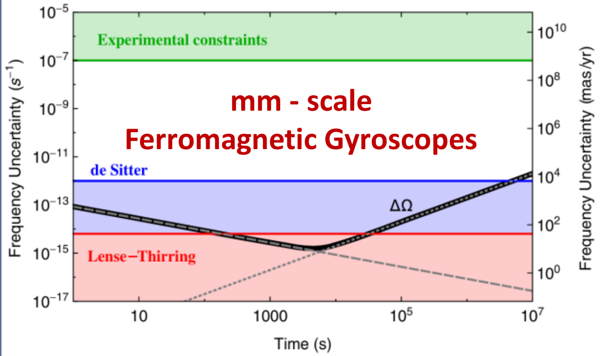
Gravitation
Earth, Mass…

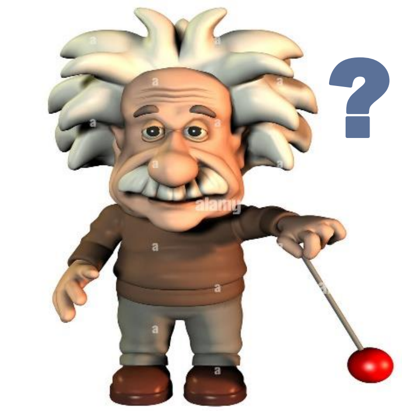


Q: What happens to the spin and how to measure it?

Source of Precession	Geodetic Precession	Frame-Dragging Precession	Spin-Gravity Precession	
Basic Formula	$\Omega_{geo} = \frac{3GMv}{2c^2R^2}$	$\Omega_{fra} = \frac{2GI\omega_E}{c^2R^3}$	$H_{sg} = \chi_e \vec{S} \cdot \vec{g} + \chi_N \vec{I} \cdot \vec{g}$ $(\chi \cong \hbar/c \sim 10^{-42} \text{kg m})$	
	G: Gravitational Constant 6.6743×10^{-11} $m^3 kg^{-1} s^{-2}$ R: earth radius v: orbit speed M: Earth mass 5.9722×10^{24} kg c: light speed I: moment of inertia $\sim 10^{38}$ m^2 kg ω_E: Earth rotation angular frequency		χ: Coupling coefficient between spin and gravitation field e: electron N: nucleus $\vec{S}$: electron spin $\vec{I}$: nuclear spin $\vec{g}$: gravity accelation	
Typical Frequency	~ 10^{-13} Hz	~ 10^{-15} Hz	~ 10^{-8} Hz (estimated value)	
Methods & Results	Classical Angular Mom.	Quantum Angular Mom.	Classical Angular Mom.	Quantum Angular Mom.
	YES	YES	?	YES
	Phys. Rev. Lett. 106, 221101 (2011)	Phys. Rev. D 103, 044056 (2021)		*Electron* Spin (~ 10^{-4} Hz) Phys. Rev. D 78, 092006 (2008) *Proton* Spin (~ 10^{-3} Hz) Phys. Rev. D 96, 075004 (2017) *Neutron* Spin (~ 10^{-7} Hz) Phys. Rev. Lett. 130, 201401 (2023)







The basic idea for measuring exotic spin-dependent interactions

^{39}K - ^{3}He Princeton University, USA

PRL **103**, 261801 (2009) PHYSICAL REVIEW LETTERS week ending 31 DECEMBER 2009

Limits on New Long Range Nuclear Spin-Dependent Forces Set with a K-^{3}He Comagnetometer

G. Vasilakis, J. M. Brown, T. W. Kornack, and M. V. Romalis
Department of Physics, Princeton University, Princeton, New Jersey 08544, USA
(Received 1 September 2008; revised manuscript received 23 September 2009; published 29 December 2009)

A magnetometer using spin-polarized K and ^{3}He atoms occupying the same volume is used to search for anomalous nuclear spin-dependent forces generated by a separate ^{3}He spin source. We measure changes in the ^{3}He spin precession frequency with a resolution of 18 pHz and constrain anomalous spin forces between neutrons to be less than 2×10^{-8} of their magnetic or less than 2×10^{-3} of their gravitational interactions on a length scale of 50 cm. We present new limits on neutron coupling to light pseudoscalar and vector particles, including torsion, and constraints on recently proposed models involving unparticles and spontaneous breaking of Lorentz symmetry.

DOI: 10.1103/PhysRevLett.103.261801 PACS numbers: 14.80.Mz, 04.80.Cc, 21.30.Cb, 24.80.+y

Two Spin Species

$$\frac{\Delta\nu_a}{\Delta\nu_b} = \frac{\gamma_a B + \varepsilon_a}{\gamma_b B + \varepsilon_b}$$

Reduce Common-Mode Magnetic-Field Noise

^{199}Hg - Neutron PSI, Switzerland

PHYSICAL REVIEW X **7**, 041034 (2017)

Search for Axionlike Dark Matter through Nuclear Spin Precession in Electric and Magnetic Fields

C. Abel,[1] N. J. Ayres,[1,*] G. Ban,[2] G. Bison,[3] K. Bodek,[4] V. Bondar,[5] M. Daum,[3] M. Fairbairn,[6] V. V. Flambaum,[7] P. Geltenbort,[8] K. Green,[9] W. C. Griffith,[1] M. van der Grinten,[9] Z. D. Grujić,[10] P. G. Harris,[1] N. Hild,[3] P. Iaydjiev,[9,‡] S. N. Ivanov,[9,§] M. Kasprzak,[5] Y. Kermaidic,[11] K. Kirch,[12,3] H.-C. Koch,[3] S. Komposch,[3,12] P. A. Koss,[5] A. Kozela,[13] J. Krempel,[12] B. Lauss,[3] T. Lefort,[2] Y. Lemière,[2] D. J. E. Marsh,[6] P. Mohanmurthy,[3,12] A. Mtchedlishvili,[3] M. Musgrave,[1,¶] F. M. Piegsa,[14] G. Pignol,[11] M. Rawlik,[12,†] D. Rebreyend,[11] D. Ries,[14,3,12] S. Roccia,[15] D. Rozpędzik,[4] P. Schmidt-Wellenburg,[3] N. Severijns,[5] D. Shiers,[1] Y. V. Stadnik,[7] A. Weis,[10] E. Wursten,[5] J. Zejma,[4] and G. Zsigmond[3]
[1]*Department of Physics and Astronomy, University of Sussex, Falmer, Brighton BN1 9QH, United Kingdom*
[2]*Normandie Univ, ENSICAEN, UNICAEN, CNRS/IN2P3, LPC Caen, 14000 Caen, France*
[3]*Paul Scherrer Institute, CH-5232 Villigen PSI, Switzerland*
[4]*Institute of Physics, Jagiellonian University in Kraków, 30-348 Kraków, Poland*
[5]*Instituut voor Kern- en Stralingsfysica, Katholieke Universiteit Leuven, B-3001 Leuven, Belgium*
[6]*King's College London Department of Physics, London, WC2R 2LS, United Kingdom*

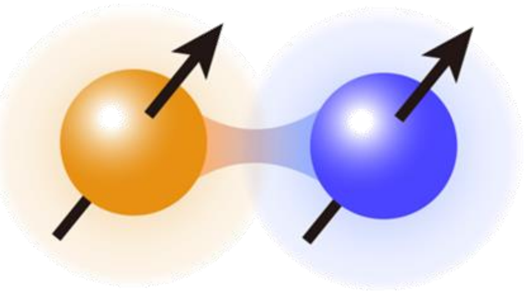
^{85}Rb – ^{87}Rb California State University, USA

PHYSICAL REVIEW D **96**, 075004 (2017)

Constraints on long-range spin-gravity and monopole-dipole couplings of the proton

Derek F. Jackson Kimball,* Jordan Dudley, Yan Li, Dilan Patel, and Julian Valdez
Department of Physics, California State University–East Bay, Hayward, California 94542-3084, USA
(Received 5 July 2017; published 5 October 2017)

Results of a search for a long-range monopole-dipole coupling between the mass of the Earth and rubidium (Rb) nuclear spins are reported. The experiment simultaneously measures the spin precession frequencies of overlapping ensembles of ^{85}Rb and ^{87}Rb atoms contained within an evacuated, antirelaxation-coated vapor cell. The nuclear structure of the Rb isotopes makes the experiment particularly sensitive to spin-dependent interactions of the proton. The spin-dependent component of the gravitational energy of the proton in the Earth's field is found to be smaller than 3×10^{-18} eV, improving laboratory constraints on long-range monopole-dipole interactions by over 3 orders of magnitude.



^{129}Xe – ^{131}Xe University of Science and Technology

PHYSICAL REVIEW LETTERS **130**, 201401 (2023)
Editors' Suggestion Featured in Physics

Search for Spin-Dependent Gravitational Interactions at Earth Range

S.-B. Zhang,[1] Z.-L. Ba,[1] D.-H. Ning,[1] N.-F. Zhai,[2] Z.-T. Lu,[1,3,*] and D. Sheng[2,3,†]
[1]*CAS Center for Excellence in Quantum Information and Quantum Physics, School of Physical Sciences, University of Science and Technology of China, Hefei 230026, China*
[2]*Department of Precision Machinery and Precision Instrumentation, Key Laboratory of Precision Scientific Instrumentation of Anhui Higher Education Institutes, University of Science and Technology of China, Hefei 230027, China*
[3]*Hefei National Laboratory, University of Science and Technology of China, Hefei 230088, China*
(Received 23 January 2023; revised 6 March 2023; accepted 15 March 2023; published 15 May 2023)

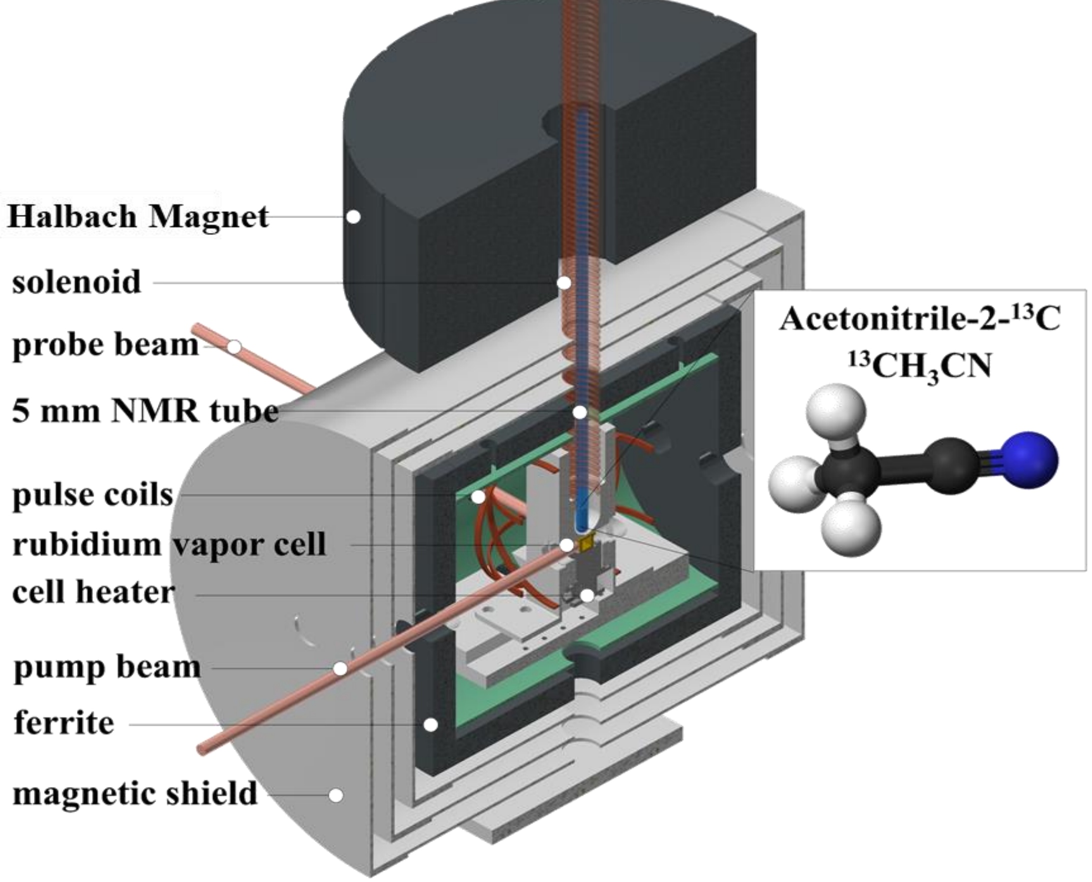
Among the four fundamental forces, only gravity does not couple to particle spins according to the general theory of relativity. We test this principle by searching for an anomalous scalar coupling between the neutron spin and the Earth's gravity on the ground. We develop an atomic gas comagnetometer to

Comagnetometer with Single-Species Molecule: ZULF NMR

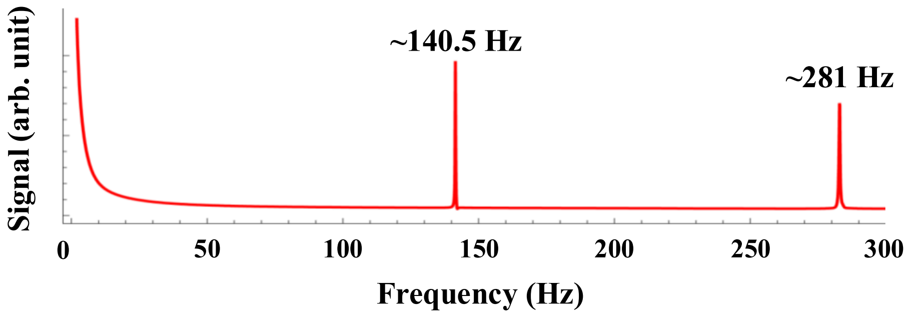
ZULF NMR: Zero- to ULtralow-Field Nuclear Magnetic Resonance

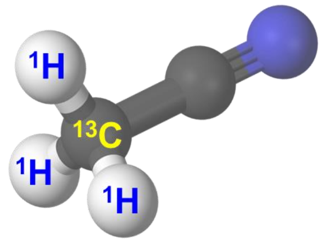
@ Mainz, Germany (2018)

Phys. Rev. Lett. **121**, 023202 (2018)

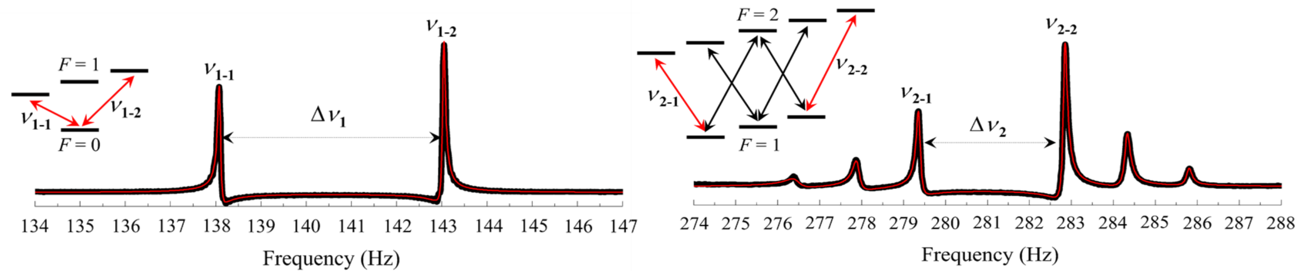


Acetonitrile-2-^{13}C: no magnetic field





Acetonitrile-2-^{13}C: with magnetic field



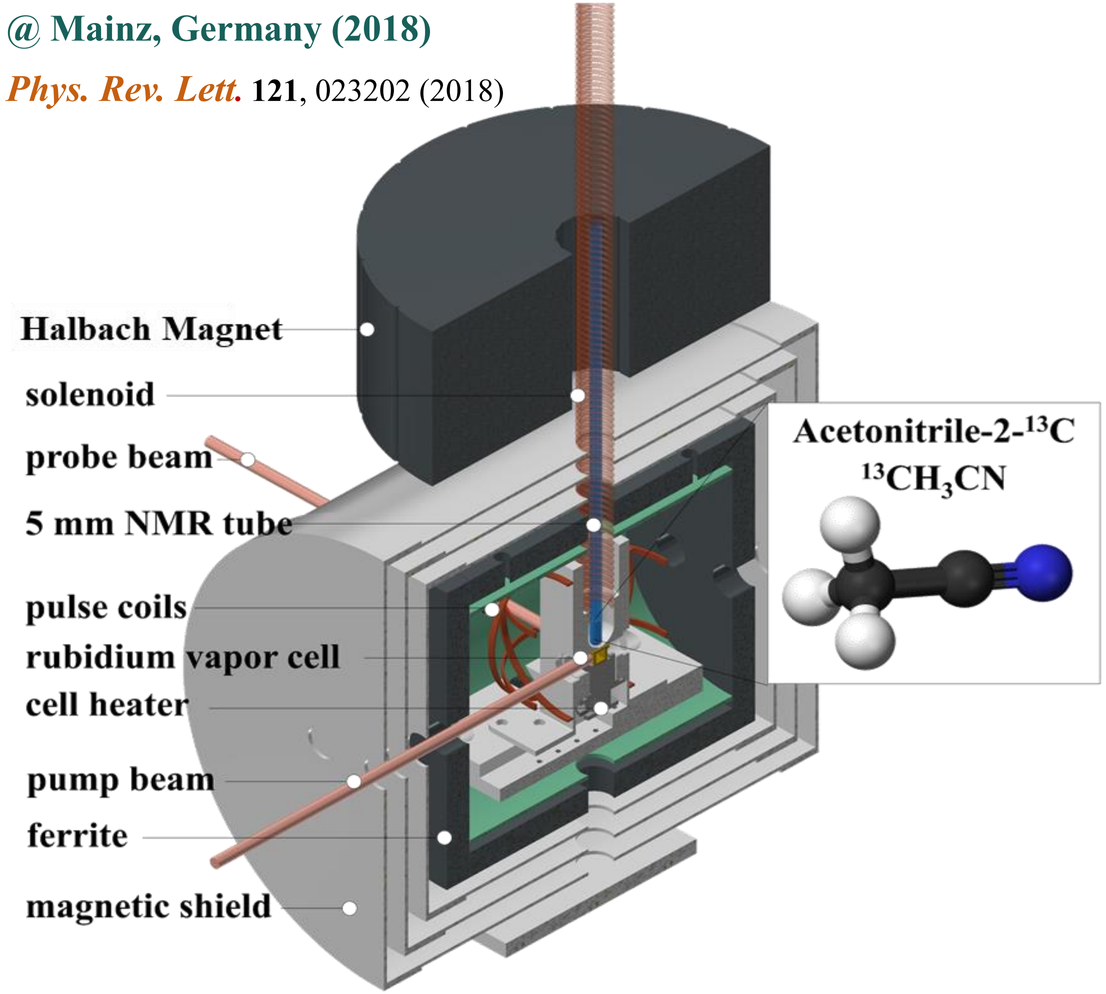
Measurement Type	Single Shot (Thermal)	Day Average (Thermal)	Single Shot (Hyper Polarization)	Day Average (Hyper Polarization)
Frequency Resolution (Hz)	10^{-4}	10^{-6}	10^{-7}	10^{-9}

Comagnetometer with Single-Species Molecule: ZULF NMR

ZULF NMR: Zero- to ULtralow-Field Nuclear Magnetic Resonance

@ Mainz, Germany (2018)

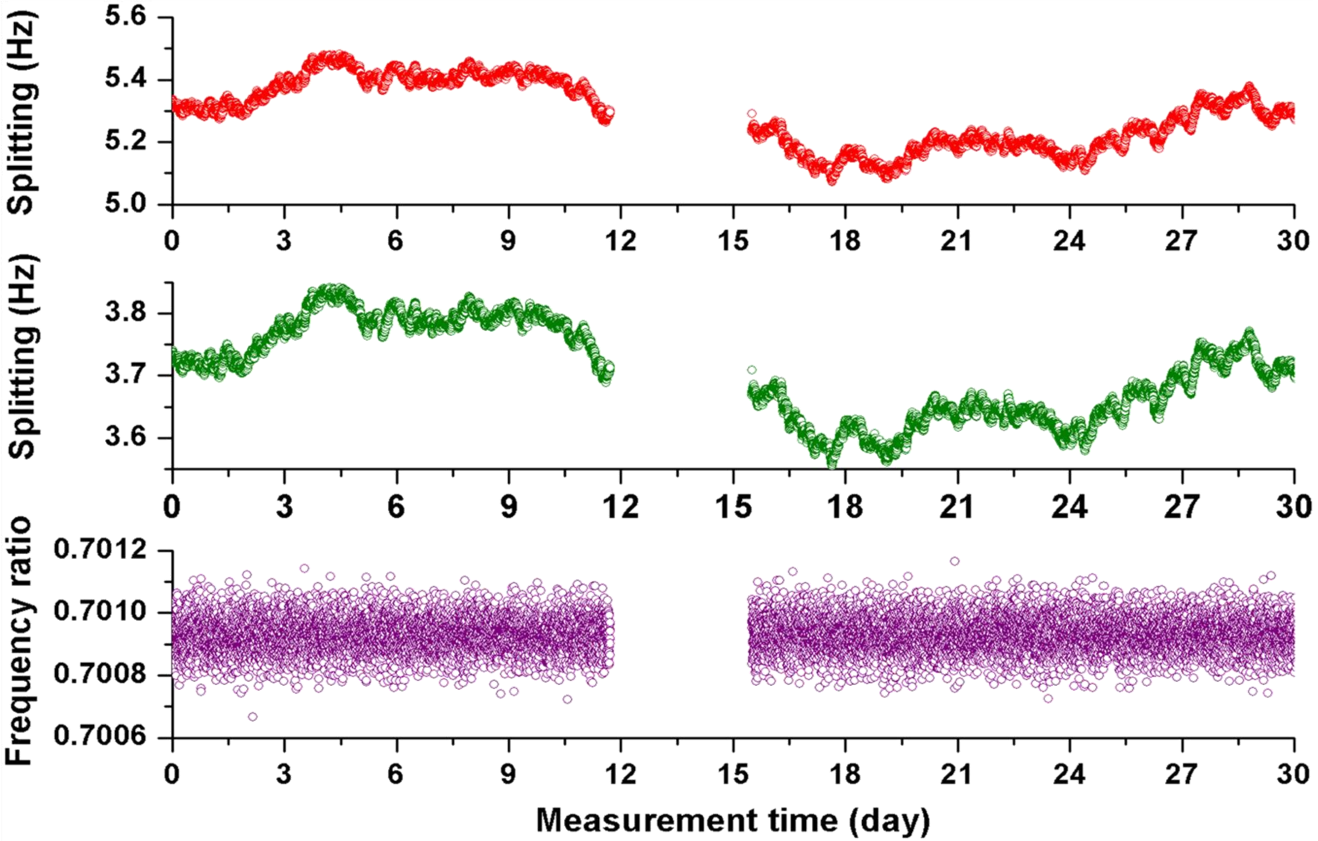
Phys. Rev. Lett. **121**, 023202 (2018)



Phys. Rev. Lett. **122**, 191302 (2019)

Phys. Rev. Lett. **123**, 16 (2019)

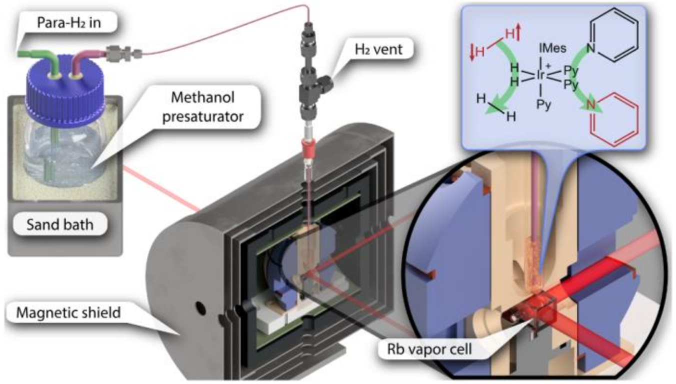
CASPEr: Cosmic Axion induced Spin Precession Experiment

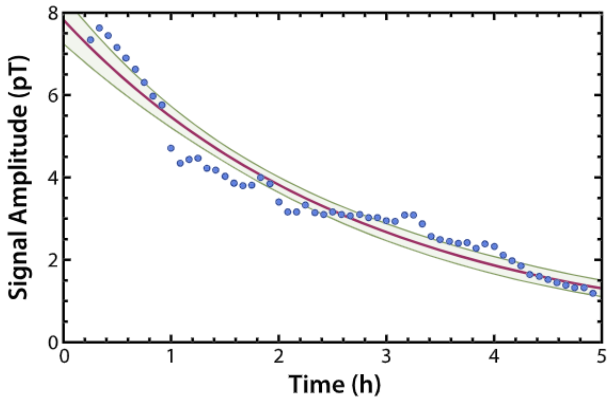


Budker AG

ParaHydrogen Induced Polarization (PHIP) + ZULF NMR

Long-Lasting Detection of SABRE-Derived Nuclear Magnetization

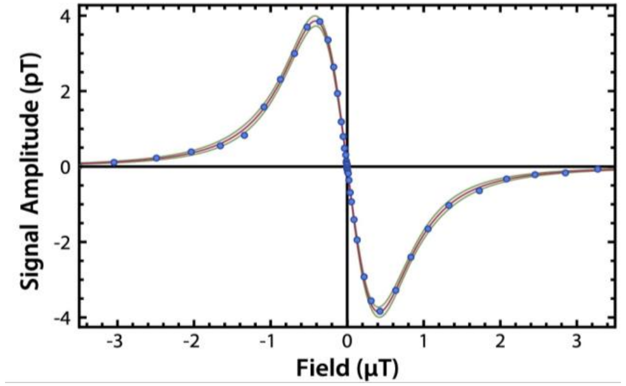




Magn Reson Chem. 59, 1208 (2021)

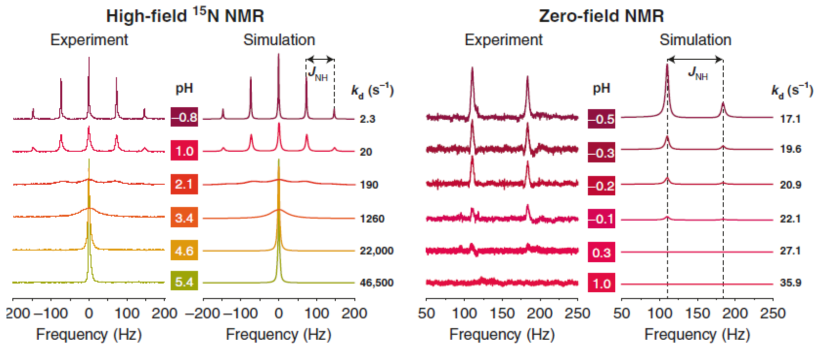
Dr. **John Blanchard**

Dr. **Barbara Ripka**



Observation of Chemical Exchange on ZULF NMR

Nature Communications 10, 3002 (2019)

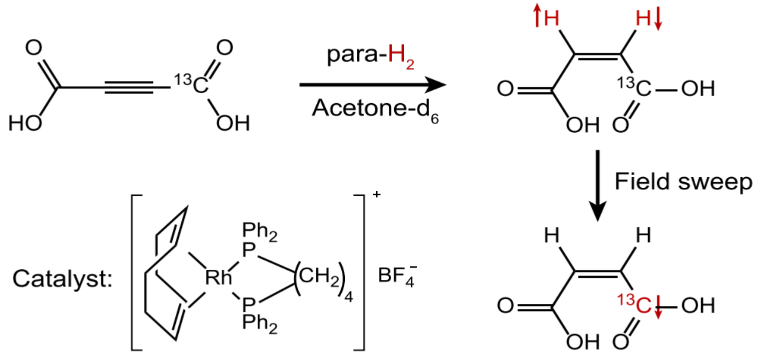


Dr. **Danila Barskiy**

Polarization transfer via field sweeping on ZULF NMR

J. Chem. Phys. 150, 174202 (2019)

Dr. **James Eills**



Budker AG

2015

Married
PhD degree
Baby

2016

2019

PhD candidate, 3-months' visit, Nitrogen Vacancy Centers in Diamond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Dr. Lykourgos Bougas


Dr. Arne Wickenbrock


Georgios Chatzidrosos


Prof. Dr. Yannick Dumeige

Postdoc, 3 years, Zero- to Ultralow-Field Nuclear Magnetic Resonance, CASPEr


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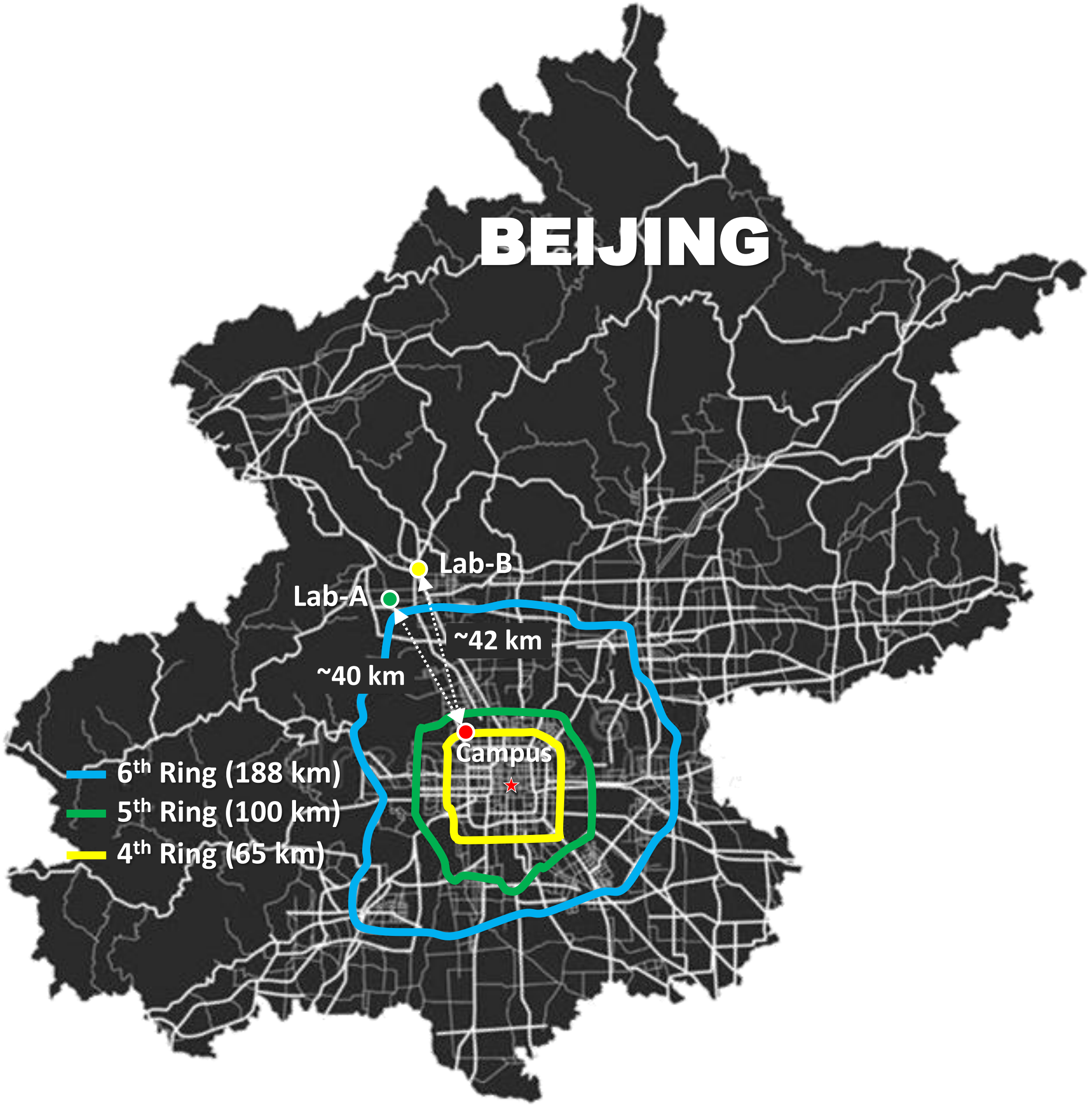
Dr. Kirill Sheberstov

CASPEr Group: Arne, Nate, Gary, Hector, Marina, Martin, Prof. Derek J. Kimball, Yevgeny…

Assistant Professor, **Peking University**, Atomic magnetometry in Fundamental Physics & Biomagnetism

Lab-A for Exotic Physics @ PKU



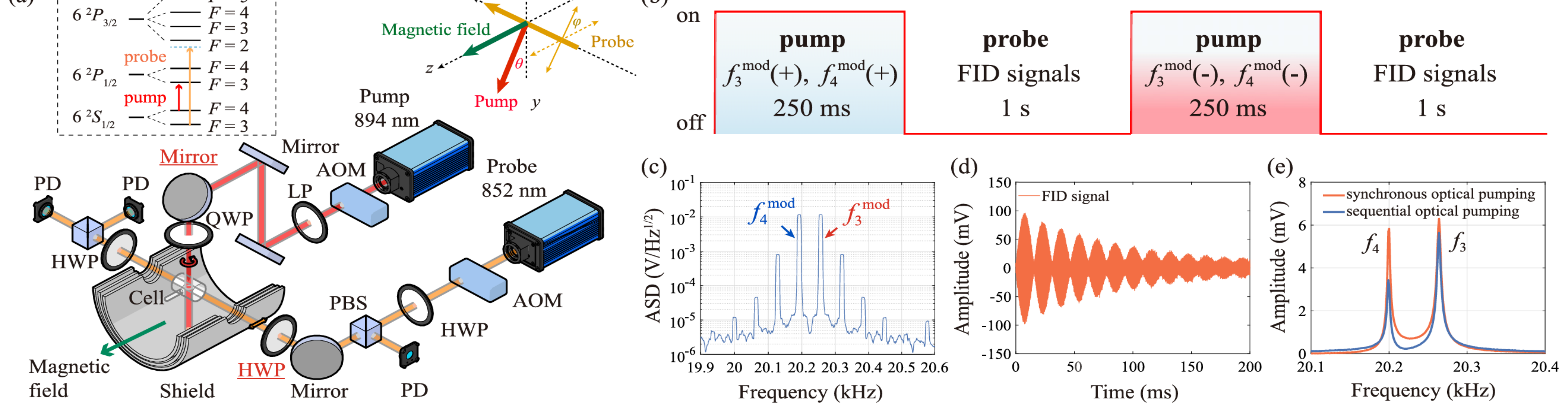
Comagnetometer with Single-Species Atom: Cesium

Two Ground States of Alkali-Metal Atom Precess at Different Frequencies under Magnetic Field

		Potassium 39	Rubidium 85	Rubidium 87	Cesium 133
Gyromagnetic Ratio (Hz/nT)	$F = I + 1/2$	+ 7.0053	+ 4.6674	+ 6.9958	+ 3.4986
	$F = I - 1/2$	- 7.0075	- 4.6756	- 7.0237	- 3.5098

See: Phys. Rev. A **110**, 063122 (2024)   *Phys. Rev. D* (Accepted)

Measurement Type	Single Shot	Day Average
Frequency Resolution (Hz)	10^{-4}	10^{-7}



Comagnetometer with Single-Species Atom: Cesium

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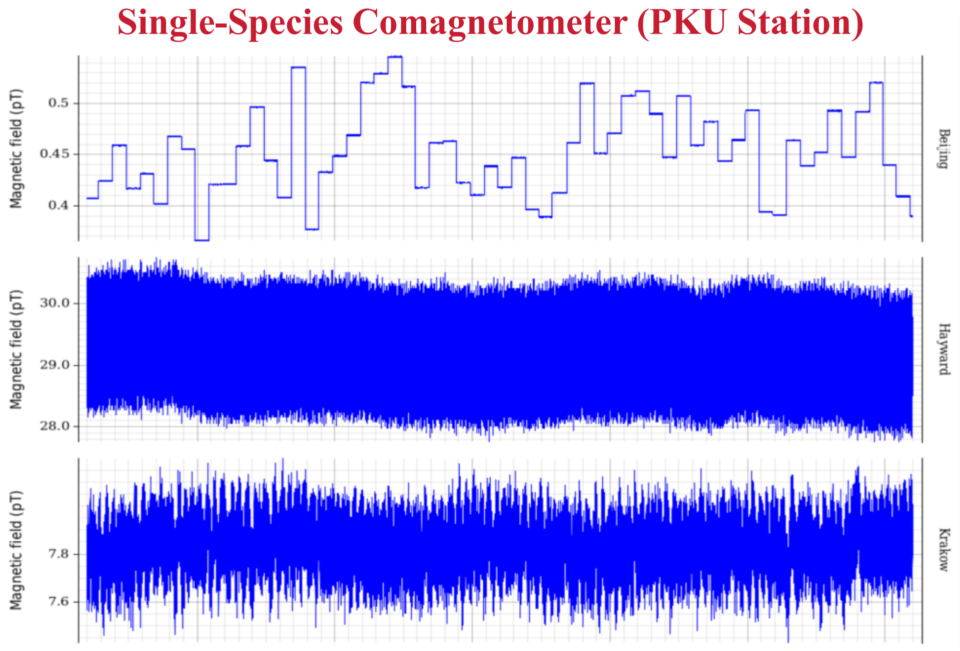
	$F = I - 1/2$	- 7.0075	- 4.6756	- 7.0237	- 3.5098

See: Nature Physics **17**, 1396 (2021)

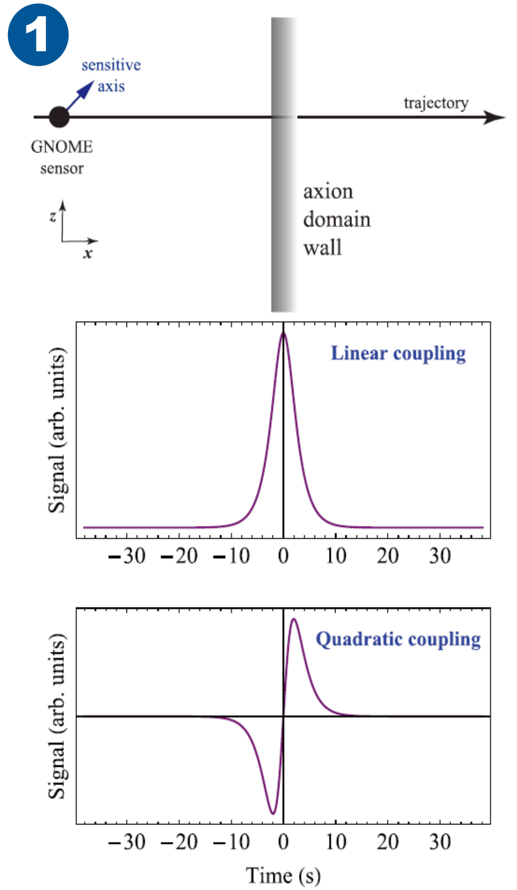
Advanced GNOME (With Comagnetometers)

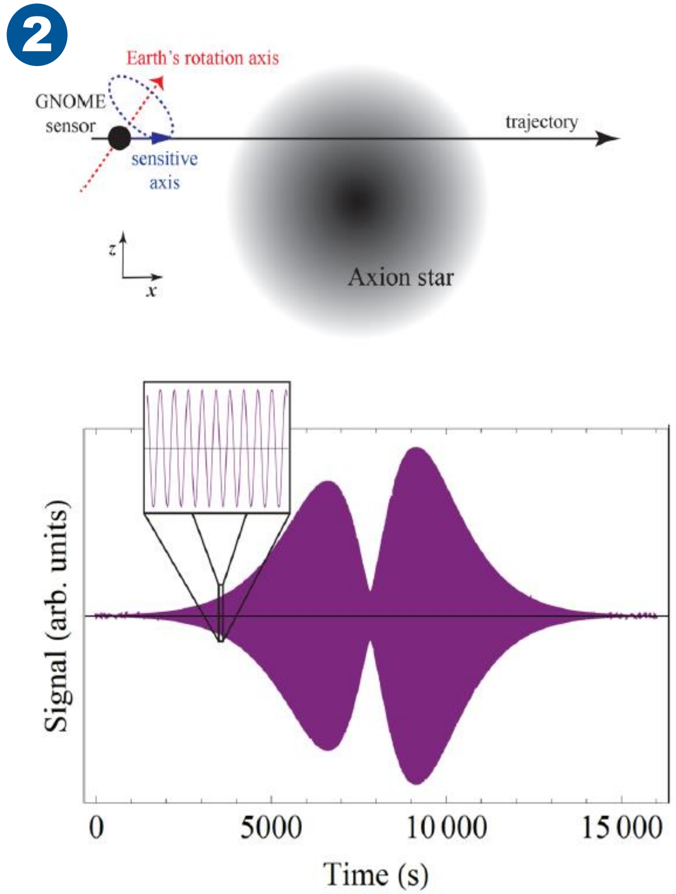


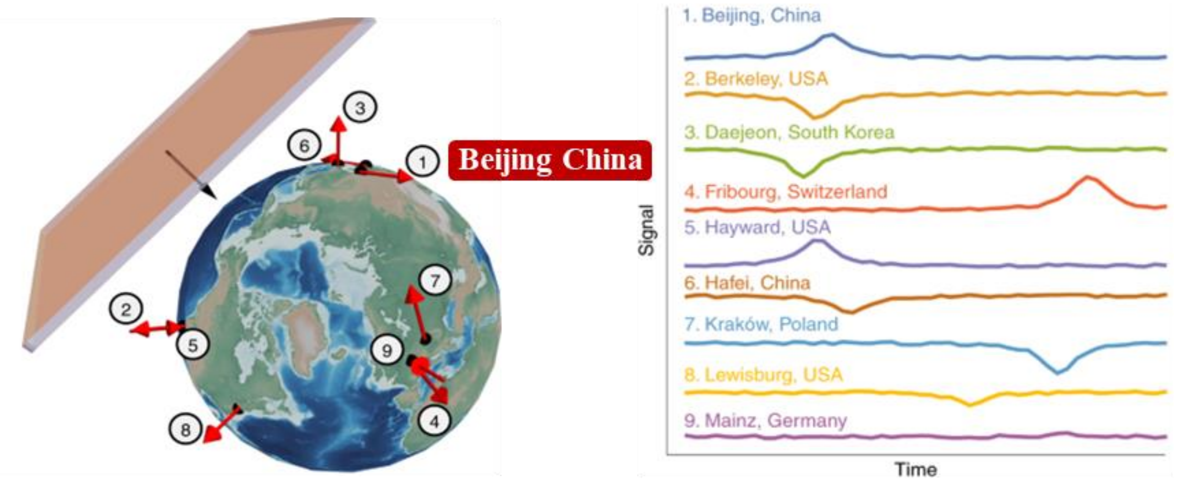
GNOME (magnetometer) & aGNOME (comagnetometer)

GNOME: Global Network of Optical Magnetometer for Exotic Physics

Searches for Axion Domain Wall (Topological Defect) or Axion Stars *See: Nature Physics* **17**, 1396 (2021)







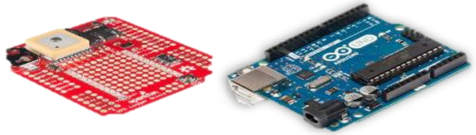
Time Synchronization with GPS

↓

Sensor Calibration (Per Hour)

↓

Data Processing and Upload



Time Synchronization & Calibration @ GNOME

Magnetometer Signal (Optimized)

(100 fT/Hz$^{1/2}$, BW 200 Hz)

Disturbance & Fault Monitoring

Sensor	Laser	Cell	Temperature
Environment	Vibration	Magnetic	Acceleration

GPS Signal (Time Stamp)

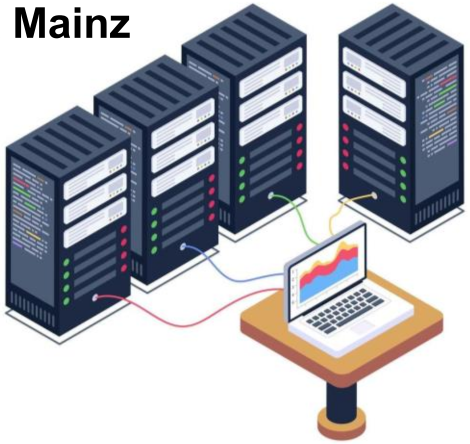
Data Acquisition System

CH1: Magnetometer

CH2: Disturbance & Fault

Data Upload & Saving

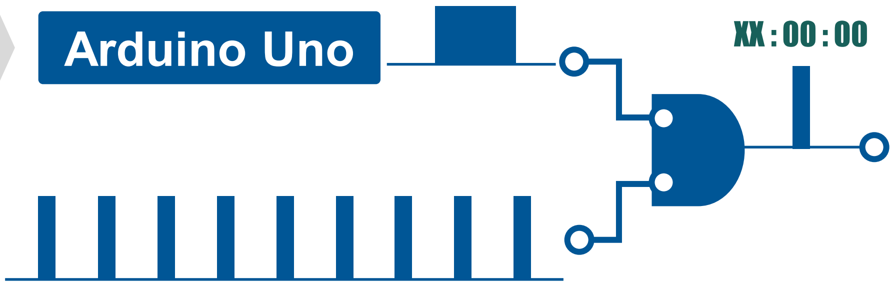
@ Mainz



GPS Signal

GPS Pulse

Arduino Uno



Function Generator

Frequency Sweep Sinusoidal (1-190 Hz)

Magnetic-Field Coil

Frequency Sweep Magnetic Field

Some Thoughts of GravNet (Transient Signal)

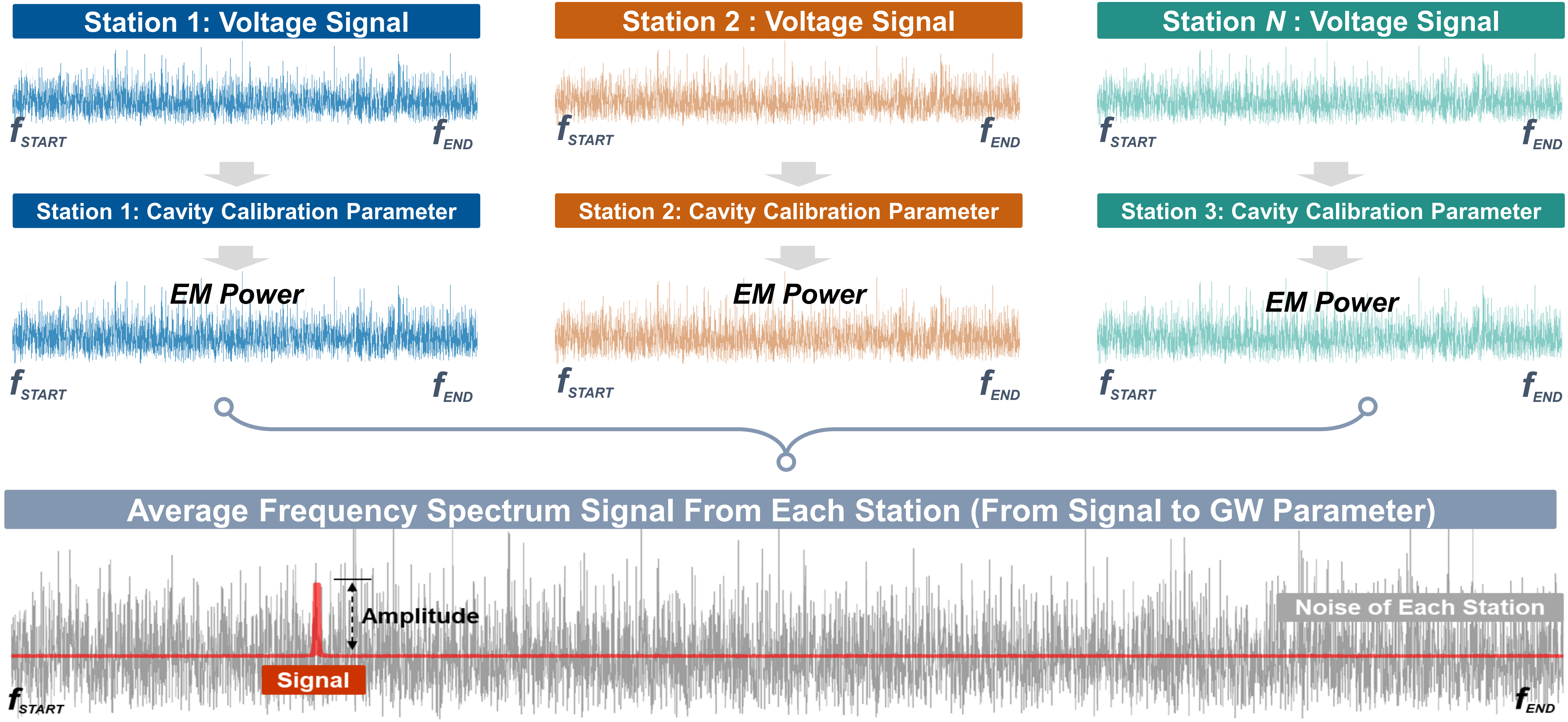
Detection of High Frequency Gravitational Wave Signals

1. Incoming GW →
2. Interacting with Cavity →
3. Generating HF EM Field →
4. EM Enhanced by Cavity ↓
5. EM Field Readout (HF) →
6. Frequency Mixing (LF) →
7. **Coherent Averaging** →
8. Fourier Trans.

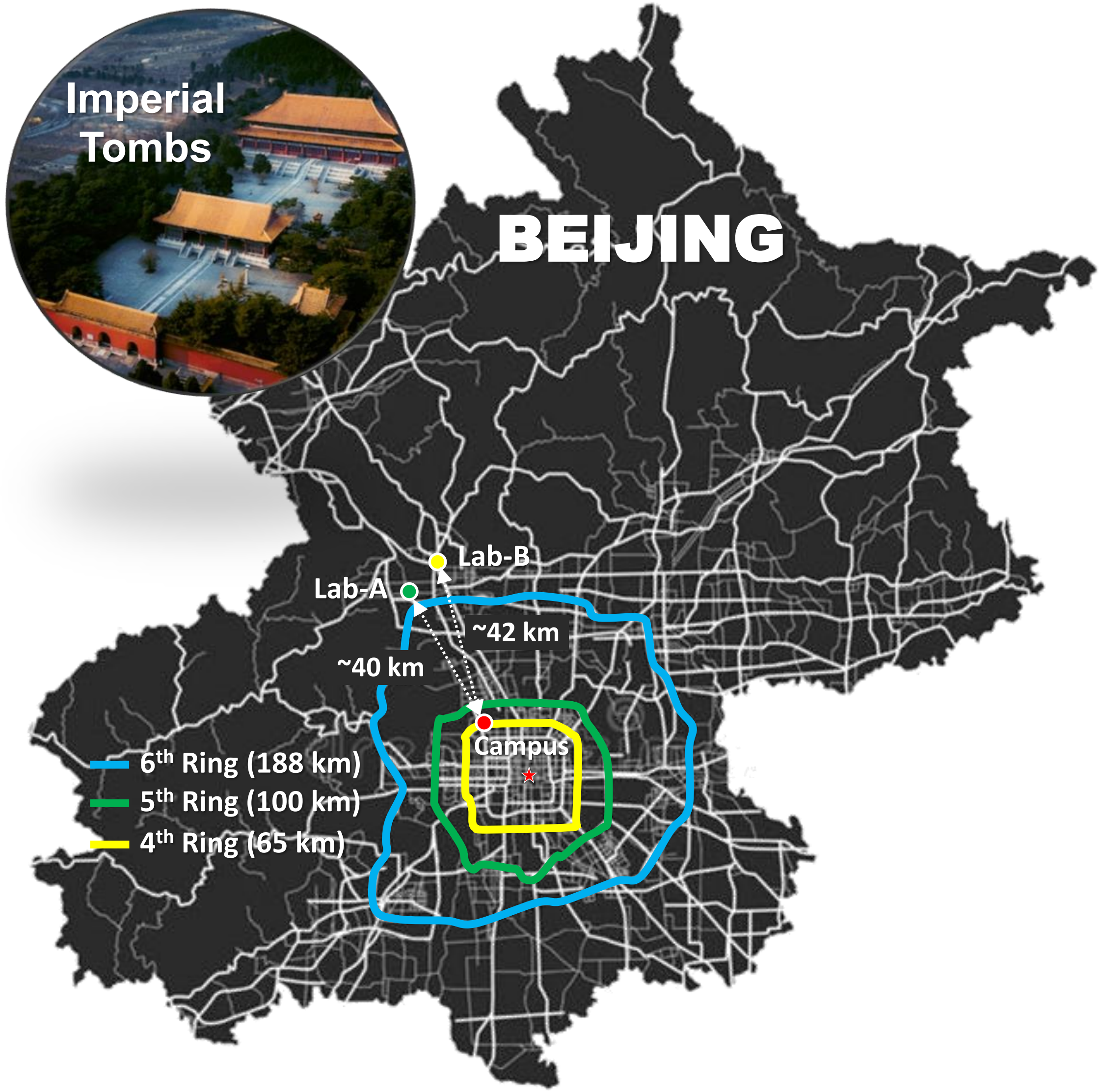
Suppose we could not observe the signal from single shot and have no idea where the frequency is

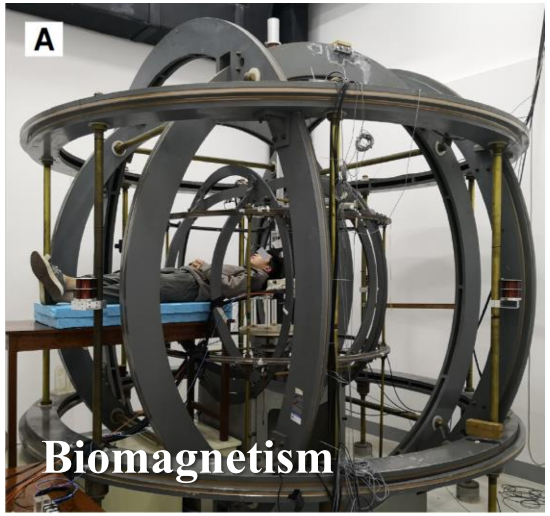
Calibration 1:	The Starting Frequency of the Spectrum for Each Station	For Averaging
Calibration 2:	Relationship between Input MW Signal with Output Signal	For Conversion
Calibration 3:	Q Factor, Bias Magnetic Field Amplitude of Each Station	For Conversion
Calibration 4:	Inject MW Field for each station and perform spectrum averaging	For Network

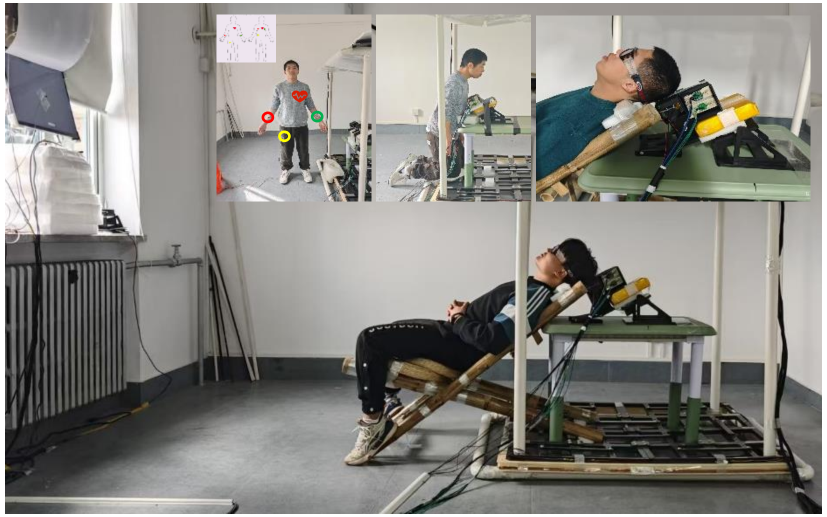
Some Thoughts of GravNet (Transient Signal)

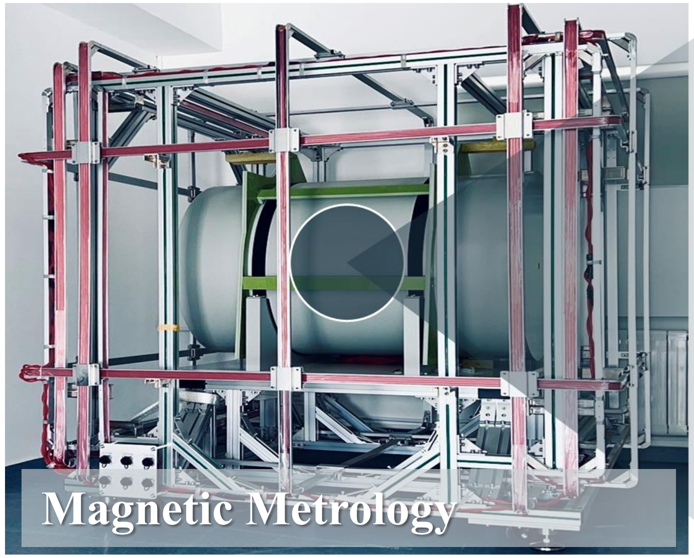


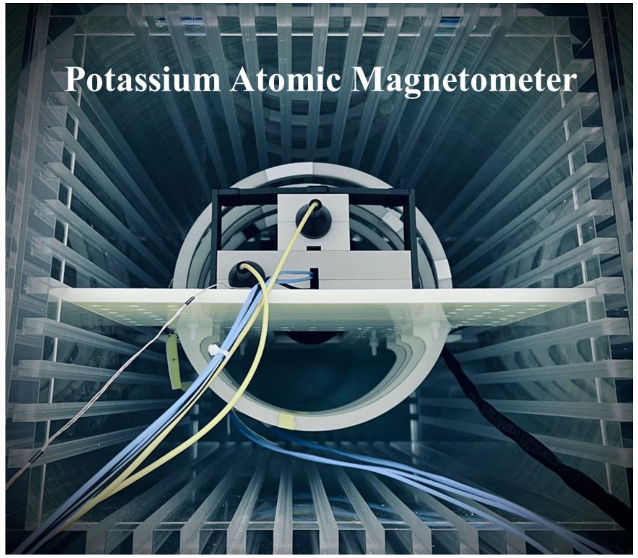
Lab-B for Biomagnetism & Metrology @ PKU











Atomic Magnetometry for Biomagnetism (*Brain*, *Heart*,...)

Science Advances 6, eaba8792 (2020)

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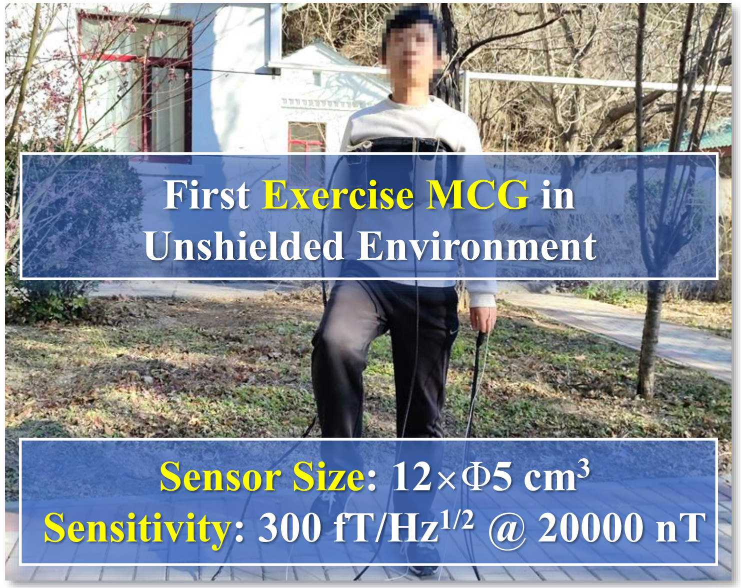

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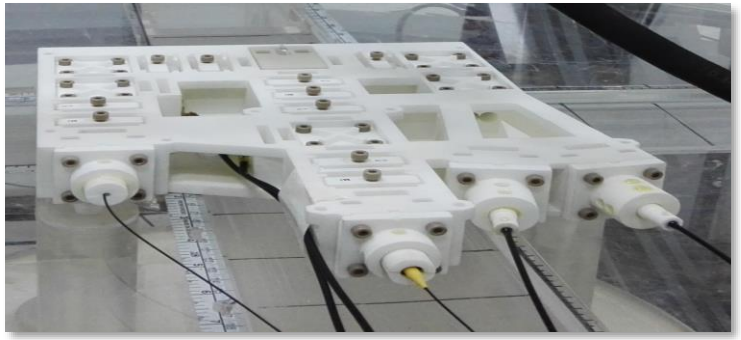
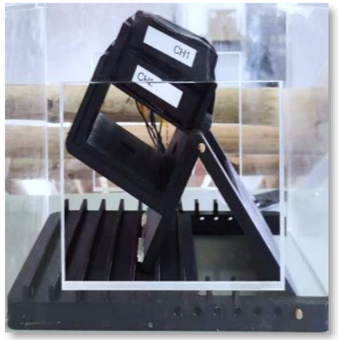
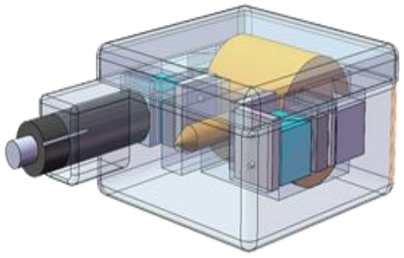
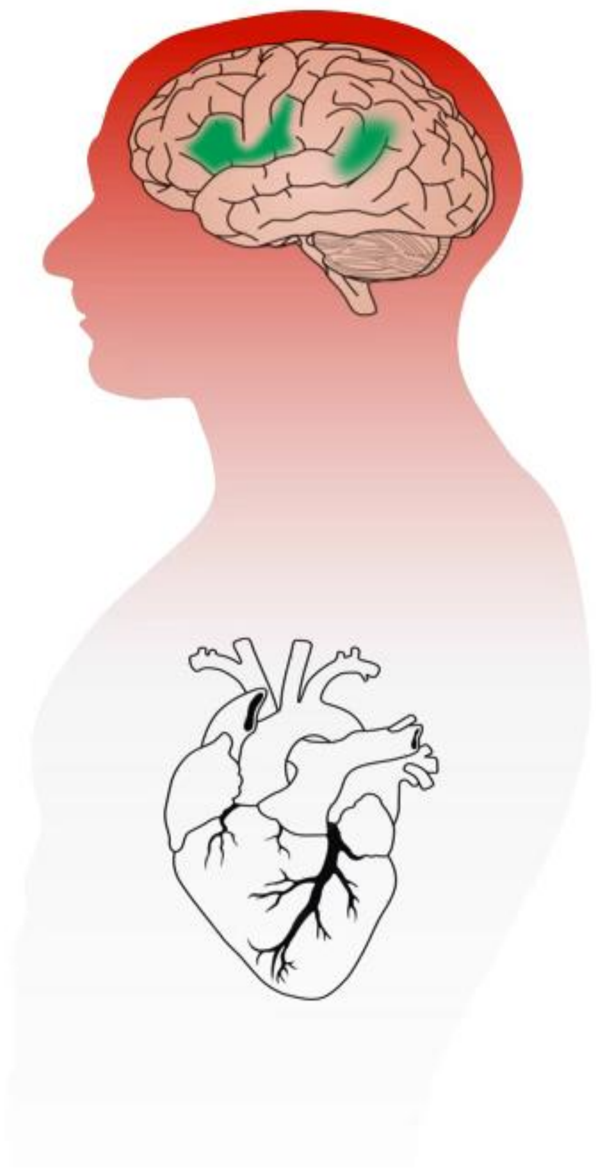






Atomic Magnetometry for Biomagnetism (*Brain*, *Heart*,...)



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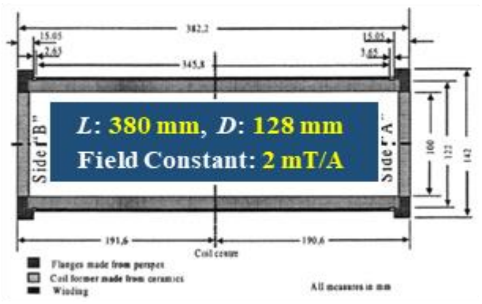
Atomic Magnetometry for Magnetic Field Metrology

Q: To what degree can we say that the magnetometer measurement result is *accurate*?

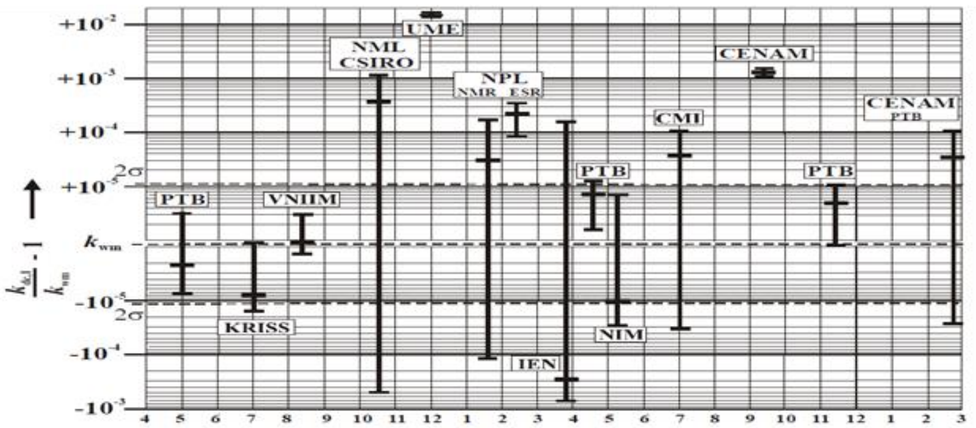
1 Standard Magnetic-Field Coil



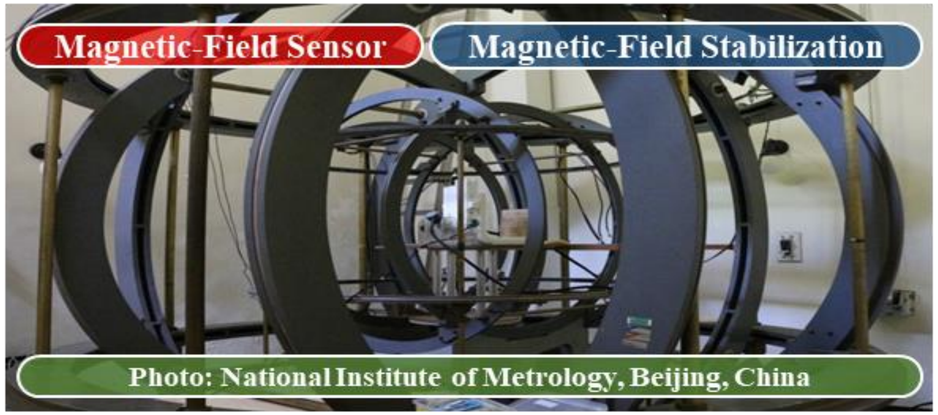
2 Standard Coil Distribution

Korea	Russia	Australia	Turkey	China
KRISS	VNIIM	CRISO	UME	NIM
UK	Italy	Germany	Mexico	USA
NPL	IEN	PTB	CENAM	NIST

4 International Comparison-Phys. Const.



3 Magnetic-Field Standard Transfer



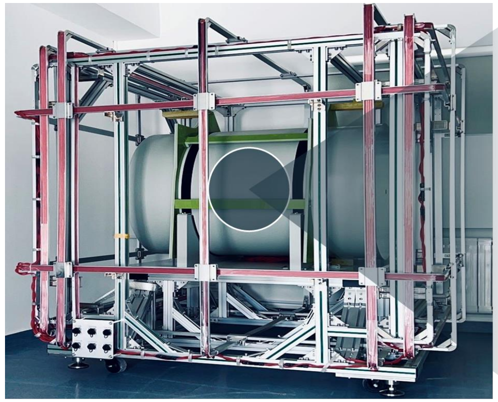
Atomic Magnetometry for Magnetic Field Metrology

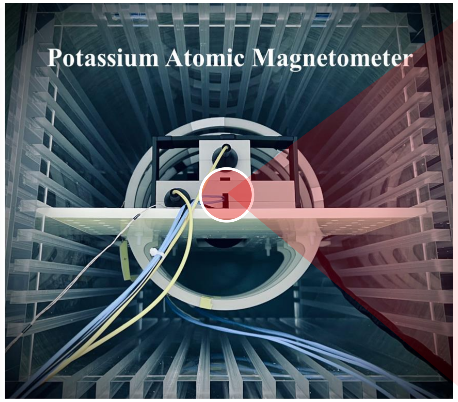
A Prototype Magnetic Field Stabilization System @ PKU

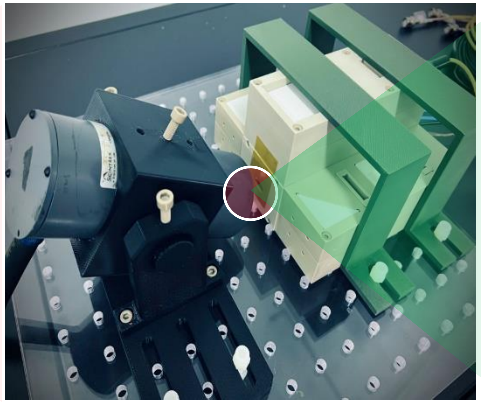
±10^5 nT *Generated Magnetic Field* | **1 pT** *Peak-To-Peak Noise Level* | **Passive + Active** *Magnetic Shielding* | **^{3}He** *Magnetometer for Calibration*

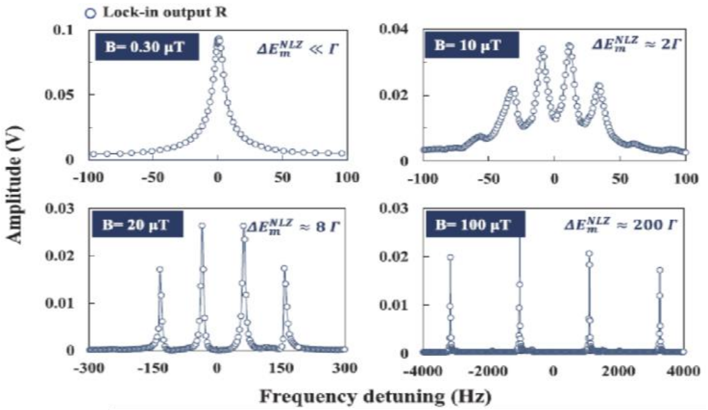
Magnetic Field Generation and Stabilization

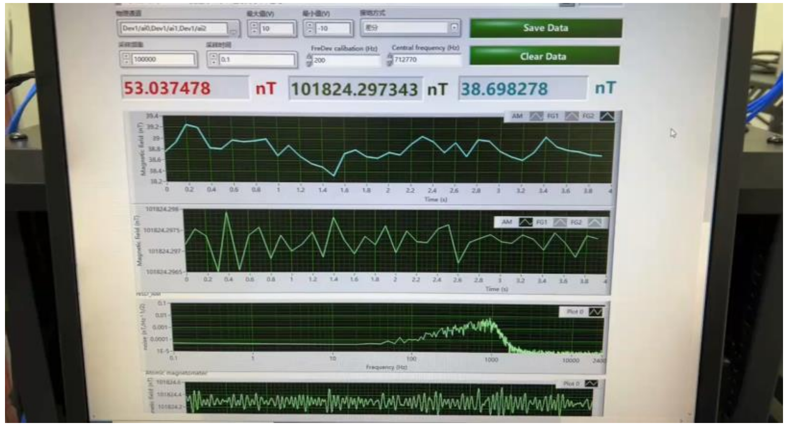
^{3}He High Accuracy Magnetometer

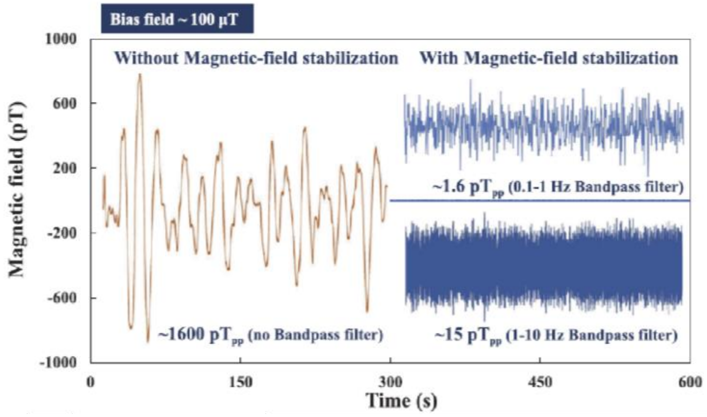










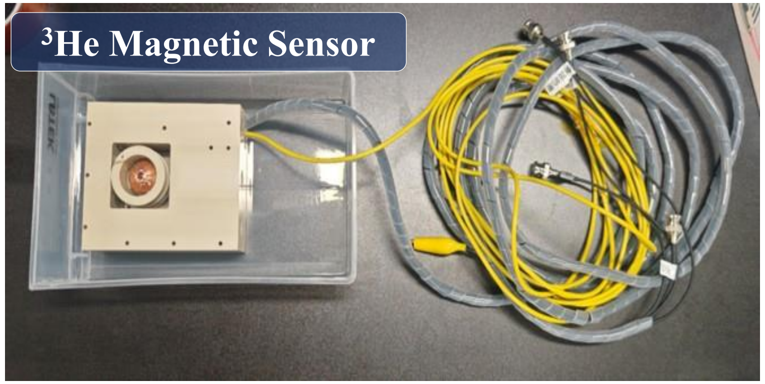


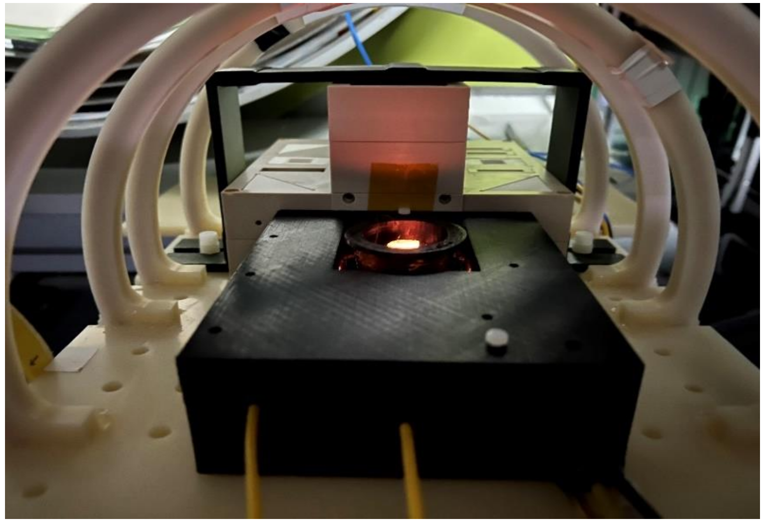
Atomic Magnetometry for Magnetic Field Metrology

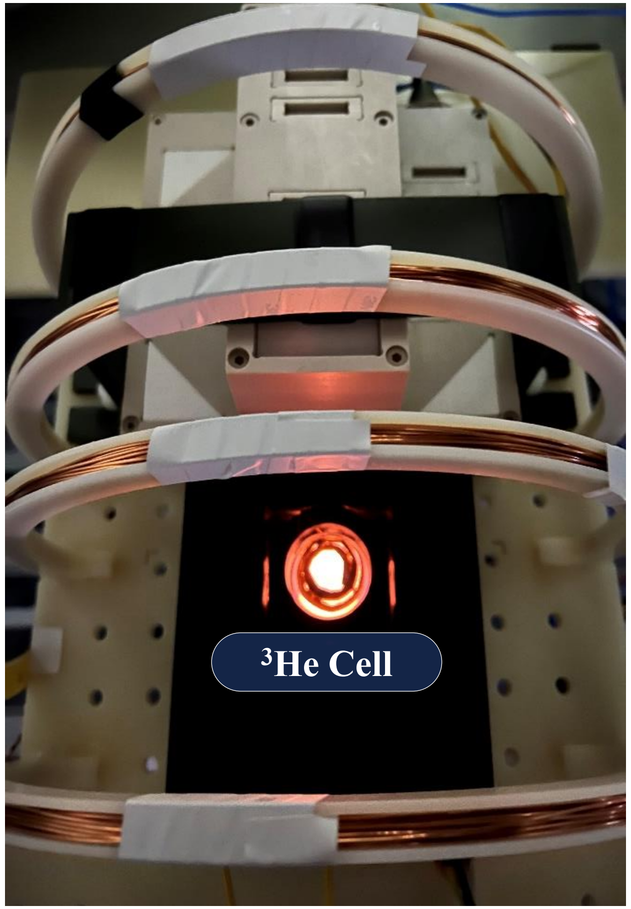
A Prototype Magnetic Field Stabilization System @ PKU

±10^5 nT *Generated Magnetic Field* | **1 pT** *Peak-To-Peak Noise Level* | **Passive + Active** *Magnetic Shielding* | **^{3}He** *Magnetometer for Calibration*

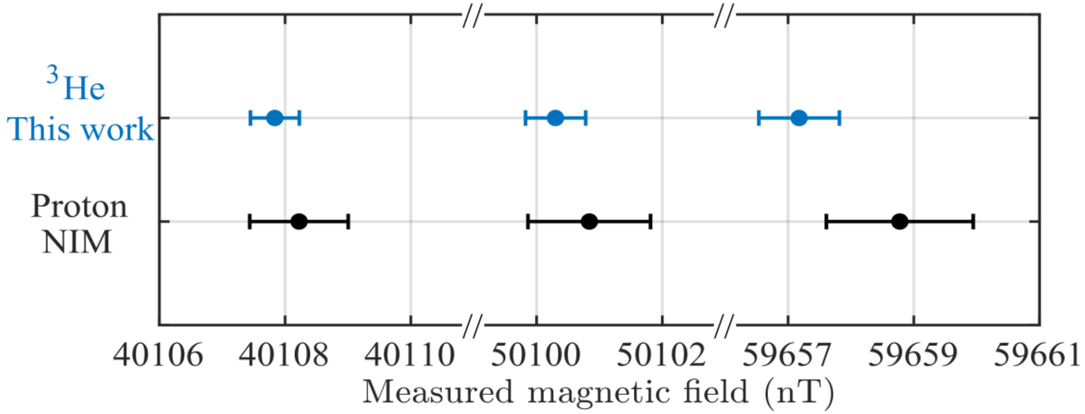
Magnetic Field Generation and Stabilization







^{3}He High Accuracy Magnetometer



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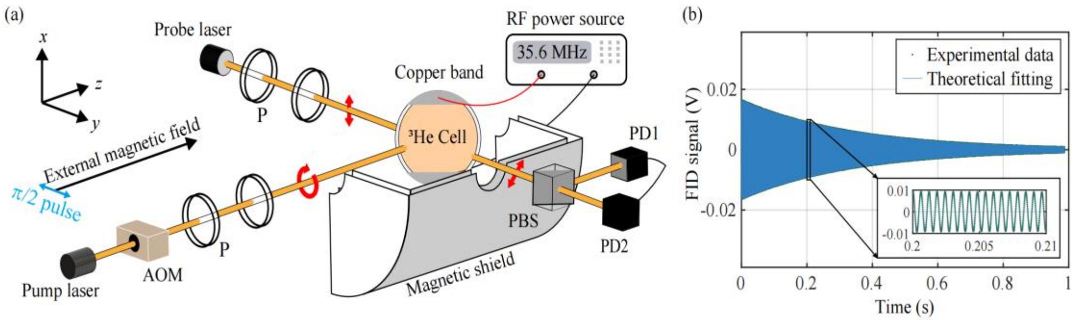

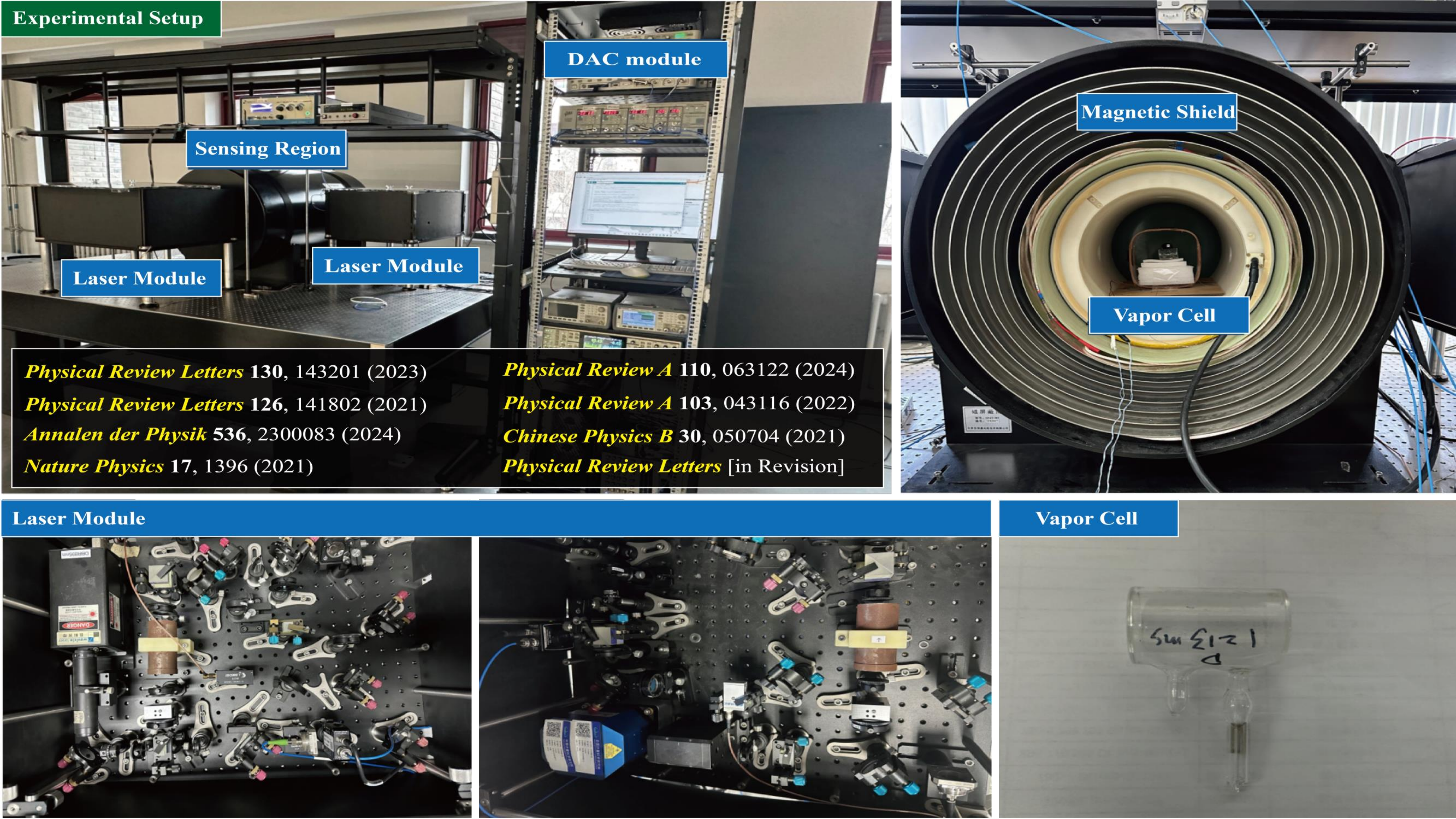

Experimental Setup
DAC module
Sensing Region
Laser Module
Laser Module
Physical Review Letters 130, 143201 (2023)
Physical Review Letters 126, 141802 (2021)
Annalen der Physik 536, 2300083 (2024)
Nature Physics 17, 1396 (2021)
Physical Review A 110, 063122 (2024)
Physical Review A 103, 043116 (2022)
Chinese Physics B 30, 050704 (2021)
Physical Review Letters [in Revision]
Magnetic Shield
Vapor Cell
Laser Module
Vapor Cell

Science Advances **6**, eaba8792 (2020) *Physical Review Letters* **133**, 093201 (2024) *iScience* **27**, 110167 (2024)
Science Advances **9**, eadg1746 (2023) *Physical Review Applied* **20**, 024042 (2023)
Springer Nature **161** (2021) [Chapter] **Software Copyright: Magnetoencephalography signal preprocessing**
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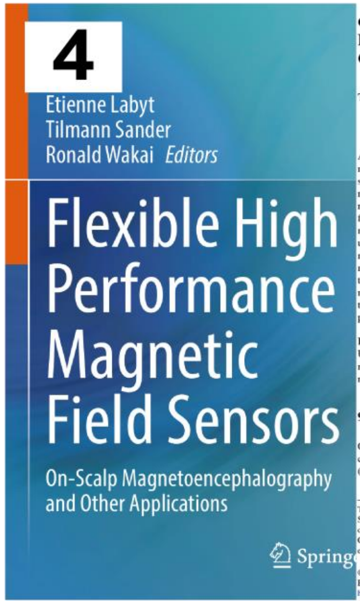

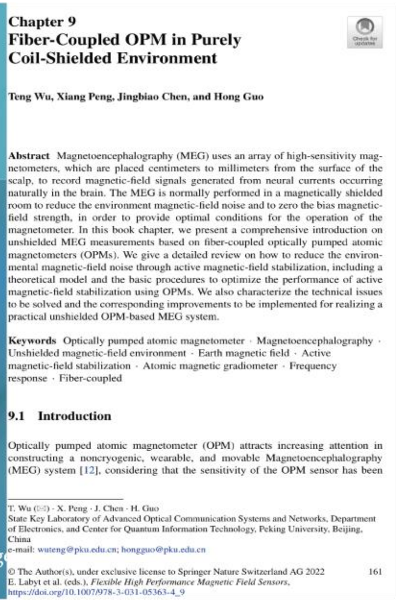

Chapter 9
Fiber-Coupled OPM in Purely Coil-Shielded Environment

Teng Wu, Xiang Peng, Jingbiao Chen, and Hong Guo

Abstract Magnetoencephalography (MEG) uses an array of high-sensitivity magnetometers, which are placed centimeters to millimeters from the surface of the scalp, to record magnetic-field signals generated from neural currents occurring naturally in the brain. The MEG is normally performed in a magnetically shielded room to reduce the environment magnetic-field noise and to zero the bias magnetic-field strength, in order to provide optimal conditions for the operation of the magnetometer. In this book chapter, we present a comprehensive introduction on unshielded MEG measurements based on fiber-coupled optically pumped atomic magnetometers (OPMs). We give a detailed review on how to reduce the environmental magnetic-field noise through active magnetic-field stabilization, including a theoretical model and the basic procedures to optimize the performance of active magnetic-field stabilization using OPMs. We also characterize the technical issues to be solved and the corresponding improvements to be implemented for realizing a practical unshielded OPM-based MEG system.

Keywords Optically pumped atomic magnetometer · Magnetoencephalography · Unshielded magnetic-field environment · Earth magnetic field · Active magnetic-field stabilization · Atomic magnetic gradiometer · Frequency response · Fiber-coupled

9.1 Introduction

Optically pumped atomic magnetometer (OPM) attracts increasing attention in constructing a noncryogenic, wearable, and movable Magnetoencephalography (MEG) system [12], considering that the sensitivity of the OPM sensor has been

T. Wu (✉) · X. Peng · J. Chen · H. Guo
State Key Laboratory of Advanced Optical Communication Systems and Networks, Department of Electronics, and Center for Quantum Information Technology, Peking University, Beijing, China
e-mail: wuteng@pku.edu.cn; hongguo@pku.edu.cn

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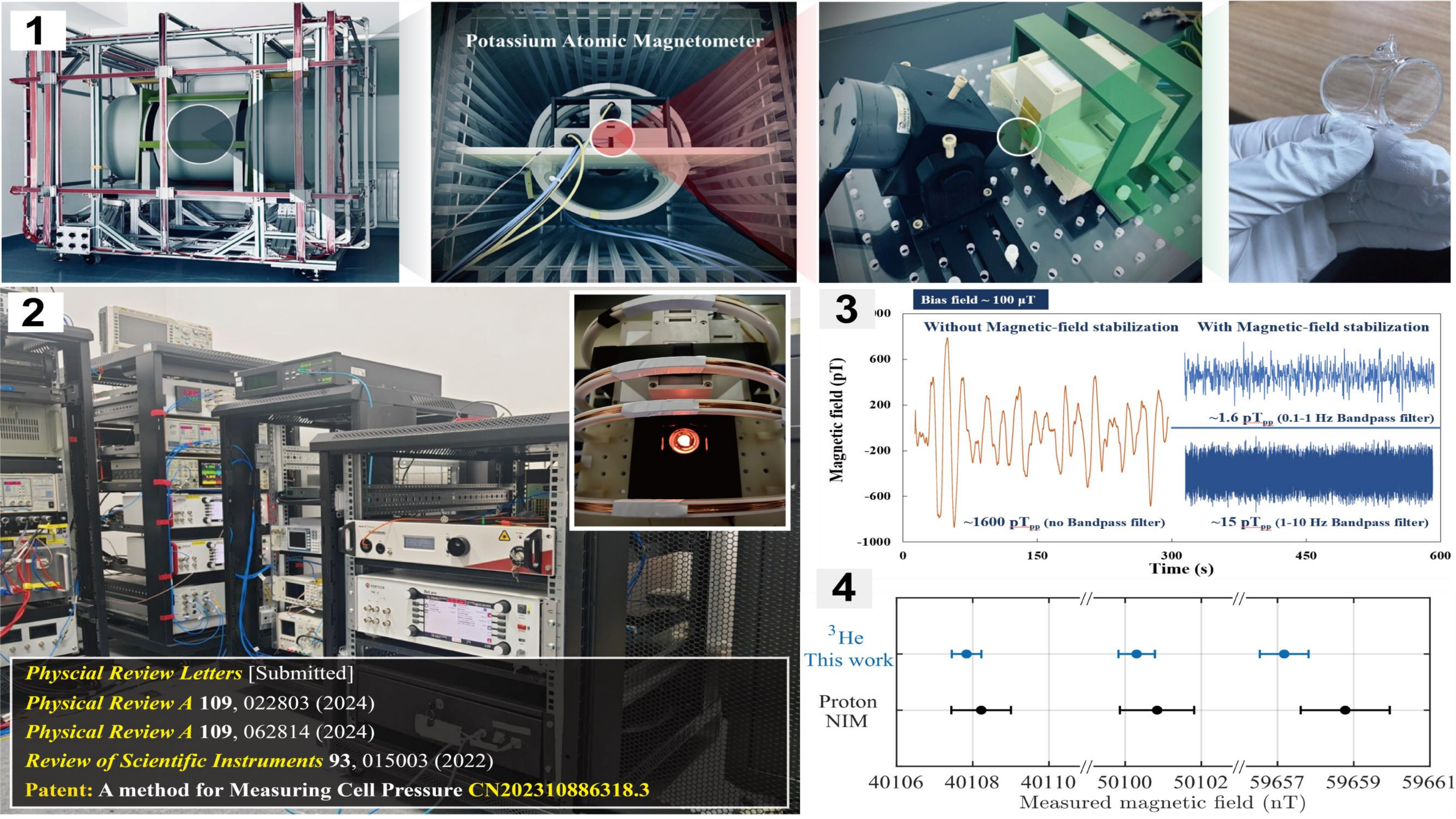
E. Labyt et al. (eds.), *Flexible High Performance Magnetic Field Sensors*,
https://doi.org/10.1007/978-3-031-05363-4_9


1
Potassium Atomic Magnetometer
2
Physcial Review Letters [Submitted]
Physical Review A 109, 022803 (2024)
Physical Review A 109, 062814 (2024)
Review of Scientific Instruments 93, 015003 (2022)
Patent: A method for Measuring Cell Pressure CN202310886318.3
3
Bias field ~ 100 μT
Without Magnetic-field stabilization
With Magnetic-field stabilization
~1.6 pT_pp (0.1-1 Hz Bandpass filter)
~1600 pT_pp (no Bandpass filter)
~15 pT_pp (1-10 Hz Bandpass filter)
Magnetic field (pT)
600
200
-200
-600
-1000
0
150
300
450
600
Time (s)
4
3He This work
Proton NIM
40106
40108
40110
50100
50102
59657
59659
59661
Measured magnetic field (nT)

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National Hi-Tech Research and Development (863) Program (1986 - 2016)

National Key Research and Development Program (2017 -)

National Science Foundation of China (NSFC)

China Manned Space Engineering

Prof. **Hong Guo**

Group Leader | Director

Assoc. Prof. **Xiang Peng**

^{4}He OPM | Cell Fabrication

Asst. Prof. **Teng Wu**

Alkali-OPM | Applications

Dr. **Wei Xiao** (PostDoc)

Alkali-OPM | Experiment

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