LEBIT Service Level Description

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Revision History

Revision	Issued	Changes
R001	13 September 2024	Original Issue

Authorizing Document

None.

Authorized Documents

None.

Authorized Committees and Boards

None.

Named Program Roles

None.

Awareness Training

None.

Enabling Training

None.

1 Objective

This document describes the level of service FRIB will be able to provide for the operation of LEBIT and for user support for experiments with this scientific instrument.

2 Abbreviations

BOB: Beam Observation Box

FT-ICR: Fourier Transform Ion Cyclotron Resonance

LAS: Laser Ablation Ion Source

PI-ICR: Phase Imaging Ion Cyclotron Resonance

RFQ: Radiofrequency Quadrupole

SIPT: Single Ion Penning Trap

TOF-ICR: Time of Flight Ion Cyclotron Resonance

3 LEBIT Overview

LEBIT is a Penning trap mass spectrometry facility [1] designed for experiments using radioactive and stable beam beams produced by FRIB and/or local ion sources. The primary use of LEBIT is as a high-precision mass spectrometer for mass measurements of rare isotopes. Ion beams are cooled and bunched with an RFQ cooler/buncher [2]. Bunched ion beams can then be sent to one of two Penning trap mass spectrometers. One Penning trap [3] is located in a 9.4 T superconducting solenoid magnet where measurements can be performed with the TOF-ICR or PI-ICR techniques. The second superconducting solenoid, with a central field strength of 7 T, contains a Penning trap where mass measurements will be performed using the FT-ICR technique. This is the SIPT spectrometer, and it is currently under development [4] and not yet available for use. More details can be found in the listed references.

4 Standard Configuration

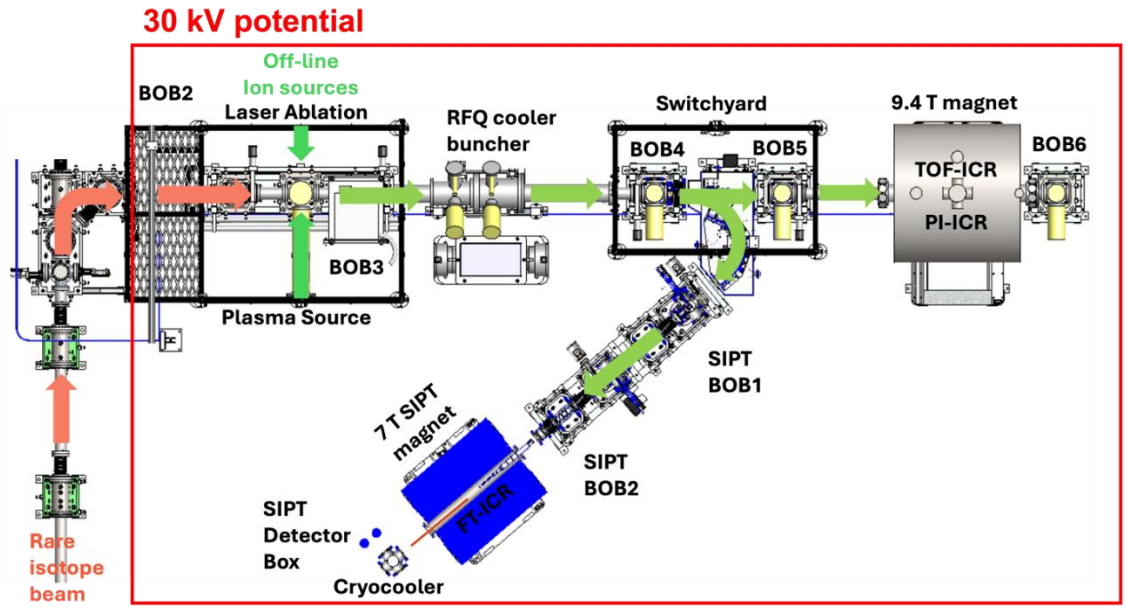

Figure 1 - Layout of the LEBIT facility.

4.1 Configuration and Operational Features

LEBIT, shown in Fig. 1, is located in room 1361A on a HV platform that is used to bias the facility up to 30 kV. Rare isotope ions are delivered from the beam stopping facility in N4. Ions are also available from two local ion sources, a plasma ion source for gaseous beams, and a laser ablation ion source (LAS) that can produce ions from an installed solid target. The local ion sources are useful in providing reference ions. Regardless of the source used, all ions are injected into the radiofrequency quadrupole (RFQ) cooler/buncher which is responsible for confining the ion beam while cooling it down via collisions with a helium buffer gas. The ions are collected at the end of the device in a potential well and released as pulses for efficient capture in the original 9.4 T Penning trap mass spectrometer.

LEBIT can currently be used to perform mass measurements using two different techniques: TOF-ICR and PI-ICR. It can also be used as an ultra-high-resolution mass separator to deliver purified beams to subsequent detector systems.

4.1.1 TOF-ICR Mode

TOF-ICR is the original technique developed for high-precision mass measurements of rare isotopes. It is easy to use, the resulting data is relatively simple to analyze, and it is the technique least susceptible to systematic effects. However, it is a destructive technique and is most susceptible to contaminant ions in the beam. This is the technique of choice if the beam purity is good, the half-life is greater than 100 ms, and the delivered rare isotope rate is greater than 1 pps.

4.1.2 PI-ICR Mode

PI-ICR is a relatively new technique that uses the position of the ions as they strike the detector to perform a mass measurement. It is able to achieve a higher precision than TOF-ICR for the same measurement time in the trap and is less susceptible to contaminant ions. PI-ICR is also a destructive technique and introduces more sources of systematic errors. Measurements take longer to set up than TOF-ICR and data analysis is more involved. This is the technique of choice if the desired precision can't be achieved with TOF-ICR due to short half-lives, if the rate of contaminant ions is too high for TOF-ICR, or if the delivered rare isotope rate is less than 1 pps.

4.1.3 Mass Separator Mode

LEBIT can be used as an ultra-high-resolution mass separator to purify beams for subsequent delivery to another end station installed after BOB6. This mode is typically used for delivery of isomerically purified beams. The beams are delivered with an energy of 30 keV/q. Multiple limitations apply and must be evaluated on a case-by-case basis (e.g., half-lives, required resolving power, purity levels, ion throughput, etc.). Due to the limited space available, each case needs to be evaluated to ensure that the end station can be accommodated.

4.2 Electronics and Data Acquisition

All electronics, controls, and data acquisition software to perform mass measurements and/or deliver purified beam to the final MCP detector in BOB6 will be provided and are the full responsibility of the LEBIT Instrument Scientist.

4.3 Analysis Software and Tools

Custom, gui-based, analysis software is available for TOF-ICR and PI-ICR. These software packages can be provided for off-line use upon request with no guarantee of support on personal or non-FRIB computers.

All LEBIT software is run from dedicated computers in Data-U3. The use of these computers is restricted to instrument and beam scientists, as well as trained users for some of the functionality. In standard configuration, these programs provide access to:

- Phoebus CSStudio tuning page for the interface between the d-line and LEBIT
- Slow control of LEBIT ion beam transport system and ion sources using LEBITCentralCommand software
- DAQ and LEBIT timing cycle control via Mass Measure software
- TOF-ICR resonance fitting using Eva software
- PI-ICR resonance fitting using PI-ICR Visualization GUI software
- Online mass analysis of TOF-ICR and PI-ICR data using SOMA software

4.4 Ancillary Systems

Ancillary detector systems can be installed after BOB6, if space allows. Integration with other control systems will be limited to receiving a timing signal indicating the time of ion ejection from the Penning trap. Since the LEBIT timing generator is on a HV platform, it is the responsibility of the experimenters to translate the TTL signal on HV to a signal that integrates with their system.

5 Instrument Support Level

5.1 Support by Instrument Scientist

FRIB provides support of LEBIT by an Instrument Scientist. Setup of the instrument will be coordinated by the Instrument Scientist. On-site support is normally available from 9 a.m. to 5 p.m. on working days. On-call support for critical technical assistance during the experiment can be requested by contacting the operator in charge (OIC), who will then make the decision to call the Instrument Scientist.

The Instrument Scientists responsible for LEBIT will provide the following support:

- Answer technical questions for users during the preparation of experiment proposals.
- Provide software packages necessary for using the LEBIT data acquisition system and performing data analysis.
- Ensure the proper functioning of the device as specified in the standard configuration.
- Perform device setting changes during the experiment as required by the experimenters.
- Provide support during the experiment to ensure proper functioning of the device.
- Assist users in inspecting and understanding the on-line data from LEBIT detectors.
- Assist users during the off-line analysis phase.

5.2 Additional Support

LEBIT Instrument Scientists can train users to operate part of the LEBIT equipment. Training sessions are offered once per experiment, at a pre-arranged time with the experimenters. These trainings will be at a basic level and provide enough information to minimally operate the instrument. It is the responsibility of the user to assemble a collaboration that is capable of fully

executing the experiment to achieve the science goals. Offered training segments (with approximate training durations) include:

- Overview and operation of LEBIT ion transport system (2 hours)
- Operation of local ion sources (2 hours)
- Setting up and running scans using Mass Measure (2 hours)
- Performing systematic checks to verify mass precision (1/2 day)
- Fitting and online data analysis (1 hours)

6 Instrument Specific User Responsibilities

The LEBIT users follow the FRIB Roles and Responsibilities of Scientific Users document [1]. In more detail, the FRIB expectations for LEBIT users are:

- Taking the leading role during the preparation and running phase of the experiment.
- Have sufficient training and a team in place to be able to operate LEBIT for their experiment
- Being responsible for the integrity and safety of their experimental system (if applicable).
- Informing the LEBIT Instrument Scientist about required beam properties and experimental setup prior to the first ERR.
- Responsible for timely identification of utilities and services needed for their experiment.
- Communicating pre- and post-experiment LEBIT space occupation duration.
- Communicating to the LEBIT Instrument Scientist an execution plan on or before the date of the final ERR.
- Communicating any incident to the Operator-in-Charge (OIC) and the LEBIT Instrument Scientist.
- Discussing changes of the experiment in a timely manner. Some requests may need to engage different system experts who may only be available during weekdays and normal business hours.
- Keeping the vault space allocated to the experiments tidy and leave the vault and Data-U space as found or better.
- Performing any desired systematic measurements to ensure device performance meets the requirements of the experiment.
- Providing targets or gases for local ion sources if any beam other than $^{39}K^{+}$ is required.
- Maintaining a pressure of <1E-6 Torr or better in their setup as needed for LEBIT Penning trap operation (if applicable).

6.1 Prior to Start of Experiment and During Setup

Every experiment will go through FRIB's multi-step Experiment Readiness Review (ERR) process [2]. The LEBIT Instrument Scientist will meet with the users prior to the first ERR to prepare for it. Required resources other than those already stated in the approved proposal need to be identified by the user at this time. Resources available for the preparation and the setup of an experiment include:

- Mechanical design support
- Installation and alignment support
- Vacuum support including leak checking
- Electric and plumbing work
- Data Acquisition Support for user-owned instrumentation (if applicable) [3]

- Control system support for archiving of process variables (e.g. Faraday cup readings)

Before the start of the experiment, the LEBIT Instrument Scientist will meet with the user to develop an operations plan which will include the vault access, the expected tuning time to experiment and any beam changes planned. The spokesperson is responsible for developing a shift schedule with at least two people on shift at any time. The experimenters on shift must possess the ability to execute the experiment.

6.2 During Experiment

A pilot beam will be tuned to LEBIT through the cooler/buncher in DC mode and placed on the Faraday cup immediately after the cooler/buncher, at which point the user will take control of the beam. Any questions specifically regarding LEBIT during the experiment should be directed to the LEBIT Instrument Scientist.

6.3 After Experiment

After the conclusion of an experiment, the users are obliged to remove any ancillary equipment from 1361A in the previously agreed upon timeline. Data will be transferred to the spokesperson and also maintained by the LEBIT Instrument Scientist.

7 Additional Instrument Support Not Covered in this Service Level Description

Any request for support not covered in this service level description must be submitted to the FRIB Manager for User Relations prior to the submission of an experiment proposal for pre-approval.

Appendix

[1] Roles and Responsibilities of the Scientific Users, FRIB-S30206-PG-000028

[2] FRIB Experiment Readiness Review Program, FRIB-S30206-PG-000033

[3] Scientific Data Acquisition Service Level Description, FRIB-S30206-RC-008646