

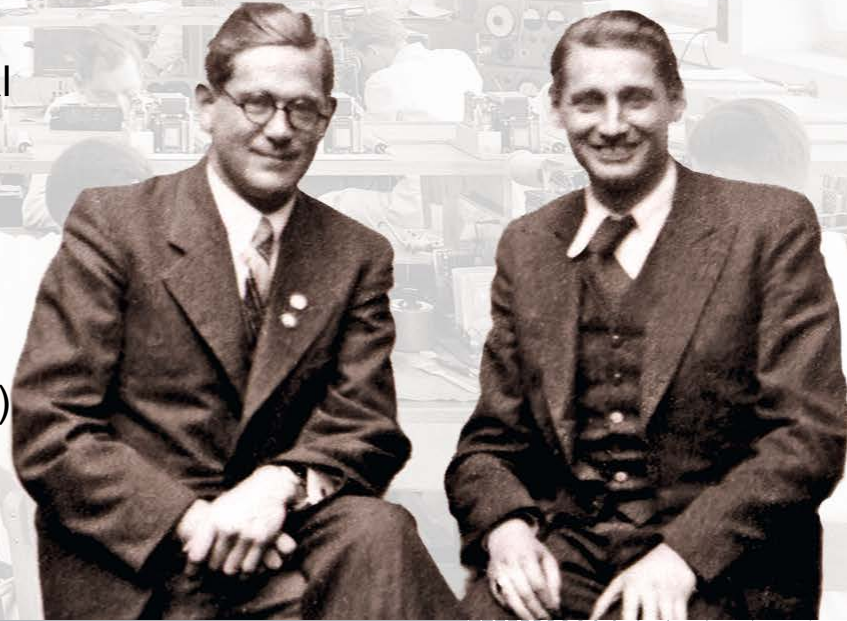
# Rohde und Schwarz solutions for accelerator's techniques applications

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Rohde & Schwarz International GmbH

# Rohde&Schwarz: Private and Family-Owned Since 1933

- Company is 100% owned by the 1<sup>st</sup> and 2<sup>nd</sup> Generation descendants of founders Dr. Lothar Rohde and Dr. Hermann Schwarz (50%/50%)
- Independent - no dependence on financial or capital markets
- Stability - shareholders transfer shares to new generations – no shareholder can sell their shares per company bylaws
- Highest R&D re-investment in the industry (17-18%)
- Long term customer relationship and support focus



# Business fields

Test and  
Measurement



Broadcast and  
Media



Aerospace | Defense | Security



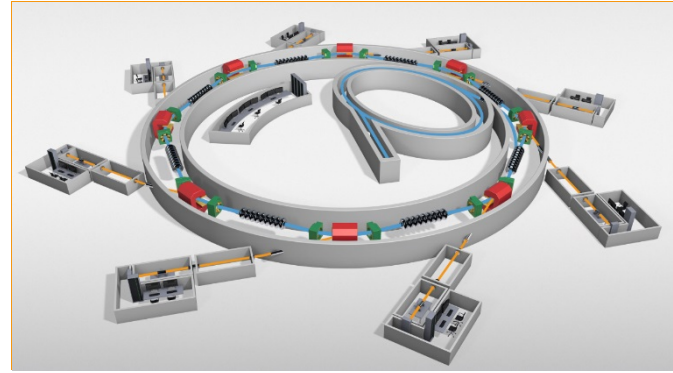
Networks and  
Cybersecurity



Service



# R&S Solutions for Particle Acceleration



Oscilloscopes  
for beam focus,  
beam stabilization

Fast-Response Amplifier  
in feedback loop for  
betatron tuning /  
stochastic cooling  
→ beam lifetime

Beam lines:  
Separate research  
customers with  
individual experiments

Amplifiers  
for pre-injector  
LINAC, booster +  
storage Ring

Power Meters for  
Power Distribution  
Monitoring.  
Remote operation  
through Ethernet!

Phase noise tester  
to verify low jitter  
performance of  
LLRF circuits

# Typical Frequencies and their Locations

		Example			
Application Field	Accelerator Type	Name, Location or Remark	Particle	RF Frequency	Speed or Particle Energy
Medicine	Cyclotron	CC-12 by NIIIEFA, Russia	H-	76.4 MHz	
Medicine	Cyclotron	CC-18/9 by NIIIEFA, Russia	H- / D-	38.2 MHz	
Medicine	Cyclotron	MCC-30/15 by NIIIEFA, Russia	H- / D-	40.68 MHz	
Industry	LINAC	Market Survey	Ions	100 to 600 MHz	
Industry	LINAC	Market Survey	Electrons	0.9 GHz to 9 GHz	
Science	LINAC	GANIL, France	H- / D-	88 MHz + 88 MHz	up to 4% + 20% of light speed
Science	LINAC	XFEL, Germany	Electrons	1.3 GHz + 3.9 GHz	17.5 GeV
Science	Pre-injector LINAC	NSLS II, Brookhaven US	Electrons	2998 MHz	200 MeV
Science	Booster Ring	NSLS II, Brookhaven US	Electrons	499.68 MHz	200 MeV to 3 GeV
Science	Storage Ring	NSLS II, Brookhaven US	Electrons	499.68 MHz	3 GeV
Science	Pre-injector LINAC	APS, Argonne National Lab., Chicago, US	Electrons	2856 MHz	200 MeV
Science	Pre-injector LINAC	DLS, Diamond Lightsource, UK	Electrons	3 GHz	100 MeV
Science	Booster Ring	DLS, Diamond Lightsource, UK	Electrons	500 MHz	100 MeV to 3 GeV
Science	Storage Ring	DLS, Diamond Lightsource, UK	Electrons	500 MHz	3 GeV
Science	LINAC for Positrons	APS, Argonne National Lab., Chicago, US	Positrons	2856 MHz	450 MeV
Science	LINAC for Heavy Ions	in general; 1st section of LINAC	Heavy Ions	30 MHz to 200 MHz	
Science	LINAC for Heavy Ions	in general; further sections of LINAC	Heavy Ions	2x (30 MHz to 200 MHz)	

## Industry Applications

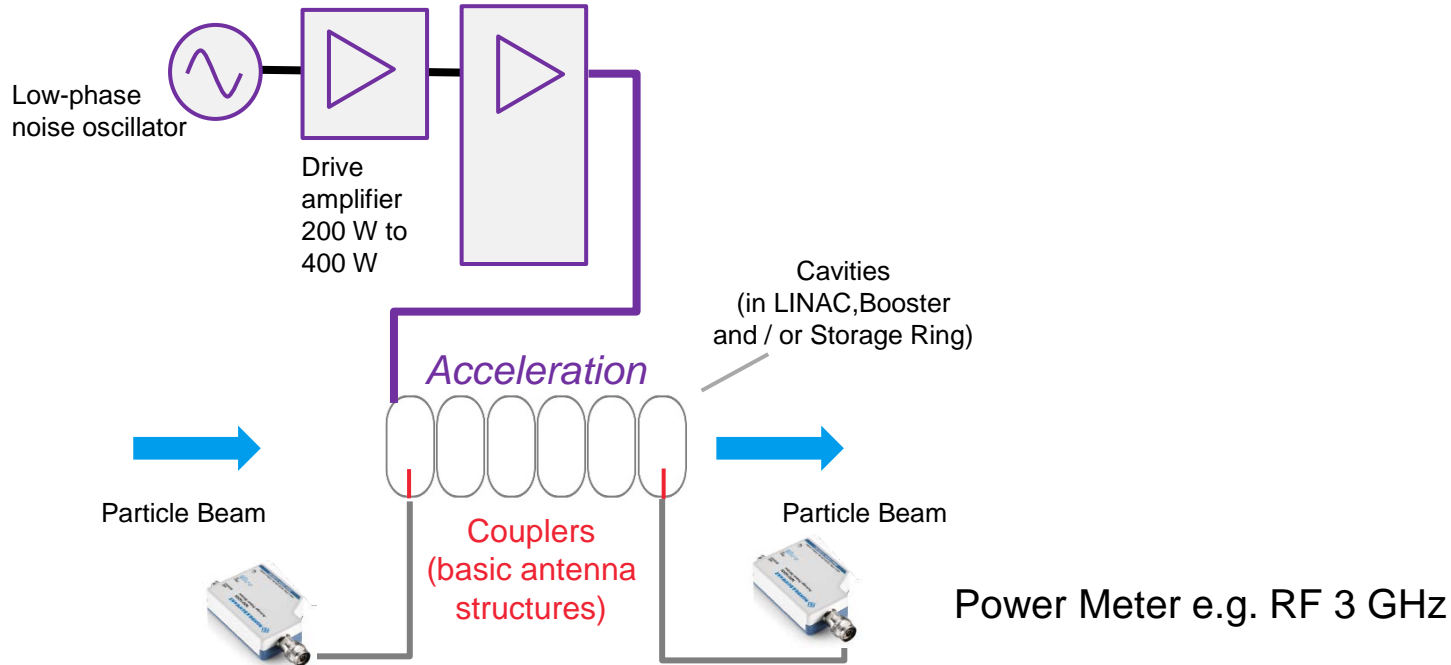
Ion implantation in semiconductors

Hardening of metal surfaces --> cutting tools, artificial human joints

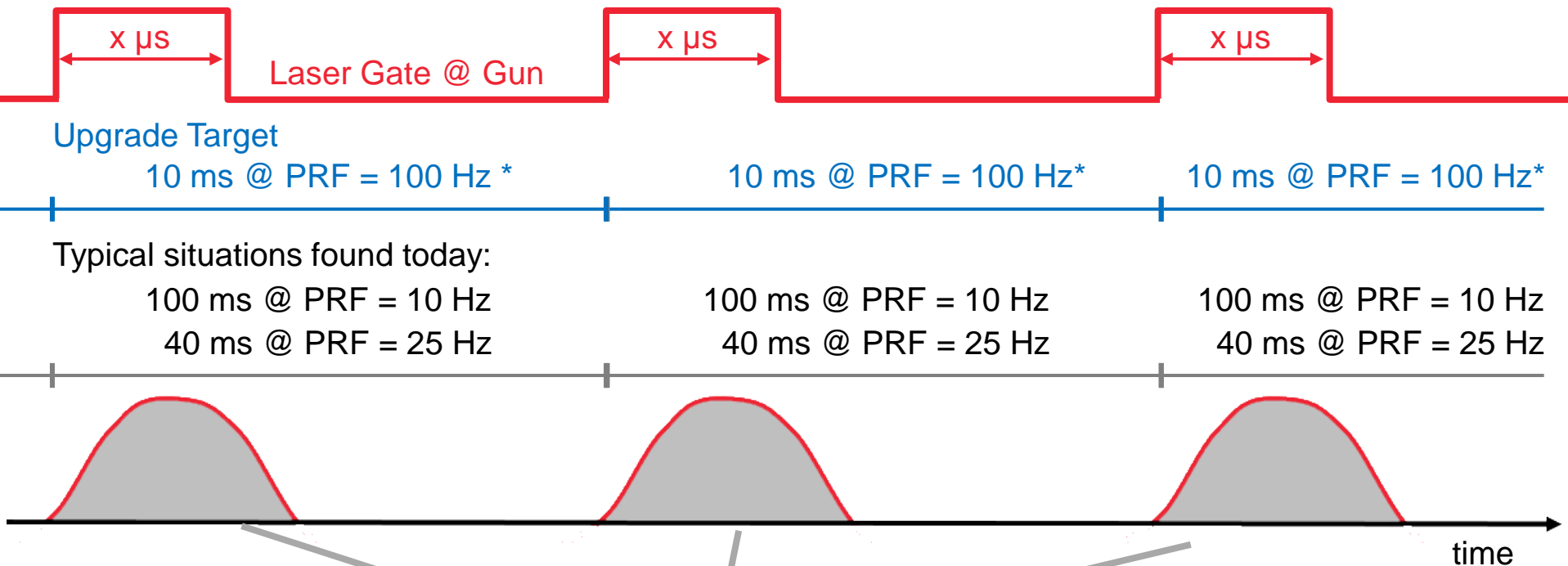
Hardening of ceramics and glasses

# Most useful cases: Acceleration Process

## Power Distribution Monitoring



# Most useful cases: Particle Beam - Electron Macro-Bunches - Monitoring



Typical situations found today:

100 ms @ PRF = 10 Hz  
40 ms @ PRF = 25 Hz

100 ms @ PRF = 10 Hz  
40 ms @ PRF = 25 Hz

100 ms @ PRF = 10 Hz  
40 ms @ PRF = 25 Hz

Pulses at monitoring sensor output caused by electron macro bunches.

Typical tests:  
mask test for safety interlock  
waveform capture for general monitoring  
pulse to pulse jitter

\*) The 100 Hz requirement is supported by the R&S RTO2000 series.



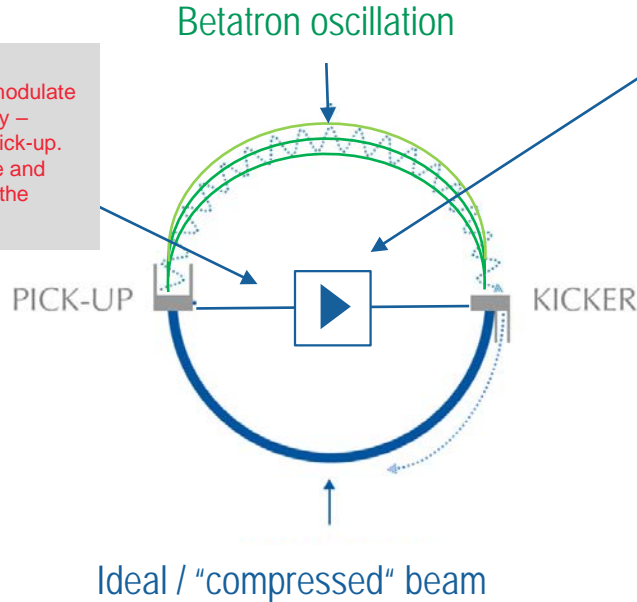
# Most useful cases: Betatron Oscillation & Stochastics Cooling



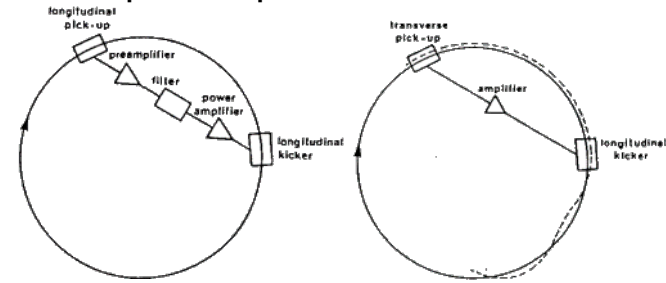
2 to 4 GHz  
around 100 Watt

Beam feedback:  
signal on the kicker will modulate  
beam position and energy –  
inducing a signal in the pick-up.  
Low additive phase noise and  
Short electrical length of the  
circuit is required

Samples (waveforms)  
provided by the pick-up  
undergo an evaluation  
algorithm. The resulting  
samples (new waveform)  
have to be amplified and  
fed to the kicker.



## Setup examples



For Pick-up and feedback  
circuit verifications:



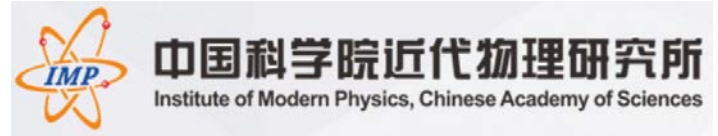
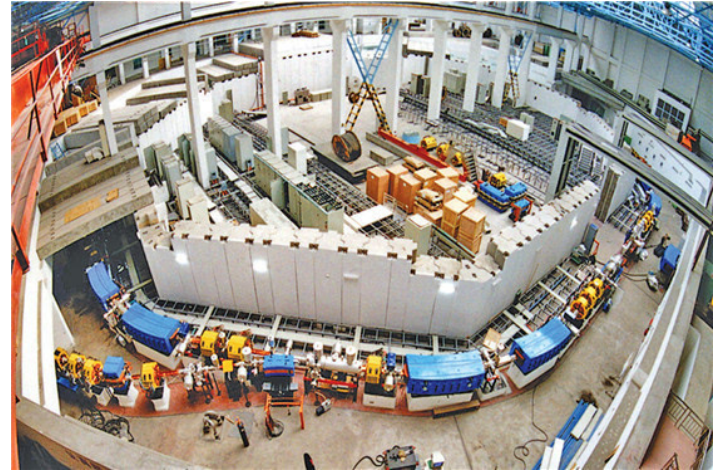
Source: <https://cds.cern.ch/record/156497/files/cer-000067787.pdf>



# R&S Solutions Overview

# Success Example 1

Accelerator Name	HIRFL
City, Country	Lanzhou, China
Application	Synchrotron radiation source for Physics and material and medical science
Products of Interest/Qty.	Power amplifiers BBA150 Spectrum analyser FSV Oscilloscopes RTO
Link	<a href="http://www.imp.cas.cn/kzyb2017/201705/t20170524_4796495.html">http://www.imp.cas.cn/kzyb2017/201705/t20170524_4796495.html</a>



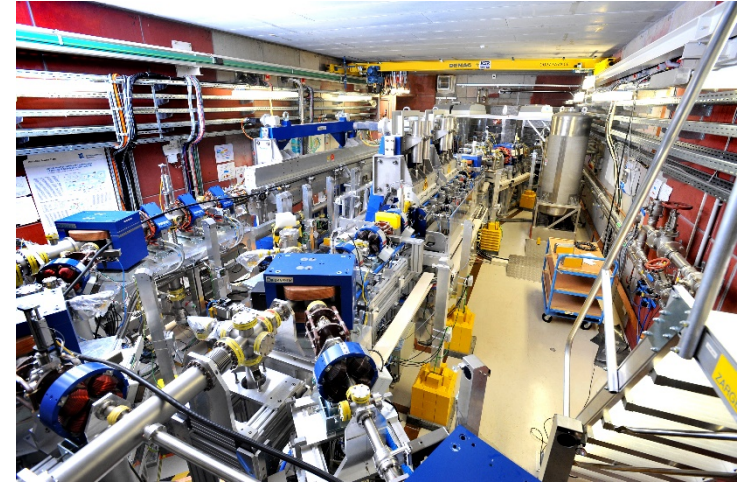
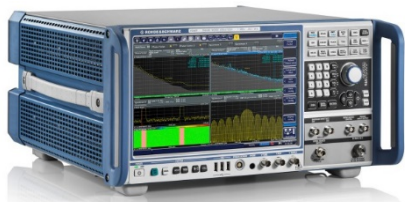
# Success Example 2

Accelerator Name	AC of IHEP
City, Country	Beijing, China
Application	Design of electron sources, optimization of beam quality and operational parameters
Products of Interest/Qty.	Spectrum analyser FSV Oscilloscopes RTO Signal generators SMA100B Power sensors NRP VNA ZNB
Link	<a href="http://www.ihep.cas.cn/zdsys/lpapt/">http://www.ihep.cas.cn/zdsys/lpapt/</a>



# Success Example 3

Accelerator Name	ELBE (Helmholtz) (Electron Linac for beams with high Brilliance and low Emittance)
City, Country	Dresden, Germany
Application	High power radiation source for materials science
Products of Interest	Phase Noise Analyzer FSWP8
Link	<a href="https://www.hzdr.de/db/Cms?pNid=145">https://www.hzdr.de/db/Cms?pNid=145</a>

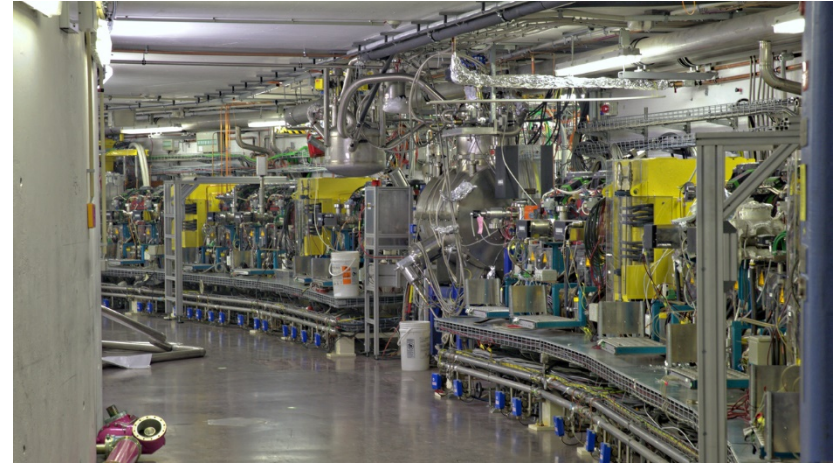


**ELBE.**

 **HELMHOLTZ**  
ZENTRUM DRESDEN  
ROSSENDORF

# Success Example 4

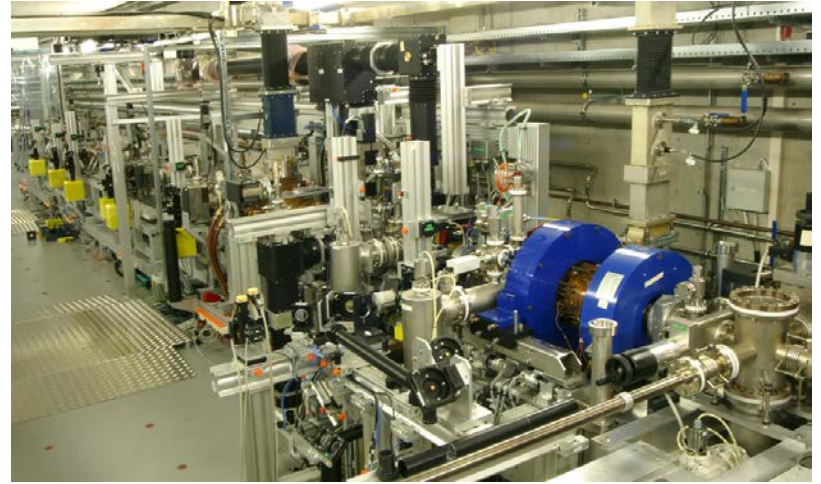
Accelerator Name	BESSY II (Helmholtz)
City, Country	Berlin, Germany
Application	Synchrotron radiation source for materials science
Products of Interest	Power amplifiers BBA130-Dxxx for beam forming
Link	<a href="https://www.helmholtz-berlin.de/quellen/bessy/index_en.html">https://www.helmholtz-berlin.de/quellen/bessy/index_en.html</a>



**HZB** Helmholtz  
Zentrum Berlin

# Success Example 5

<b>Accelerator Name</b>	<b>DESY PITZ</b>
City, Country	Zeuthen, Germany
Application	Design of electron sources, optimization of beam quality and operational parameters (support for DESY Hamburg)
Products of Interest	Phase Noise Analyzer FSWP8
Link	<a href="http://pitz.desy.de/e145643/e149703/">http://pitz.desy.de/e145643/e149703/</a>



# Oscilloscopes: New R&S® RTP High-Performance Oscilloscope

## At a glance

### ■ Models:

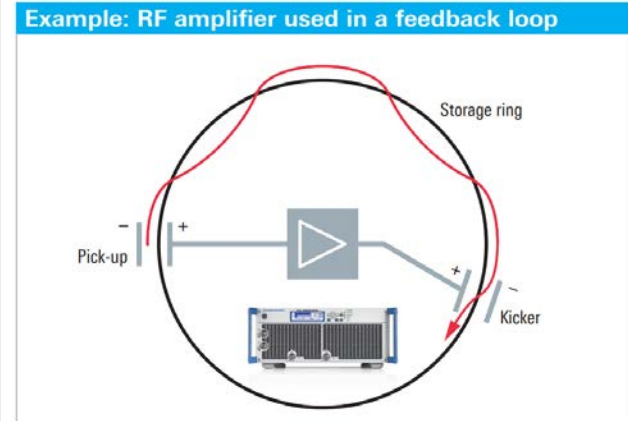
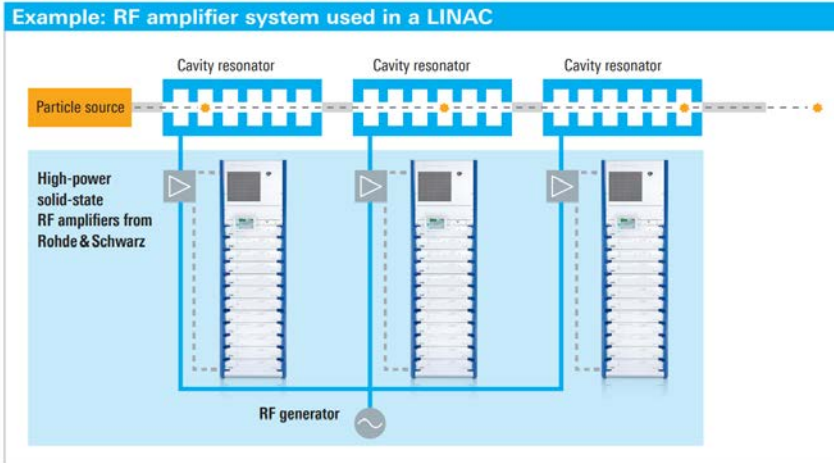
- Bandwidth 4, 6 and 8 GHz models
  - (4 channels / 20 GSa/s)
- Superior analog performance
  - Fastest update rate: approx. 1,000,000 wfms/s
  - Deep Memory: 50 MSa/ch std.; max. 2 GSa
  - Realtime deembedding
  - Trigger up to full bandwidth
  - Up to 16 bit resolution in HD-mode
- 
- HW options: 16 GHz diff. pulse source, 16 digital channels MSO , Multi-ch. power probe, 2 analog / 8 dig. channel generator



# Amplifiers: At a glance



RF amplifier family	Frequency range	Max. CW output power
R&S®BBA150	9 kHz to 6 GHz	2.5 kW/200 W
R&S®BBL200	9 kHz to 250 MHz	10 kW
R&S®TxR9	87.5 MHz to 108 MHz	80 kW
R&S®TxV9	170 MHz to 254 MHz	32 kW
R&S®TxU9	470 MHz to 862 MHz	80 kW





# Phase Noise Tester : FSWP

## At a glance

- Frequency range from 1 MHz to 8/26.5/50 GHz
- (with external mixers up to 500 GHz)
- High sensitivity for phase noise measurements thanks to cross-correlation and extremely low-noise internal reference sources
  - Typ.  $-172$  dBc (1 Hz) at 1 GHz carrier frequency and 10 kHz offset
  - Typ.  $-153$  dBc (1 Hz) at 10 GHz carrier frequency and 10 kHz offset
- Simultaneous measurement of amplitude noise and phase noise



# Power sensors : At a glance

- Maximum dynamic range:  $-70$  dBm to  $+45$  dBm
- Frequency range: DC to 110 GHz
- More than 50 000 readings/s
- Flexible operation with R&S®NRX base unit, laptop/PC and many Rohde & Schwarz instruments
- Control and monitoring via LAN and USB
- Easy LAN operation from a web browser



# Conclusion

- Rohde & Schwarz is your partner for high-energy particle acceleration in the LINAC, booster and storage ring, as well as for precise beam stabilization and monitoring, and scientific measurements at the beam line.
- Wide Portfolio of success stories for accelerator's technique
- The most popular parts of the portfolio for accelerator's applications are:
  - - oscilloscope RTP
  - - power amplifier BBA
  - - Phase Noise Tester FSWP
  - - Power sensors NRP
- And we happy today to Open of the Rohde&Schwarz-CANDLE Training Laboratory !!



Thank you for attention!!



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