2016 NIBS Award winners

D-Pace President and Buckley Systems' Chief Scientific Officer, Morgan Dehnel, presented the D-Pace sponsored 2016 prize at the 5th International Symposium on Negative Ions Beams and Sources at St. Anne's College in Oxford, UK.

Prof. Katsuyoshi Tsumori, Prof. Yasuhiko Takeiri, Dr. Katsunori Ikeda, and Dr. Haruhisa Nakano of the National Institute for Fusion Science in Toki, Japan received the 2016 NIBS award which includes a plaque and $5000 for their recent contributions regarding the diagnostics, and theoretical & applied physics of beam sources for negative ion based neutral beam injectors.

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Upcoming 2017 Conferences and Events

Buckley Systems and/or D-Pace will have a presence at all these events. Please contact us if you would like to arrange a specific meeting with us while we are there.

- **May 14-19 IPAC'17: Copenhagen, Denmark**

  8th International Particle Accelerator Conference

- **June 10-14 SNMMI 2017: Denver, Colorado**

  Society of Nuclear Medicine and Molecular Imaging

- **July 11-13 Semicon West: San Francisco, California**

  Industry supply chain showcase

- **July 31 – August 4 AccApp'17: Quebec City, Canada**

  Thirteenth international topical meeting on nuclear applications of accelerators

- **August 20-24 IBIC'17: Grand Rapids, Michigan**

  International Beam Instrumentation Conference

- **October 15-20 ICIS 201717: Geneva, Switzerland**

  International Conference on Ion Sources

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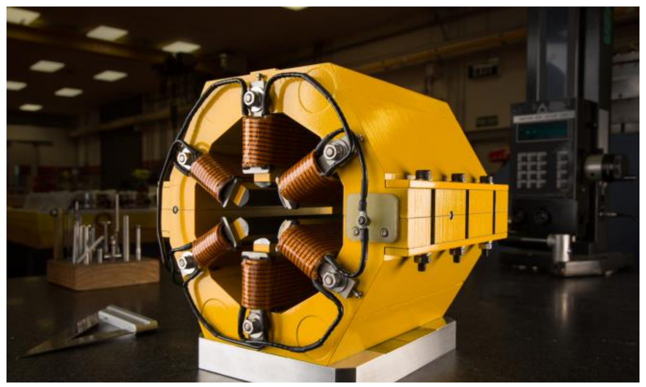
If you would like to subscribe to an email edition, please contact info@buckleysystems.com



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BUCKLEY SYSTEMS
Ingenious at work

Buckley Systems Technical Bulletin

This issue

50 years of ion source industry in New Zealand

2016 marked 50 years since a team of graduate physicists from Auckland University set up a business to produce polarized ion sources. The success of the Auckland Nuclear Accessory Company (ANAC) and the businesses the founders have since been involved with, has made a huge impact on the ion implantation industry across the globe.

To celebrate this milestone, a documentary about the early days of ion implantation has been produced. Called *Atoms at Work* it features Hilton Glavish, Barry McKinnon, John Ruffell and Ian Walker. The film backgrounds the history of the company and the spinoffs that have created over 1.2 billion dollars in export business for New Zealand from $100,000 in research funding.

Bill Buckley was involved in producing the high-power, precision electromagnets required by ANAC from a very early stage and the relationships built there have since seen Buckley Systems become a world leading manufacturer of ion beam equipment.

UniBEaM beam profiling scanner

UniBEaM25 is a brand new particle beam profiling system using optical sensor fibers rather than traditional metal. It is used to measure the beam current intensity profile of ions, electrons and X-rays. For beamline operators, beam profilers are crucial for verifying beam width and position, as well as beam intensity and shape.

Developed at the University of Bern, commercialized by D-Pace and manufactured by Buckley Systems, UniBEaM has many unique advantages including a large dynamic range, no electromagnetic susceptibility and an insertion length of only 70 mm. UniBEaM is a turnkey system consisting of a probe, controller, cables and spare fibers which can be changed in under two minutes once the beamline is vented.

The UniBEaM probe has two 200 µm diameter cerium doped sensing fibers. The horizontal and vertical fibers move through the beam in steps as small as 25 µm. The fibers scintillate in the visible spectrum and this light is detected by a high-sensitivity photo-sensor located in the UniBEaM controller. The signal is then amplified, digitized, and displayed on a monitor. UniBEaM25 was designed for a nominal 25 mm diameter beam. UniBEaM75 and UHV compatible versions of UniBEaM are available.

D-Pace launched an early adopter program (EAP), with first participants in the program including the University of Bern, University of Michigan and Australia National University.

UniBEaM is capable of measuring beam currents over the ranges of pico-Amp (pA), nano-Amp (nA), micro-Amp (µA) to milli-Amp (mA), and kinetic energy ranges of kilo-electron Volt (keV), Mega-electron Volt (MeV) to Giga-electron Volt (GeV), and with the charged particle types ranging from light ions to heavy ions, but also including electrons. In addition, the device has proven useful in measuring X-rays, though the results are still preliminary. UBCO, TRIUMF and D-Pace have recently won a Canadian NSERC ENGAGE award to prove out the UniBEaM25's x-ray capabilities.

The UniBEaM25 has already undergone extensive testing at the Ion Source Test Facility (ISTF) at Buckley Systems, University of Bern and University of Michigan. Test results are being compiled and are available to interested parties.

Morgan Dehnel, Buckley Systems' Chief Science and Innovation Officer says, "We are excited about the launch of UniBEaM and our early adopter program. We believe UniBEaM will fill a long-standing void in compact, low-cost beam diagnostics."

ISTF produces three white papers in 2016

The Buckley Systems / D-Pace Ion Source Test Facility (ISTF) is currently being used to research C^-, H^- and D^- ions. The research has resulted in two papers presented at IPAC 2016 and one paper presented at NIBS 2016.

Experiments have been undertaken using a TRIUMF licensed, filament-powered, volume-cusp ion source and an extensively modified, RF powered ion source licensed from the University of Jyväskylä, Finland. The filament cusp ion source was able to produce 400 µA of C_2^- using acetylene. With further development, it is hoped to progress the output towards 0.5 mA.

The filament source also produced 18 mA of H^- and 6 mA of D^-. Experiments with the RF source have produced 10 mA of H^- and 3.5 mA of D^-.

Copies of the white papers are available online at: www.d-pace.com/about/publications.

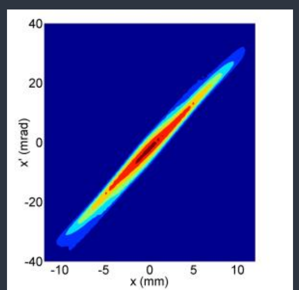
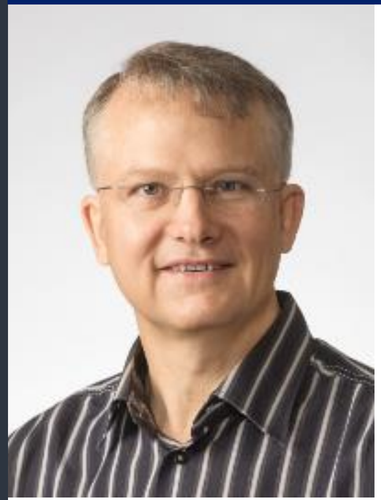


Image shows x-x' phase space scans obtained with the RF ion source for the 6.1 mA H^- beam tune. The normalized 4-RMS emittance is 0.41 mm·mrad and contained 85% of the beam.



Morgan Dehnel Ph.D., P.Eng.

Chief Science and Innovation Officer

International representative for a global business.

Growing up as a child in the backwoods of British Columbia, a 13 year-old Morgan stepped into the mobile library that called at his small village of Corra Linn and on impulse, took out a book about particle acceleration. He can't remember the title but it sparked a fascination with science that remains undiminished today.

In 1983 after completing a Bachelor's degree in Engineering Physics and a Master's degree in Electrical Engineering at the University of British Columbia, Morgan departed for Europe on a backpacking holiday with his future wife. While in Switzerland he took the opportunity to go on a guided tour of the facilities at CERN and decided that accelerator physics was what he really wanted to be involved in. Returning home, Morgan found there were no openings at the TRIUMF facility on UBC's campus. However, Ebco, a major supplier to TRIUMF that was undertaking a technology-transfer program to commercialize cyclotrons for medical radioisotopes offered him a job as a beamline engineer. Later, Morgan completed a PhD at TRIUMF/UBC in applied accelerator physics developing a new ion source and injection system for Ebco's TRPET Cyclotron.

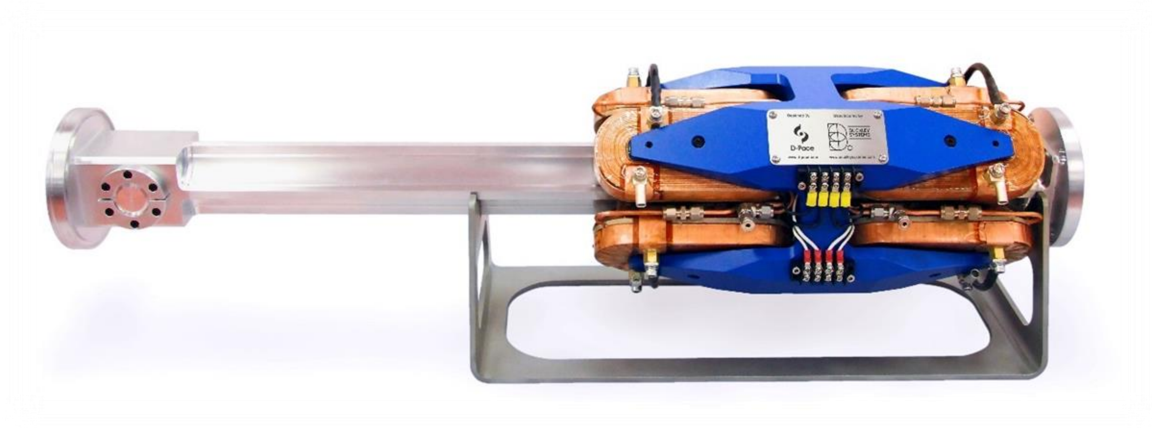
Shortly after graduating in 1995, Morgan founded Dehnel Consulting Ltd (DCL). The new company quickly established its credentials with the commercial accelerator industry in Canada, the United States, Asia and Europe before the company began to diversify its activities by licensing technology developed at TRIUMF and other research institutes.

To reflect the growing and changing nature of his business, the name was changed in 2004 to D-Pace (Dehnel Particle Accelerator Components and Engineering). As a small business, capital for development was always tight until Buckley Systems, one of D-Pace's major suppliers of components, purchased a 50% stake in the company in 2014. The partnership has allowed Morgan to pursue exciting opportunities including development of stages one and two of the Ion Source Test Facility (ISTF) based in Auckland, New Zealand. The facility has proved to be a huge benefit to both companies, allowing research into new ion sources plus real-world testing of new beam diagnostic products and beamline magnet systems. "We first licensed the volume cusp ion source from TRIUMF in 2001

and it is incredibly exciting to see all our development work paying off" says Morgan.

As part of the Buckley Systems / D-Pace partnership, Morgan has become the Chief Science and Innovation Officer for Buckley Systems, further cementing the relationship between the two companies. Morgan will remain based in Nelson, British Columbia, Canada as he is close to clients in North America and in a similar time zone. In addition, "With video-conferencing, it's easy to keep in touch with clients around the world" comments Morgan. "Plus, with a manufacturing and research base in New Zealand, we can work on problems overnight and often have solutions by the following morning."

Morgan is still excited about accelerator physics and is keen to take full advantage of the synergies between D-Pace and Buckley Systems to develop new applications.



Technology news

Mini-PET is a compact beamline for Positron Emission Tomography (PET) radioisotope production collaboratively designed and built by Buckley Systems and Dehnel - Particle Accelerator Components and Engineering (D-Pace). The Mini-PET system allows the radioisotope target to be moved away from the cyclotron, facilitating the use of local shielding to reduce prompt gammas and neutrons. More importantly this attenuates residual target radiation, minimizing ionizing radiation exposure to research and maintenance staff.

In addition, dynamic focusing and steering provide increased control of the proton beam, greatly improving radioisotope production rates.

Over 30 years Buckley Systems has garnered a wealth of experience crafting particle accelerator systems to the highest standards for the semi-conductor, medical and research sectors.

Once engineering drawings were finalized, Buckley Systems set to work on the manufacture of the beamline. With over 280 staff, quality materials and fully equipped machine, coil and integration shops, manufacturing particle accelerator systems is where Buckley Systems excels.

Magnet yoke halves and poles were individually machined from solid 1006 low carbon steel to tolerances as low as 30 µm using one of thirty CNC machines at the Machine Shop's disposal. Where tighter tolerances are required, the entire assembly is EDM wire cut. This effectively keeps parts tolerance stacking to an absolute minimum.

The coil assembly consists of a water cooled aluminum plate sandwiched between the quadrupole and steering coils. Quadrupole coils were of the copper strip / Mylar insulated variety for high current densities while the low power steering coils were wound from enameled solid wire. All coil components including electrical links, terminals and thermal sensor mounts were epoxy vacuum impregnated in a full mold.

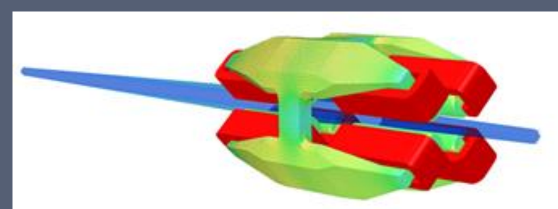
The result: a compact, robust, well cooled, integrated coil.

Using 6061 aluminum alloy for its low residual radioactivity, low gas permeability, low magnetic susceptibility and easy machining properties, Buckley Systems shaped the individual vacuum tube components and seamlessly fused them together. The end product was a high acceptance cross shaped vacuum tube that served not only to hold high vacuum but also to align all eight poles, support the system via its flange ends and to facilitate longitudinal movement of the magnetic elements relative to the target.

All parts were thoroughly dimensionally checked using co-ordinate measuring machines before plating the pole surfaces with a durable layer of nickel for corrosion protection and painting the yoke.

Once in the Integration workshop, the coils, poles and yokes were assembled and aligned before making power, coolant and sensor connections. The electromagnet was then fully tested electrically, magnetically and mechanically in Buckley Systems calibrated, temperature controlled test laboratory. Magnetic 3D Hall probe scans and rotating coil results were cross referenced with FEA models to ensure that the system met specification.

The finished electromagnet was then coupled to its cleaned and sealed vacuum chamber before being carefully packed to ensure the system was delivered in perfect condition. A document package which draws together check sheets, test data and instruction manuals accompanies every shipment.



Magnetostatic and charged particle beam analysis of the Mini-PET system

Strip coil manufacture

Many of Buckley System's electromagnet coils are wound from copper strip.

While this seems like a simple process, strict manufacturing tolerances need to be observed to ensure the coil works to specification.

Coils are wound around a former using copper strip and an insulation material (usually Mylar). Great care is needed to ensure that the coil contains the correct number of turns, is within the designed size and the layers of copper do not short out. Trained and highly skilled staff monitor every step of the process, making adjustments to compensate for minute changes in copper thickness which can result in large dimensional changes over many turns.

When wound, the coils are checked, tested, terminated, then fiberglass wrapped before being vacuum impregnated with special epoxy resin and oven cured.

Finished coils undergo additional quality testing to ensure they meet Buckley Systems' exacting standards and will give the long, trouble-free service life that our coils are renowned for.