Transformer Development at Bergoz Instrumentation

I.FAST-REX Kick-Off Meeting

8-9 February 2021

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The company at a glance

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Bergoz Instrumentation

- Spin-off from CERN,
  founded in 1981 by J. Bergoz
- Buy-out on October 1st, 2018
- Located in Saint-Genis-Pouilly, France

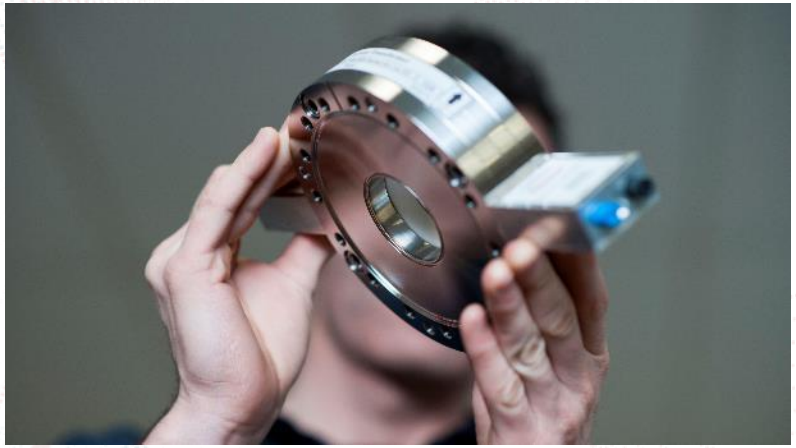
- 2 M€ revenue, >95% export
- 9 People: 1 CEO, 1 physicist,
  3 master degree engineers,
  4 qualified technicians
- 4 Decades of knowledge and know-how

Bergoz Instrumentation - www.bergoz.com - info@bergoz.com

Our Mission

Provide non-destructive diagnostics solutions for low current measurements

- Leverage our close **collaboration** with end-users, provide pertinent technical advice and customer support
- Continuously develop and improve instruments to fulfil present and **new needs** of the particle accelerators community
- Innovate to propose **new solutions** to the medical, industry, energy, environmental and utilities sectors
- Sustain our ability to manufacture **high quality** current transformers and electronics for low current measurements



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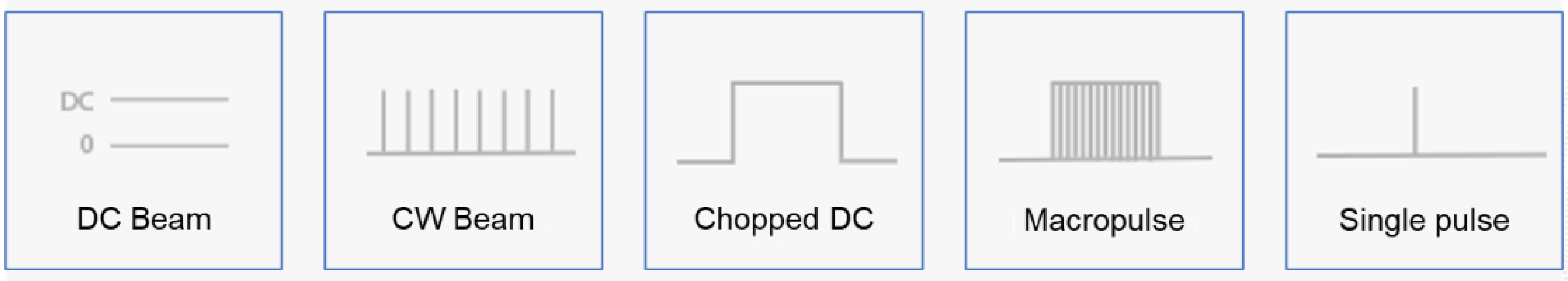
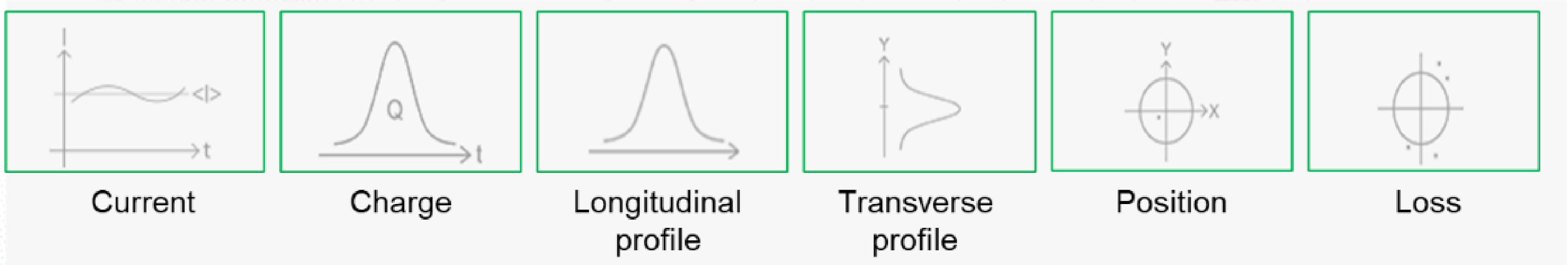
Our Measurement Solutions

- Beam Structure



- Diagnostics

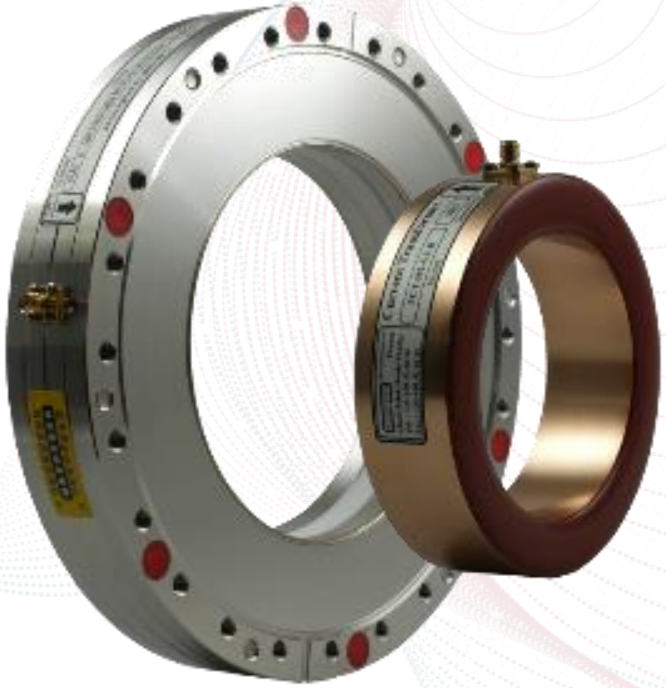


- Beam pulse charge resolution 10fC
- Beam average currents 1µA (100nA coming soon) to 20A
- Beam pulse longitudinal profiles >500ps FWHM to ms and DC
- Beam position 100µm single pulse, 1µm CW
- Beam Loss count rate >10MHz, spurious <0.1Hz
- Beam transverse profile >10^6 dynamic range

Our Products

- Passive Current Transformers

  FCT, ICT



- Beam Position Monitor Electronics

  MX-BPM, LR-BPM,
  S-BPM, BB-BPM

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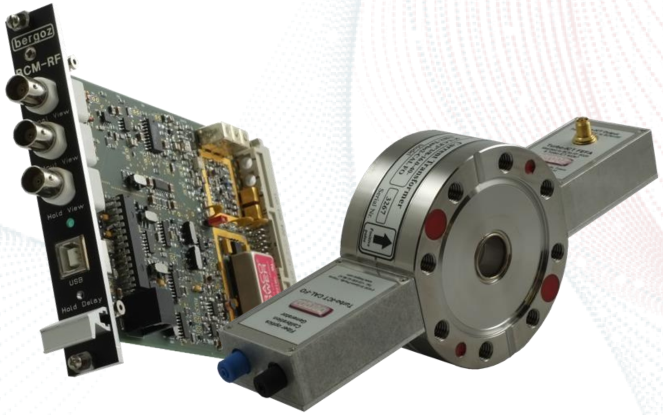
Our Products

- Active Current Transformers (with electronics)

  NPCT & NPCT-E
  IPCT
  ACCT & ACCT-E-RM
  CWCT & BCM-CW-E
  Turbo-ICT & BCM-RF-E
  ICT & BCM-IHR-E

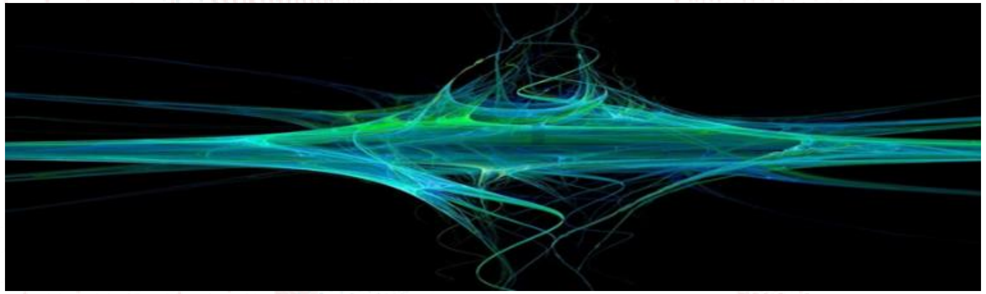


- Others

  Beam Loss Monitor,
  Vibrating Wire Monitor

Our Markets

- **Particle accelerators in fundamental particle and nuclear physics**
  - Particle colliders
  - Ion accelerators
- **Particle accelerators in material science, biology**
  - Synchrotron light source → Photons
  - FEL → UV, Visible UV
  - XFEL → Hard X-rays
  - Neutron Spallation → Neutrons
- **Particle accelerators in nuclear waste transmutation, subcritical reactors**
  - HPPA → Neutrons
- **Medical accelerators in cancer treatment**
  - Electron, Proton, Ion accelerators
- **Laser plasma wakefield accelerators**
  - Next generation accelerators targeted to advance all types of applications



- **Industry**
  - Leakage currents, discharge currents

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Some of our Customers

- **Synchrotron Light Source**

  SSRF (China), LNLS (Brazil), ESRF (France)
- **Neutron Spallation Source**

  ESS (Sweden), CSNS (China), SNS (USA)
- **Free Electron Laser**

  SwissFEL (Switzerland), PAL XFEL (South Korea)
- **Laser Plasma Wakefield**

  LOASIS (USA), CoRELs (South Korea)
- **Cancer Therapy**

  IBA (Belgium), AVO-ADAM (UK)
- **Accelerator Driven System**

  MYRRHA (Belgium), CiADS (China)
- **Leakage currents**

  Techimp (Italy), RTI (Germany)

Our contribution to I.FAST REX

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I.FAST REX Objectives

- Mitigate intensity fluctuations of slowly extracted beam from synchrotrons by means of detailed parameter simulations, related experimental verifications, and active beam control.
- Produce a prototype of improved hardware for power supply control to achieve a current stability in the range of $\Delta I/I < 10^{-6}$.
- Design and produce a high-performance RF-amplifier with versatile control for knock-out extraction.

Task of Bergoz Instrumentation is to develop and build a current sensor with sufficient resolution.


Proposal Submission Forms

Please check our wiki for help on navigating the form.

Horizon 2020

Call: H2020-INFRAINNOV-2019-2020

(Demonstrating the role of Research Infrastructures in the translation of Open Science into Open Innovation)

Topic: INFRAINNOV-04-2020

Type of action: RIA

Proposal number: 101004730

Proposal acronym: I.FAST

Deadline Id: H2020-INFRAINNOV-2020-2

Table of contents

Section	*Title*	*Action*
1	General information	
2	Participants & contacts	
3	Budget	
4	Ethics	
5	Call-specific questions	

How to fill in the forms

The administrative forms must be filled in for each proposal using the templates available in the submission system. Some data fields in the administrative forms are pre-filled based on the steps in the submission wizard.

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This proposal version was submitted by on Brussels Local Time. Issued by the Funding & Tenders Portal Submission System.

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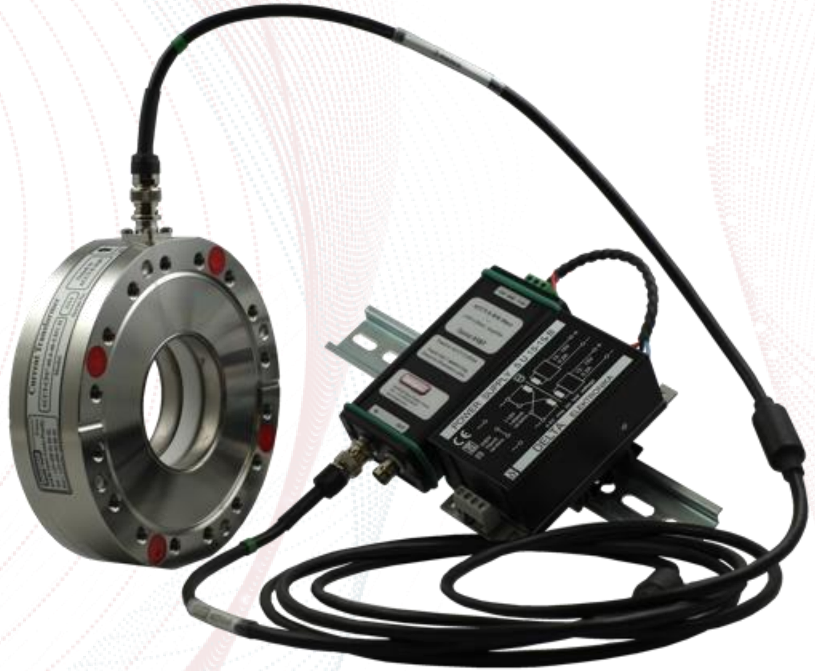
DC and AC Current Sensing Experience

- For DC to 3 MHz measurements, we have two types of sensors:

NPCT
(also called DCCT)

ACCT



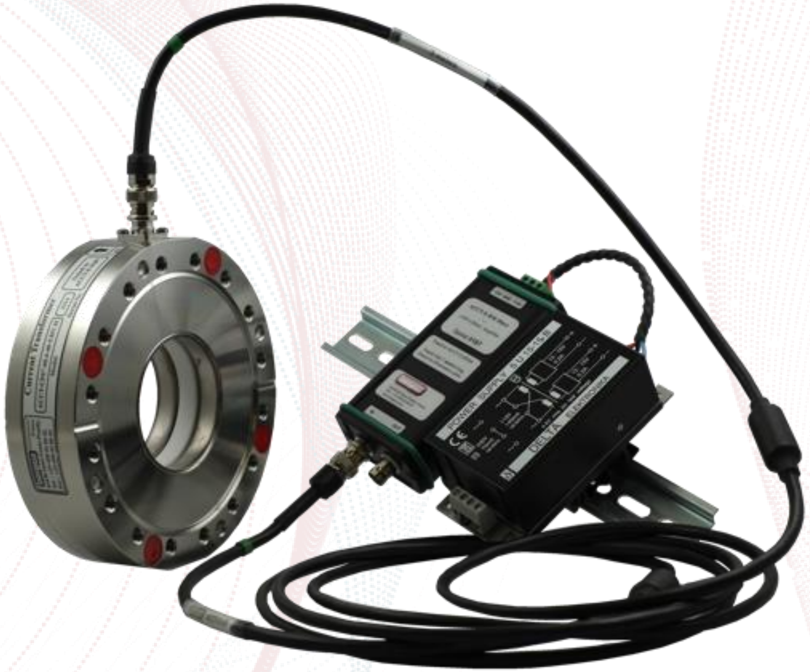
- Both are based on original work started in the 1960s at CERN.
- The (N)PCT was commercialized by Bergoz Instrumentation in the 1980s and is sold all over the world since then.

NPCT and ACCT Working Principles

NPCT

- High sensitivity flux-gate magnetometer with current compensation.
- Combined with current transformer in a common feedback loop to enlarge bandwidth.

ACCT



- AC current transformer with active feedback electronics to compensate transformer droop.

I.FAST REX Current Sensor

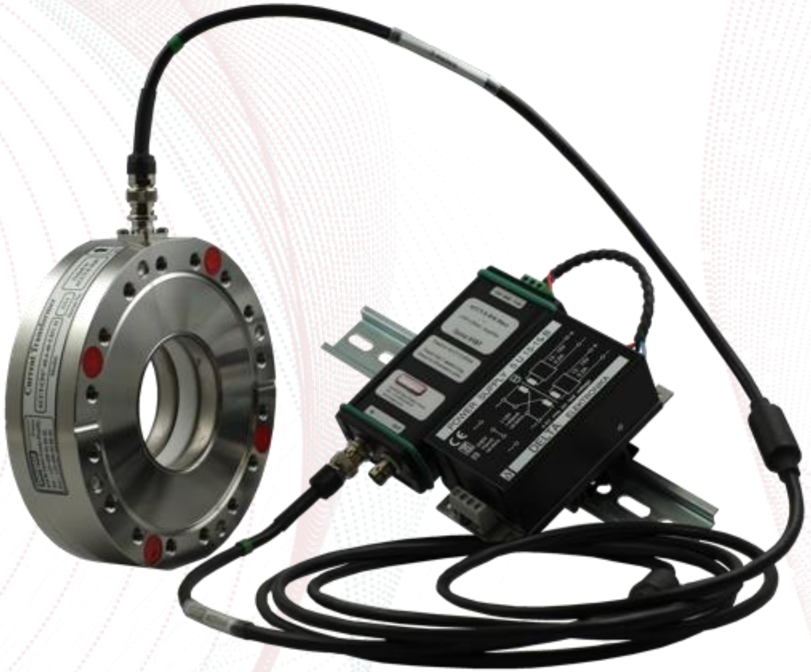
- Either ACCT or NPCT could be used as a basis for the I.FAST REX current sensor development.
- The choice depends on the requirements.
- If DC measurements are needed, NPCT will be chosen.
- If a few 0.1Hz minimum frequency are o.k., ACCT will be chosen.
- Though we could also develop something new…

NPCT and ACCT Performance (typical)

NPCT

- Maximum current = 20A
- Resolution (abs.) = 50µA (10kHz BW)
- Resolution (rel.) = 2.5×10^{-6} (10kHz BW)

ACCT



- Maximum current = 600mA
- Resolution (abs.) = 0.4 µA (10kHz BW)
- Resolution (rel.) = 0.7×10^{-6} (10kHz BW)

Development Challenges

- Resolution of NPCT and ACCT is fine.
- But their maximum current is not.
- How can we push maximum current without degrading resolution?

- High permeability materials will saturate due to strong DC magnetic field of the current, neither ACCT nor NPCT will properly work (in their current states).
- Shielding cannot be used to mitigate such fields.
- One could use:
  - active compensation, which introduces ripple and requires some power
  - low permeability materials, which complicates modulation (NPCT) or enlarges lower cut-off frequency (ACCT)

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Required Specs for Success

- Electrical specifications:
  - Minimum and maximum DC current,
  - AC fluctuations peak-peak current and frequency range,
  - Measurement bandwidth, resolution (frequency dependent), accuracy (=systematic measurement error),
  - ...
- Geometrical specifications:
  - Aperture size, maximum outer dimensions, weight,...
- Others:
  - Power consumption, impact on primary current, electrical insulation of sensor and wire, shielding from environmental noise,...
- Not to forget: Who provides the ADC?
  - Sampling rate >2×f_{max}, ENOB>=20 for 10^{-6} resolution

In-House Testing Possibilities

- In house, we can test with signals from DC to GHz.
- Maximum currents are up to a few 100mA AC and up to 500A DC.

- For higher currents, we need some external test bench, i.e. several kA power supply.

Let's resolve!