Robust Wire Scanner for High Intensity Beam Profile Diagnostics

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Outline

- RadiaBeam – an accelerator company
- Need for Fast Wire scanner
- Phase I feasibility results
- Engineering
  - Diagnostics
  - Timing
  - Layout
- Phase II experiment studies at JLab
- Summary
RadiaBeam

an accelerator company
RadiaBeam at a glance

A quick overview.

The Beam Team

- Founded in 2004
- Approximately 55 employees and growing
  - PhD Scientists (12), Engineers (22), Machinists (10), Technicians (6), and Administrative (5)
- 32,000 ft² headquarters
  - Located in Santa Monica, CA, near Los Angeles
  - Fabrication shop, radiation bunkers, laboratories
- In-house design, engineering, manufacturing & testing
- $11 million revenue in 2017

- Current product line:
  - Linac systems and betatrons
  - RF structures
  - Magnetic optics
  - Beam diagnostics
- Strong R&D program in the following areas
  - Advanced acceleration techniques
  - Improved industrial and medical accelerators
  - Novel accelerator components and instrumentation
We love beams.

**RadiaBeam’s purpose is to contribute meaningfully to the world of accelerator science and technology.**

High-energy particle beams are cool.

That is why we do what we do. We are a company founded by accelerator physicists, for accelerator physicists.

We are driven by an entrepreneurial spirit to make our operations as efficient and profitable as possible, without sacrificing our purpose.

Our work shows our love for accelerators. We understand what our products do and want them to fulfill their purpose to the greatest extent possible.

In less than a decade, we became the predominant accelerator R&D company in the US. We believe our innovative approach has the potential to serve large commercial markets, such as radiotherapy and X-ray inspection, with superior accelerator products.
Global Locations

Three locations in US and one in the EU.

HQ – Santa Monica, CA
Sales & R&D – San Jose, CA
Detector R&D – Boston, MA
EU Sales & R&D – Geneva, Switzerland
Sales, R&R – Thailand (some day)

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Our Products

More than 1,000 products delivered since 2004. Everything we build has been custom designed, engineered, and built in-house. Several new products are designed and launched every year.
Wide range of offerings

A small selection of key components
Our Customers

Research institutions, universities, and industrial. More than 50% of our sales are exports.
BNNT Wire Scanner Development

The *Ultra Wire Scanner*
RadiaBeam’s experience

• RadiaBeam is experienced company in particle beam and radiation diagnostics
  • Array of various customizable modular diagnostics
  • Relations with National Labs, universities, industrial partners, US and international
  • Currently offer a wire scanner for XFELs, installed at the PAL-XFEL
  • Motion control + diagnostics for Dechirper at SLAC
  • Nearly one-hundred actuated beam diagnostics in service

• Commercialization of wire scanner for multi-use applications
  • Use lessons-learned for streamlining product
  • Modular components for “quick” customization
Background

- **Wire scanners**
  - Diagnostics for particle accelerators that provide transverse profile information
  - Thin wire moves through beam; interception produces X-rays
  - Simultaneous measurement of position and X-ray signal

- **Issues**
  - Resolution depends on wire thickness
  - Damage threshold of thin wires (intense beam application)
Current designs

Typical Designs

• Single-ended actuator
• Typically use traditional rotary motors
• Tend to use rotary encoders, causing error in measured position
• Basic wires: tungsten, silicon carbide, carbon, CNT

State-of-the-art

• XFEL wire scanners
  • Fast linear motors
  • Dual encoders, one fast-triggering, one absolute
  • Dual-ended reduces vibrations
• Cherenkov fiber signal detectors
• Advanced control scheme
• Flying and rotary wires
Project Goals and Relevance

- **Project Goal:** Develop Fast Wire Scanner with robust BNNTs
  - As a product, not an experiment

- **DOE NP Relevance:** Beam diagnostics for high power beam are necessary technology for DOE NP accelerators (and others)
  - Improve current designs mechanically
  - Integrated system for drop-in operations
  - Realize truly novel designs – more physics driven, less manufacturing driven
    - BNNT for high resolution
    - BNNT for robust operation under extreme conditions
Project basics

- Boron-Nitride Nanotubes (BNNT)
  - Similar to CNT
  - Mechanically robust and superior at high temperatures
  - Ideal for Wire scanner for intense beam application
- Tested in Phase I feasibility studies
  - Survivability
  - Integrability
  - Photon emission (flourescent, coherent?) also key
- Current project
  - Engineer fast wire scanner with BNNT
  - Also compatible for traditional radiators
  - Complete mechanical system “plug and play” with detectors, motion, etc
BNNT feasibility studies – Phase I

- Beam mounted on fork
- Profile reconstruction
- Anomalous photon emission
  - useful for benchmarking

Reconstructed beam spot: overlaid images

Spooled HTP BNNTs left, with SEM image, inset right.
Engineering
RadiaBeam fast wire scanner
Vacuum assembly

- An improvement over our XFEL wire scanner used at PAL-XFEL
- Uses our standard “re-entrant” bellows for robust and continuous operation – excels in superconducting areas
- Singular strong back for reproducibility
- Rad-hard fast encoders
- Triple redundant fail-safes built in
RadiaBeam fast wire scanner

- Custom interaction chamber
- Swappable wire card
  - BNNT or other (Tungsten, Carbon, etc)
  - Minimize downtime when wires fail
Optical setup

- Optical layout for imaging light emission off BNNT
- Secondary: Monitor for “health” of fibers in-situ
- Built upon our wide-range of beam imaging products
- Allows a new measurement format
Lab integration

- 6-axis alignment
- Vacuum pumps
- “Grout-up” delivery
- Particulate-free processing
- Certified hydrocarbon-free to LCLS-II standards
- Spare wire-cards
- Beam loss monitors
- Future: Control system
JLAB & BNNT collaboration

- Continued characterization of BNNT threads
  - Specifically for wire scanner application
  - Tensile strength, temperature and radiation resistance
  - Failure modes

- Test at two facilities
  - GTS facility: 40 MeV, 5-50kW
  - Low energy test with focus on fluorescence or prompt emission
  - CEBAF: first with pulsed mode, second MHz

- Measurements
  - Beam loss: Cerenkov fiber + PMT
  - Current loss: directly from custom card
  - Emission: fast photodiode and camera

- Integrate into JLAB eco-system

- Testing commences October 2018, CEBAF test 2019
Beyond Phase II

- Develop fully integrable, drop-in wire-scanner
  - Further develop control system in-house
- Further investigate physics mechanisms of emission to determine if viable for other diagnostics
  - Planar radiator with BNNT “fabric”