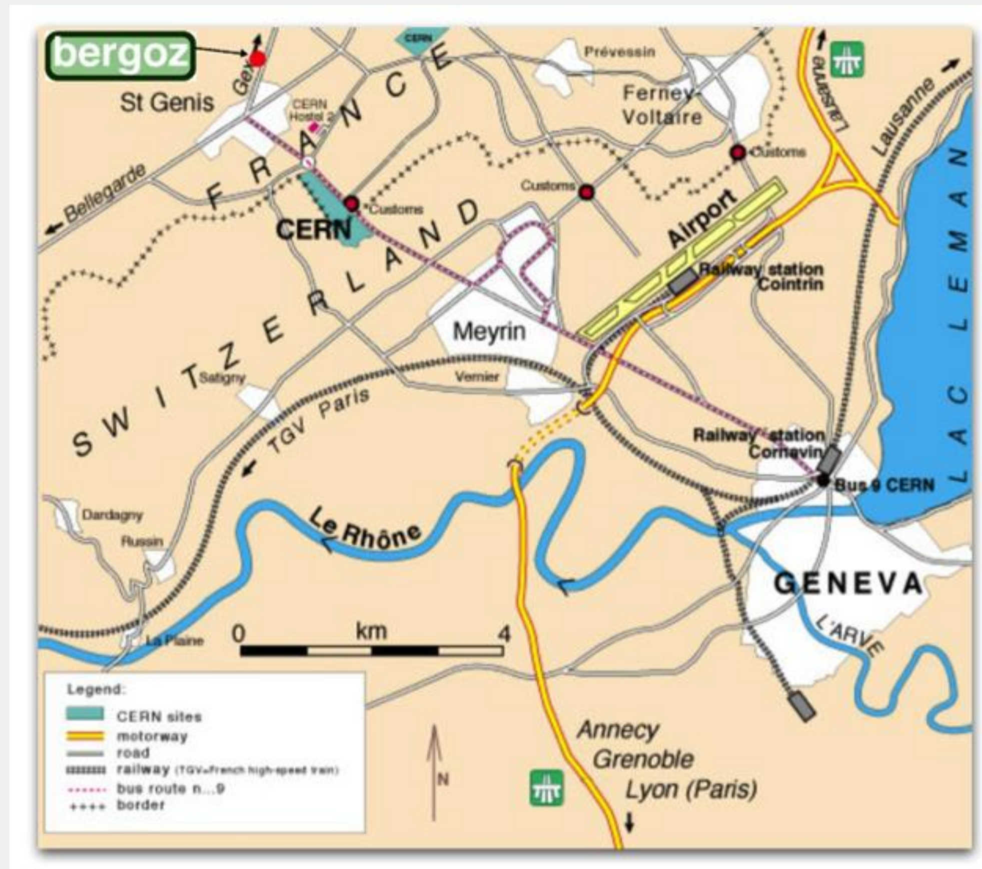
Joint University Accelerator School 2013

Welcome to Bergoz Instrumentation

www.bergoz.com

- Legal form: Sàrl
- Founded in 1981 by Julien Bergoz & Klaus Unser
- Paid-up capital 152 K€
- CEO : Julien Bergoz
- Number of employees: 11
- Turnover : 1.5 MEuros



Distribution network

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Instrumentation

Beam Instrumentation products
USA: GMW Associates, California
Japan: REPIC Corporation, Tokyo
Other countries : direct sales

Industrial products:
USA: GMW Associates, California
Japan: REPIC Corporation, Tokyo
Other countries : direct sales

Our customers:

The World of Synchrotron Radiation

More than 80 synchrotron light sources in the world
Each of them uses our instruments

Our customers:

Neutron Spallation Sources

Most if not all spallation neutron sources worldwide use our beam instruments:

SNS, Oakridge TN, U.S.A.

SINQ, PSI Villigen Switzerland

PEFP, Taejon, Korea

CSNS, Chengdu, Sichuan, China

J-PARC, Tokai Mura, Japan

Our customers:

Laser-plasma wakefield accelerators

All laser-plasma use our Integrating Current Transformer and Beam Charge Monitor to measure the charge of their femtosecond-long bunches

Integrated Parametric Current Transformer (IPCT)

To measure:

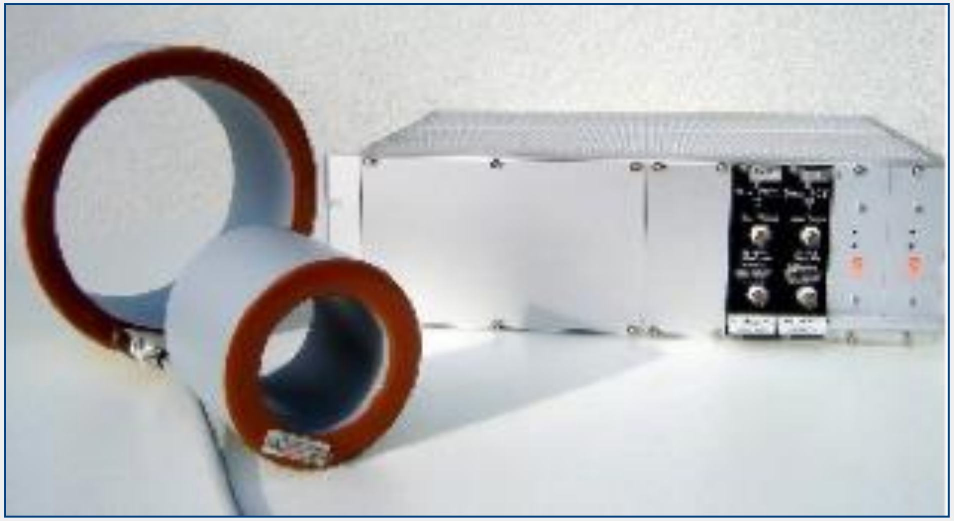
- Low current at very-high voltage
- Return ground current, DC and AC
- Leakage current, DC and AC
- Sum of low currents
- Power tube grid current
- Electrostatic corona discharge
- Electrochemically-induced current
- Standby battery charging current

New Parametric Current Transformer

Less than 0.5 uA resolution

10 kHz bandwidth

20 mA-20A range



Based on DCCT operating principle invented at CERN by Klaus Unser in 1966 for the ISR, known as Flux-gate, second-harmonic detection, also Zero-flux™ transformer

Waveform monitoring

AC Current Transformer

Wide Band version

Bandwidth up to 1 MHz

Noise down to 5 µArms

Lower cutoff (-3dB) < 3 Hz

High Resolution version

Bandwidth up to 300 kHz

Noise down to 1 µArms

Lower cutoff (-3dB) < 3 Hz

Waveform monitoring

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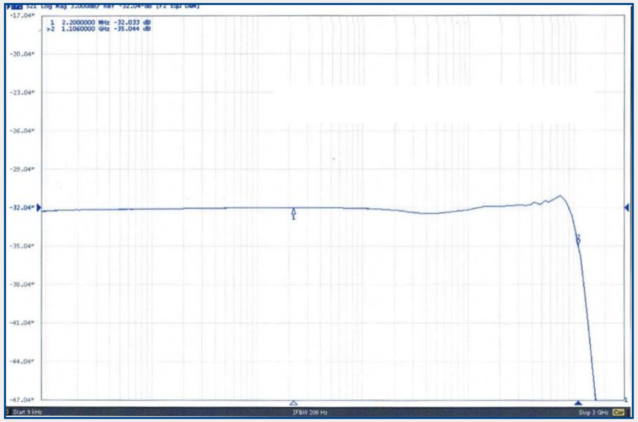
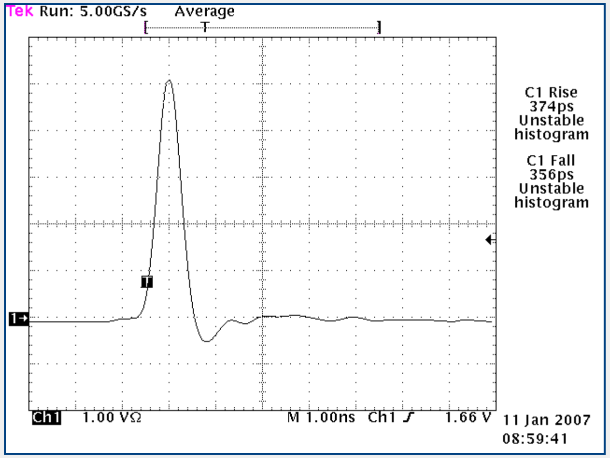
Fast Current Transformer

Bandwidth up to 1.75 GHz

200 ps risetime

Sensitivity up to 5V/A





Charge monitoring

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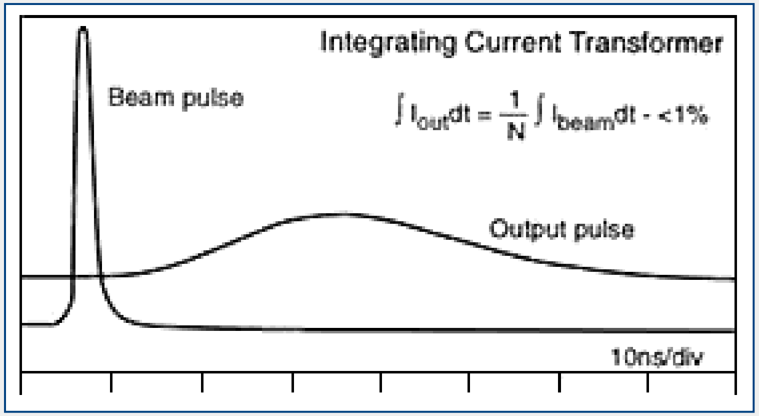
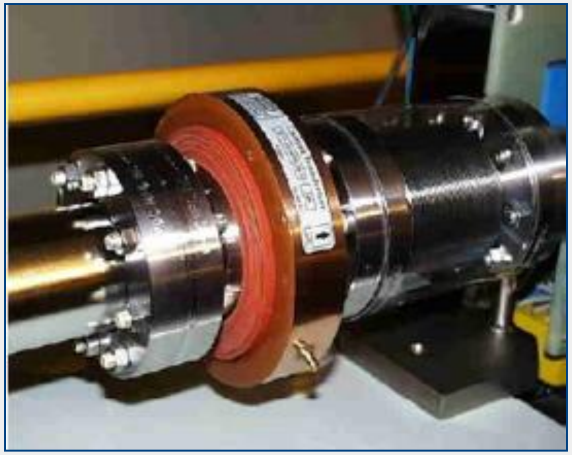
Integrating Current Transformer





Beam Charge Monitor

Measures single pulses with 1pC resolution and stored beam current with 10 nA res.

In-flange.FCT, ICT, ACCT, NPCT

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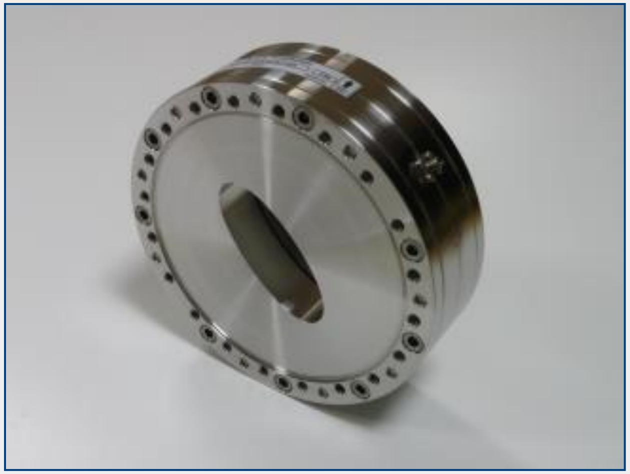
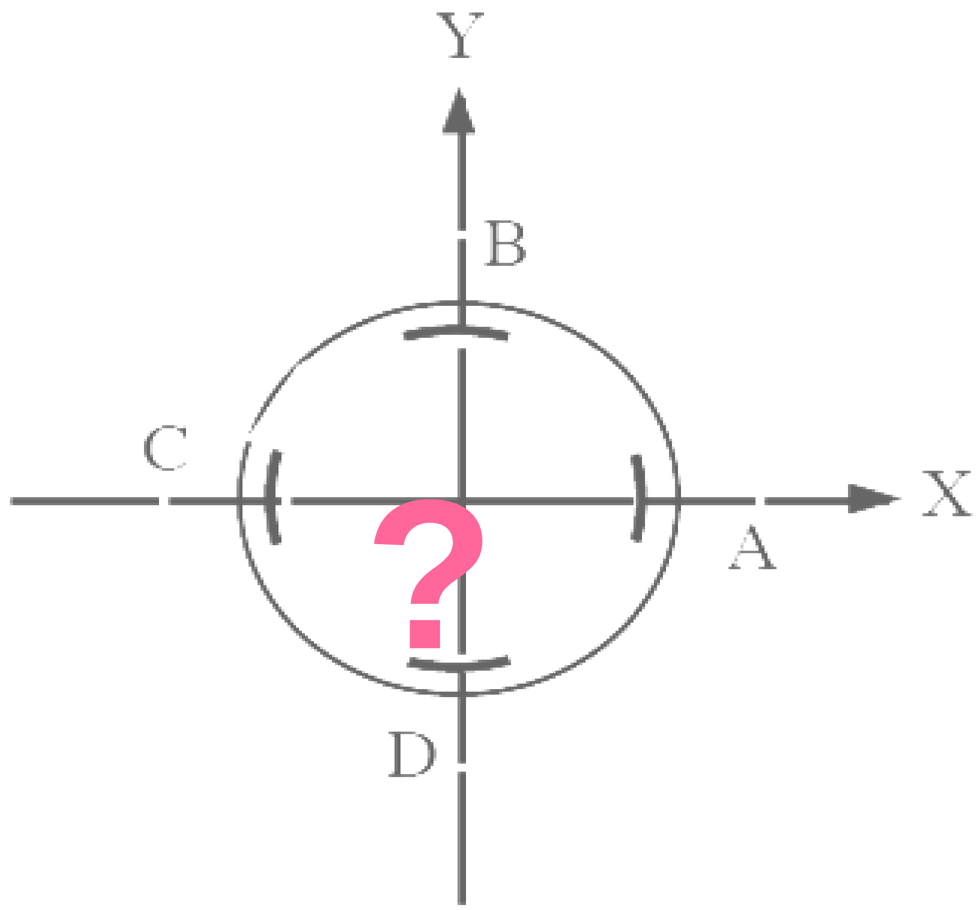
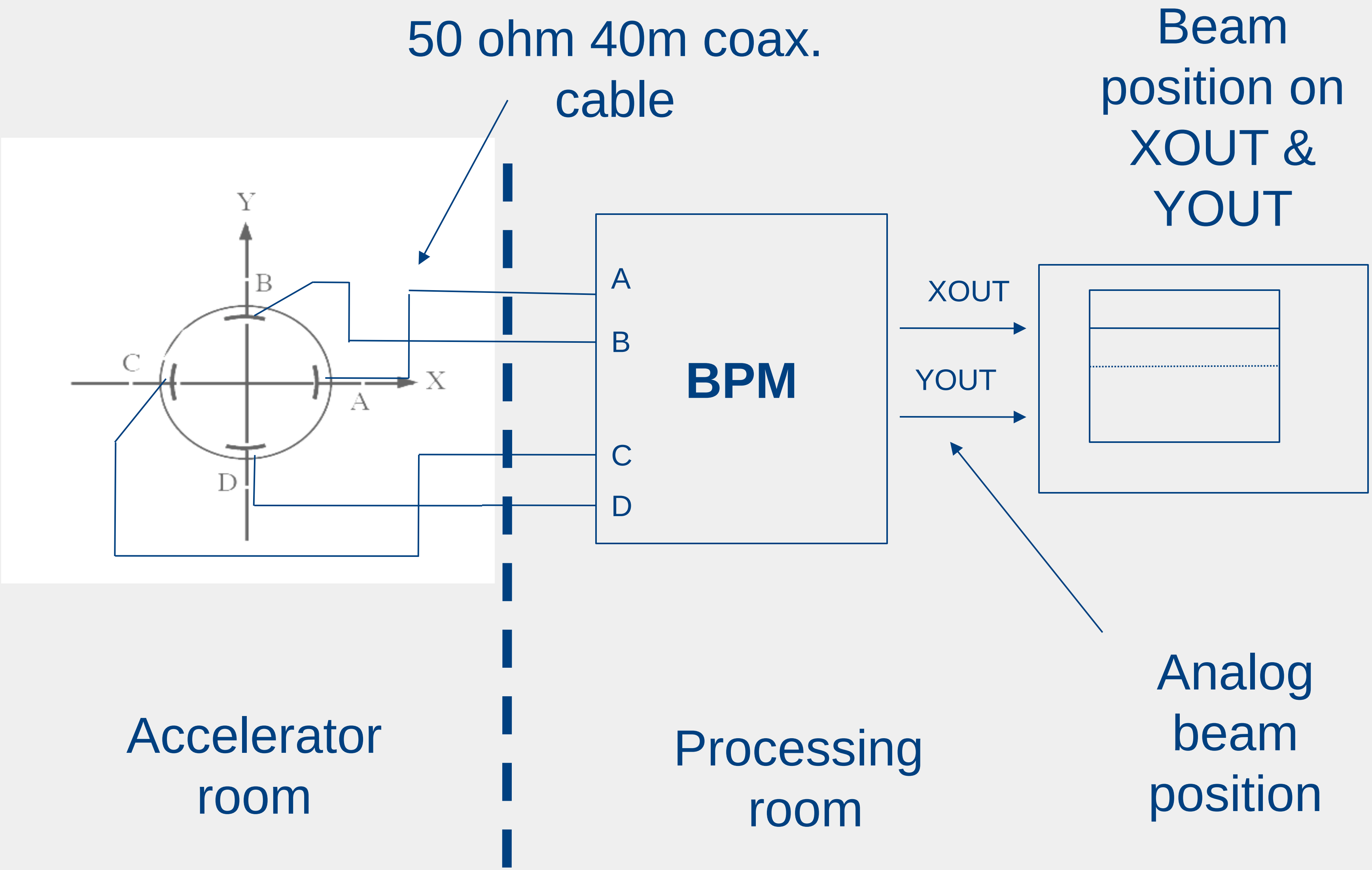


Simple installation
Ceramic break integrated
Vacuum down to 10^{-10} mbar

Beam Position Monitoring - BPM



Beam Position Monitoring - BPM



Beam Position Monitor

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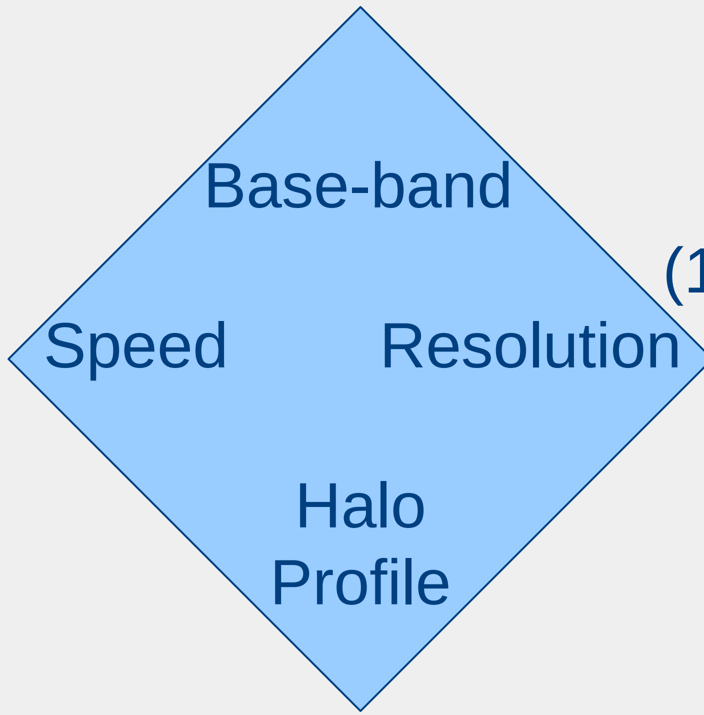
BB-BPM (1 MHz to 11 MHz)

LR-BPM
S-BPM
(100 MHz to 3 GHz)
Resolution : 100um
Wide-band output



MX-BPM
(100 MHz to 900 MHz)
Resolution : 1um
Narrow-band output

VWM
High Dynamic range
High resolution

Multiplexed Beam Position Monitor

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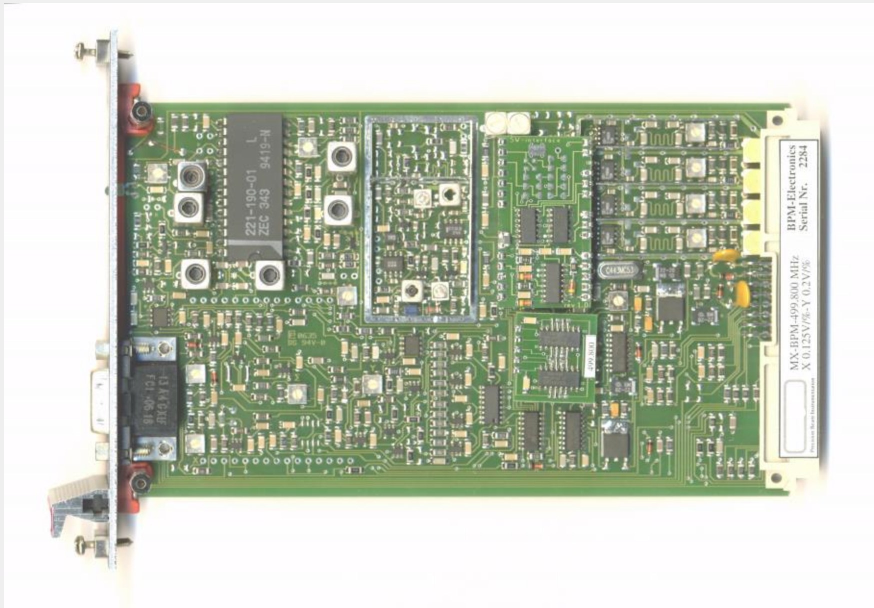
MX-BPM

Multiplexed input BPM processor for Synchrotron close orbit measurement

1 um rms noise in 34-mm BPM pickups
8-kHz beam position sampling rate
Pre-calibrated
No software: X and Y voltage outputs ready to use
Compact: 16 processors in 19” x 3U chassis



Simple to install, simple to use, reliable
>3000 units used world-wide
Most used BPM processor?

EPICS / TANGO microIOC integration by Cosylab

Log-ratio Beam Position Monitor

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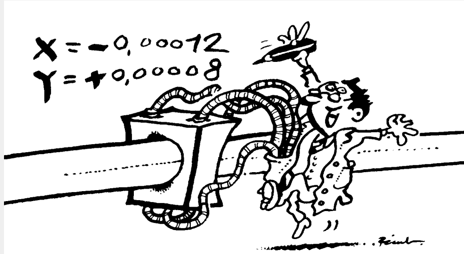
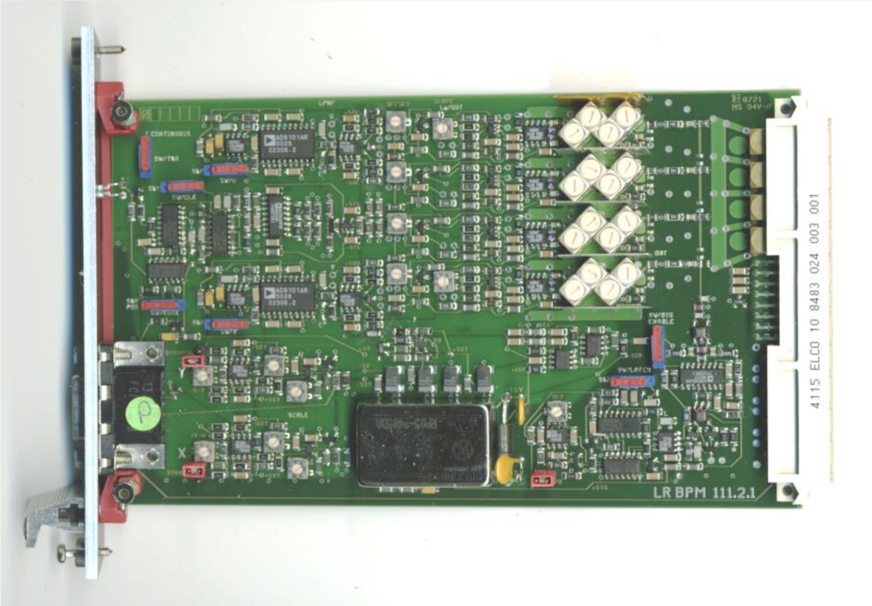
LR-BPM (100 MHz to 800 MHz)
S-BPM (1,56 GHz, 2,856 GHz and 2,999 GHz)
Parallel, simultaneous processing of four BPM inputs
for Linacs, Transfer lines



Measures single pass of bunch or macropulse, holds X and Y voltages until next bunch with ~100um resolution

X and Y output are voltages tracking beam lateral movement with 5 MHz bandwidth



Simple to install, simple to use, reliable
Compact: 16 modules in 19” x 3U chassis
>400 units used world-wide

EPICS / TANGO microIOC integration by Cosylab bergoz

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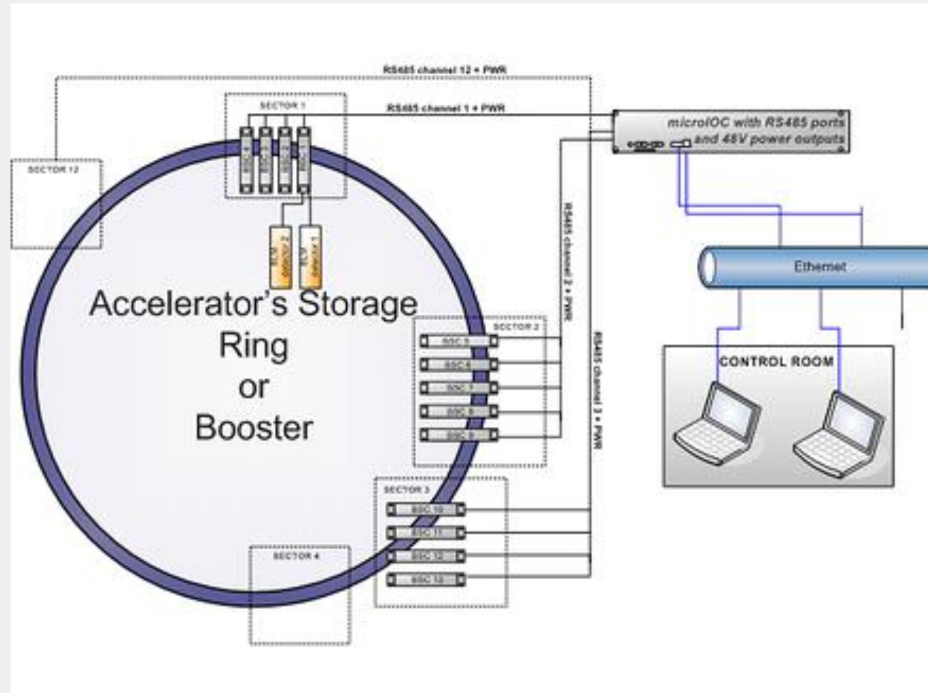
Beam Loss Monitor (BLM)



Measure & localise beam losses.

PIN photodiodes mounted face to face detect charged particles

Insensitive to synchrotron radiation photon

Up to 10 MHz counting

Vibrating Wire Monitor (VWM)

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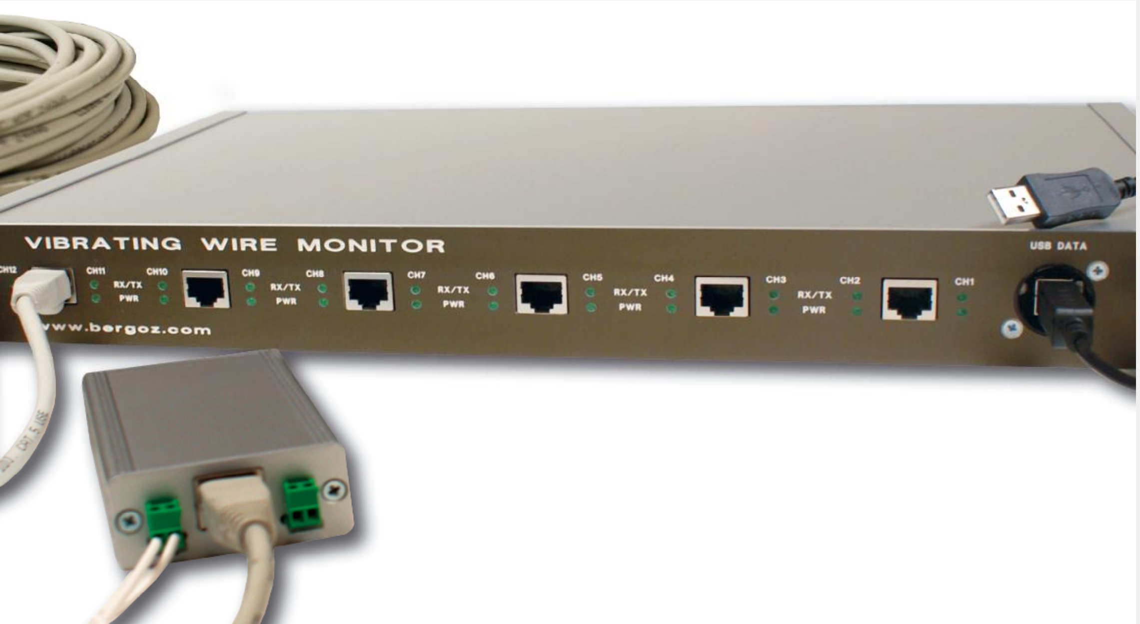
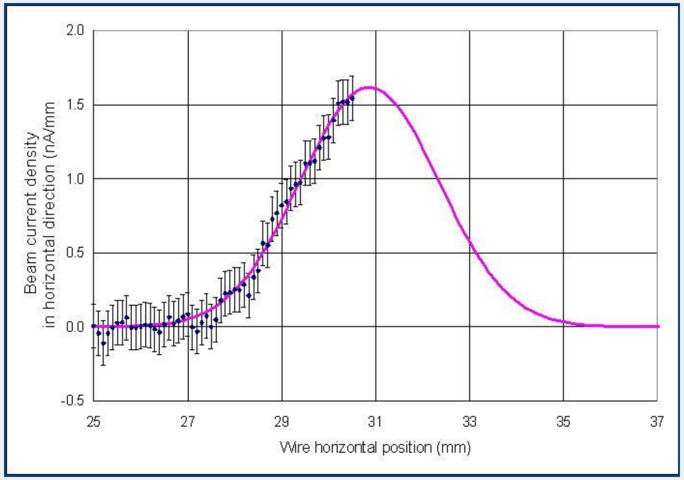
To measure beam transverse profile and HALO

Protons, ions, electrons, photons, neutrons

Thermal resolution : 1mK (for tungsten wire)
Dynamic range : 10^6





Turbo-ICT and BCM-RF electronics

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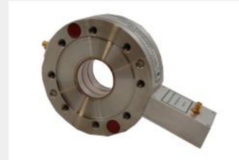
Low single-bunch charge measurement :

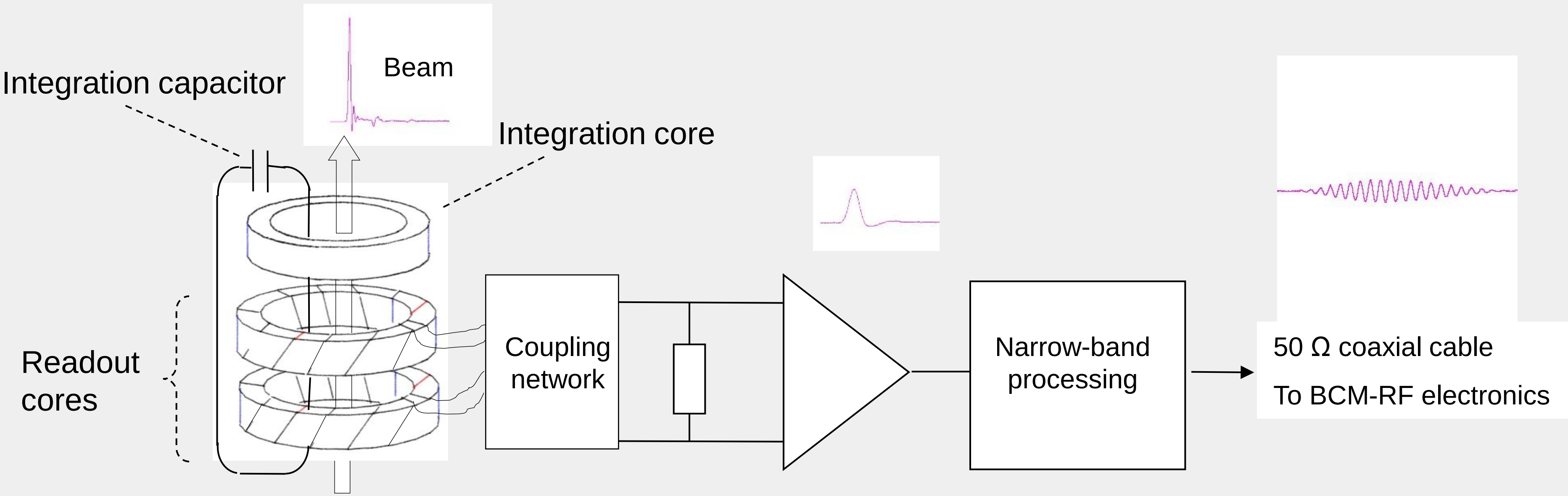
- < 5 pC @ 1% resolution « already measured at PSI with beam »
- 2 MHz repetition rate
- 66 dB dynamic range, from 0.1 pC to 200 pC
- could also measured current form CW beam (10 uArms @ 1% resolution)

Turbo-ICT with its front-end
(Integrating current transformer)

BCM-RF electronics in chassis
(Beam charge monitor)

Turbo-ICT principle





- Integration time is reduced by 25 compared to traditional ICT.

⇒Signal increases by 25 and noise by √25.

- Multiple cores could be used to catch more signal from beam.

- Readout cores are coupled to a low noise amplifier.

- Narrow-band processing. The wide-band signal from the amplifier is converted to a 180 MHz single tone resonance. Apex amplitude is proportional to the bunch charge.

⇒increases noise immunity.

⇒ decreases insertion losses in cable.

⇒ improves impedance matching.

BCM-RF electronics

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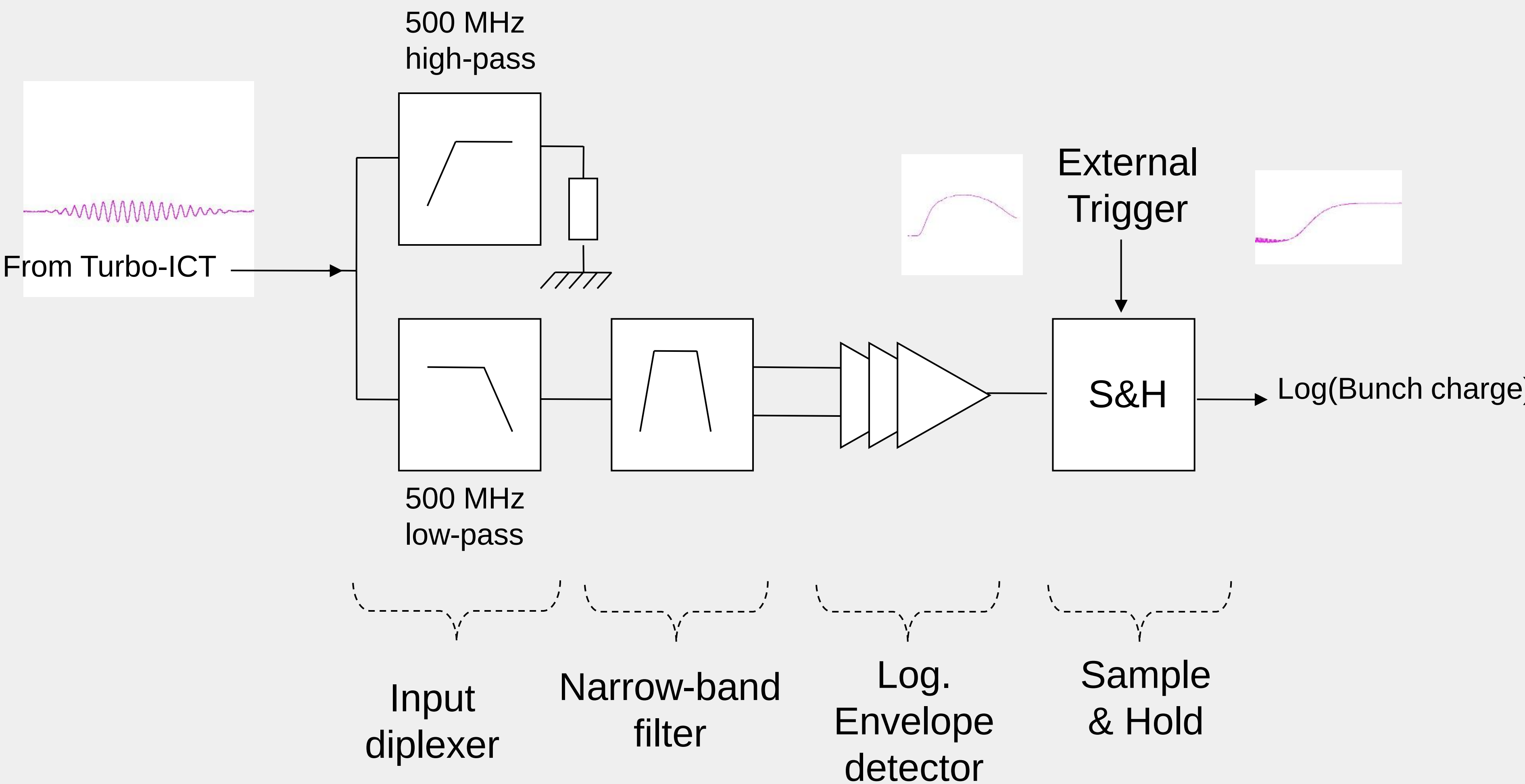
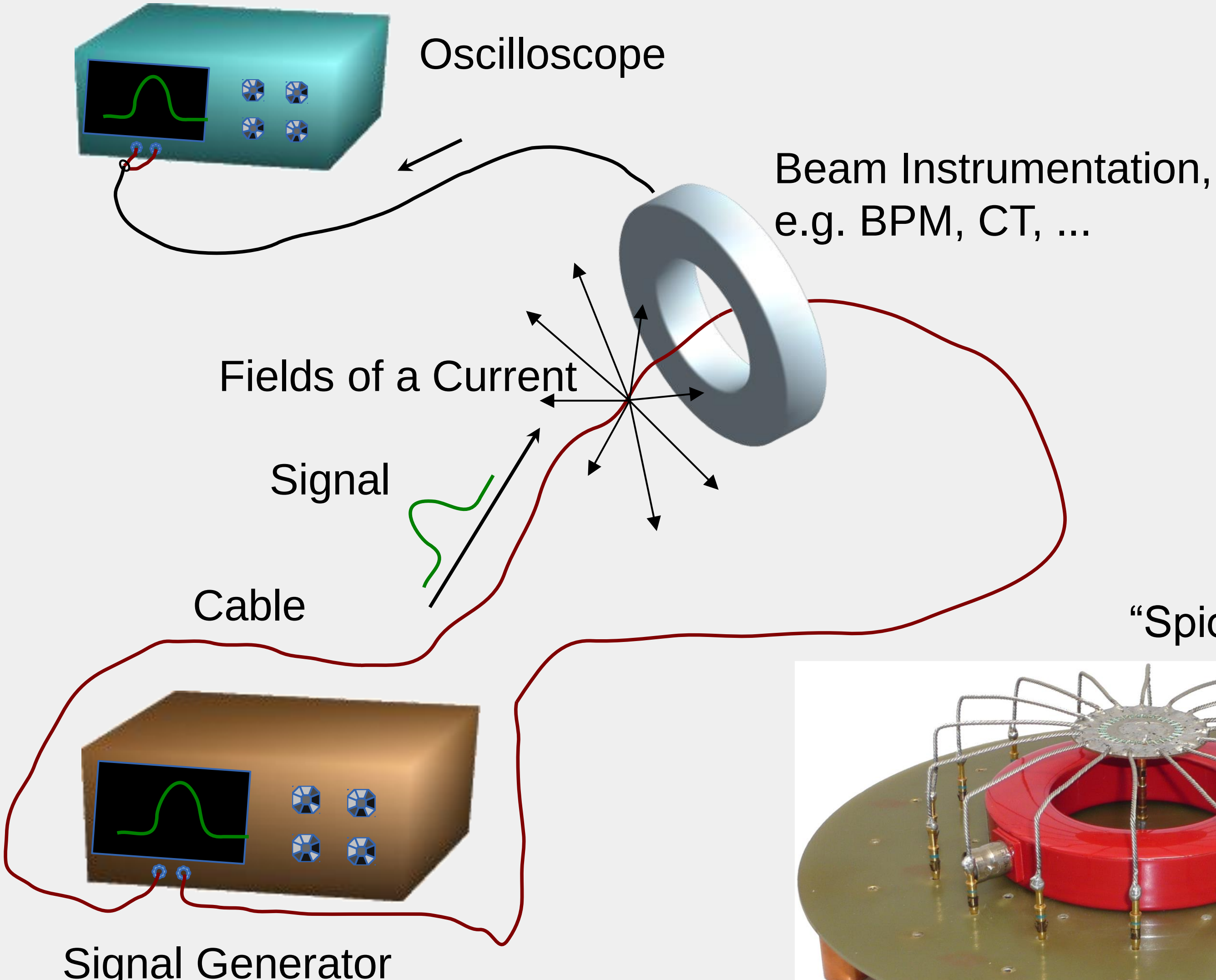
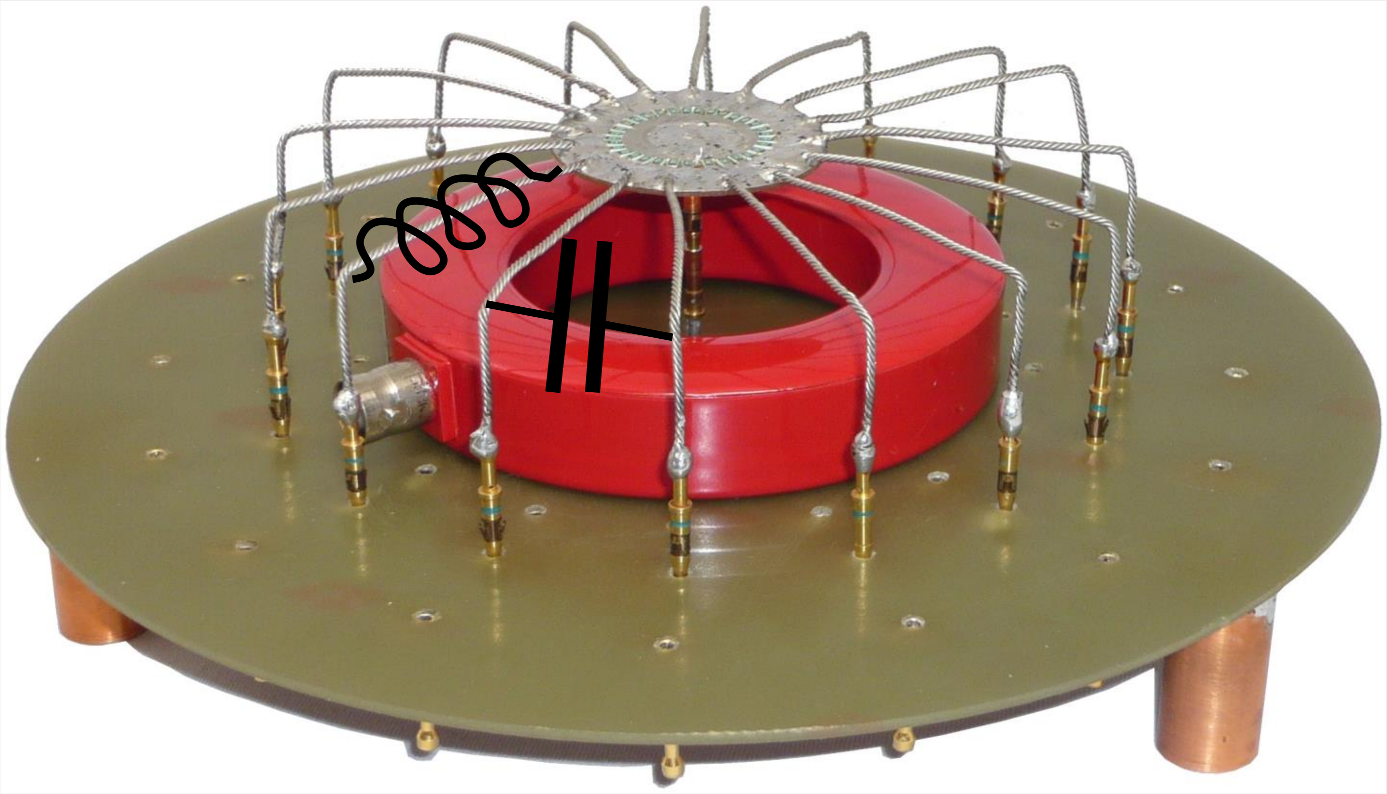


Bench Testing in the Lab



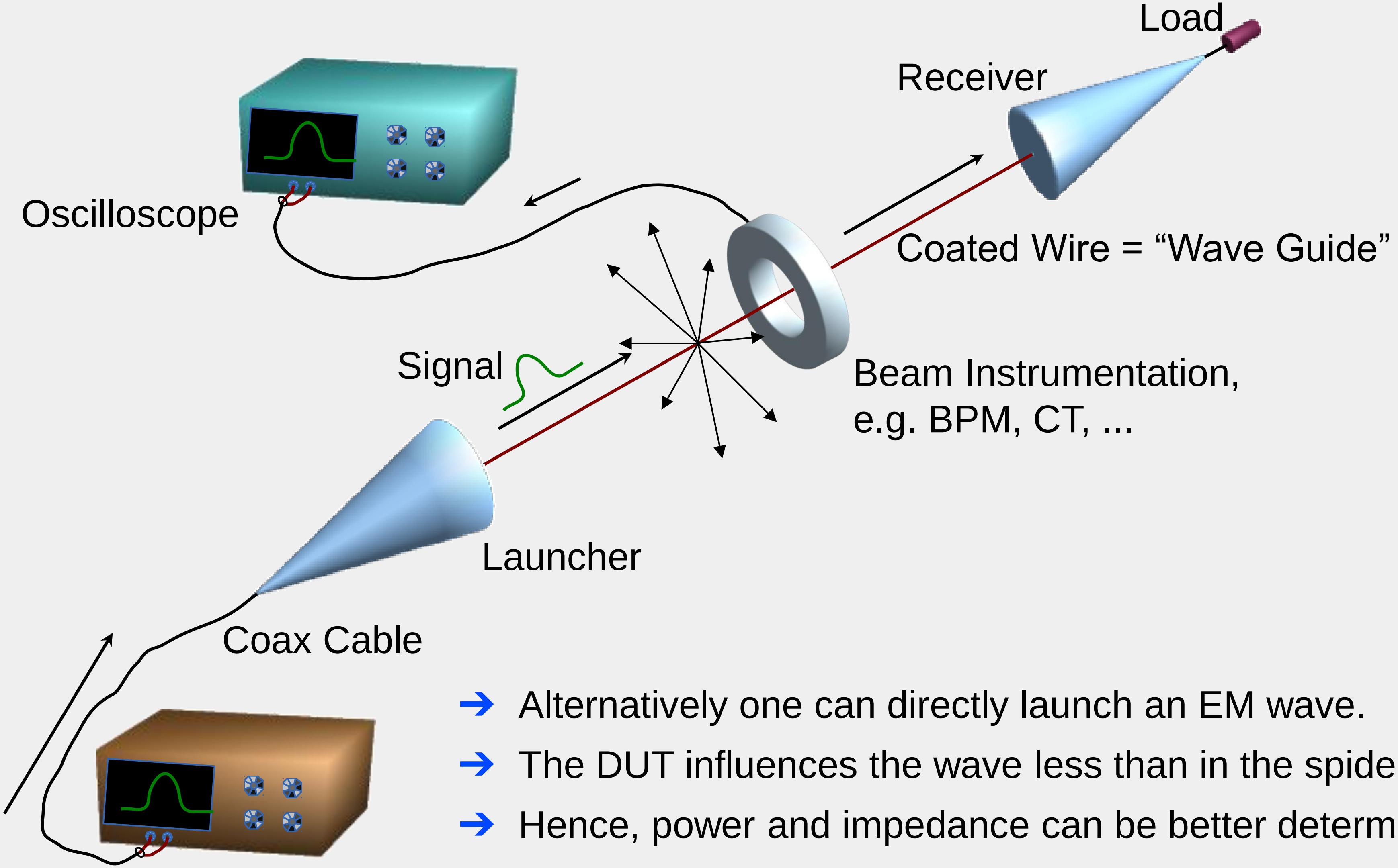
“Spider”

The Spider



- Works well up to some 100 MHz.
- At higher frequencies the impedance is not matched.
- Hence, it gets harder and harder to properly know the current.
- Above 1GHz resonance start to dominate and it is basically impossible to make accurate measurements.

The Goubau Line



- ➔ Alternatively one can directly launch an EM wave.
- ➔ The DUT influences the wave less than in the spider.
- ➔ Hence, power and impedance can be better determined.
- ➔ Even at many GHz the fields behave well, i.e. weak resonances, no capacitive couplings,...

EM Field around a realistic Wire

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- ➔ Solution of Telegraph Equation taking into account imperfections (Sommerfeld 1899, Goubau 1950).
- ➔ A fundamental TM mode outside a wire of radius r_w ($r > r_w$) :

radial electric field:

$$E_r = \frac{I\,e^{i(\omega t - hz)}}{2\pi r_w} \frac{h}{\omega\varepsilon} \frac{H_1^{(1)}(\gamma r)}{H_1^{(1)}(\gamma r_w)}$$

like fields around beam of charged particles!

azimuthal magnetic field:

$$H_\varphi = \frac{B_\varphi}{\mu} = \frac{I\,e^{i(\omega t - hz)}}{2\pi r_w} \frac{H_1^{(1)}(\gamma r)}{H_1^{(1)}(\gamma r_w)}$$

Hankel Functions, i.e. Bessel Functions

longitudinal electric field:

$$E_z = \frac{I\,e^{i(\omega t - hz - \pi/2)}}{2\pi r_w} \frac{\gamma}{\omega\varepsilon} \frac{H_0^{(1)}(\gamma r)}{H_1^{(1)}(\gamma r_w)}$$

Typical instrumentation for accelerator facilities

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Linac:
Waveform observation with FCT / ACCT
Beam position monitoring with Log-ratio BPM
Charge measurement with ICT and BCM / Turbo-ICT and BCM-RF

Linac-to-booster transfer line:
Waveform observation with FCT
Beam position monitoring with Log-ratio BPM
Charge measurement with ICT and BCM/ Turbo-ICT and BCM-RF

On the Booster:
Stored beam current with NPCT, injection efficiency
Beam position monitoring with MX-BPM or LR-BPM
Beam Loss monitoring with BLMs

On the Booster-to-storage ring Transfer Line:
Charge extracted from the booster and injection into storage ring with ICT and BCM / Turbo-ICT and BCM-RF or NPCT
Beam position monitoring with Log-ratio BPM

On the storage ring:
Stored beam current and lifetime measurement with NPCT
Closed orbit position measurement with MX-BPM
First turn position measurement with LR-BPM
Beam loss monitoring with BLMs…….

End of Presentation