Report of the IOTA review committee

February 23, 2012

Reviewers:
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Introduction and the Charge to the Committee

The internal review of the IOTA program at ASTA took place at Fermilab on Feb 23, 2012.

The Integrable Optics Test Accelerator (IOTA) is a proof-of-principle experiment for the demonstration of new concepts of nonlinear integrable accelerator lattice. FY12 is going to be the 1st year of significant funding support of the experiment and before committing to the spending, FNAL Accelerator Physics Center (APC) has organized a one day mini-review of the experiment.

All aspects of the experiment have been presented at the review, including:
1) theoretical foundations of the IOTA method
2) numerical computer simulation of the beam stability in IOTA
3) overall design and plan of the experiment
4) technical preparedness of the design of key components of IOTA
5) schedule of implementation, cost and resources
6) plan of beam studies and experiments beyond Phase I

The presentations focused in particular on items 3 and 4 above (magnets, vacuum, RF, injection, diagnostics, power supplies, mechanical support and alignment, beam dump, safety, controls and overall integration).

The Committee has been asked to review all the above-mentioned aspects of the proposal, and provide a short summary report and a recommendation whether the project team should go ahead with major IOTA purchases anticipated for FY12.

Findings

A summary of the history of research on integrable non-linear systems (INLS), the review of the properties of such systems, as well as detailed descriptions of the system design was presented during the review. The possible applicability of such systems to future colliders and high intensity machines was highlighted. This project fits well both the mid-term vision of Fermilab, aimed at intensity frontier and advanced accelerator R&D, as well as the long term vision.

The proposed IOTA ring will be built in the (currently under construction) NML electron beam facility, also known as the Advanced Superconducting Test Accelerator (ASTA). ASTA is one of the new flagship projects at Fermilab, which will become a user facility in the future (a search for the Director of ASTA has been opened a week ago). The first three experiments recommended for ASTA by the Accelerator Advisory Committee are a) the double emittance exchange experiment; b) the x-ray radiation experiment; and c) the IOTA experiment. IOTA is an electron storage ring that will be used to conduct accelerator research. There is no other machine like IOTA and it will provide unique experimental opportunities.

The IOTA ring will have 4-fold symmetry with one insertion for injection, extraction, and RF; one insertion expected to be used for electron lens and optical stochastic cooling experiments; and four insertions for nonlinear elements. The ring fits easily into the allotted space. An initial experimental program was presented, consisting of 4 different experiments with different nonlinear elements. Four different practical implementations of INLS were presented –two with nonlinear magnets, and two with electron lenses. Two possible optical stochastic cooling experiments were also presented.

Machine parameters and lattice designs for the 4 different INLS experiments have been investigated. Initial subsystem requirements (injection system, RF, magnets, nonlinear magnets, vacuum, and diagnostics) have been determined, but for certain systems, in particular for nonlinear magnets, detailed engineering design has yet to be performed. Several systems, such as magnets, BPMs and vacuum system are sufficiently standard and well developed, having benefited from the engineering design efforts synergic with NML beamlines.

Several possible techniques for nonlinear magnet fabrication were presented – an iron-dominated magnet, the machining of helical coils from a copper sleeve, and direct coil winding on a mandrill (which has been performed at BNL for many years).

Substantial frequency map analysis has been done on the IOTA ring to understand magnet tolerances.

Initial M&S cost estimates, rough labor estimates, and a very rough schedule were presented. It is planned to construct IOTA in about 2.5 yrs, so that it will be ready for experiments by mid-FY14. The plan is based on an assumption of

$500K/yr for M&S, with contingency covered by extending the schedule. No risk analysis was presented.

Overall Comments & observations

The project is developed by a very qualified team of physicists, who develop all aspects of the project from theoretical simulations to cost estimate. Several subsystems, for example magnet-vacuum integration have been considered by engineers. It is also understood that an integration engineer will join the project part time in the near future.

The cost estimate was focused on M&S for the base ring, not the experiments or labor. For the largest cost items, the estimate is based on existing budgetary quotes. There are a number of elements and subsystems which will be reused or provided as in-kind contribution. The longest lead-time (18mo) system is the magnet system, and specifications for this system are sufficiently advanced so that procurement of this system can start within a couple of months.

There are a number of possible experiments with different designs of nonlinear elements foreseen. These are not yet prioritised or included in the cost estimate, although the octupoles have been described as probably the most efficient way to start.
The positive effect of integrability requires maintaining rather tight alignment tolerances, of the order of 10 microns or better. Not all rotational errors (pitch, tilt and yaw) have been studied yet. Serious consideration of supporting and positioning for ring components and nonliniear elements has not begun, and that cost has not been included in the cost estimate.

The number of BPMs for the ring is determined from the criteria of having one BPM for a certain betatron phase advance, and as a result, the number of BPMs foreseen is about half the number of quadrupoles. It is also understood that doubling the number of BPM bodies (without electronics) will cost about $50k. The only diagnostics in IOTA capable of turn-by-turn measurements, besides a single intensity monitor, are the BPM's.

NML beam parameters appear to be adequate for the IOTA experimental program. The IOTA experiment requires 50-150 MeV beam, which is expected to be readily available in FY13 at ASTA.

Substantial additional design and engineering work will be required to produce nonlinear magnets suitable for IOTA experiments. Tolerances on magnet fabrication and alignment appear to be very stringent. The design of magnet supports and adjusters will have to be performed taking these stringent tolerances into account.

The power needed for IOTA (250 kW max.) is available, and it is assumed that there is sufficient water cooling available.

While the IOTA facility will support a scientific program, its construction is an engineering project that requires a risk analysis and adherence to the Fermilab Engineering Manual.

Recommendations

Investigate the benefits of increasing the number of BPMs or at least consider putting in provisions to add BPM's in the future.

Investigate effect of misalignment errors that were not yet included.

Translate the physics requirements of alignment into an engineering design that can achieve the requirement.

Discuss with Technical Division how the measurements of all magnets will be performed.

It should be verified that the ASTA water cooling system has sufficient capacity for the needs of IOTA.

Continue to update M&S cost estimates as the engineering design matures.

Develop a high-level multi-year schedule with appropriate level of detail for a project of this scale, which includes design, procurement, and installation plans for each year.

Proceed with your most urgent procurements.

Collaborations for the experiments (nonlinear studies, OSC) should be developed with other institutions and in-kind contributions to experiments secured.

Conduct an overall risk analysis of the project and, as the project progresses, of the individual components. This will allow concentration of effort on the most vulnerable aspects of the project and increase the probability of success.

Appendix: Agenda of the meeting

Thursday 23 February 2012

08:45 - 09:00 Executive Session

09:00 - 09:30 Integrable Systems 30'
(Introduction; the "big picture", connection to Intensity Frontier.)
Speaker: Slava Danilov (ORNL)

09:30 - 10:00 IOTA Experimental Goals 30'
Speaker: Sergei Nagaitsev (FNAL)

10:00 - 10:30 Overall IOTA Design, Subsytems, Special Magnet Design 30'
Speaker: Alexander Valishev (Fermilab)

10:30 - 10:45 Break

10:45 - 11:05 Nonlinear Magnet Section Design Based on Multipoles 20'
Speaker: Holger Witte (Brookhaven Nat'l Lab)

11:05 - 11:30 Numerical Simulations (tracking) 25'
Speaker: Dmitry Shatilov (Fermilab)

11:30 - 12:00 Optical Stochastic Cooling Proposal 30'
Speaker: Valeri Lebedev (Fermilab)

12:00 - 13:00 Lunch

13:00 - 13:20 Schedule, Costs 20'
Speaker: Sergei Nagaitsev (FNAL)

13:20 - 14:00 Question & Answer Session 40'

14:00 - 14:30Closeout 30'