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Radiation Resistant Magnetic Field Sensing Solution

August 10, 2016

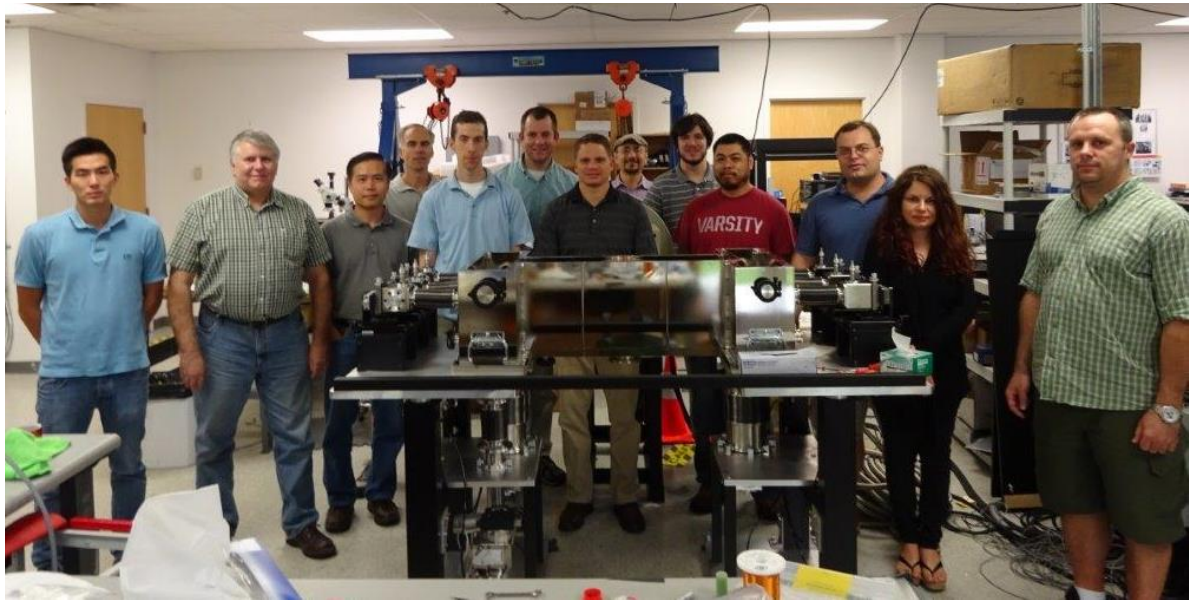
Dr. Brian Geist

Vice President

MicroXact Inc.

SBIR Project: DE-SC0009507

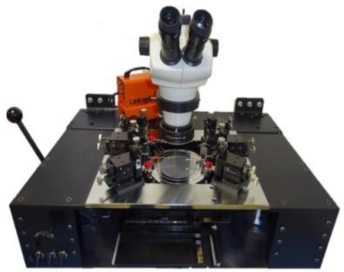
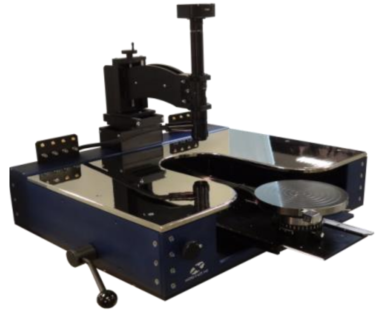
Background of MicroXact Inc.

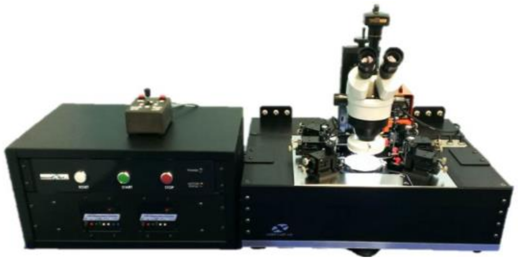


- MicroXact was found in 2004.
- Organically grown (no outside investors)
- Strong technical staff
- Located at Virginia Tech Corporate Research Center, Blacksburg, VA, USA
- International network of sale reps/ distributors in all key markets (S. Korea, EU, Russia, Japan, China, India, Philippines, Malaysia, Australia, Saudi Arabia, Taiwan), office in Singapore
- Mostly serving academia/R&D. Few systems are installed/ used in production of highly specialized components.

Products at a glance

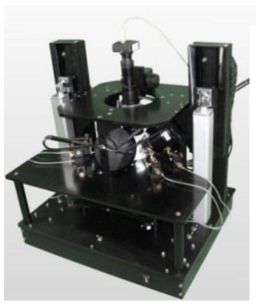
Manual probers for 100mm, 150mm and 200mm wafers. Cost-competitive and customizable to end-user needs

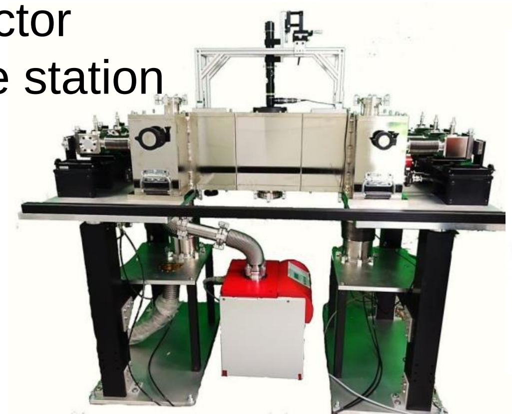



Semi-automated probers for 100mm, 150mm, 200mm and 300mm wafers. Very cost-competitive and customizable to end-user needs

Fully-automated probers for 100mm, 150mm, 200mm and 300mm wafers. The most cost-competitive solution on the market.


Magnetic probe station. The first 3D vector magnetic probe station on the market.




Specialty probers: laser cutting probers, cryogenic probers

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Transitioning SBIR/STTR program into commercial sales

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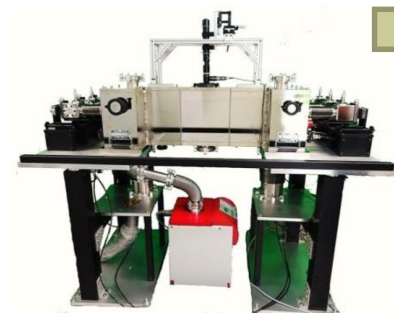
AFOSR Phase I & Phase II STTR Program FA9550-11-C-0018; 2010-2013



$1.215M commercial sales after 3 years with quick growth of the sales (>$0.5M of sales just in 7 months this year sales)

AFOSR Phase I & Phase II STTR Program FA8750-12-C-0157; 2011-2014

>$2M commercial sales to date and counting

Addressed Problem

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- Highly localized (due to field gradients) magnetic field measurements (from 0.2T to 2.5T with $dB/B<10^{-4}$) are needed in the high radiation (Mrads/year) environments of rare isotope beam facility at MSU and pretty much any other accelerator facilities in US and worldwide.

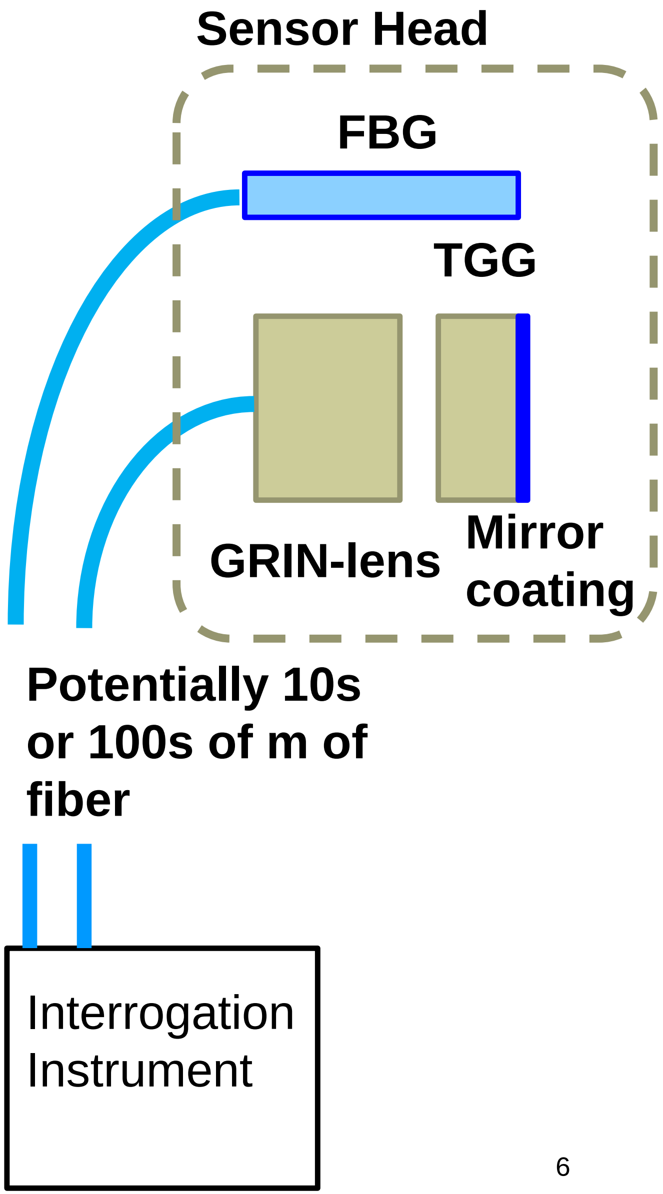
- Typical electronic sensors (even hardened) survive only a few weeks in such environments, and sensor replacement (downtime of ~$10k/day, not counting the price of instrumentation) is costly.

- Fiber optics temperature and strain sensors are already proven to be radiation hard, however to date, fiber optic magnetic field sensors meeting necessary technical specifications have not been demonstrated.

- This project is targeting development

Fiber optic magnetic field sensing, our solution

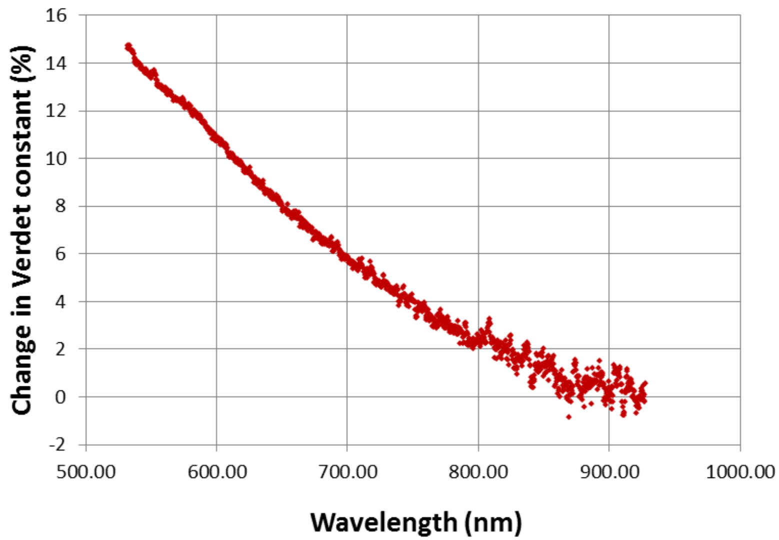
- Terbium Gallium Garnet (TGG) is paramagnetic with high Verde constant (for 632nm wavelength it shows 134 rad $T^{-1}m^{-1}$) that can be used for highly sensitive, highly localized (possibly down to mm^3)fiber optic magnetic field sensing of large magnetic fields.
- However, its Verdet constant is highly temperature dependent, calling for a fiber Bragg grating (FBG) sensor to be co-located with it.
- Multi-wavelength approach for TGG interrogation will increase sensitivity, range and lengthen service life.
- The solution is expected to be relatively inexpensive: interrogation instrument $25k, replicable sensor head (probably below $2k) and offer significant savings over time.

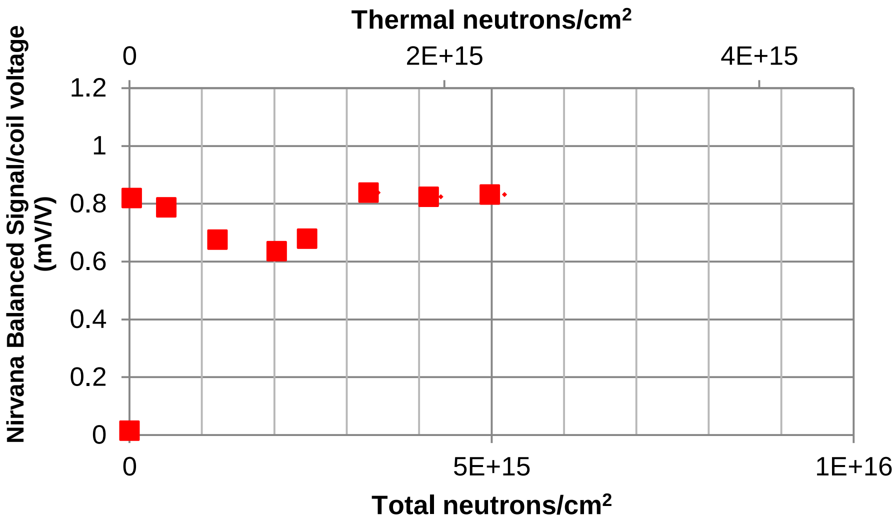


Study of radiation effects on TGG absorption

Verdet Constant (in rad/(T•m)) of TGG crystals with a 2 cm length

	532 nm	632 nm
Non-irradiated	-233.76 ± 9.38	-211.85 ± 2.62
Non-irradiated B	-215.30 ± 10.60	-195.46 ± 4.27
Irradiated	-187.23 ± 5.52	-190.48 ± 3.82





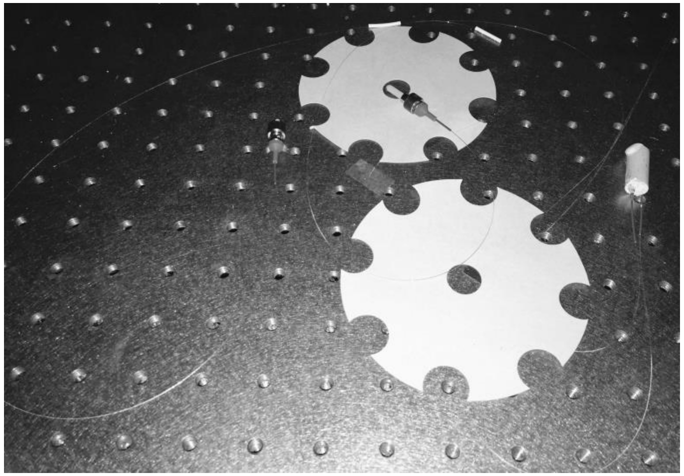
Estimated percent change in the Verdet constant as a function of wavelength after exposure to radiation—At wavelengths above 800 nm, the degradation of the signal is in the background noise

Sensor response to an applied magnetic field as a function of thermal neutron and total neutron exposure

Ceramic and silica as structural members used to encase the sensors in order to minimize radiation damage cross-section of the sensors

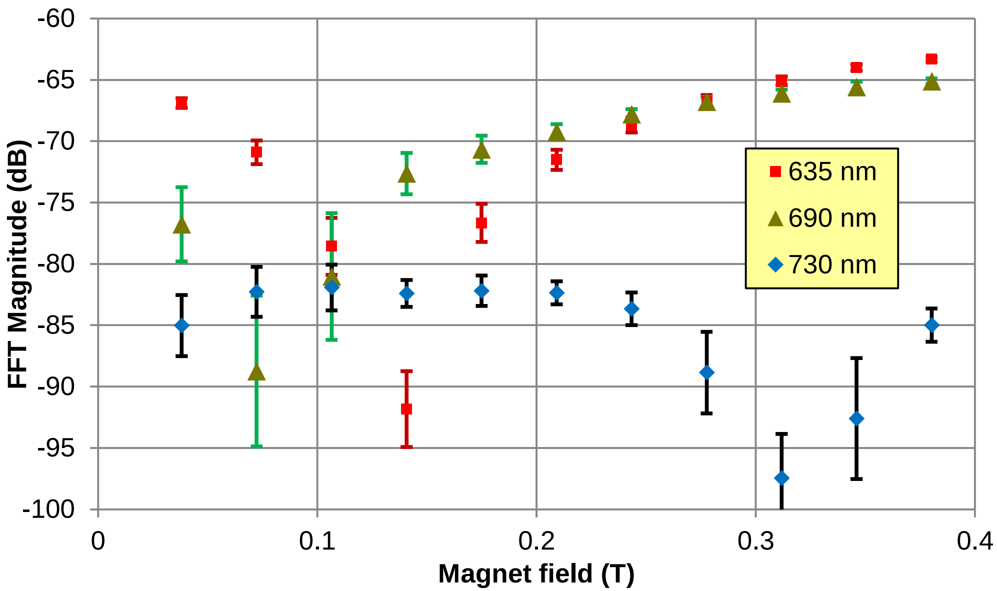
1100 series aluminum used for reflective surfaces to minimize particle emission half-life of the sensors

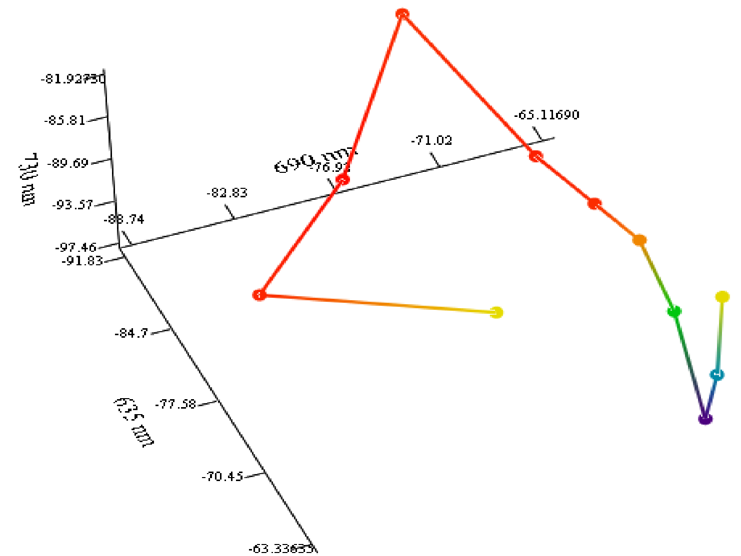
TGG sensor consists of a TGG crystal, two GRIN lens collimators and two mirrors.



Fiber Bragg grating co-located with the magnetic field sensor for measuring temperature.

Data presented last year:





- Absence of ambiguity is demonstrated to 0.5T with 1cm long TGG crystal.
- Suppression of electronic noises in the circuitry key to success– Optical receiver board optimization and fabrication by Bluewire Prototypes

bluewire PROTOTYPES

http://www.bluewireproto.com/

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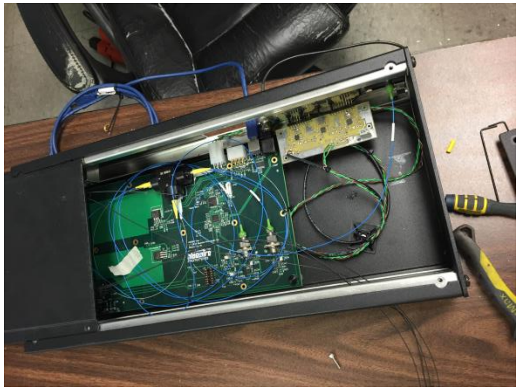
System status

- Proprietary sensor design and construction (completed, sensor performance verified in house)
- Proprietary, patent-pending sensor interrogation instrumentation to enable significantly better dynamic range and sensitivity. System development is in its final stage
- Advanced software enabling straightforward integration with auxiliary instrumentation.

Stand-alone system prototype for interrogation of up to 3 sensors



Fiber optic receiver board

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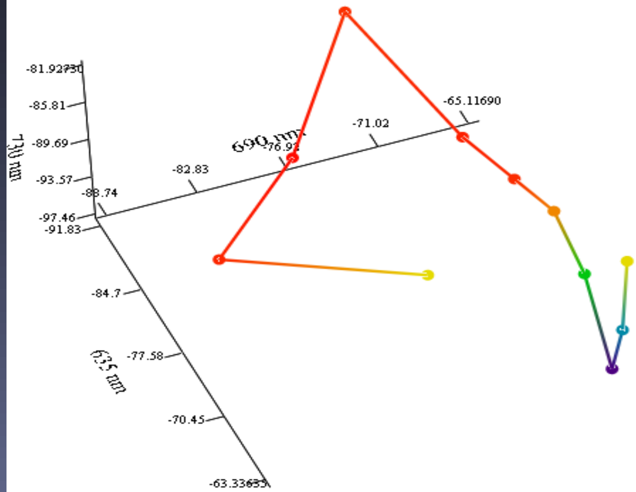
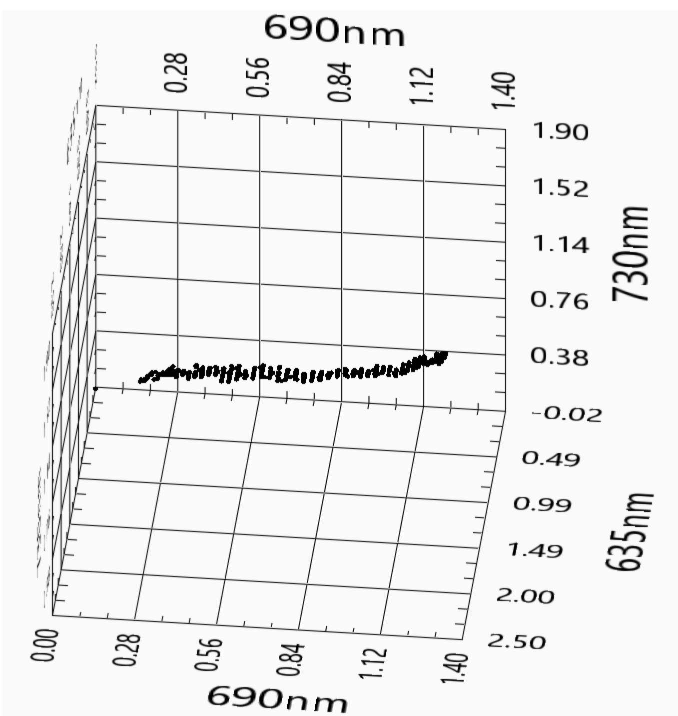
Old data

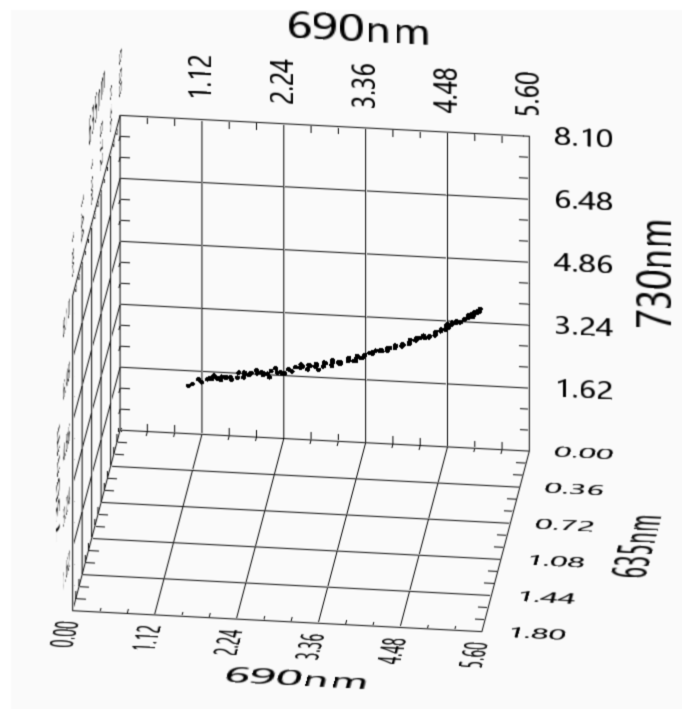


Instigated new board design with analog processing and optimized for low noise and increased sensitivity

Data collected at 10 Hz



Data collected at 2 Hz



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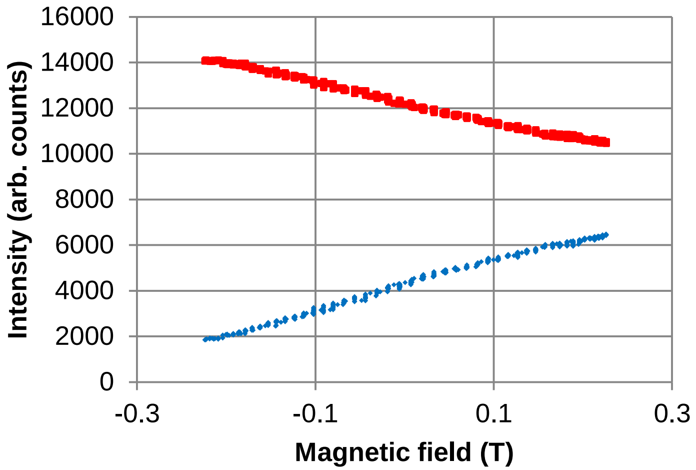
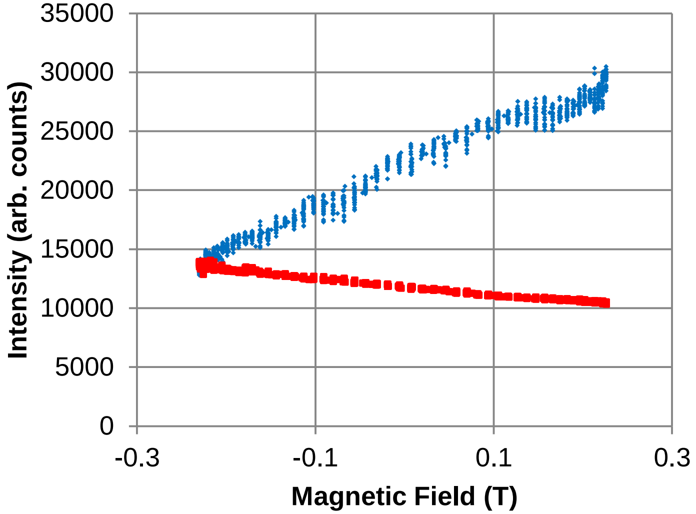
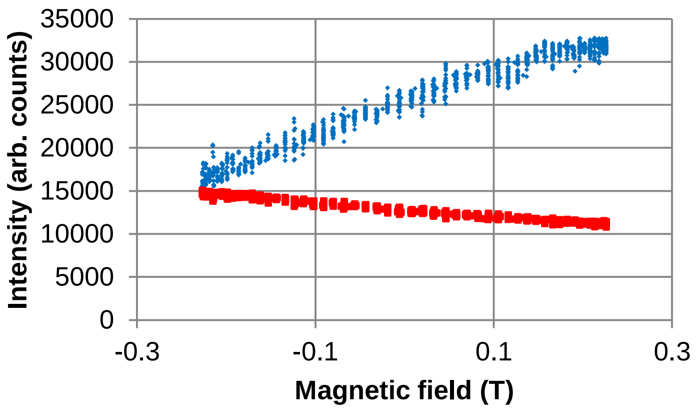


Sensor response at the 635 nm excitation wavelength, vertical (<±1.0%) and horizontal (<±1.0%) polarizations measured at 10 Hz.



Sensor response at the 690 nm excitation wavelength, vertical (±1.5%) and horizontal (±10%) polarizations measured at 10 Hz.



Sensor response at the 720 nm excitation wavelength, vertical (±1.5%) and horizontal (±10%) polarizations measured at 10 Hz.

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Synergy in the reverse direction

An automated PID controlled 0.6 Tesla 3D magnetic field prober being constructed for a commercial customer in Singapore based on technology developed on an STTR funded project being used to qualify SBIR project magnetic field sensors during build testing.

Future plans

- Completion of interrogator development
- Final testing of interrogator/sensor at ORNL.
- One more testing of the system at OSU NRL.
- Final testing of the system at MSU FRIB

Conclusions and recognition

- New sensor/interrogation instrument design will result in significant cost savings to DoE through eliminating the need for frequent probe replacement/recalibration.

- Initial contacts with a number of accelerator facilities in US confirmed strong interest of the community for the solution under development

- Special thanks to Elizabeth Bartosz and Manouchehr Farkhondeh, Topic Associate and Program Manager respectively.

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