8. Project Narrative

Cover Page

Company Name & Address: Particle Beam Lasers, Inc.
18925 Dearborn Street
Northridge, CA 91324-2807

Principal Investigator: Dr. Shailendra Chouhan

Project Title: Novel Design for High Field, Large Aperture Quadrupoles for Electron-Ion Collider

Topic No 29: Nuclear Physics Accelerator Technology

Subtopic (h): Magnet Development for Proposed Future Electron-Ion Colliders (EIC)

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Identification and Significance of the Problem or Opportunity

The Office of Nuclear Physics (NP) of the Department of Energy (DOE) requested the Nuclear Science Advisory Committee (NSAC) [1] to help make a long range plan. The NSAC recommended in the 2015 Long Range Plan (LRP) that the proposed Electron Ion Collider (EIC) be the highest priority for new construction for Nuclear Science [2]. Currently two sets of designs are being considered for the Electron Ion Collider (see Fig. 1): one design is proposed by Brookhaven National Laboratory (BNL) as shown on the left [3]; and the other design is proposed by the Thomas Jefferson National Accelerator Facility (JLAB) as shown on the right [4]. The EIC requires development of several key technologies. One key technology is the development of high field gradient quadrupoles needed for the proton or ion beams in order to achieve a high luminosity Interaction Region (IR). These high field gradient quadrupoles also have certain special requirements such as a field free region for the nearby electron beams.

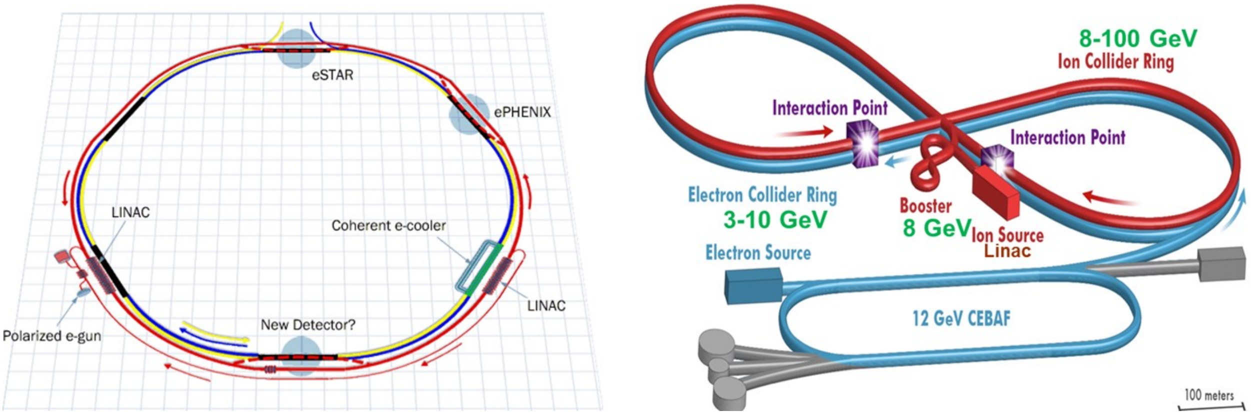


Fig. 1: Electron Ion Collider as proposed by BNL (left) and by JLAB (right).

Fig. 2 shows the current IR region in the BNL and in the JLAB designs [5]. To achieve high luminosity, both IR designs need a high field quadrupole for the proton and ion beams. The stated requirement in the current designs and in the FOA is a pole tip field ≥ 8 T. Taking into account the peak field and the extra margin needed in the IR magnets, some of these designs are at the limit of NbTi technology and will likely need Nb_3Sn technology.

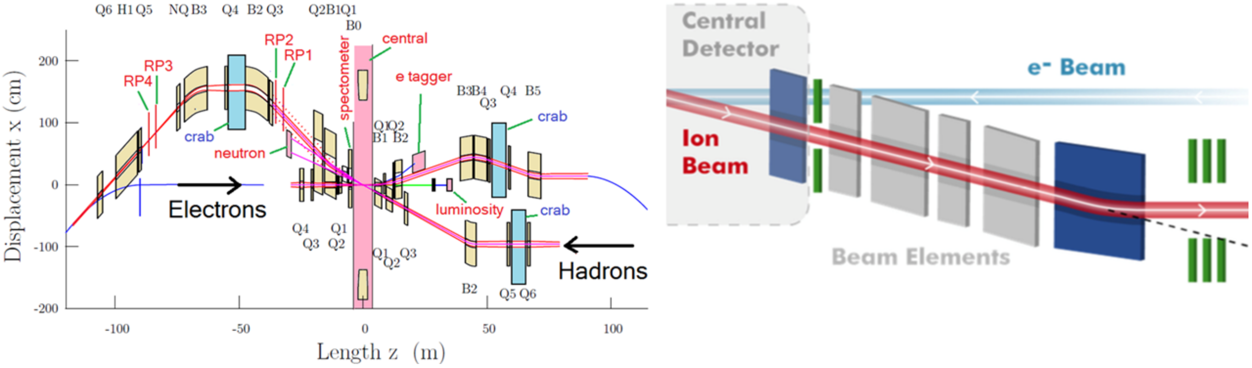


Fig. 2: Proposed layout of the Interaction Region of the BNL (left) and JLAB (right) designs of the EIC.

The present design of the EIC quadrupoles and in fact of most superconducting quadrupoles in accelerator and beam line magnets is based on a cosine two-theta design. The cosine two-theta design is considered to be more efficient in creating field (gradient), particularly for quadrupoles. The specific design approach for the EIC, as shown in Fig. 3, is based on active shielding (together with a thin magnetic shield) to obtain a field free region for the passage of the electron beam [6]. Fig. 3 shows the main Nb_3Sn coils creating the high field gradient for the proton or ion beams and outer NbTi coils (with an opposite polarity to the main coils) providing active cancellation of the field in a region outside it. The design is based on cosine two-theta coils. Fig. 3 (right) shows the present design of the high gradient quadrupole Q1PF (the closest quadrupole to the interaction point) in the BNL design. The gradient for the proton or ion beams in the present design is 140 T/m for the 96 mm aperture generated by the Nb_3Sn coils and a near field free region for the electron beam with the help of field cancelling NbTi coils. The IR design of the Jefferson Lab Electron Ion Collider (JLEIC) needs several high field quadrupoles, as shown in Fig 4 [6].

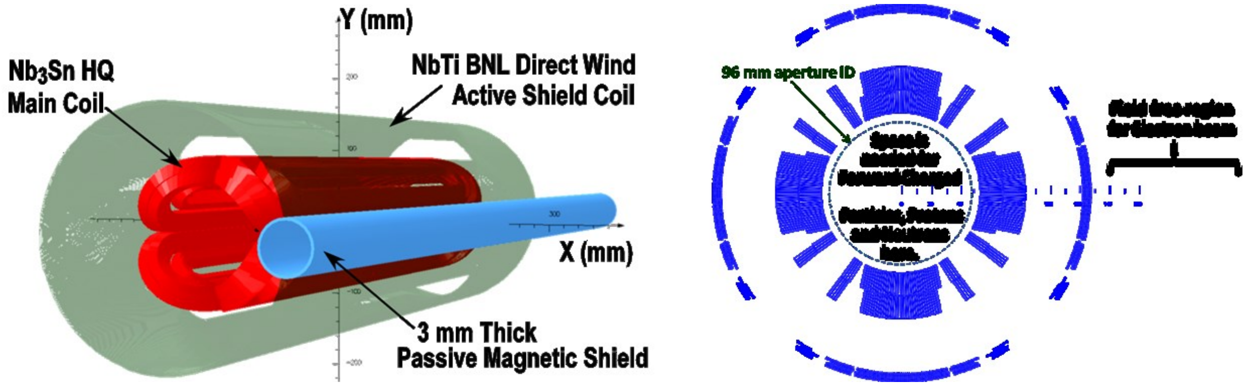


Fig. 3: 3-d and 2-d models of the current approach wherein the main Nb_3Sn quadrupole coils provide the high field gradient for the proton or ion beams and NbTi coils with opposite polarity create a near field-free region for the electron beam but also reduce the gradient generated by the main coils. The cross-section of the present cosine two-theta design of the Q1PF quadrupole is shown on the right.

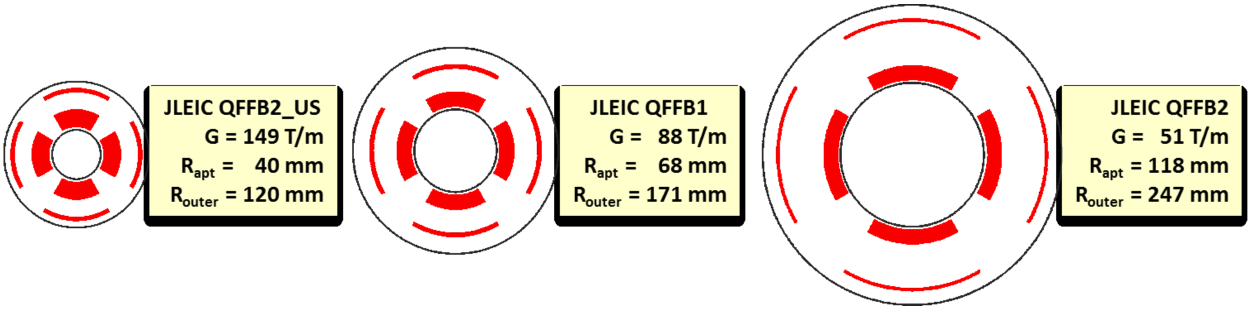


Fig. 4: Design parameters of the JLAB design of the EIC (JLEIC) and a conceptual representation of the conventional cosine two-theta design [6].

We propose to develop an innovative high field quadrupole design by using an R&D approach based on simple racetrack coils whose efficiency approaches that of the cosine two-theta designs. The coil configuration close to the beam is similar to that in the Panofsky quadrupole [7]. The design also creates a field-free region which can be optimized for an individual application. In addition, this design facilitates an R&D approach that is particularly cost-effective and suitable when only a few quadrupoles with different apertures are needed. Whereas in a large production, the cost of material and labor play a much bigger role than the cost of R&D together with the cost of engineering and design, in a small production like this the cost of material (such as the cost of superconductor) is a smaller part of the net overall cost to project. In such cases a better figure of merit in measuring the efficiency of conductor (or superconducting coils) should be the ability to create the field at the desired performance rather than the amount of conductor used. The design and technical approach presented here makes racetrack coils more attractive for applications such as an Electron Ion Collider. Moreover, magnets made with the simpler 2-d racetrack coil are generally expected to have a better quench performance than the more conventional designs, as the conventional designs require complex ends needed to clear the bore tube which are more susceptible to quenching problems.

Technical Approach

The basic ability of a coil to create field in quadrupoles differs significantly from that of dipoles. Whereas in an ideal dipole (for example in a *cosine theta dipole*), the bore field increases linearly with the coil width (t) irrespective of the coil radius (a), in an ideal quadrupole the increase in field gradient with t saturates as it increases as $log(1+t/a)$. Furthermore, to achieve high gradients in quadrupoles, it is much more important that the conductor be placed close to the coil radius at the midplane. In the *cosine two-theta shell geometry*, all conductor blocks are at the same radius whether they are at the midplane or at the pole. However, in most quadrupole designs with *flat racetrack coils* [9]-[11], the conductor is closer to the pole and away (even missing) from the midplane (see Fig. 5). Therefore, these types of quadrupole designs with *flat racetrack coils* produce a significantly lower maximum field gradient.

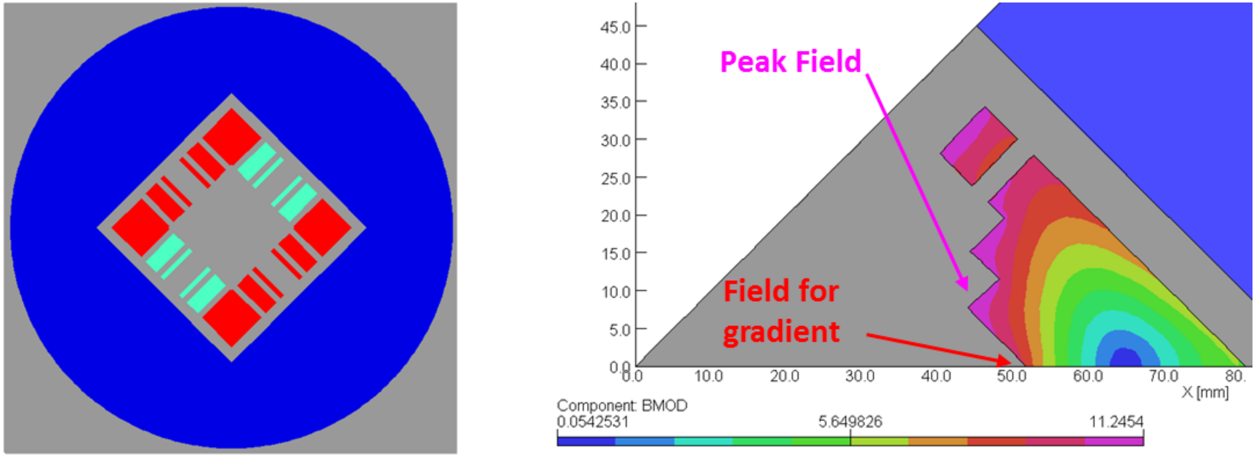


Fig. 5: Earlier BNL quadrupole designs [9] with flat racetrack coils. In such designs, turns at the midplane are away from the coil radius. Two types of coils (see left) are used for maximizing conductor at the midplane and a special coil structure is used on the right to minimize the peak field.

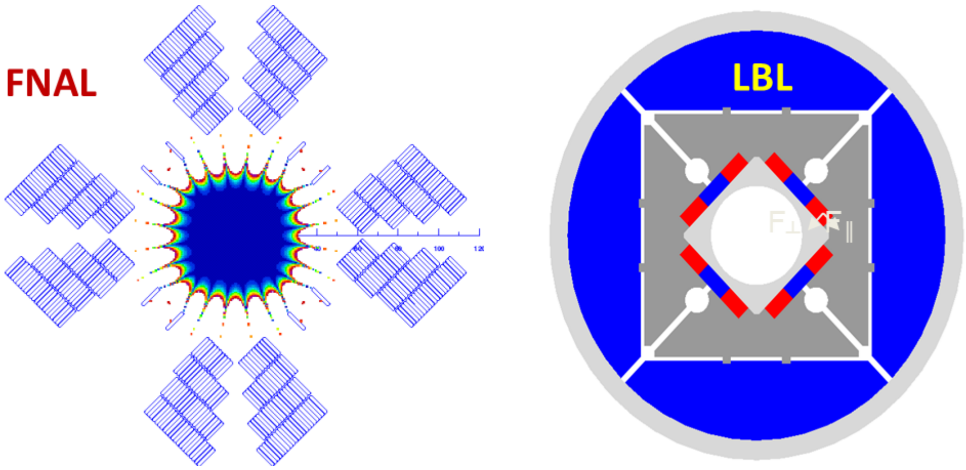


Fig. 6: An earlier quadrupole design with flat racetrack coils from Fermilab [10] and LBNL [11]. In such designs, the turns at the midplane are away from the coil radius.

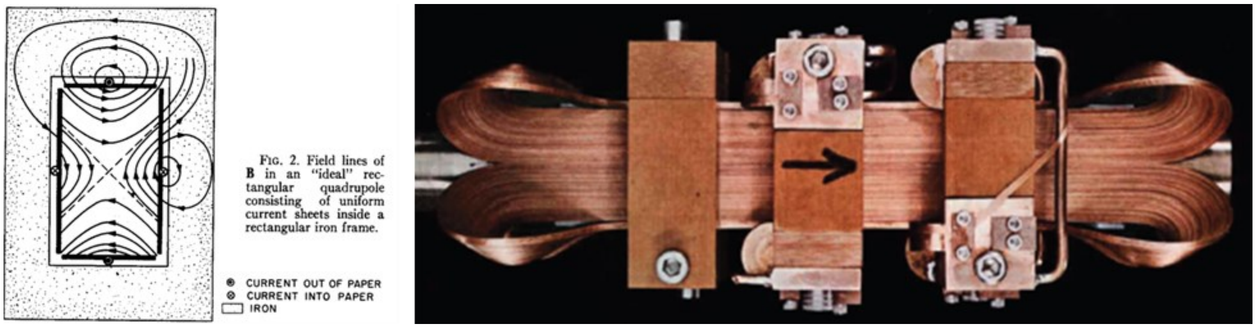


Fig. 7: Rectangular aperture Panofsky quadrupole design (left) and superconducting quadrupole built with Nb_3Sn tape (right).

The modular quadrupole design (see Fig. 8), originally proposed for the LHC IR high gradient quadrupoles [12], overcomes the problem of having conductor radially distant. The designs shown in Fig. 7, such as in the "Panofsky quadrupole", proposed about six decades ago [7], creates a gradient which is close to the gradient that is achieved in cosine two-theta quadrupoles. A rectangular superconducting quadrupole [8] built over four decades ago with Nb_3Sn tape is shown in Fig. 7 (right), however, it has complex ends. These designs allow crucial conductor at the midplane to be at a radius similar to that in the conventional cosine two-theta quadrupoles and thus essentially overcomes the disadvantages of the racetrack coil designs shown in Fig. 5 and Fig. 6.

The modular design (see Fig. 8) allows simple flat racetrack coils to be used. In addition, large bend radii in the ends may also allow the use of "react & wind" Nb_3Sn technology. The design, however, uses twice as much conductor as in a conventional design. Therefore, such a design is attractive where only a few magnets are needed and where a higher conductor cost can be tolerated in favor of high performance, or where the use of flat racetrack coils with large bend radii is critical.

We refer to these designs as "*Modular Designs*" because the quadrupole coils are made of simple racetrack modules. Several such coil modules can be stacked, and the individual coil modules as well the magnet aperture in "Proof-of-Principle" magnets can be changed, to carry out a fast-turn-around, low cost and systematic quadrupole magnet R&D program, as has been successfully done for dipole magnet R&D programs at various laboratories based on the common coil design.

There are two styles of *Modular Designs* shown in Fig. 8 – *Simpler* (see left) and *Symmetric* (see right). Let us first follow the simpler design based on four sets of racetrack coils (A and B). Most of the gradient is generated by blocks A^+ and B^-, with return blocks A^- and B^+ reducing the gradient. However, in an optimized design, as shown later, this reduction in field is accompanied by a field free region that is needed for the electron beam.

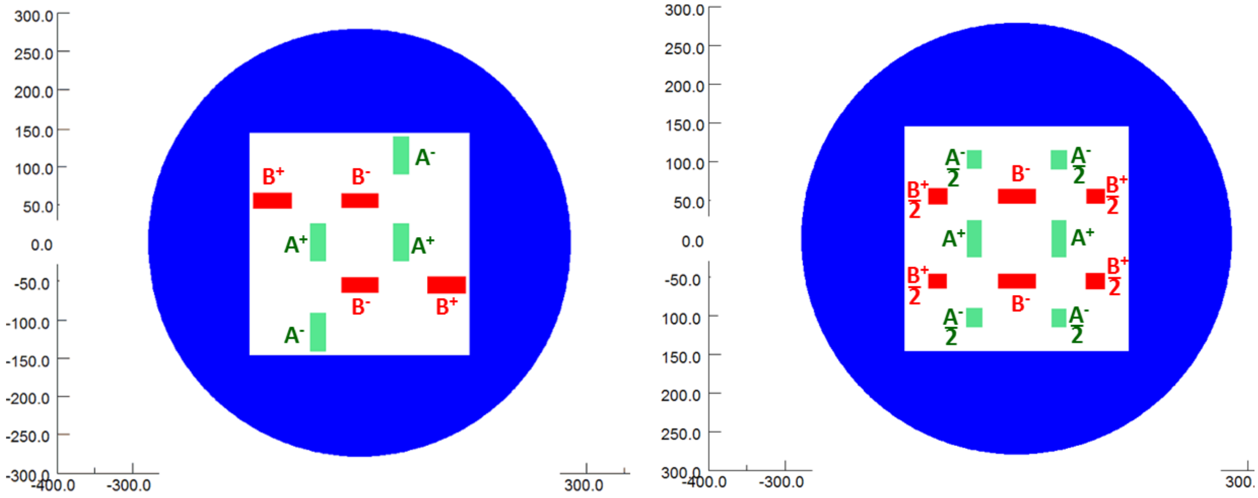
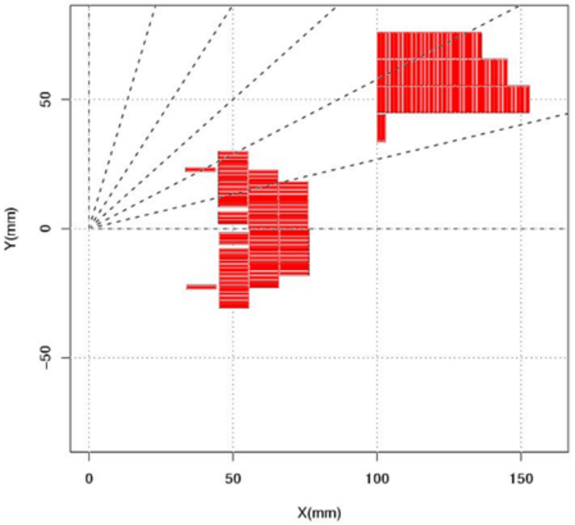


Fig. 8: Two versions of the modular quadrupole designs. The one on the left is simpler and uses four sets of racetrack coils and one on the right is symmetric and uses eight sets of racetrack coils.

The simpler design lacks the eight-fold quadrupole symmetry in the cross-section and therefore in addition to the normal field harmonics b_6, b_{10}, b_{14}, etc., one would also expect skew harmonics a_6, a_{10}, a_{14}, etc. The rest of the skew and normal harmonics are still zero in an ideal geometry free of construction errors because of the four-fold rotational symmetry. An optimized cross-section [12] for a 90 mm aperture quadrupole is given in Fig. 9.



n	a_n	b_n
6	-0.0049	-0.0015
10	0.0006	0.0075
14	0.0018	0.0231
18	0.0000	0.0000

Fig. 9: A 90 mm aperture modular quadrupole design optimized for field quality [12]. Harmonics are given at a with respect to the field at the midplane at a reference radius of 30 mm (2/3 of coil radius) in the units of 10^{-4}.

The *Symmetric Style* of the *Modular Design* concept is shown in Fig. 8 on the right. That design is based on eight sets of racetrack coils (instead of the four sets in the simpler design) with each set of coils having ½ the number of turns that were in the simpler design. The cross-section has perfect quadrupole symmetry as shown in Fig. 8 (right) with the return blocks placed symmetrically on the two sides of the mid-planes. However, to accommodate this topology in the magnet ends, coils *A* and *B* need to have different lengths and one needs to go inside (interleave) the other. In order to allow the interleaving, the coils need to have at least part of their center island free of support structure as shown in Fig. 10.

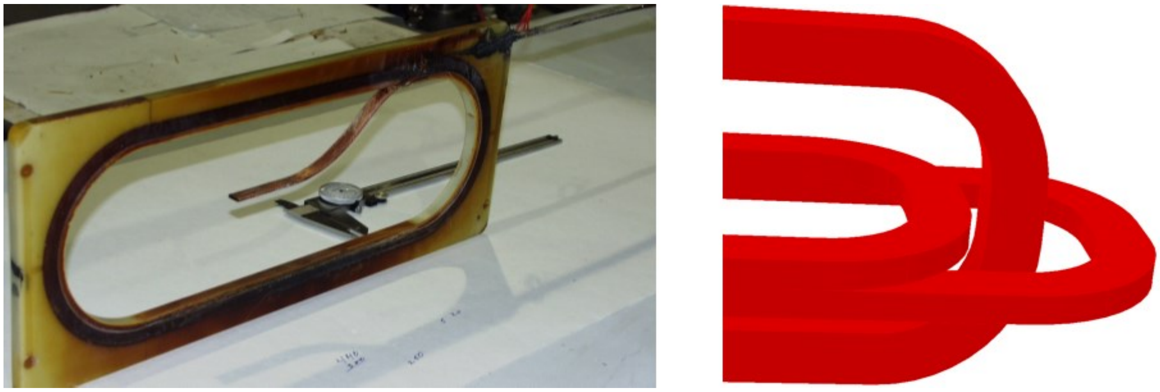


Fig. 10: An impregnated Nb_3Sn coil built at BNL with space (an island) free of any structure in the magnet ends (left) which allows for accommodating interleaving coils (right) as needed in the symmetric design.

A 2-d cross-section of the symmetric design including an iron yoke is shown in Fig. 11 (left). Importantly, it was noticed [13] that such a design naturally creates a low field region. This is primarily because the return portion of the racetrack coil has an opposite polarity which naturally acts as a field cancelling coil. The field in the region where the electron beam will traverse in an Electron Ion Collider can be further reduced by incorporating an iron shield as shown in Fig. 11 (right). The field contour and the field lines when additional shielding iron is used is shown in Fig. 12 (left) and the field with and without shielding is compared in Fig. 12 (right). This shows the applicability of this design for building high field gradient quadrupoles for proton or ion beams while simultaneously obtaining a low-field region for the electron beam.

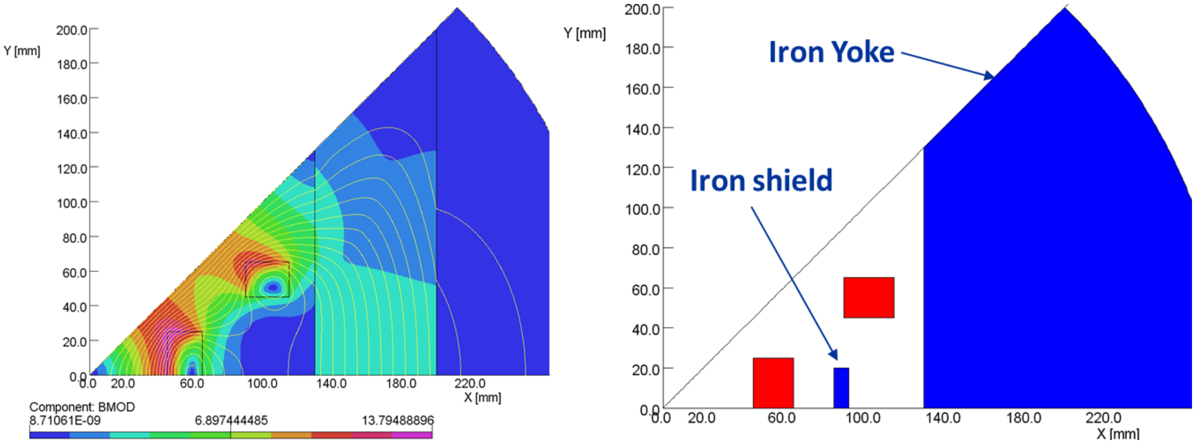


Fig. 11: An octant of the symmetric modular design with an included iron yoke. Field contour and field lines are shown on the left and the possibility of further reducing the field in the path of electron beam with additional iron shielding is indicated on the right.

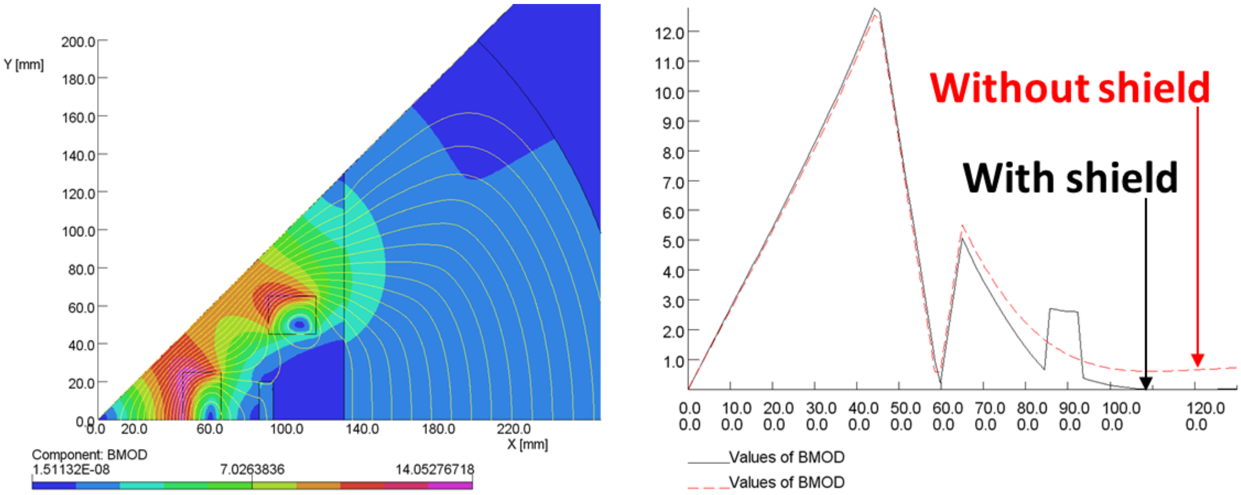


Fig. 12: Field contour and field lines in an octant of the symmetric high field modular quadrupole design with an iron shield included are shown in the left. Reduction in magnetic field with the additional magnetic shielding in the region of the electron beam, as needed in an electron ion collider, is shown on the right.

Anticipated Public Benefits

The proposed modular design consists of simple flat racetrack superconducting coils that can be stacked as cassettes for carrying out systematic and varied magnet R&D within a Modular Program. This modular approach is expected to obtain results similar to the positive results obtained with the common coil magnet design [14] that facilitated a cost-effective, rapid-turn-around R&D program. Such R&D is particularly useful in the early stages of an accelerator program where the machine and magnet parameters cannot be frozen without a feedback from proof-of principal magnets. This is also useful if several magnets of different apertures are needed. The benefit of such approach is expected to be useful in other fields such as in accelerators and beamlines for high energy physics and medical applications.

Moreover, since the proposed project aims to benefit the science of building colliding beam accelerators for nuclear physics research, the most immediate beneficiaries are researchers working in nuclear physics around the world. The market for colliding beam accelerators is small when measured in number of units – typically only one or two such devices are constructed every 10 to 20 years. However, the market as measured in dollars can be significant, with project costs in the range of hundreds of millions of dollars. Enabling supporting technology for such significant investments is important for the eventual success of the project, assisting to get the most scientific output possible for the money spent.

Technical Objectives

The main technical objective of the proposed project is to develop a modular design technology for the production of high field gradient quadrupoles for the interaction region of the Electron Ion Collider. These high field gradient quadrupoles must also simultaneously ensure that there is a nearly field free region nearby for the passage of the electron beam. In Phase I, we will develop magnetic and mechanical designs of the Q1PF quadrupole. In addition, we will develop a more detailed design of the Proof-of-Principle quadrupole that can be built in Phase II. This will involve structural design concepts for this new design based on the use of racetrack coils. In Phase I, we will also carry out 3-d magnetic designs to demonstrate that good integrated field quality can be obtained in the EIC interaction region magnets. In addition, it will be demonstrated that the field in the region where the electron beam traverses can be kept within acceptable limits. The CAD design will also show that such coils can be assembled with proper support structures. We will further develop the concept of modular design to show that the same racetrack coils can be used to study quadrupoles of different apertures.

Work Plan

We outline our plan for Phase I with a series of specific tasks listed below:

Task 1: Perform a magnetic design for the Q1PF quadrupole

Optimize the cross-section of the modular designs for both the "*simpler*" and the "*symmetric*" configuration for the Q1PF design. The design should meet the field and field quality requirements with adequate margin (at least 20%) for the proton and ion beams. The design should also create a nearly field-free region for the electron beam. The maximum and integral values of the field along the electron beam path will be lower than the maximum specified at that time. 3-d design optimization will also be performed to achieve an integrated value of the field harmonics so that they fall within the maximum allowed specifications. There is an inherent lack of symmetry in the nominal design as can be seen on the left of Figure 13. The problem is apparent at an axial position 30 mm (2/3 of the coil radius) from the origin on the X-axis and on the Y-axis (see Fig. 13 left where the computed integral values, 172.627 and 167.268, are listed at the bottom). One way to overcome this issue in an integral sense is to make one coil layer bigger than the other in a 2-layer design (see Fig. 13 middle and Fig. 7 left). One can see from the number shown at the bottom of the plot that the integral asymmetry can be practically eliminated (see Fig. 13 right where the computed integral values, 172.000 and 172.001 are listed at the bottom). The actual harmonics will be minimized with the help of computer code such as ROXIE. This task will be carried out jointly by the PBL and BNL teams.

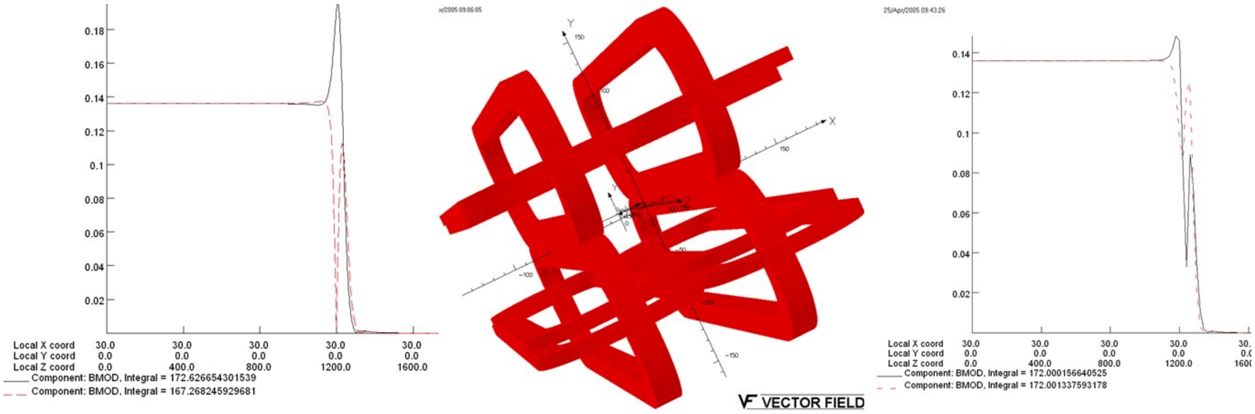


Fig. 13: Field on the horizontal and vertical axis at 2/3 of the coil radius showing missing symmetry in the design (left), a proposed design to overcome this lack of symmetry of the integrated field (middle), and the resulting field showing an integrated symmetry once the design is implemented (right).

Task 2: Perform mechanical analysis of the optimized Q1PF quadrupole design

A mechanical analysis with the code ANSYS and COMSOL will be performed on the optimized cross-section design obtained from task 1. This task will be performed along with task 3 so that deflections, stress and strain on the conductor are kept within the acceptable limits of Nb_3Sn. This task will be carried out jointly by the PBL and BNL teams.

Task 3: Develop a mechanical structure design for the Q1PF modular quadrupole

Developing mechanical structure concepts is an important task of Phase I. The structure should be such that it can be easily assembled while deflections, stress and strain on the assembled coil are kept to within acceptable limits during operation. The detailed engineering design of the structure will be carried out in the initial part of Phase II. This task will be carried out jointly by the PBL and BNL teams.

Task 4: Develop a Proof-of-Principle modular design that can be built and tested in Phase II

Building an actual high field Nb3Sn quadrupole is beyond the budget of Phase II. However, a proof of principle quadrupole design will be developed in Phase I that can be built and tested in Phase II. Even though the option of building a Nb_3Sn quadrupole will be evaluated, it is likely that actual Phase II construction will be a NbTi quadrupole. We will try to develop this design for a short length model magnet of one of the quadrupoles of the Electron Ion Collider, either for the BNL IR design or for the JLAB IR design. We will perform both magnetic and mechanical analysis. This task will be carried out jointly by the PBL and BNL teams.

Task 5: Design mechanical structure for the Proof-of-Principle modular quadrupole design

We will develop a more detailed design of the mechanical structure of the Proof-of-Principle magnet to be built in Phase II than that carried out in task 3 for the Q1PF quadrupole. This design will be an essential part of the Phase II proposal. This task will be primarily carried out by BNL with active participation of the PBL team.

Task 6: Design flexible structure concepts for modular R&D with modular design where the magnet aperture and individual racetrack coils can be changed

The high field quadrupole designs proposed herein are inherently modular since the racetrack coils can be stacked or their relative positions changed. These coil modules need not have the same width. *Modular Design* offers a rapid-turn-around and a relatively simple mechanism for carrying out a versatile magnet R&D program. As shown in Fig. 14, the modular design approach offers an opportunity to vary quadrupole apertures in R&D magnets while using the same coil modules. To change aperture in R&D magnets, one just needs to change the spacing between the coils (Fig. 14). One can obtain a significant high field gradient even with a single layer of coils when they are close together. This task will be primarily carried out by BNL with an active participation of the PBL team.

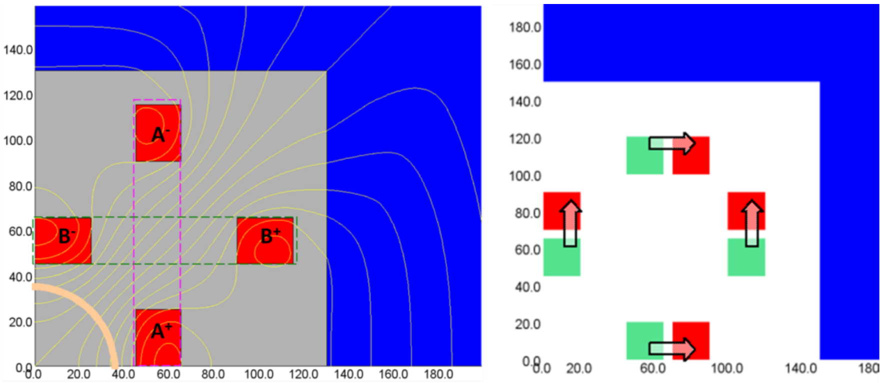


Fig. 14: Modular design for flexible R&D where the racetrack coils A and B (see left) are moved outward (see right) to obtain larger aperture.

Task 7: Write project summary and prepare the Phase II proposal

Both the PBL and BNL teams will participate in identifying the key components for a Phase II proposal and in writing the Phase I final report. The key component of the Phase II proposal will be making the detailed plans for the work to be carried out in Phase II where the Proof-of-Principle modular quadrupole is to be built and tested.

Performance Schedule

Task 1: Perform a magnetic design for the Q1PF quadrupole – Weeks 1-16.

Task 2: Perform mechanical analysis of the optimized Q1PF quadrupole design – Weeks 12-24.

Task 3: Develop a mechanical structure design for the Q1PF modular quadrupole – Weeks 16-28.

Task 4: Develop a Proof-of-Principle modular design that can be built and tested in Phase II – Weeks 9-24.

Task 5: Design mechanical structure for the Proof-of-Principle modular quadrupole design – Weeks 13-26.

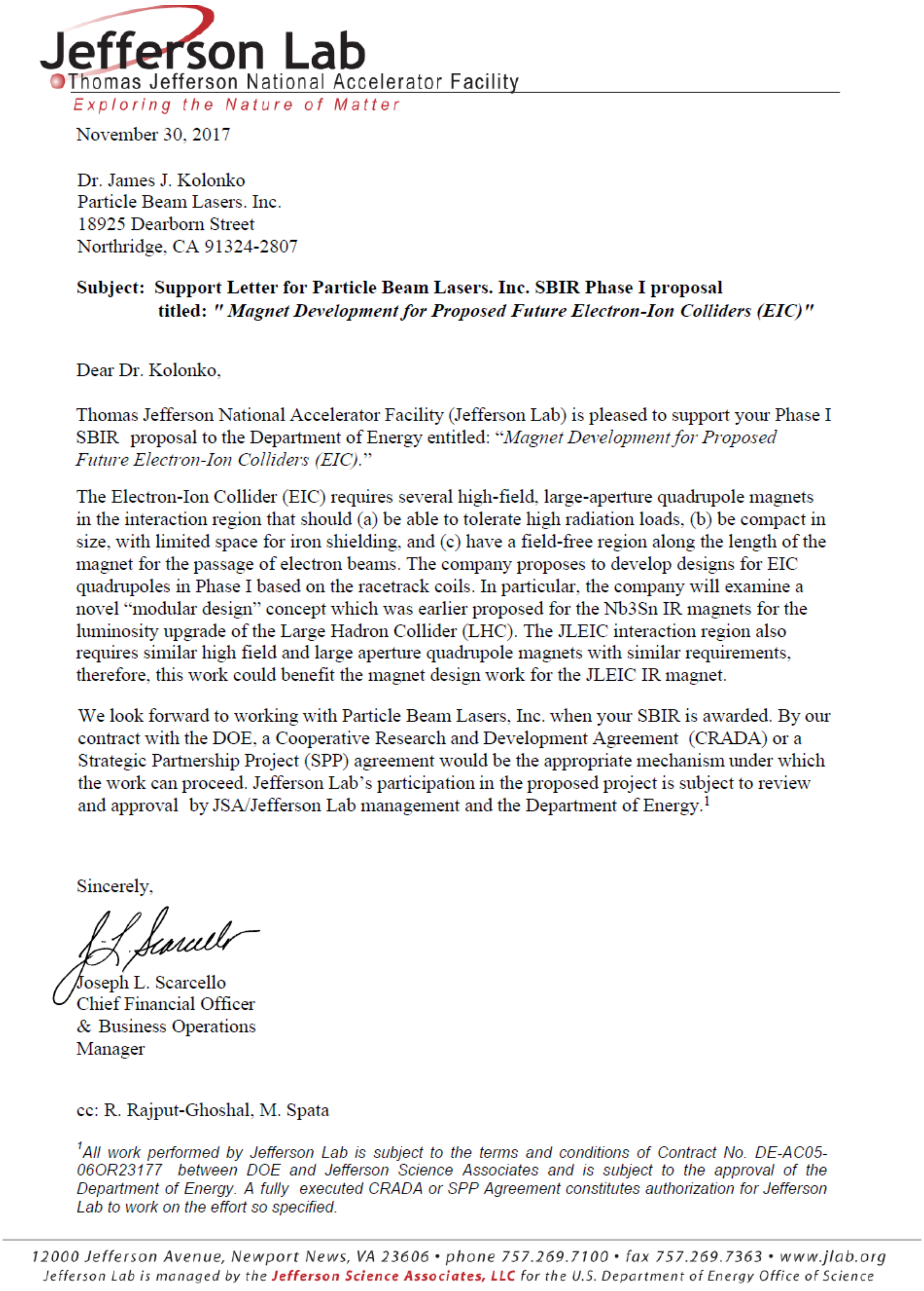
Task 6: Design flexible structure concepts for modular R&D with modular design where the magnet aperture and individual racetrack coils can be changed – Weeks 12-34.

Task 7: Write project summary and prepare the Phase II proposal – Weeks 35-39.

Related Research and R&D

The PBL/BNL team has established a strong R&D position in superconducting magnet technology [14-16]. One of the outstanding accomplishments of this effort is the achievement of world record fields in HTS solenoids. One HTS solenoid designed and built through a PBL/BNL SBIR produced a field of ~16 T (a record field at that time), exceeding its nominal field by more than 30% as the proposal was for 12 T [15]. Another major achievement of this team is the recent demonstration of a significant HTS/LTS dipole magnet [16] with a field which is still a record at this time for a hybrid HTS/LTS dipole. The team also played a significant role in optimizing a Nb_3Sn dipole design [14].

Letter of Support from Jefferson Lab:



Jefferson Lab
Thomas Jefferson National Accelerator Facility
Exploring the Nature of Matter

November 30, 2017

Dr. James J. Kolonko
Particle Beam Lasers. Inc.
18925 Dearborn Street
Northridge, CA 91324-2807

Subject: Support Letter for Particle Beam Lasers. Inc. SBIR Phase I proposal titled: "*Magnet Development for Proposed Future Electron-Ion Colliders (EIC)*"

Dear Dr. Kolonko,

Thomas Jefferson National Accelerator Facility (Jefferson Lab) is pleased to support your Phase I SBIR proposal to the Department of Energy entitled: "*Magnet Development for Proposed Future Electron-Ion Colliders (EIC).*"

The Electron-Ion Collider (EIC) requires several high-field, large-aperture quadrupole magnets in the interaction region that should (a) be able to tolerate high radiation loads, (b) be compact in size, with limited space for iron shielding, and (c) have a field-free region along the length of the magnet for the passage of electron beams. The company proposes to develop designs for EIC quadrupoles in Phase I based on the racetrack coils. In particular, the company will examine a novel "modular design" concept which was earlier proposed for the Nb3Sn IR magnets for the luminosity upgrade of the Large Hadron Collider (LHC). The JLEIC interaction region also requires similar high field and large aperture quadrupole magnets with similar requirements, therefore, this work could benefit the magnet design work for the JLEIC IR magnet.

We look forward to working with Particle Beam Lasers, Inc. when your SBIR is awarded. By our contract with the DOE, a Cooperative Research and Development Agreement (CRADA) or a Strategic Partnership Project (SPP) agreement would be the appropriate mechanism under which the work can proceed. Jefferson Lab's participation in the proposed project is subject to review and approval by JSA/Jefferson Lab management and the Department of Energy.[1]

Sincerely,

J.L. Scarcello

Joseph L. Scarcello
Chief Financial Officer
& Business Operations
Manager

cc: R. Rajput-Ghoshal, M. Spata

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[1] *All work performed by Jefferson Lab is subject to the terms and conditions of Contract No. DE-AC05-06OR23177 between DOE and Jefferson Science Associates and is subject to the approval of the Department of Energy. A fully executed CRADA or SPP Agreement constitutes authorization for Jefferson Lab to work on the effort so specified.*

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Jefferson Lab is managed by the ***Jefferson Science Associates, LLC*** *for the U.S. Department of Energy Office of Science*

Principal Investigator and Other Key Personnel

Shailendra Chouhan will serve as Principal Investigator for the proposed project. In addition, Dr. R. Scanlan, Mr. R. Weggel, Dr. E. Willen, Dr. D. Larson and Mr. J. Kolonko will play key roles for Particle Beam Lasers, Inc. (PBL). Ramesh Gupta will be sub-grant PI for Brookhaven National Laboratory (BNL). Other key players at BNL include M. Anerella and J. Schmalzle.

Dr. Chouhan has 15 years of experience in the field of superconducting magnets. Dr. Chouhan is a physics graduate of Devi Ahilya University, Indore, India, where he received a Ph.D. in physics. After graduation in 2002, Dr. Chouhan joined ANKA, Forschungszentrum Karlsruhe GmbH, Karlsruhe, Germany as a postdoctoral fellow where he worked in the field of superconducting undulator magnets (an insertion device) for two years. In 2004, he joined the National Synchrotron Light Source, Brookhaven National Laboratory, Upton, New York as a research associate. During his two-year tenure at NSLS, he worked on the design, development and testing of a short period SC undulator prototype and a permanent magnet undulator. He also proposed a new concept for a variable polarized superconducting undulator. He presented this new concept as an oral talk at the Particle Accelerator Conference on the 16th of May 2005, in Knoxville, TN. Soon afterwards, in 2006, he joined the National Superconducting Cyclotron Laboratory. Over the last 11 years at Michigan State University, he was involved in many projects such as the hall "C" horizontal bend (HB) superconducting magnet for Jefferson Lab's 12 GeV upgrade project, magnets for the existing coupled cyclotron facility at MSU and Texas AMU, high field, large gap magnets for the High Rigidity Spectrometer (HRS) and the Isochronous Separator with Large Acceptances Recoil Separator (ISLA) design for experiments with reaccelerated rare isotope beams and hundreds of new magnet designs and developments (including both room-temperature and superconducting) for the Facility for Rare Isotope Beams (FRIB). At present, fabrication of the magnets for FRIB is in an advanced state.

Dr. Scanlan has had 35 years of experience in the field of superconducting magnets and materials at General Electric R&D Laboratory, Lawrence Livermore National Laboratory, and Lawrence Berkeley National Laboratory. From 1995 to 1999, he was Program Head for Superconducting Magnet Development at LBNL, during which time a world-record 13 T Nb_3Sn dipole magnet was built and tested. In 1991, he shared the IEEE Particle Accelerator Conference Award with Dr. David Larbalestier for "the development of NbTi superconducting material for high current density application in high field superconducting magnets", and in 2011 he received the IEEE Council on Superconductivity award for "Continuing and Significant Contributions in the Field of Applied Superconductivity".

Robert J. Weggel will be the PBL magnet designer for this Phase I project. He has been PI for PBL on several recent SBIR/STTR projects (see related research section). Mr. Weggel has had over 50 years of experience as a magnet engineer and designer at the Francis Bitter National Magnet Laboratory at MIT and Brookhaven National Laboratory and as a consultant in magnet design. In the course of his career he has authored over 100 peer-reviewed articles concerning resistive and superconducting magnets as well as hybrid high-field versions.

Dr. Erich Willen, a PBL employee, will contribute his expertise in the areas of magnet design and magnetic field quality. Some years ago he served as PI on a related SBIR entitled "Magnet Coil Designs Using YBCO High Temperature Superconductor." Dr. Willen became the head of the Magnet Division at BNL in 1984 and led the development of the SSC and RHIC superconducting magnets.

Dr. Ramesh Gupta will be sub-grant Principle Investigator (PI) for the work performed in the Superconducting Magnet Division (SMD) at the Brookhaven National Laboratory (BNL). Dr. Gupta has more than three decades of experience in the design of superconducting accelerator magnets for various applications. His current interests include developing and demonstrating HTS magnet designs and technology for particle accelerators and beam lines.

Managerial controls for a successful project.

To ensure a successful project, PBL will hold regular technical meetings and compare progress made against the performance schedule above. Four times during the course of the project the technical staff will meet to ensure that important milestones are being met in a timely way. In the final meeting, PBL senior management will also travel to participate. At the final meeting, held approximately six weeks prior to project completion, the team will identify any problems as well as ensure ways to solve them. We will also plan for the Phase I final report and Phase II proposal at that final face to face meeting.

Facilities/Equipment

The PBL PI, Dr. Shailendra Chouhan, will be responsible for the overall direction of the program. The Superconducting Magnet Division (SMD) at BNL working in collaboration with the PBL Principal Investigator and other personal will jointly perform magnetic and mechanical design tasks within the scope of Phase I proposal. In addition to a variety of cryogenic facilities, SMD has access to simulation and engineering software tools that will aid in the design of coils and magnets. The design software available includes ROXIE, OPERA2d, OPERA3d and in-house software for magnetic design, ANSYS for mechanical design, and Pro/ENGINEER and AutoCAD for engineering design. The BNL Magnet Division has been a major player in the development of conventional superconducting magnets over the last four decades and of HTS magnets for over a decade. It has dedicated coil winding machines, cryo-coolers and other equipment. The Division has a staff of about 35 scientists, engineers, technicians, administrative staff and others. Construction will be carried out in a 55,000 ft^2 multipurpose complex at the Division. The infrastructure (space, tools, test equipment, etc.) that are part of the Division will be made available for the Phase I and Phase II work. The value of the infrastructure at BNL is well over $1 million which is a very valuable "in-kind" contribution crucial to the project.

Research Institution (RI)

This grant application involves a formal collaboration between Particle Beam Lasers, Inc. and a research institution, Brookhaven National Laboratory (BNL). As can be found in the attachments found in block 12, what follows is the requested identifying information for this collaboration:

Name and address of the institution:

Brookhaven National Laboratory
Building 460
P.O. Box 5000
Upton, NY 11973-5000

Name, phone number, and email address of the certifying official from the RI:
Erick Hunt
Manager, Research Partnership
(631) 344-2103
ehunt@bnl.gov

Other Consultants and Subcontractors

BNL will be a subcontractor for the Phase I effort. There will be no other consultants or subcontractors on the Phase I effort. The value of the Phase I subcontract is $45,000.

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