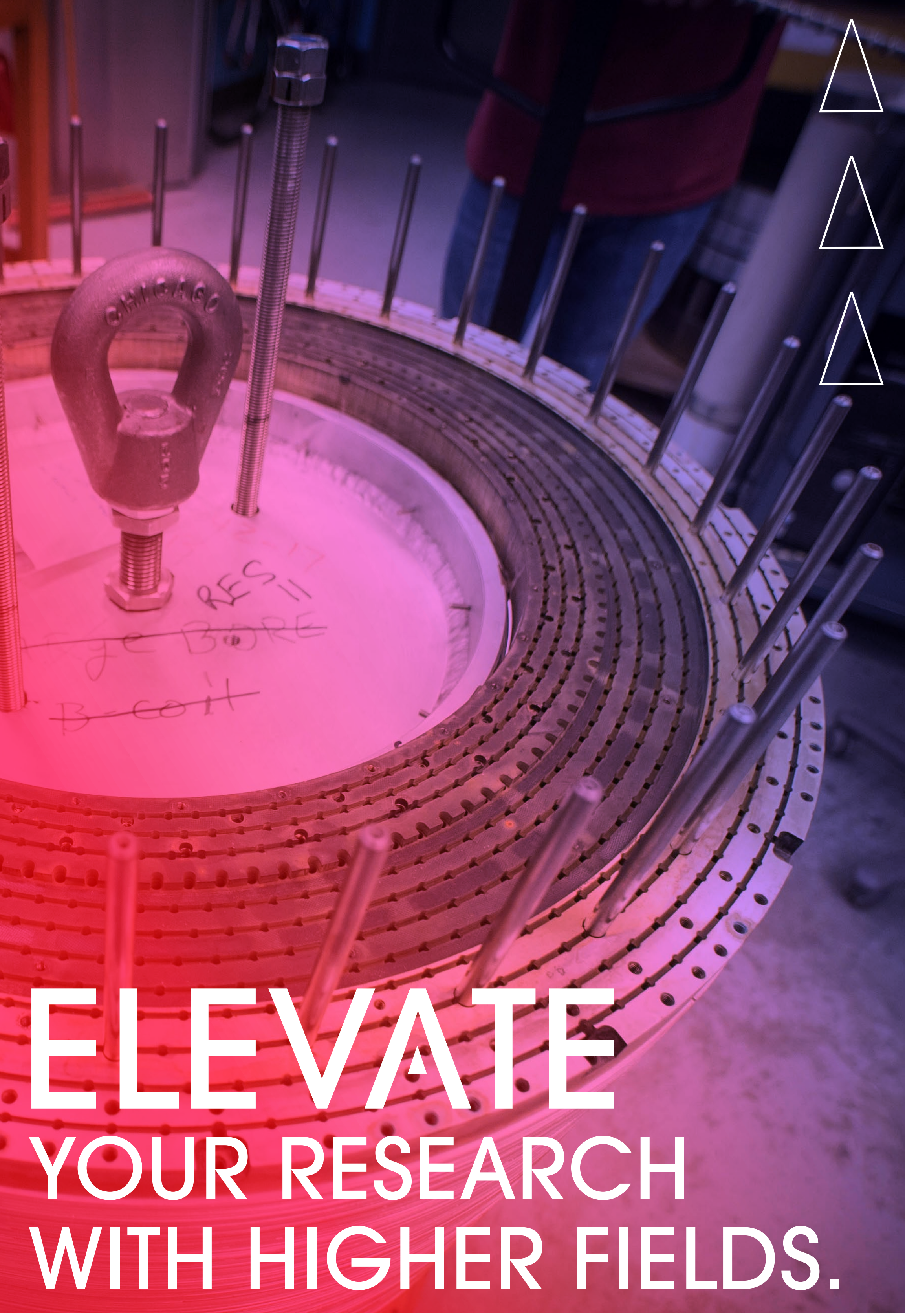


ELEVATE YOUR RESEARCH WITH HIGHER FIELDS.

NATIONAL HIGH MAGNETIC FIELD LABORATORY

NationalMagLab.org

FLORIDA STATE UNIVERSITY
UNIVERSITY OF FLORIDA
LOS ALAMOS NATIONAL LABORATORY

A HIGHER PEAK IS WAITING FOR YOU

Submit a proposal to experiment - FREE OF CHARGE - at the largest and highest-powered magnet laboratory in the world.

Perform experiments on our fleet of world-record magnets or work with our dedicated support scientists to conduct dozens of measurement techniques across condensed matter physics, materials research, magnet engineering, chemistry, biochemistry, geochemistry, bioengineering, and biology.

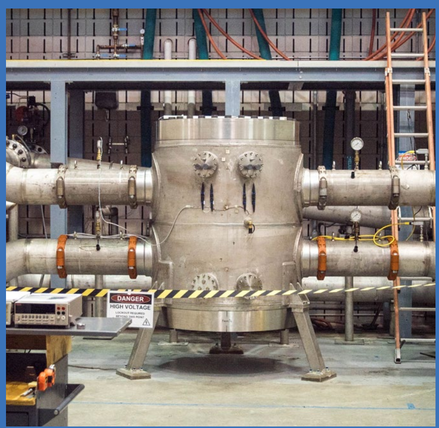
The only lab of its kind in the United States, the National High Magnetic Field Laboratory (National MagLab) is headquartered at Florida State University with branch campuses at the University of Florida and Los Alamos National Lab.

ON THE COVER

DC FIELD FACILITY

Turn to page 5 to learn more about the 41 T resistive magnet at the MagLab's DC Field Facility.

For a complete list of available instruments and techniques visit our webpage: NationalMagLab.org/user-facilities/dc-field

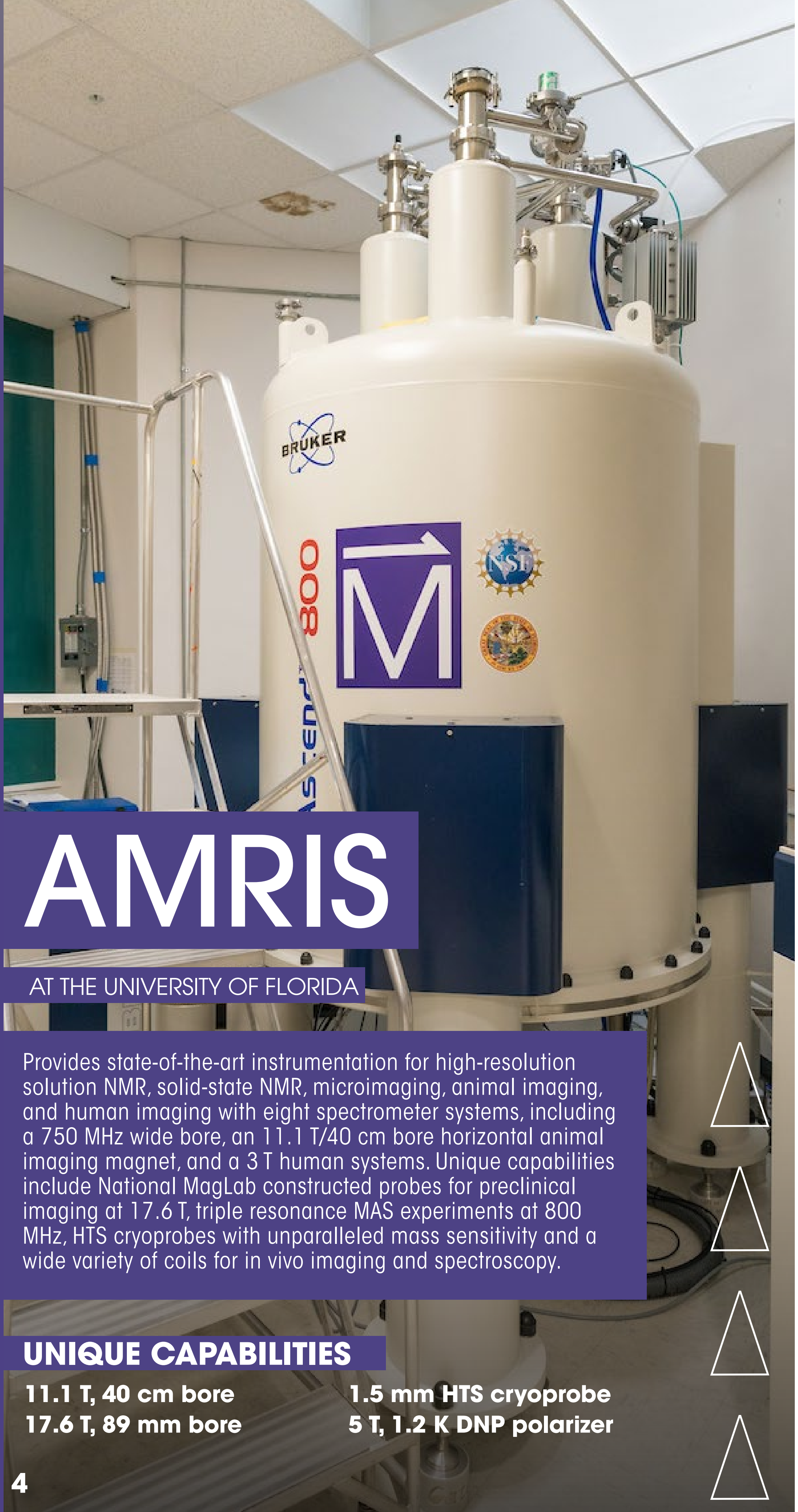


Seven distinct user facilities offer unique capabilities in high magnetic field research. Find the facility that elevates your research:

- **Advanced Magnetic Resonance Imaging and Spectroscopy (AMRIS) Facility**
- **DC Field Facility**
- **Electron Magnetic Resonance (EMR) Facility**
- **High B/T Facility**
- **Ion Cyclotron Resonance (ICR) Facility**
- **Nuclear Magnetic Resonance/Magnetic Resonance Imaging (NMR/MRI) Facility**
- **Pulsed Field Facility**

We understand that there are times along your research journey that can feel like climbing a mountain, and our experienced support staff act as guides to help you reach new heights. As a user, you have access to experts in cryogenics, electronics, instrumentation, safety, machining/welding, and technical support to aid your work. We also offer financial support for first-time PI travel expenses or to cover short-term dependent care costs.

On our quest for ever-higher peak fields, the National MagLab's **Magnet Science & Technology group** and **Applied Superconductivity Center** work to find the materials and develop the technologies that lift your research to new pinnacles.



AMRIS

AT THE UNIVERSITY OF FLORIDA

Provides state-of-the-art instrumentation for high-resolution solution NMR, solid-state NMR, microimaging, animal imaging, and human imaging with eight spectrometer systems, including a 750 MHz wide bore, an 11.1 T/40 cm bore horizontal animal imaging magnet, and a 3 T human systems. Unique capabilities include National MagLab constructed probes for preclinical imaging at 17.6 T, triple resonance MAS experiments at 800 MHz, HTS cryoprobes with unparalleled mass sensitivity and a wide variety of coils for in vivo imaging and spectroscopy.

UNIQUE CAPABILITIES

11.1 T, 40 cm bore
17.6 T, 89 mm bore
1.5 mm HTS cryoprobe
5 T, 1.2 K DNP polarizer

Advanced Magnetic Resonance Imaging and Spectroscopy Facility

NMR Spectroscopy

NMR systems supporting spectroscopy of solution-state and solid-state samples are available from 500 to 800 MHz. Unique probes include a 1.5 mm, ^{13}C-optimized cryoprobe for mass-limited samples; a 10 mm ^{13}C, ^{31}P, ^{23}Na-optimized cryoprobe for perfusion and DNP studies; triple resonance Low-E MAS probes for biomolecular solid-state NMR applications; and a probe with gradients strengths up to 30 T/m for diffusion measurements in novel materials.

Imaging and MRI/S

Capabilities for imaging and diffusion measurements, on materials, in vitro cells, ex vivo tissue samples, and live animals, include MRI/S hardware for several nuclei (^{1}H, ^{2}H, ^{13}C, ^{19}F, ^{31}P) to characterize small animal biology; dissolution DNP for metabolic flux measurements and imaging metabolites; and microcoils coupled to strong planar gradients for imaging down to 10 µm resolution. Experiments are supported on horizontal bore 4.7 and 11.1 T systems as well as vertical bore 14.1 and 17.6 T systems.

DNP

A custom-built dissolution DNP polarizer is operating at 5 T/140 GHz/1.2 K. A range of RF inserts offer multinuclear capabilities for solid state studies of polarization dynamics and support in-vivo metabolic studies via MRI/S on 4.7 and 11.1 T scanners. A 3.35 T/95 GHz/1.2 K Hypersense polarizer is available for metabolic flux measurements on two 600 MHz NMR systems. Available perfusion probes include a 10 mm Cryoprobe, and both 15mm and 20 mm room temperature probes.

NMR Probes

The National MagLab supports an NMR probe development program with pioneering low electric-field (Low-E) probes for solid-state NMR applications featuring reduced sample heating, homogeneous B_1 fields, high S/N, and reproducible performance across samples with varying dielectric properties. Solution-state NMR cryoprobes, utilizing inductively-coupled, high-temperature superconducting coils, enable ground-breaking sensitivity for ^{13}C detected NMR measurements using 30 µl sample volumes. A 5 mm 800 MHz cryoprobe is also available for metabolic and protein analysis.

MRI Coils

Coils, ranging from 50 µm ID for excised tissue imaging to a 79 mm ID for rat whole body imaging, are integrated with gradients of up to 1.5 T/m for routine applications. The probes come with modular animal cradles and support features, such as heated water lines, anesthesia, and physiology monitoring, to ensure the well-being of the animals during imaging and to enable accurate and reproducible positioning. Coils ranging from 50-500 µm in size can be configured with a perfusion apparatus for imaging of live tissue slices. An annual RF coil workshop is offered to train users in building and testing RF coils tailored for specific frequencies and applications using the latest coil construction and testing methodologies, as well as designing and simulating their coils using CAD and electromagnetic simulation software.

HOW TO REQUEST MAGNET TIME

Our magnets are open to all scientists — free of charge — via a competitive process, and we accept proposals throughout the year.

1. **Prepare documentation**
   A proposal and prior results report are required.
2. **Create a user profile on NationalMagLab.org/request-magnet-time**
   Returning users simply need to log in.
3. **Submit a request**
   Upload files and provide details about the proposed experiment.

Read the User Policies & Procedures for complete guidelines or contact the AMRIS Facility: **AMRIS-info@magnet.fsu.edu**

DC FIELD

AT FLORIDA STATE UNIVERSITY

The strongest magnetic fields in the world, coupled with state-of-the-art instrumentation and experimental expertise.

UNIQUE CAPABILITIES

Max. Field Ranges:
- **Superconducting: 20 – 32 T**
- **Resistive: 25 – 41.5 T**
- **Hybrid: 36 - 45 T**

Bore: **32 – 50 mm**

Temperature: **0.02–1000 K**
Current: **100 fA–10 kA**
Voltage: **10 nV–1 kV**
Pressure: **0–10 GPa**

DC Field Facility

The capability to move your research to new levels awaits you at a dedicated user facility that offers users the unparalleled combination of the strongest, quietest, DC magnetic fields in the world, coupled with state-of-the-art instrumentation and experimental expertise.The MagLab DC Field Facility contains 16 resistive magnet cells multiplexed to a stable, quiet, high-precision 56 MW DC power supply including the world record 45 T hybrid magnet, which offers scientists the strongest continuous magnetic field in the world, the 36 T series connected hybrid magnet enabling NMR at 1.5 GHz and the 25 T Split Helix magnet that provides unmatched optical access & fields. The 32 T superconducting magnet provides high fields for very long periods of time in a low-noise environment. Rounding out the lineup are a number of superconducting magnets giving a wide range of magnet and sample environment combinations that enable research in high magnetic fields at temperatures from twenty millikelvin to a thousand kelvin.

Experimental Capabilities:

- Electrical Transport
- Surface Conductivity
- Heat Capacity
- Torque Magnetometry
- AC Susceptibility
- DC Susceptibility
- High Pressure
- Dielectric Measurements
- Microwave
- Dilatometry
- Surface Acoustic Wave Spectroscopy
- Resonant Ultrasound
- Pulse-Echo Ultrasound
- Raman Spectroscopy
- Ultra-Fast Magneto-Optics
- FIR Spectroscopy
- NMR
- EMR
- UV/Vis/NIR Magneto-Optics
- Ultra-Low Temperatures

DC Power System:

- 4 Power Supply Modules:14 MW – 700 V @ 20 kA ea
- Active Filter for Ripple Reduction
  - Transistor Passbank
  - 10-100 PPM Ripple
- 28 MW (8000 ton) Chiller Capacity
- 56 MW Heat Exchange Capacity
- 16.3 M Liter Chilled H_2O Storage

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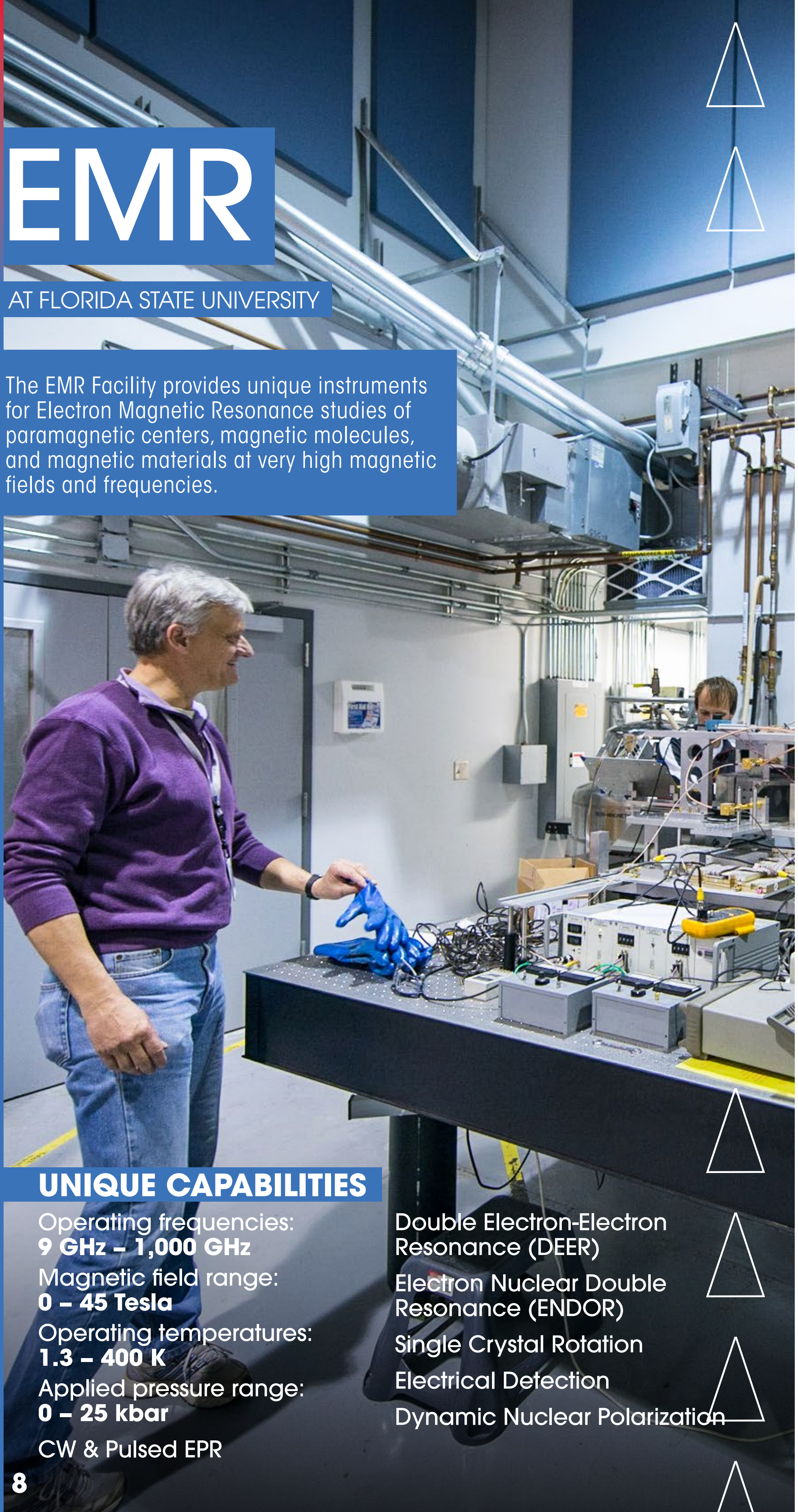

EMR

AT FLORIDA STATE UNIVERSITY

The EMR Facility provides unique instruments for Electron Magnetic Resonance studies of paramagnetic centers, magnetic molecules, and magnetic materials at very high magnetic fields and frequencies.

UNIQUE CAPABILITIES

Operating frequencies:
9 GHz – 1,000 GHz

Magnetic field range:
0 – 45 Tesla

Operating temperatures:
1.3 – 400 K

Applied pressure range:
0 – 25 kbar

CW & Pulsed EPR

Double Electron-Electron Resonance (DEER)

Electron Nuclear Double Resonance (ENDOR)

Single Crystal Rotation

Electrical Detection

Dynamic Nuclear Polarization

Electron Magnetic Resonance Facility

Anything with an unpaired electron

EMR stands for Electron Magnetic Resonance, which covers a variety of magnetic resonance techniques associated with the electron. The most popular of these techniques is Electron Paramagnetic/Spin Resonance (EPR/ESR), but also includes (Anti)Ferromagnetic Resonance (AFMR and FMR), as well as electron cyclotron resonance (CR). In simplified terms, EMR can be performed on any sample that has unpaired electron spins (or unfilled bands).

Applications across many disciplines

EMR has proven to be an indispensable tool in a large range of applications in physics, materials science, chemistry, and biology, including studies of impurity states, molecular clusters, antiferromagnetic, ferromagnetic and thin film compounds, natural or induced radicals, optically excited paramagnetic states, electron spin-based quantum information devices, transition-metal based catalysts; and for structural and dynamical studies of metallo-proteins, spin-labeled proteins, and other complex bio-molecules and their synthetic models.

Why high field?

High fields and frequencies provide high resolution, sensitivity, and access to high field phases in magnetic materials. They can address systems with large fine structure splittings, which occur in many compounds containing heavier elements such as transition metals, lanthanides, and actinides. EMR spectroscopy performed across a wide field range, and at multiple frequencies, allows users to independently constrain multiple interaction parameters that often define complex spin systems and structures.

A large variety of techniques

A wide range of frequencies up to 1,000 GHz is accessible for continuous-wave spin resonance. Pulsed EPR is available at high power at 95 GHz and lower power up to 395 GHz. Single crystal rotation, ENDOR, and electrical detection are all possible. Contact us for your specific needs.

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3 **Submit a request**
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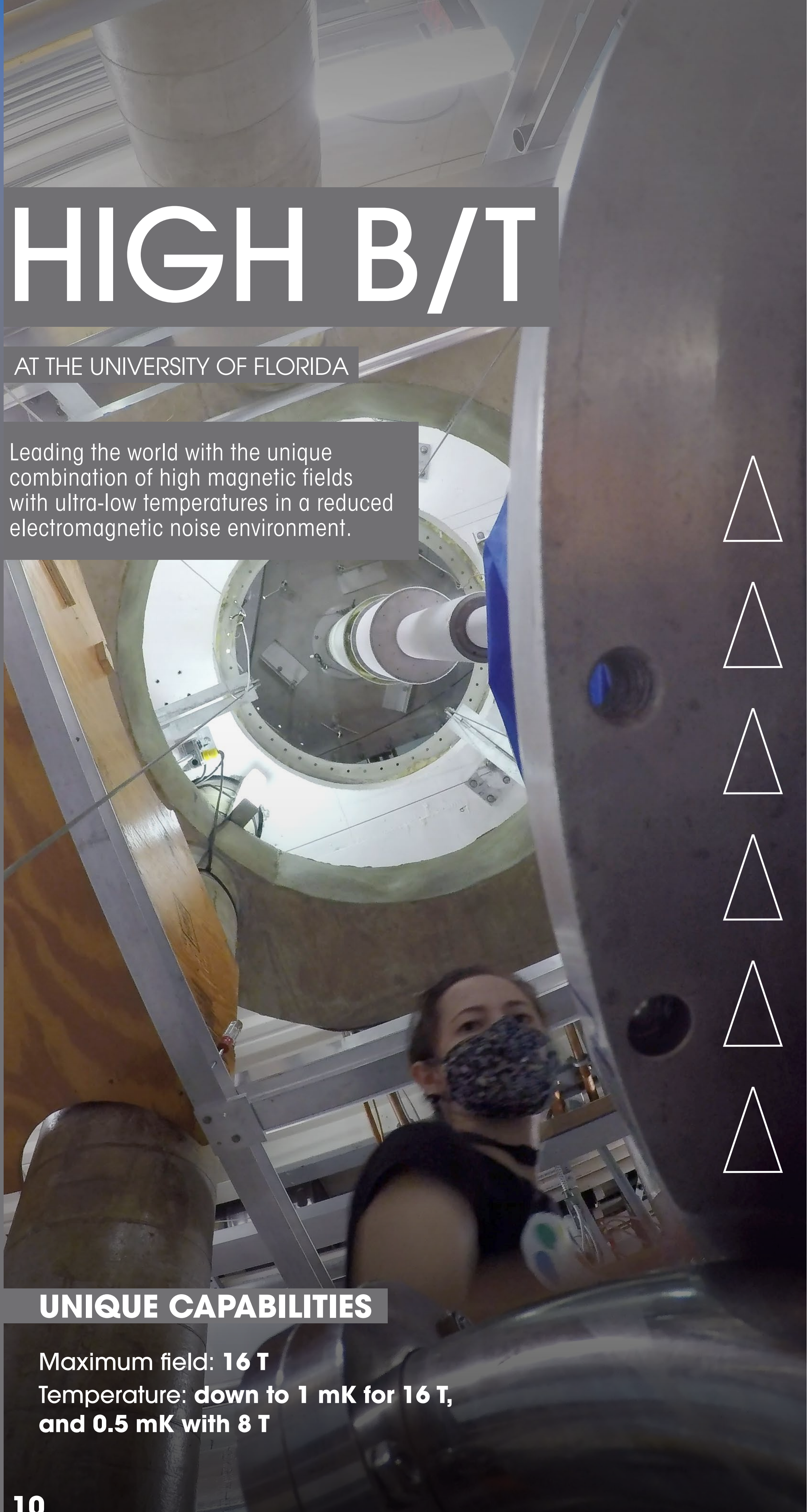
Read the User Policies & Procedures for complete guidelines or contact the EMR Facility: **EMR-info@magnet.fsu.edu**



HIGH B/T

AT THE UNIVERSITY OF FLORIDA

Leading the world with the unique combination of high magnetic fields with ultra-low temperatures in a reduced electromagnetic noise environment.

UNIQUE CAPABILITIES

Maximum field: **16 T**

Temperature: **down to 1 mK for 16 T, and 0.5 mK with 8 T**

High B/T Facility

Extreme experimental conditions

The mission of the High B/T facility is to support MagLab users in realizing challenging experiments at the combined extremes of sub-mK temperatures and high magnetic fields. In addition, the ultra-quiet electromagnetic environment required to reach these temperatures is ideal for highly sensitive low noise measurements. Two demagnetization cryostats are available to all qualified users, with no prior experience in magnetic refrigeration required.

A third system is presently being added to the instrument inventory. A "fast-turnaround" instrument, with minimum temperatures down to 10 mK and magnetic fields up to 16 T, is used to test experimental samples and cells before being transferred to one of the ultra-low temperature stations.

Local faculty and staff members assist users with planning and performing their measurements, which often require special adaptations to be compatible with these extreme conditions.

Measurement capabilities

Experimental capabilities include platforms for rotating samples at sub-mK temperatures, magnetic and dielectric susceptibility, transport studies, ultrasound measurements, and pulsed NMR spectrometry.

Refrigerator	Minimum Temperature	Maximum Field	Available Space
Bay 3, $PrNi_5$ + Cu Demag	1 mK	16 T	20 mm diameter
Bay 2, Cu Demag	0.5 mK	8 T	32 mm diameter
Bay 1 > *being designed/assembled – dry dilution refrigerator + demag stage specifications to be finalized*			
Fast-turnaround: Being Renovated/Relocated being renovated/relocated dilution refrigerator	10 mK	16 T	63 mm diameter

New probe/technique development

New probes and measurement techniques, e. g. thermal transport and specific heat, may be developed and made available to users, based on demand and feasibility. For example, enhanced magneto-caloric materials are being deployed for new "on-chip" low temperature and high magnetic field platforms for the study of quantum materials.

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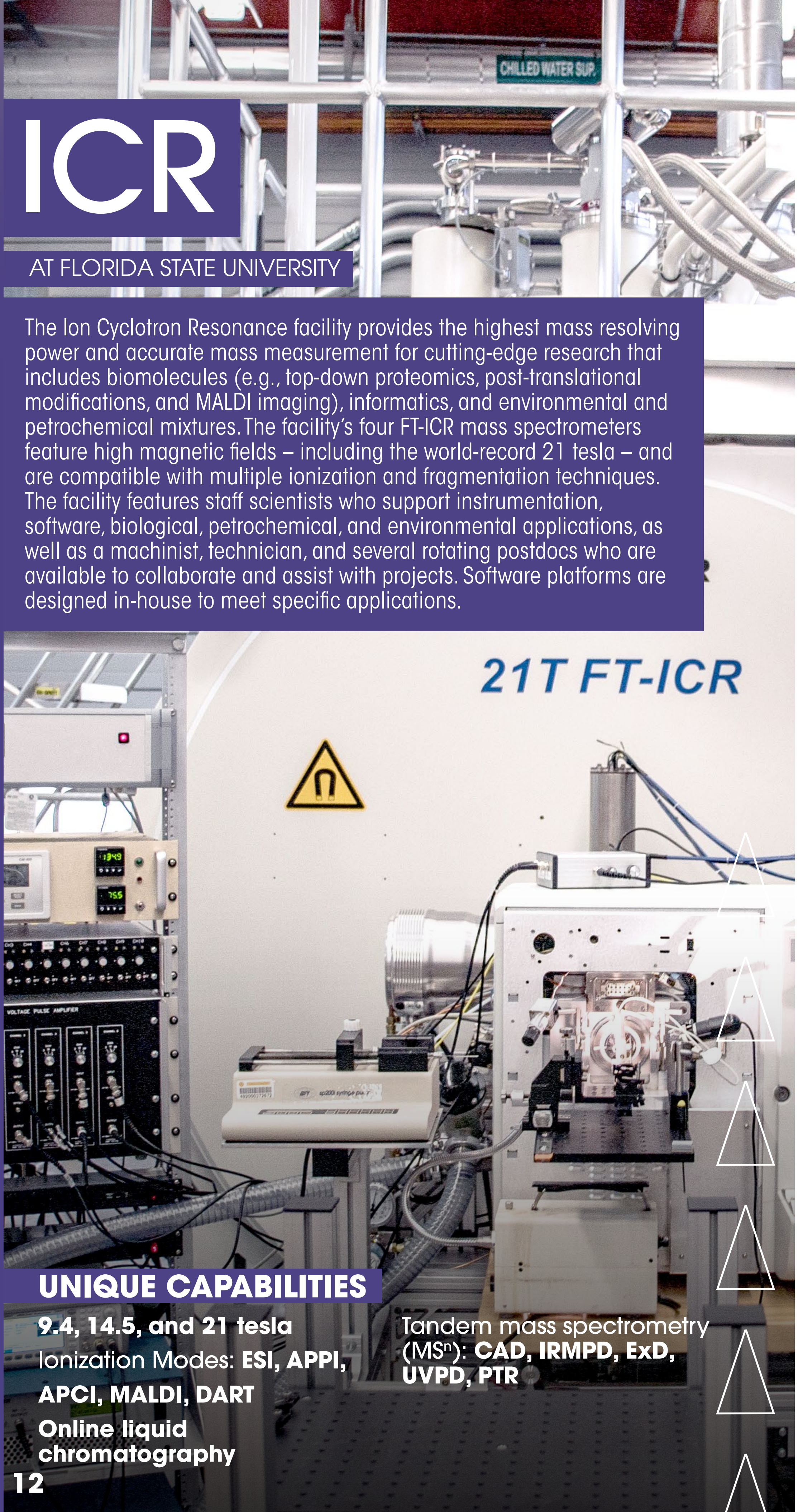

ICR

AT FLORIDA STATE UNIVERSITY

The Ion Cyclotron Resonance facility provides the highest mass resolving power and accurate mass measurement for cutting-edge research that includes biomolecules (e.g., top-down proteomics, post-translational modifications, and MALDI imaging), informatics, and environmental and petrochemical mixtures. The facility's four FT-ICR mass spectrometers feature high magnetic fields – including the world-record 21 tesla – and are compatible with multiple ionization and fragmentation techniques. The facility features staff scientists who support instrumentation, software, biological, petrochemical, and environmental applications, as well as a machinist, technician, and several rotating postdocs who are available to collaborate and assist with projects. Software platforms are designed in-house to meet specific applications.

UNIQUE CAPABILITIES

9.4, 14.5, and 21 tesla

Ionization Modes: **ESI, APPI, APCI, MALDI, DART**

Online liquid chromatography

Tandem mass spectrometry (MS^n): **CAD, IRMPD, ExD, UVPD, PTR**

Ion Cyclotron Resonance Facility

The 21 T Hybrid FT-ICR Mass Spectrometer

The combination of high magnetic field and strict control of the number of trapped ions results in external calibration broadband mass accuracy of better than 100 ppb rms, and resolving power greater than 600,000 ($m/\Delta m_{50\%}$ at m/z 400) is achieved at one mass spectrum per second. Novel ion storage optics and methodology increase the maximum number of trapped ions that can be delivered to and efficiently detected in the FT-ICR cell, thereby improving dynamic range for tandem mass spectrometry and complex mixture applications.

C. L. Hendrickson, et. al., 21 Tesla Fourier Transform Ion Cyclotron Resonance Mass Spectrometer: A National Resource for Ultrahigh Resolution Mass Analysis, *Journal of the American Society for Mass Spectrometry*, 26, 1626-1632 (2015).

14.5 T Hybrid FT-ICR Mass Spectrometer

The 14.5 T instrument is configured identically to the 21 T instrument, and provides external calibration broadband mass accuracy of better than 300 ppb rms, and resolving power greater than 400,000 ($m/\Delta m_{50\%}$ at m/z 400) is achieved at one mass spectrum per second.

T. M. Schaub, et. al., High Performance Mass Spectrometry: Fourier Transform Ion Cyclotron Resonance at 14.5 Tesla *Analytical Chemistry,* 80, 3985-3990 (2008).

9.4 T FT-ICR Mass Spectrometers

These two custom-built instruments are available for direct infusion applications, and to provide an optimized platform for future instrumentation development. The instruments are designed around custom vacuum chambers for improved ion optical alignment, minimized distance from the external ion trap to magnetic field center, and high conductance for effective differential pumping. One of the magnets has a 220 mm bore diameter that is ideal for instrumentation development.

N. K. Kaiser, et. al., A novel 9.4 tesla FTICR mass spectrometer with improved sensitivity, mass resolution, and mass range, Journal of the American Society for Mass Spectrometry 22, 1343-1351 (2011).

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Read the User Policies & Procedures for complete guidelines or contact the ICR Facility: **ICR-info@magnet.fsu.edu**

NMR

AT FLORIDA STATE UNIVERSITY

The NMR Facility features magnets and spectrometers operating up to 1.5 GHz, dynamic nuclear polarization NMR at 600 MHz, in vivo/ex vivo MRI at 900 MHz, and a wide array of in-house built probes.

UNIQUE CAPABILITIES

36 T SCH magnet for NMR at 1.5 GHz

In-house made probes (low-E, low-gamma, fast MAS)

600 MHz MAS DNP NMR

900 MHz ultra-wide bore NMR/MRI

Nuclear Magnetic Resonance and Magnetic Resonance Imaging Facility

14 NMR Spectrometers

There are 14 NMR spectrometers at the MagLab, ranging from the 36 T series connected hybrid (SCH) platform, to the 600 MHz dynamic nuclear polarization (DNP) NMR instrument, to the 900 MHz/105 mm bore magnet utilized for animal MRI, to an assortment of solid-state NMR (ssNMR) spectrometers operating at 900, 830, 800, 600, and 500 MHz and a solution NMR spectrometer (with a cryoprobe) at 800 MHz. These instruments are used for applications to biomolecular solids, materials, and a wide variety of chemical compounds, as well as for development of powerful new methods for enhancing signal and resolution in NMR spectra and MRI images.

NMR at 1.5 GHz: The Series Connected Hybrid (SCH)

The 36 T SCH is the highest-field NMR instrument in the world, operating at ^{1}H frequencies of 1.0, 1.2, and 1.5 GHz. It is equipped with a Bruker Avance NEO console, and has 1.3 mm HXY, 2.0 mm HCN low-E, and 3.2 HX (low-gamma) MAS and HX static (oriented sample) probes for ssNMR applications to biosolids and materials, with more probes under development.

Dynamic Nuclear Polarization (DNP) NMR at 600 MHz

Our 600 MHz DNP magic-angle spinning (MAS) NMR system features at 395 GHz gyrotron (connected via a quasioptical table) as its microwave source, a sweepable 14.1 T/89 mm magnet (±1.28 T), as well as a Bruker Avance III HD console and 3.2 mm HX DNP MAS probe. DNP NMR experiments operating at 100 K permit unprecedented gains in signal, allowing for studies of biological, organic, and inorganic materials that were thought to be impossible to probe with ssNMR. New 1.3 and 1.9 mm probes are also under development.

Magnetic Resonance Imaging (MRI) at 900 MHz

The 900 MHz/105 mm bore magnet, which was designed, built, and commissioned at the MagLab, is part of the highest-field MRI instrument in the world. Its large bore size allows imaging of small animals (up to 350 g). Probes and expertise at the MagLab allow not only for ^{1}H MRI/S, but MRI/S of other nuclei, including ^{19}F, ^{23}Na, ^{31}P, and ^{35}Cl.

Solid-State NMR from 500 to 900 MHz

Our fleet of mid- to high-field ssNMR spectrometers include one 500 MHz, two 600 MHz, two 800 MHz, one 830 MHz, and one 900 MHz platforms, with a cornucopia of double- and triple-channel MAS and static (oriented sample) probes for biosolids and materials NMR. This collection of instruments is used by hundreds of users annually, and provides great versatility for investigations requiring specialized tuning, low-E coils, low- or high-temperature operations, and fast MAS.

Probes

Key to the success of the NMR Facility is the in-house design, construction, and implementation of NMR and MRI probes. The NMR Technology Group designs probes for ssNMR (MAS, fast-MAS, oriented sample, etc.) and MRI, as well as design of RF circuits and coils for both routine and specialized applications, including probes that implement high-temperature superconducting (HTS) materials. As a result, our users have access to a dizzying array of experimental possibilities.

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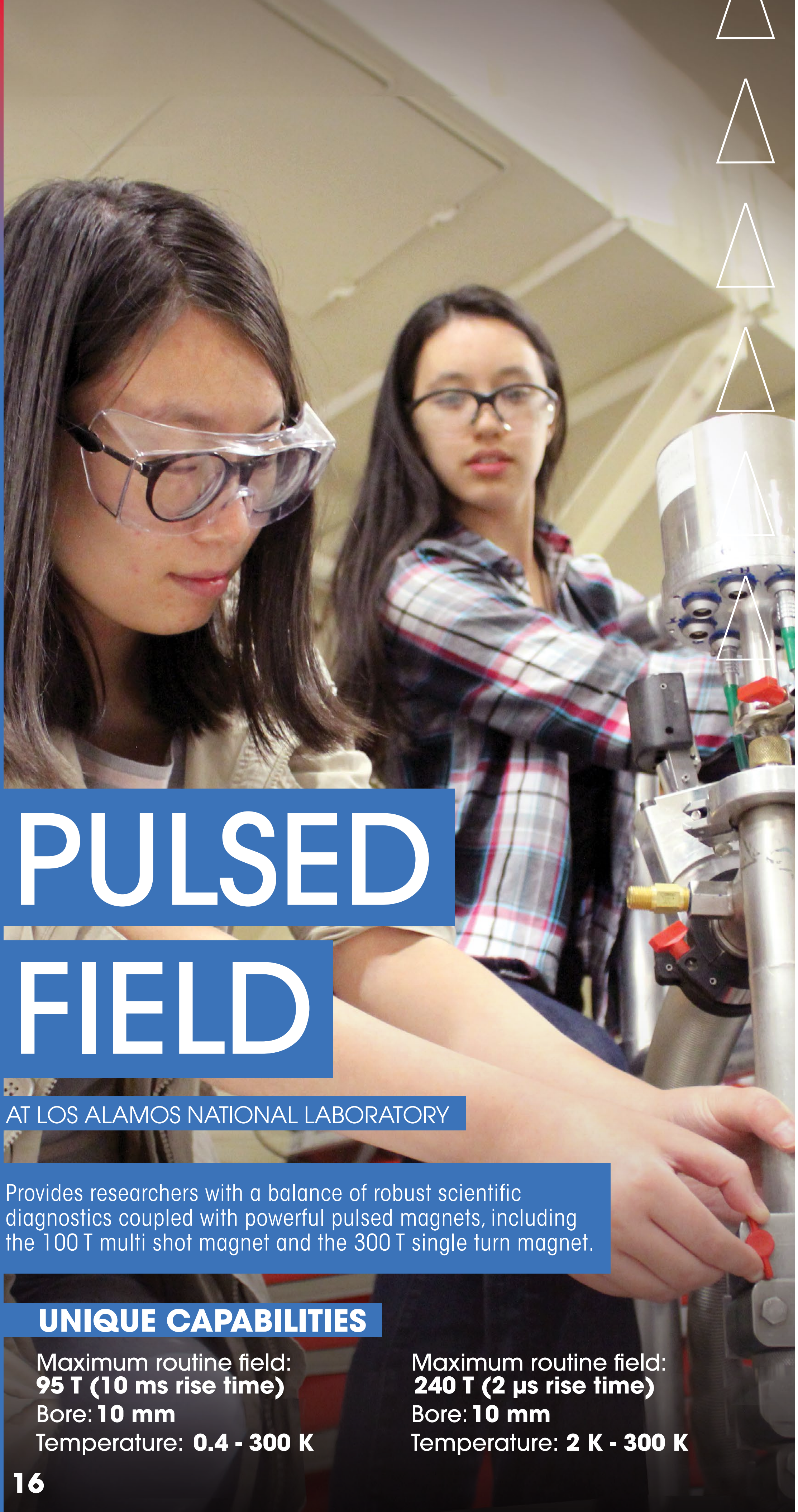
Read the User Policies & Procedures for complete guidelines or contact the NMR Facility: **NMR-info@magnet.fsu.edu**



PULSED FIELD

AT LOS ALAMOS NATIONAL LABORATORY

Provides researchers with a balance of robust scientific diagnostics coupled with powerful pulsed magnets, including the 100 T multi shot magnet and the 300 T single turn magnet.

UNIQUE CAPABILITIES

Maximum routine field:
95 T (10 ms rise time)
Bore: **10 mm**
Temperature: **0.4 - 300 K**

Maximum routine field:
240 T (2 μs rise time)
Bore: **10 mm**
Temperature: **2 K - 300 K**

Pulsed Field Facility

Overview

Scientific exploration of matter in extreme magnetic fields (> 45 T) is only possible by utilizing pulsed magnets. At the MagLab Pulsed Field Facility, located in New Mexico at the Los Alamos National Laboratory, we invite qualified researchers from all over the world to use our pulsed magnets, our state-of-the-art experimental techniques, and our staff's scientific expertise to advance their scientific discoveries. Our most utilized pulsed magnets are our four 65 T capacitor driven magnets; the results obtained from these magnets then lead many of our users to conduct experiments in 75 T, 100 T, or even 300 T magnet systems. For use in these magnet systems, we maintain an array of standard measurement techniques, as well as develop custom instrumentation as needed for a given user experiment.

Our World Leading Pulsed Magnets

- **Capacitor Bank Driven**
  65 T Short Pulse, 15 mm bore, 8 ms rise time
  75 T Duplex, 15 mm bore, 12 ms rise time
  300 T Single Turn, 10 mm bore, 2 μs rise time

- **Generator Driven**
  60 T Controlled Waveform, 35 mm bore
  100 T Multi-shot, 10 mm bore

Experimental Capabilities

- Electrical Conductivity, Resistivity, Hall Effect
- Heat Capacity
- RF Contactless Conductivity
- Pulse-Echo Ultrasound
- Cyclotron Resonance
- Pulsed IV and Jc
- Microwave Conductivity and Spectroscopy
- Electron Paramagnetic Resonance (EPR)
- Dilatometry, including Fiber Bragg
- Dielectric, Electric Polarization, and Multiferroic measurements
- Magnetometry, Compensated coil susceptometry, Extraction, and Torque
- Broadband absorption, reflection, and photoluminescence spectroscopy (300-1600 nm)
- Ultrafast pump-probe studies and time-domain THz spectroscopy (under development)
- Custom Measurement Development

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GUIDANCE FROM THE GROUND UP

OPPORTUNITIES FOR STUDENTS, POST-DOCS AND EARLY CAREER SCIENTISTS

The National MagLab supports the professional and career development of students and postdocs.

Research Experience for Undergrads (REU)

This summer internship lets undergraduates explore science at the extremes of magnetic fields, pressure, and temperature while working alongside some of the finest scientists, magnet designers, and engineers in the world.

MagLab User Summer School & Theory Winter School

These weeklong workshops help advanced graduate students, postdocs or early career theorists or experimentalists develop practical experience. User Summer School features hands-on tutorials on measurement techniques combined with practical exercises and expert talks to provide a full package of ways to broaden your skills. Theory Winter School offers lectures and poster presentations on subjects of continuing relevance in condensed matter and materials research theory. (available for Tallahassee facilities only).

Fellowships

FSU Physics Masters-to-PhD Bridge Program

This program helps talented students who lack preparation in some areas of undergraduate physics to transition into Florida State University's physics PhD program, or similar programs elsewhere in the United States. The program supports up to four Bridge Fellows each year. These fellows will initially be appointed as research interns at the National MagLab in the summer prior to enrollment in the physics graduate program.

The lab has two prestigious named fellowships - The **Crow Fellowship** and the **Dirac Fellowship** - which provide 2 year appointments for postdocs.

Connect with us on social media for updates and application information for these opportunities:
@NationalMagLab

FUNDING RESOURCES FOR USERS

Scientists who share the results of their experiments use our facilities for free. In addition, the MagLab offers several funding opportunities to assist with dependent care, travel, and other expenses.

First-Time User Fund

MagLab facilities are generally available to users without cost. To encourage new research activities, first-time PIs may request modest support for travel expenses (available for Tallahassee facilities only).
$1,000 for international users; $500 for domestic users
Discuss your request with the applicable facility director. There is no deadline.

Dependent Care Travel Grant

Subject to the availability of funding, the MagLab offers small grants of up to $800 for qualified, short-term dependent care expenses.

Visiting Scientist Program

This program provides greater access to our facilities and seeds research programs that advance the laboratory. Funding is principally to support travel and local expenses. Requests for stipends are considered but given a lower priority.

Learn more about these programs:
nationalmaglab.org/user-resources/funding-opportunities