BROOKHAVEN NATIONAL LABORATORY
PROPOSAL INFORMATION QUESTIONNAIRE
LABORATORY DIRECTED RESEARCH AND DEVELOPMENT PROGRAM

PRINCIPAL INVESTIGATOR	**Masahiro Okamura**	**PHONE**	**x3577**
DEPARTMENT/DIVISION	**CAD - NPP**	**DATE**	**June 17, 2021**
OTHER INVESTIGATORS	**Sergey Kondraschev**		
TITLE OF PROPOSAL	**Development of ECRIS for 211Astatine production**		
TYPE A			
PROPOSAL TERM (month/year)	From **Oct. 2021**	Through **Sep. 2024**	

SUMMARY OF PROPOSAL

Description of Project: To modernize BNL's medical isotope production capability, one of the most critical accelerator devices is the ion source. To upgrade the isotope producer facility, the beam energy, current and number of beam species needs to be expanded. For the beam energy upgrade, we already have well-established technologies including a high duty factor linear accelerator. However, to increase the beam current and provide additional ion species, a new ion source needs to be developed.

One of the important needs in the country is the production of radioactive astatine, ^{211}At, which emits alpha particles that can kill cancer cells. The primary method to produce ^{211}At is the reaction ^{209}Bi(^{4}He, 2n)^{211}At, which requires an intense He beam. The half-life of ^{211}At is only 7.2 hours and such a short half-life makes it very difficult to deliver ^{211}At throughout the country. To overcome this difficulty, an alternative way to provide ^{211}At to the patient is to use ^{209}Bi(^{7}Li, 5n)^{211}Rn and the ^{211}Rn/^{211}At generator. The half-life of ^{211}Rn is 14.6 hours, which allows the distribution of ^{211}At to many more medical facilities. This requires a high-power Li beam.

At the C-AD we have a number of world-class ion sources including EBIS, LIS, OPPIS and H- source. However, these sources cannot produce high-duty factor lithium-ion beams. The most suitable ion source type for this purpose is an Electron Cyclotron Resonance Ion Source (ECRIS), which can be operated in continuous wave (CW) mode. The design and production of a state-of-the-art ECRIS can be done at C-AD, but, presently, there is no high current ECRIS to provide Li^{3+} beam in the world. Since lithium is a chemically very active material and may induce corrosion in the interior of a plasma chamber, research on Li ECRIS is needed.

The objective of the project is to build a prototype ECRIS, which will supply fully stripped intense lithium and helium beams.

Expected Results: We use a variable frequency Traveling Wave Tube Amplifier (TWTA) as a microwave source with a compact plasma chamber. Then the beam performance and long-term operational stability will be examined. The accumulated knowledge and technologies will enable us to build a milliampere class ECRIS. This is a critical component for a BNL proposal for a large transformative isotope production facility at BNL with an estimated cost of several hundred million dollars.

PROPOSAL

1. Background

- Intense He and Li beams are needed to produce Astatine which is an alpha emitter.
- Ion source is a key device to realize a new medical isotope facility at BNL.
- ECRIS is the most suitable ion source for the facility. We have world-class ion sources but no ECRIS.
- Lithium is a chemically active material. Handling of lithium must be established.
- To provide an intense and stable Li^{3+} beam, a prototype study is indispensable.

Astatine-211 (^{211}At) is a very useful radioactive substance that can be used in alpha emitter radiation therapy to kill cancer cells (ref. 1, 2). The radioactive substance is injected into a vein, travels through the blood, and collects in certain tissues in the body, such as areas of bone with cancer. This type of radiation may cause less damage to nearby healthy tissue. At BNL, we have produced medical isotopes for the nations using the 200 MeV proton linear accelerator. However, to fulfill future demands including At^{211}alpha emitters, more versatile ion beams are demanded.

To produce ^{211}At, a bismuth target is irradiated by a helium ion beam. The reaction is shown in Fig. 1. The half-life of ^{211}At is only 7.2 hours. Although ^{211}At decays steeply, a few hours may be required to process the irradiated bismuth target and then the delivery time is not negligible as well. To overcome the short half-life issue, an alternative reaction is proposed. Instead of helium beam, lithium beam is used as a driver beam and ^{211}Rn is created (ref. 3). ^{211}Rn decays to ^{211}At and its half-life is 14.6 hours. This relatively long half-life is useful so that the astatine produced in the new facility can be delivered to a wider area. For these reactions, we must have a new linear accelerator that can deliver intense both helium and lithium beams at BNL. To build a new facility, the most challenging device is the ion source. Research on high-duty-factor linear accelerators has been vigorously carried out, and the technology for their fabrication is already well established. However, an ion source capable of generating reliable, high-power lithium ions at a high duty factor has not yet been realized. Therefore, the development of a new type of ion source is necessary.

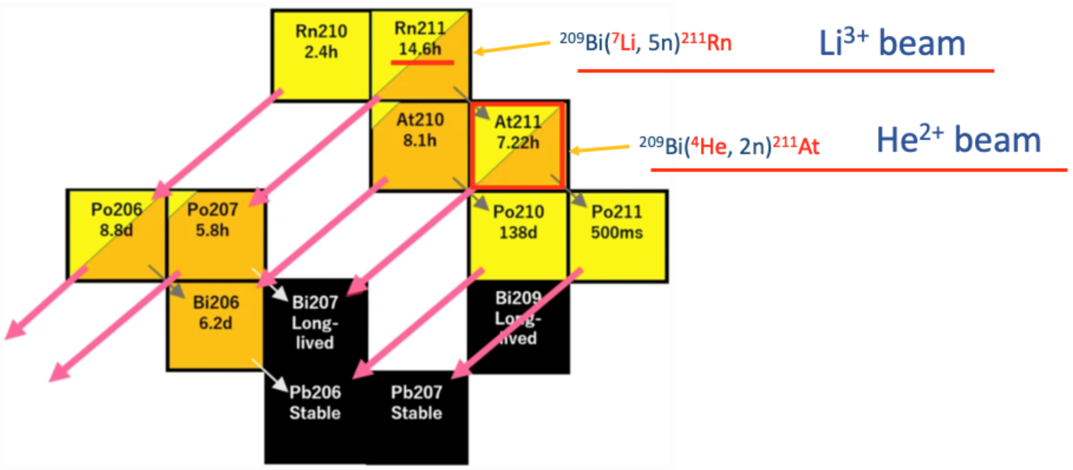


Figure 1 Nuclear chart and decay processes related to ^{211}Rn and ^{211}At.

At the CAD, several world-leading powerful ion sources are in operation. However, all those ion sources were developed to deliver beams to the synchrotron complex. The most upstream synchrotron is the booster ring, which can only accept less than a few tens microseconds of the injected beam pulse length. Only the magnetron ion source can provide a longer pulse since it is used for the BLIP. However, it cannot provide high charge state ion beams. To meet all the requirements for the new isotope facility, an electron cyclotron resonance ion source (ECRIS) has to be developed. The characteristics of the existing ion sources and an ECRIS were shown in Table 1. Thermal surface ion sources are often used to provide lithium beams, but they can only provide a single charged beam and are not applicable to medical isotope facilities (ref. 4)

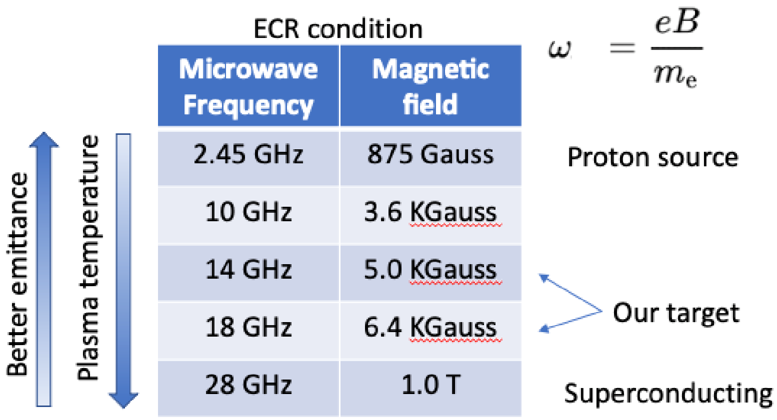
Table 1 Characteristics of ion sources at CAD

	Li^{3+} capability	He^{2+} capability	High current	CW like operation
EBIS	✓	✓		
LIS	✓		✓	
OPPIS				
H^- magnetron			✓	
ECRIS	✓	✓	✓	✓

2. Basics of ECRIS

The first ECRIS to produce multicharged heavy ion beams were reported in the early 1970's by Geller (ref. 5) and Jaeger (ref. 6). Since then, many cyclotron-based laboratories have put a great deal of effort into the development of ECRIS. The structure of the present high performance ECRIS is essentially same as the ion source built in the 1970's. The improvement of the ion source performance in the last three decades was mainly due to the understanding of the ECR plasma and use of modern technology (i.e., superconducting magnet, permanent magnet technology). Especially in the last decade, key components of the ECRIS (magnetic field configuration, gas pressure, chamber size) have been investigated and the total performance of state-of-the-art ECRIS is dramatically improved. We can use those accumulated knowledges to the project.

Electron cyclotron resonance (ECR) is a phenomenon observed when the frequency of incident radiation of a microwave coincides with the natural frequency of rotation of electrons in magnetic fields. A free electron in a static and uniform magnetic field will move in a circle due to the Lorentz force. The angular frequency ($\omega = 2\pi f$) of this cyclotron motion for a given magnetic field strength B is given by $\omega = eB/m$, where e and m are the electron's charge and mass respectively. By increasing the microwave frequency, electron's velocity increases and higher plasma temperature is achieved and accordingly a higher magnetic field is required. However, above 28 GHz, a superconducting magnet is required, and this regime is typically used for very heavy ion production (ref. 7). For our proposal, a range from 14 GHz to 18 GHz are appropriate. This relationship is summarized in Fig. 2.



ECR condition

$$\omega = \frac{eB}{m_e}$$

Microwave Frequency	Magnetic field
2.45 GHz	875 Gauss
10 GHz	3.6 KGauss
14 GHz	5.0 KGauss
18 GHz	6.4 KGauss
28 GHz	1.0 T

Figure 2 Relationship between microwave frequency and magnetic field.

To confine a high-temperature plasma, hot electrons are confined by three-dimensional mirror field barriers. Electrons are bounced back when they move from weak to strong magnetic field regions. For axial confinement, two solenoids are used. To confine the radial direction, a multipole cusp field is used. The confined volume is called as ECR zone and ions are stripped by hot electrons and became high charge states. At one of the axial ends of the ECR zone, a beam extraction electrode is placed. On another side of the zone, typically microwave and gas are fed. To achieve a good performance of an ECRIS, the magnetic field distribution is a very important factor.

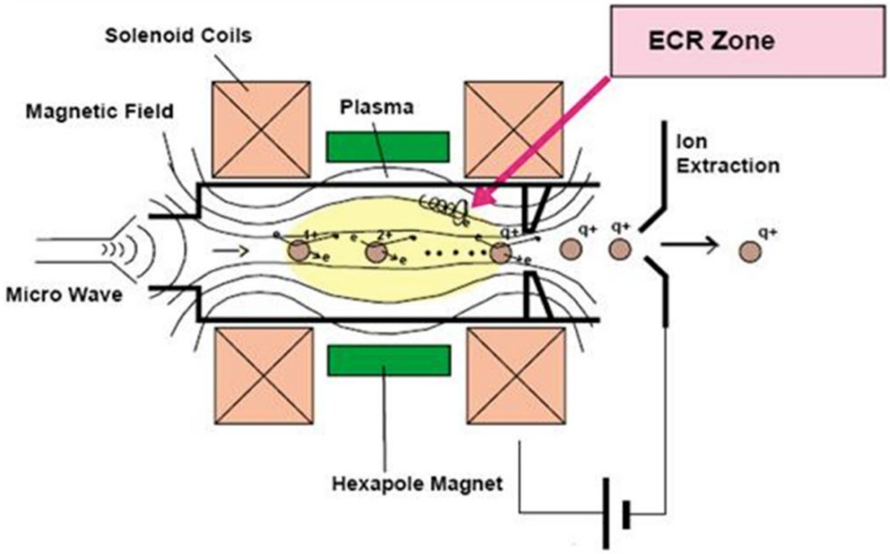


Figure 3 Schematic view of ECRIS.

3. Project Objectives

The objective of the project is to build a prototype ECRIS which will supply sub-milliampere fully stripped lithium beam and intense helium beams. Also, we will establish lithium vapor production scheme for the robust operation. Through this process, possible problems and areas for improvement will be identified. The results and design parameters of the prototype will be essential information to fabricate milliampere class ECRIS for the BNL's future isotope facility.

4. Proposed Research and Methods

At the beginning of the project, we will develop the optimal concept of a prototype ECRIS capable to generate sub-milliampere of a fully stripped lithium beam. The optimization will include a choice of rf frequency (from 14 GHz to 18 GHz), plasma chamber volume, and magnetic system structure to generate high beam intensity. A higher rf frequency provides a higher beam current, and the expected gain is up to 50%. At the same time, a higher rf frequency requires a more complicated magnetic system. The microwave output device that we plan to procure is shown in Fig. 4. As another knob, we can put a higher microwave power to increase the beam current. Generally, an ion output rises linearly with increasing of the fed power, which can be increased to several kW. Accordingly, a large size plasma

Parameters	XTD-750DBSL	XTD-750DBS
FREQUENCY RANGE (extended frequency coverage available)	17.3 to 18.1 GHz (optional 17.3 to 18.4 GHz)	
OUTPUT POWER		
Traveling Wave Tube	750 W (58.8 dBm) Peak [illegible] CW max.	750 W (58.8 dBm) CW
Rated Power at Amplifier Flange	[illegible]	[illegible]

Figure 4 18GHz traveling wave tube amplifier, TWTA.

volume will be required which needs larger size magnets. We also investigate magnet type, permanent or electric. A permanent base magnetic system will reduce the construction cost and simplify the operation. However, a typical strong magnet, which is $Nd_2Fe_{14}B$, will be degraded by heat. It will be important for us to develop a clever insulation structure since the plasma gives off significant heat. In addition, the design of beam extraction electrodes will be studied.

The most challenging component of high intensity Li^{3+} ECRIS is the lithium vapor supplier into the plasma chamber. A high temperature oven inserted into the chamber (ref. 8) is widely used, however this scheme may not provide enough lithium vapor. The development of a reliable lithium supply subsystem is crucial for project success. We will develop dedicated system which consists of lithium evaporation chamber, lithium vapor transfer line, special leak valve for precise control of lithium vapor pressure in the plasma chamber at the level 10^{-8} Torr. All parts of the subsystem should be kept at above 200 ºC. Also, we will examine laser ablation of lithium in the chamber. This may be able to simplify the lithium supply system. A vapor pressure curve and the lithium supply systems are shown in Fig. 5. The Another challenge is related to the high chemical activity of lithium, so only special materials should be used everywhere including the leak valve. Development of custom leak valve may be required. Temperature of interior wall of the plasma chamber should be also elevated above a certain temperature to prevent sticking of lithium atoms before being ionized. When we use a permanent hexapole cusp magnet, the thermal insulation needs to be analyzed closely. Initial vacuum at the level of 10^{-8} Torr should be established inside hot plasma chamber.

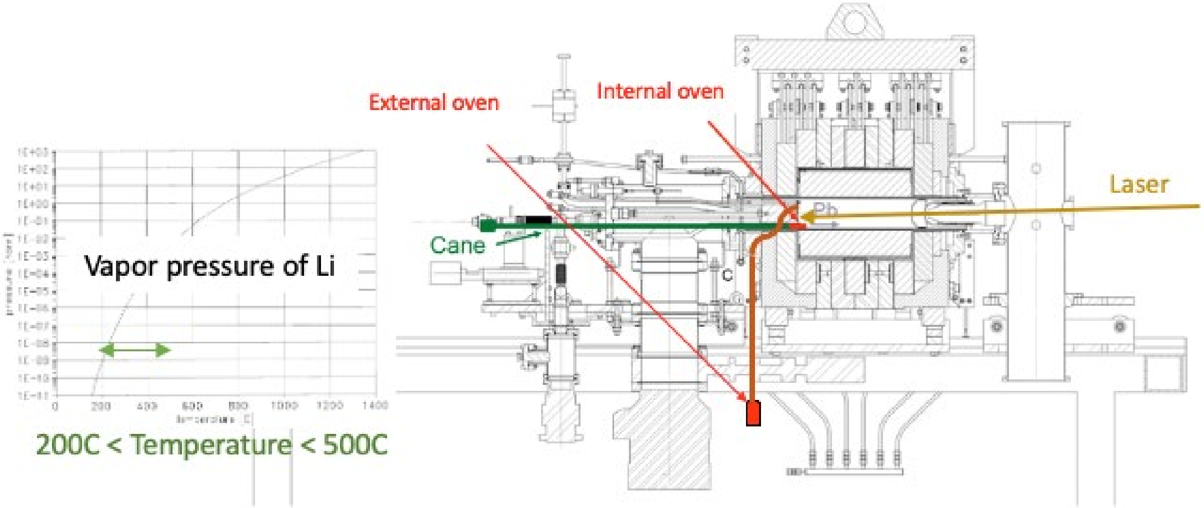


Figure 5 Lithium vapor pressure and possible vapor suppliers.

Later in the project, a test bench for high current Li^{3+} ECRIS characterization and optimization will be designed and build. It consists of high voltage isolation platform, ion beam optics elements and a large aperture analyzing magnet. Diagnostics system will include two large aperture Faraday cups, two scintillator-based ion beam viewers, and a pepper-pot emittance probe. We will measure both the total ion current extracted from ECRIS and the current of Li^{3+} ion beam downstream of the analyzing magnet. Li^{3+} ion beam current will be optimized adjusting available physical parameters. Transverse profiles and emittances of both total ion beam extracted from ECRIS and Li^{3+} ion beam downstream of analyzing magnet will be measured. Most of the equipment for the ECRIS test bench including analyzing magnet and ion beam diagnostics will be re-used from other our group projects.

The results obtained will allow us to design ECRIS capable generate one milliampere beam of fully stripped lithium ions and multi milliampere helium ions for 211At production.

5. Timetable of Activities

First Year Deliverables:

1) Selection of microwave frequency and plasma chamber volume of the prototype for high current Li^{3+} ion beam generation
2) Design of lithium vapor production and supply sub-system
3) Assembling, testing and optimization of lithium vapor production and supply sub-system
   Milestone 1: completion of lithium vapor system
4) Procurement of ECRIS microwave components – TWTA, stub tuners, wave guide
   Milestone 2: Test of the microwave component

Second Year Deliverables:

1) Design of magnet assembly
2) Fabrication of magnetic system
   Milestone 1: Measuring field of the magnet assembly
3) Design of the prototype ECRIS
4) Assembling of prototype ECRIS for high current Li^{3+} ion beam generation, plasma ignition and optimization
   Milestone 2: The first ignition of a plasma
5) Design of prototype ECRIS test bench.

Third Year Deliverables:

1) Assembling of prototype ECRIS test bench
2) Li^{3+} ion beam testing and optimization
   Milestone 1: The first helium beam from the prototype ECRIS
   Milestone 2: The first lithium beam from the prototype ECRIS
3) Principal design of ECRIS capable to generate one milliampere beam of fully striped lithium ions for ^{211}At production.
   Milestone 3: Design of milliampere class ECRIS for the isotope facility

References

1. Michael R. Zalutsky, David A. Reardon, Gamal Akabani, R. Edward Coleman, Allan H. Friedman, Henry S. Friedman, Roger E. McLendon, Terence Z. Wong and Darell D. Bigner, Journal of Nuclear Medicine January 2008, 49 (1) 30-38
2. Sture Lindegren, Per Albertsson, Tom Bäck, Holger Jensen, Stig Palm, and Emma Aneheim, Cancer Biotherapy & RadiopharmaceuticalsVol. 35, No. 6
3. Eita Maeda, Akihiko Yokoyama, Takumi Taniguchi, Kohshin Washiyama, Ichiro Nishinaka, Journal of Radioanalytical and Nuclear Chemistry (2020) 323:921–926
4. R. Sah, M. Neubauer, A. Dudas, J.W. Kwan, Proceeding of IPAC'10, THPEC074 (2010)
5. S. Bliani, R. Geller, W. Hess, B. Jacquot and C. Jacquot, IEEE Transactions on Nuclear Science, vol. 19, no. 2, pp. 200-203, April 1972
6. F. JAEGER, A. J. LICHTENBERG, M. A. LIEBERMA, Plasma Physics, Vol. 14, pp. 1073 to 1100 (1972)
7. C. Lyneis, D. Leitner, M. Leitner, C. Taylor, S. Abbott, Review of Scientific Instruments 81, 02A201 (2010)
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ONE-PAGE VITA FOR EACH INVESTIGATOR

Dr. Masahiro Okamura

In 1995, I obtained PhD at Tokyo Institute of Technology and my thesis was "Design and fabrication of high efficiency radio frequency quadrupole,". As a post doc, I started to work on polarized proton beam acceleration in AGS and simulation work on Siberian Snake magnet for RHIC. It was the first attempt to fully analyze three definitional magnetic field of the helical dipole magnet. Simultaneously, I had designed low energy beam transport line for the RHIC optically pumped polarized ion source (OPPIS), which was commissioned in 1999. Then, I joined RIKEN in Japan to study laser ion source and invented ultra-high brightness heavy ion beam production method called 'direct plasma injection scheme." In parallel, I designed and fabricated a normal conducting Siberian Snake magnet in RIKEN and brought it to BNL. In 2006 I moved to CAD of BNL and joined electron beam ion source (EBIS) project and was responsible to commission the EBIS linear accelerators. Since 2010, I was PI of laser ion source development for NASA Space Radiation Laboratory (NSRL). In 2012, tenure appointment was granted. Since 2017 I'm leading Source group of CAD which is responsible to generate and accelerate heavy ion beams using a LIS, EBIS, RFQ and drift tube linear accelerator. Brightness Award was given for the invention of the DPIS in 2011 and Science and Technology Award on BNL was granted for the development of laser ion sources.

Education and Training:

Ph.D.	Degree of Ph.D. in Nuclear Engineering, 1995 Graduate School of Science and Engineering, Tokyo Institute of Technology, Tokyo, Japan Thesis Title: "Design and fabrication of high efficiency radio frequency quadrupole"
Post Doc.	Radiation Laboratory of RIKEN Apr./1995 to Apr./1998 Design of Siberian Snake magnet for RHIC Polarized beam acceleration at AGS

Research and Professional Experience:

Contract Researcher at RI-beam Factory Project	Oct./1998 to Jan./1999
Tenure Researcher	Jan./1999 to Aug./2006
RIKEN, Saitama, Japan	

Physicist	Aug. 2006-present
Tenure appointment	Dec. 2012-present

Collider-Accelerator Department
Brookhaven National Laboratory, Upton, NY

- Development of laser ion source.
- Commissioning of EBIS linacs.

M. Okamura, E. Beebe, S. Ikeda, T. Kanesue, D. Raparia, L. Muench, T. Karino, H. Haba, **^{96}Zr beam production for isobar experiment in relativistic heavy ion collider,** Review of Scientific Instruments 9, 013319 (2020)

S. Kondrashev, E. Beebe, T. Kanesue, M. Okamura, J. Ritter, R. Scott, **Design of target irradiation and diagnostic chamber to study ps-laser generated plasma as a source of singly charged ions for external injection into an electron beam ion source**, Review of Scientific Instruments 9, 023320 (2020)

118 refereed journal papers have been published.

BROOKHAVEN NATIONAL LABORATORY
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Dr. Sergey Kondrashev

Education

Ph.D. Plasma Physics and Chemistry, 1992
Moscow Engineering Physics Institute (MEPhI), Moscow, Russia
Research Advisor: Profs. Yuri A. Bykovskii and Dmitri G. Koshkarev
Thesis Title: "Ion Emission under Laser Radiation Impact on Anode of a Vacuum Diode"

M.S. Solid State Physics, with Highest Honors, 1986
Moscow Engineering Physics Institute (MEPhI), Moscow, Russia
Research Advisor: Yuri P. Kozurev

Research and professional Experience

Physicist February 2017- present
Collider Accelerator Department
Brookhaven National Laboratory, Upton, NY
- Development and operation of high intensity Electron Beam Ion Source (EBIS)

Research Fellow November 2015-February 2017
Rare Isotope Science Project
Institute for Basic Science, Daejeon, Republic of Korea
- Development and commissioning of Electron Beam Ion Source (EBIS) charge breeder

Physicist May 2015-October 2015
GSI Helmholtz Centre for Heavy Ion Research, Darmstadt, Germany
- Research and development on 28 GHz superconducting Electron Cyclotron Resonance (ECR) ion source

Scientific Consultant October 2014–April 2015
Far-Tech, Inc., San Diego, CA
- Consultation on physics and technology of Electron Beam Ion Sources (EBIS)

Visiting Scientist, Accelerator Physicist 2006-September 2014
Argonne National Laboratory, Physics Division, Argonne, IL
- Project Scientist responsible for specification, design, and commissioning of Californium Rare Isotope Breeder Upgrade (CARIBU) Electron Beam Ion Source (EBIS) charge breeder
- Development of emittance meter for stable and radioactive ion beams
- Contribution to Measurement of Actinide Neutron Transmutation Rates (MANTRA) project with responsibility for specification of laser ablation technique into Electron Cyclotron Resonance ion source
- Experimental demonstration of a two-charge state low energy beam transport line
- Study of emittance of different ion species extracted from an Electron Cyclotron Resonance (ECR) ion source

Engineer, Scientist, Senior Scientist 1986-2006
Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia
- Development of methods and apparatuses for particle and x-ray diagnostics of laser-produced plasma
- Study of ion emission from the diode with laser-produced plasma anode (as a result, a new method of generation of intense beams of molecular and cluster ions has been proposed and tested).
- Self-consistent approach to specification of laser ion source parameters was developed and applied
- Specification of laser ion source parameters for CERN LHC
- Project Leader for development, design and commissioning of 100 J/1 Hz CO2-laser for CERN LHC laser ion source project
- Development, design and commissioning of laser ion source for ITEP-TWAC facility

1. EQUIPMENT (Reference: DOE Order 413.2C for guidance on equipment restrictions)

Will LDRD funding be used to purchase equipment? Y/N_Y__

If "Yes," provide cost and description of equipment

Year 1 - $145K	Microwave components	$10K
	Li vapor supply line	$20K
	Gas feeding system	$15K
	Microwave source (TWTA)	$15K
Year 2 - $150K	All-permanent magnet sextupole	$30K
	DC power supplies for solenoids	$60K
	Solenoid magnets	$60K
Year 3 - $135K	TMP (1000 l/s) with controller	$19K
	Scroll pump	$6K
	30 kV/20 mA DC power supply	$15K
	10 kV/10 mA power supply	$10K
	500 V power supply	$2K
	Fast shutter for beam isolation	$3K

2. HUMAN SUBJECTS (Reference: DOE Order 443.1)

Are human subjects involved from BNL or a collaborating institution? Human Subjects is defined as "A living individual from whom an investigator obtains either (1) data about that individual through intervention or interaction with the individual, or (2) identifiable, private information about that individual".

If **yes**, attach copy of the current Institutional Review Board Approval and Informed Consent Form from BNL and/or collaborating institution.

Y/N N

3. VERTEBRATE ANIMALS

Are live, vertebrate animals involved?

Y/N N

If **yes**, attach copy of approval from BNL's Institutional Animal Care and Use Committee.

Y/N ___

4. NEPA REVIEW

Are the activities proposed similar to those now carried out in the Department/Division which have been previously reviewed for potential environmental impacts and compliance with federal, state, local rules and regulations, and BNL's Environment, Safety, and Health Standards? (Therefore, if funded, proposed activities would require no additional environmental evaluation.)

Y/N Y

If **no**, has a NEPA review been completed in accordance with the National Environmental Policy Act (NEPA) and Cultural Resources Evaluations Subject Area and the results documented?

Y/N ___

(**Note:** If a NEPA review has not been completed, submit a copy of the work proposal to the BNL NEPA Coordinator for review. No work may commence until the review is completed and documented.)

5. ES&H CONSIDERATIONS

Does the proposal provide sufficient funding for appropriate decommissioning of the research space when the experiment is complete? Y/N Y

Is there an available waste disposal path for project wastes throughout the course of the experiment? Y/N Y

Is funding available to properly dispose of project wastes throughout the course of the experiment? Y/N Y

Are biohazards involved in the proposed work? If yes, attach a current copy of approval from the Institutional Biosafety Committee. Y/N N

Can the proposed work be carried out within the existing safety envelope of the facility (Facility Use Agreement, Nuclear Facility Authorization Agreement, Accelerator Safety Envelope, etc.) in which it will be performed?

Y/N Y

If **no**, attach a statement indicating what has to be done and how modifications will be funded to prepare the facility to accept the work.

6. TYPE OF WORK

Select Basic, Applied or Development Development

7. ALIGNMENT WITH THE LABORATORY PRIORITIES

Type A proposals need to be clearly aligned with BNL's priority programs and initiatives. For FY22, the highest priorities for Type A proposals (not in priority order) are: Accelerator Science and Technology; Atmospheric and Climate Science; Clean Energy; Discovery Science Driven by Human-AI-Facility Integration; Isotope Production and R&D Capabilities; and Quantum Information Science and Technology. The Appendix that accompanies the solicitation clarifies the types of R&D covered in each of these areas.

The Laboratory Initiatives are in the areas of: 1. Nuclear Physics; 2. Clean Energy and Climate; 3. Quantum Information Science and Technology; 4. Artificial Intelligence and Data Science; 5. High Energy Physics; and 6. Isotope Production.

Please identify which area(s) the proposal supports.

This proposal is clearly aligned with BNL's priority programs, "isotope production and R&D capabilities." In addition, it aligns with the laboratory initiative area, "Isotope Production" and "Nuclear Physics."

8. POTENTIAL FUTURE FUNDING

Identify below the Agencies and the specific program/office, which may be interested in supplying future funding. Give some indication of time frame. This information is required.

This LDRD addresses a critical component of BNL's proposed large transformative isotope production facility with an estimated cost of several hundred million dollars. The facility will consist of a radio frequency quadrupole (RFQ), three normal conducting inter-digital structure linear accelerators, and four cryomodule super conducting linear accelerators. The final energy will reach 60 MeV/u.

9. BUDGET JUSTIFICATION

Include a description of all costs requested in your budget. You do not need to describe the Lab burdens.

This budget includes expenses for a postdoc for 2.5 years and about 30% of a physicist labor. For experimental research, since the PI is the leader of the source group, we will make the best possible use of existing equipment in CAD. We will make efficient use of the budget by narrowing down the list of additional equipment to be purchased.

In the first year, we will need to install a microwave output device. Accordingly, waveguides, tuners, and other components will be purchased. In FY2023, we will design and fabricate the magnetic devices, which will require the fabrication of permanent cusp magnets and the purchase of solenoids and their power supplies. In FY2024, we will conduct the final beam test and purchase the power supply for ion extraction, vacuum vessel, and shutter for beam diagnostics.

10. NAME OF SUGGESTED BNL REVIEWERS

Provide the name of two BNL subject matter experts who may be contacted as potential reviewers of your proposal. Their reviews will be in addition to those conducted by the Associate Lab Directors and Directors of the Computational Science Initiative and Advanced Technology Research Office, Members of the Brookhaven Council, and Scientists not associated with the research.

Dr. Deepak Raparia raparia@bnl.gov
Dr. Ady Hershkovitch hershcovitch@bnl.gov

APPROVALS (NPP)

Business Operations Manager

Susan M. Pankowski

Susan M. Pankowski

Department Chair/Division Manager

Thomas Roser

Associate Laboratory Director for
Nuclear and Particle Physics

Haiyan Gao

FY22 Budget Proposal

Li ECRIS

PI: **Masahiro Okamura**

($ in Whole Numbers)

Select project type from drop down menu>>>> C-AD LDRD

R/C	Description		FY22 Year 1		FY23 Year 2		FY24 Year 3		TOTAL
100	Salaries		173,800		182,312		193,189		549,301
	Subtotal		173,800		182,312		193,189		549,301
	Total Labor		173,800		182,312		193,189		549,301
	Total Dist. Tech. Services		-		-		-		-
300	PO Purchases		45,000		-		55,000		100,000
	Total MST		45,000		-		55,000		100,000
	Departmental Org. Burdens	7.62%	13,244	7.62%	13,892	7.62%	14,721		41,857
	Departmental Org. Burdens	0.95%	1,651	0.95%	1,732	0.95%	1,835		5,218
	Directorate Org Burdens	3.60%	6,257	3.60%	6,563	3.60%	6,955		19,775
	Distributed Org. Burdens		21,151		22,187		23,511		66,849.94
685	Distributed ODC	3.80%	6,604	3.80%	6,928	3.80%	7,341		20,873
	Total ODC		6,604		6,928		7,341		20,873
	Total Power		1,043		1,094		1,159		3,296
	Total Cost (Excluding Overhead)		363,067		378,747		377,395		1,119,208
745	Procurement	7.00%	10,150	7.00%	10,500	7.00%	9,450		30,100
746	Adj Proc Burden		-		-		-		-
735	VAB G&A	0.00%	-	0.00%	-	0.00%	-		-
711	Adj Traditional Burden		-		-		-		-
730	VAB Common Inst	43.30%	97,651	43.30%	102,370	43.30%	107,752		307,774
730	VAB Common Inst (JA Only)	11.30%	-	11.30%	-	11.30%	-		-
722	Safeguards & Securities	0.00%	-	0.00%	-	0.00%	-		-
738	FIE	0.00%	-	0.00%	-	0.00%	-		-
705	LDRD Burden	0.00%	-	0.00%	-	0.00%	-		-
	Total G&A	54.60%	97,651	54.60%	102,370	54.60%	107,752		307,774
	Project Total		470,868		491,617		494,597		1,457,082
	Full Cost Recovery	0.00%	-	0.00%	-	0.00%	-		-
	Sub Total		470,868		491,617		494,597		1,457,082
	Prior Year Carry Over		-		-		-		-
	Sub Total Project Funded Cost		470,868		491,617		494,597		1,457,082
	Expected Funding		-		-		-		-
	Total Authorized Funds (New Funds)		470,868		491,617		494,597		1,457,082
	Carry Forward		-		-		-		-
	Total Project Cost Plan		470,868		491,617		494,597		1,457,082

BNL's participation in this project will be subject to approval by DOE. BNL's participation also requires a formal agreement with the Sponsor that will contain terms and conditions which are approved by DOE. Kindly review the " DOE Guide to Partnering with DOE's National Laboratories " for information on the various partnering options and agreements. Feel free to contact Ivar

DOE Guide to Partnering with DOE's National Laboratories