Lee Teng Internship 2019: Interns, Projects, and Mentors

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**Baichuan Huan – University of California, Berkeley**

**Superconducting undulator systems development**

**Mentor:** Matt Kasa, Accelerator Systems Division – Argonne National Laboratory

Contribute to the development of aspects of the user interface, data acquisition, and analysis tools for the superconducting undulator magnetic measurement system and/or control system.

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**Kyle E. Leleux – University of Louisiana at Lafayette**

**Development of a Proton Beam Position Monitor and Muon Monitor for Accelerator Improvement Plan**

**Mentor:** Katsuya Yonehara (Fermilab)

Fermilab plans to upgrade the proton beam power at the NuMI target system up to 1-MW (NuMI Target System AIP). Building a robust beam diagnostic system is crucial to protect the target system and avoid any radiological issues. To this end, we are developing a beam diagnostic system by using two existing detectors. The first detector is based on a thermocouple sensor to find the proton beam position on the target. We will make a simple front-end readout Analog-to-Digital Converter (ADC) to reconstruct the beam position by using a raspberry pi board. The other detector is an ion chamber, called the Muon Monitor. Since the device has been operated for several years, the signal gain lost linearity. We will study the linearity as a function of the beam intensity and make a plan how to calibrate the device. The gas regulation also needs to be upgraded.

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**Jackson Morgan – Oregon Institute of Technology**

**Scanner magnet design optimization for a superconducting carbon therapy gantry.**

**Mentor:** Brahim Mustapha, Physics Division – Argonne National Laboratory

Cancer therapy with energetic carbon ions is an advanced technique with expected significant advantages over treatments with X-rays, electrons and even protons. It offers the possibility of
precise delivery of intense radiation to the tumor being treated while minimizing the adverse
effects on the surrounding healthy tissues. The most effective treatment is achieved when the
beam energy is delivered accurately to the three dimensional volume of the tumor as fast as
possible. While the depth scanning is performed by changing the beam energy, the transverse
scanning is performed using 2D beam scanning magnets. By also adjusting the intensity of the
radiation dose spot-by-spot in the tumor, the so-called intensity modulated particle therapy
(IMPT) is achieved. A key limiting factor of the widespread use of carbon ion therapy is that the
accelerators and gantries required for carbon ions are considerably larger and more expensive
than for protons because of the higher beam energy required for a comparable range in tissue.
The main goal of this student project is to optimize the design of an x-y beam scanning magnet
that meets the criteria for use on a next-generation, compact carbon ion beam gantry and could
enable very compact proton gantries.

Cassandra Phillips – Washington State University

Develop a calibration method for a slope-measuring laser profilometer, and test deformable
mirror samples.

Mentor: Lahsen Assoufid, Experimental Facilities Division – Argonne National Laboratory

Project 1
Contribute to the development and validation of absolute calibration method and procedure for
a slope measuring laser profilometer. The profilometer is designed to measure surface slope
profile of x-ray mirror with <100 nrad accuracy.

What the student will learn: basic theory and experience with x-ray optics and related metrology
measurements; data analysis and processing of metrology data; interaction and teamwork in a
multidisciplinary environment.

Project 2
Work with a multidisciplinary team to test deformable mirror samples based on magnetostrictive
film manipulation for x-ray application. The proposed work is a continuation of a past year Lee
Teng project and may involve collaboration with a Northwestern University postdoc.

What the student will learn: basic theory and experience with x-ray optics and related metrology
measurements; data analysis and processing of metrology data; interaction and teamwork in
multidisciplinary environment.
Calder Seagren – University of Chicago

**Magnetization and microscopy measurements to characterize Nb and Nb₃Sn samples before and after electron irradiation**

**Mentor:** Tiziana Spina (Fermilab)

To improve the superconducting performances of SRF cavity and superconducting magnets, Nb cut out and Nb₃Sn tube samples will be irradiated with an electron beam at 9MeV up to fluences of 10²²e/m². Magnetization and microscopy measurements as a function of T (including cryogenic temperature) are important to characterize the effects of irradiation on these BCC materials. Analysis and understanding of the acquired data in the contest of superconductivity for accelerators will be the core of the present project.

Benjamin Sims – Michigan State University

**Validation of Magnetic Elements for the Optical Stochastic Cooling Experiment at the IOTA Ring**

**Mentor:** Jonathan Jarvis (Fermilab)

Beam cooling is an indispensable element of modern storage rings and colliders and has enabled fundamental breakthroughs in accelerator-based discovery science. For example, van der Meer’s Nobel-winning stochastic cooling (SC) was vital in the accumulation of antiprotons and the delivery of the beam quality needed for the discovery of the W and Z bosons. With a limited bandwidth on the order of several GHz, conventional SC systems become ineffective for the high-density beams of modern colliders and storage rings. An extension of the SC principle to optical frequencies (~10¹⁴ Hz), termed optical stochastic cooling (OSC), would increase cooling rates by three to four orders of magnitude. This is achieved by replacing the microwave hardware of SC with optical analogs, such as undulators, light optics and optical amplifiers. The demanding requirements of OSC were accounted for in the design of Fermilab’s recently commissioned Integrable Optics Test Accelerator (IOTA) ring, which is located at the Fermilab Accelerator Science and Technology facility (FAST). As a result, it is the only machine capable of effectively demonstrating OSC in the near future.

The OSC experiment depends on a large number of specialized magnetic elements and their thorough characterization is critical for the program’s success. This Lee Teng Internship project will focus on the development and commissioning of a magnetic-measurement test stand at the IOTA/FAST facility. The student will integrate the magnetic-measurement system, develop the data-acquisition and post-processing software and validate the integrated system’s performance on the recently procured OSC chicane dipoles. Depending on the pace of the project, the student
Yisheng Tu - University of Rochester

Conceptual design of a quadrupole kicker and study of beam dynamics for generating echoes in IOTA

Mentor: Tanaji Sen (Fermilab)

The main focus of the project will be to design a quadrupole kicker using stripline electrode plates. The parameters of the kicker will be chosen to create echoes of sufficient amplitude for both electrons and protons in the IOTA ring. The design task will be to optimize the cross-sectional shape and geometry of the plates that minimize the voltage on the plates, have sufficient field uniformity and achieve these requirements in a compact 3D geometry. The design will be done with a finite element code FEMM. In addition, the student will study the beam dynamics of echo generation in the presence of a nonlinear integrable optics magnet in IOTA. This part of the project will use a beam optics design code MADX.

Ningdong Wang – University of Illinois, Urbana-Champaign

Modeling a spin-rotator solenoid array into the magnet lattice of the electron storage ring of the SuperKEKB electron-positron collider.

Mentor: Uli Wienands, Photon Sciences Directorate – Argonne National Laboratory

The student will be engaged in modeling a spin-rotator solenoid array into the magnet lattice of the electron storage ring of the SuperKEKB electron-positron collider. This project involves working with beam optics and spin motion in electromagnetic fields using state-of-the-art computer codes as used in the field. The work will be done using the code Bmad, developed at Cornell U. by David Sagan and others. A lattice description of the ring for Bmad exists. The tasks will be to first study the spin motion in the ring as it presently exists, in particular finding the stable spin direction and the variation of same with beam energy. Then a model of the spin rotator solenoids will be build using skew quadrupoles to decouple the solenoids optically. Finally, the solenoid modules need to be matched to the ring lattice. By the end of the project the student will have been exposed to real-life work of an accelerator physicist working on design aspects for a particle accelerator ring. S/He will have gained a deeper understanding of first-order beam optics and the effect of magnetic elements on a particle beam, and have worked with concepts like betatron motion, matrix optics, phase space and others. This project is part of a
larger effort spearheaded by the University of Victoria to upgrade Super KEKB for polarized electron beams.

Jinlin Xu – University of Illinois, Urbana-Champaign

Design of a beam switchyard for the ATLAS multi-user upgrade.

Mentor: Jerry Nolen, Physics Division – Argonne National Laboratory

ATLAS is a DOE Nuclear Physics facility at Argonne. It is based on a superconducting ion linac and has been a single user facility since its inauguration in 1985. In order to enhance the experimental program at ATLAS and allow more beam time for applications, an upgrade project was recently approved to convert it into a multi-user facility. Serving multiple users simultaneously requires beam delivery to different target stations at the same time. The conceptual design to combine beams at injection to the linac (~30 keV/u) and separate them in the medium-energy section (~5 MeV/u) was already developed. However, a beam switchyard required for a dedicated material irradiation station at low energy (~1 MeV/u) was not included in this study.

The main goal of this student project is to design a beam switchyard following the positive ion injector (PII) section of the linac. This includes optimization of the beam optics and the beam line elements required considering the existing space constraints.

Xu Yan – Cornell University

Numerical study of a beam extinction system for the Fermilab Mu2e Experiment

Mentor: Diktys Stratakis (Fermilab)

The Mu2e Experiment will search for the conversion of a muon to an electron in the field of an atomic nucleus with unprecedented sensitivity. This experiment uses an 8 GeV primary proton beam consisting of ~250 ns bunches, separated by 1.7 μsec. In order to improve the quality of the measurement, the out-of-time beam must be suppressed of at least 10^{-10} relative to the incoming bunch. In this study, we will examine a (pulsed) magnet-collimator system that is appropriately configured so that only in-time beam is delivered to the Mu2e Experiment. First, using the tracking code G4beamline, we will simulate the performance of such system. Then, we will examine its tolerance to the initial beam phase-space distribution, lattice alignment errors and accelerator vacuum imperfections. Finally, we will estimate the energy deposited to the collimators by the out-of-time beam.