SRF technology at RI Research Instruments GmbH

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RI Research Instruments GmbH

Advanced Technology Equipment and Turn-Key System Supplier for Research, Industry and Medical worldwide

- Linear Accelerators
- RF Cavities, Couplers, Auxiliaries
- Superconducting Accelerator Modules
- Electron and Ion Sources
- Beam Diagnostic Elements and Particle Beamlines
- Accelerator Equipment for Particle Therapy
- Specialized Manufacturing Projects

RI Research Instruments today is successfully continuing the business of the former ACCEL Instruments and former Siemens activities in accelerator and specialized manufacturing in Bergisch Gladbach (near Cologne/Köln). Blue colored buildings are the today used space in the above shown technology park.

51% of shares by Bruker EST, Inc. and management holding a significant equity stake of the company.
RI is a **project oriented company**, about 70 projects with contract volumes between < 100 kEUR to > 10 MEUR are running at RI in parallel.
World map of customers and partners in “Big Science”
Core Competences and Markets

Technologies
- RF, Accelerator
- Superconductivity
- Cryogenics
- Vacuum
- Integr. System Control
- Specialized Manufacturing
- Surface Treatment
- System Integration

Products / Services
- Linear Accelerators
- RF Cavities, Couplers
- SRF Accelerator Modules
- Electron and Ion Sources
- Beam Diagnostic Elements
- Particle Beamlines
- Precision Manuf. Components

Markets
- Fundamental Physics
- Applied Research
- Medical/ Particle Therapy
- Inspection
- Energy/Nuclear
- Advanced Technology Industry


Our strengths are based on our broad technology portfolio and the more than 20 years long track record in deliveries of products and services into the markets shown above.
RI’s specialized manufacturing

In house manufacturing technologies:

- Turning (CNC)
- 5 axis milling (CNC)
- Metal working
- Surface technology (cleaning, etching, coating)
- Joining technology (EB, TIG, vacuum brazing)
- Heat treatment
- Assembly (partly in cleanroom ISO 4) and testing
- RF, vacuum, cryogenic
- Quality Control
1200 SRF cavities produced so far, 40 SRF cavities/year in average over the last 25 years (Siemens, ACCEL, RI). RI is the world leader in SRF cavity manufacturing.
Production of CEBAF upgrade cavities

Procurement of niobium
cavity manufacturing, bulk chemistry
RF tuning (fundamental mode and HOM couplers).

- Order for 86 pieces 1.5 GHz 7-cell cavities received in July 2009
- Niobium at RI in November 2009.

- Original schedule:
  First article to be delivered in June 2010,
  last cavity to be delivered middle of 2011

- Achieved schedule:
  First article delivered July 2010,
  **84 cavities delivered in November 2010, one year after niobium supply,**
  2 last cavities delivered in March 2011 (lack of niobium material,
  additional material had to be ordered for the last two cavities).

Schedule improved by 2 shift operation on turning, milling and
electron beam welding machines.
key components of linac:
800 superconducting RF cavities, 800 RF couplers
Order for 300 cavities received from DESY in September 2010, order for additional 120 cavities received in March 2013, 420 additional cavities produced at Zanon, Italy

RI scope:
- Mechanical manufacturing of cavity, respecting the pressure vessel code
- Complete Surface preparation and helium vessel welding
- Shipping to DESY under vacuum and “ready for cold RF test”
- Extensive documentation and QA is crucial and will ensure that cavities are manufactured and treated according to detailed DESY specification. No performance guarantee.

DESY:
- Cavities will be cold RF tested at DESY (vertical test) with helium vessel already welded
- After successful test, DESY will ship the cavities under vacuum to CEA for module assembly
New infrastructure at RI for XFEL

- 150 kV EB welder from Pro Beam
- Replaces our old small EB welder
- Pallet system
- Lock chamber (1E-3 mbar)
- Weld chamber (1E-6 mbar)
- Turbo pumps

- 800°C all metal annealing furnace from TAV, Italy
- Diameter 800 x 1500 high
- 4 cavities in vertical position per run
- Cryo pump

- One more turning machine
- One more milling machine
- Two 120 C baking chambers
- 4 pumping stations including RGA for SRF cavities and dry leak checker

Tuning machine and HAZEMEMA (half cell measurement machine) supplied by DESY
The cavity must be produced according to European pressure vessel code

DESY and TÜV Nord have worked out a „simple“ qualification procedure

Test piece (2 cell cavity with helium vessel, without end groups), representing all pressure bearing parts were built using exactly the same manufacturing methods and welding parameters, that are used in the series production

Test piece parts were dimensional controlled and welds were inspected by X-rays, visual control and leak check (witnessed by TÜV Nord)

Pressure test
Cut test piece, micrographs of welds by TÜV Nord.

During the series, RI applies exactly the same welding procedures as during the test piece production
TÜV Nord does visual inspection of the welds and pressure test of the helium vessel during series production

RI has produced 2 test pieces:

Test piece one: EB welding machine 1 and TIG welder 1
Test piece two: EB welding machine 2 and TIG welder 2
XFEL cavity manufacturing impressions

End tubes, HOM couplers

Metrological inspection of dumbbells

Dumbbells and stiffening rings, welded dumbbells
XFEL cavities / subcomponents

We are now producing 16 cavities / month
1. Outside etching (BCP)
2. Weighting, US-degreasing, Electropolishing (110 µm), rinsing
3. Cleanroom (1 x HPR, ethanol rinse, drying, weighting)
4. 800 °C annealing
5. Tuning
6. Electropolishing (40 µm), rinsing
7. Cleanroom (1 x HPR, ethanol rinse, assemble blank flanges, leak check, 6 x HPR, drying, install FMS (field measurement system), leak check)
8. Check field profile (ev. tuning)
9. EB welding of ring and bellow
10. TIG welding of helium vessel
11. Cleanroom (disassemble FMS, install antennas (pick-up, HOM. High Q for vertical testing), leak check, 6 x HPR, assemble last flange, leak check and RGA)
12. 120° C baking, leak check
13. Transport under vacuum to DESY for vertical test
RI infrastructure for XFEL

Electropolishing plant for XFEL cavities
RI infrastructure for XFEL

XFEL cavity installed into EP plant receiving removal of 110 µm from the inner surface
800 C annealing furnace for hydrogen degassing, hydrogen enters the niobium during the electropolishing process
RI infrastructure for XFEL

Tuning for field flatness and frequency, tuning apparatus was developed and free issued by DESY
RI infrastructure for XFEL

Cleaning of outer and inners surface of cavity prior entering ISO4 clean room
RI infrastructure for XFEL

Work in ISO4 clean room
Ethanol rinsing station in ISO4 clean room, needed to remove sulfur from the surface produced during the electropolishing process
RI infrastructure for XFEL

- High pressure DI water rinsing station in ISO4 clean room
- The cavity is being rinsed in total 4 times during the surface preparation process
- Water pressure: 100 bar
- Total rinsing time: about 30 hours per cavity
Assembly and leak checking in ISO4 clean room,
A new 160 m² ISO 4 clean room was installed for the XFEL production
RI infrastructure for XFEL

EB welding of helium vessel parts to finished cavity
Cavity inner surface is already cleaned to ISO4 standards and sealed to ambient during EB operation
During helium vessel welding, the inner surface of the cavity is cleaned to ISO4 standards and the frequency is controlled during welding to ensure no degradation of field flatness.

After welding the cavity enters the clean room again, final assembly and high pressure water rinsing are done and the 120°C bake is done as the last preparation step.
RI infrastructure for XFEL

- 120 C baking stations for XFEL cavities
- This baking step is the last surface preparation step before shipping to DESY
- The baking is done with the cavity under vacuum for 48 hours
- The assembly to the pump stand is performed with a local ISO4 clean room
XFEL cavity production project

Status of the project:

- Prototype Phase and built up of infrastructure finished
- RI Infrastructure qualified by reference cavities, fields up to 33 MV/m reached
- Series production started in April 2013
- First series cavities tested to 29 MV/m at $Q_0$ above $10^{10}$, well above specification of 23 MV/m
- Ramp up of series production started
- Goal to deliver at least 16 cavities per month starting in July 2013
- Project should be finished in May 2015 where the last of the 420 cavities should be delivered
It has been shown once again (as done before for example for the LEP SRF modules and for the LHC magnets), that the technology transfer between institutes and industry can be done successfully even for world record specification.

Specification from DESY on needed infrastructure clear and mainly complete, DESY has always been a competent and fast reacting partner in case of questions during ramp up phase

Training given by DESY experts during the ramp up of the infrastructure was essential for the success, hot technology transfer period took about 6 – 9 months

Difficult transition phase during the pre-series phase / before the series production starts, when personnel is hired but work load is low. Effective training comes from the work with the real cavities.
## RI capabilities for future projects

<table>
<thead>
<tr>
<th>Resources (mechanical)</th>
<th>XFEL</th>
<th>post XFEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turning machine</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Milling machine</td>
<td>2</td>
<td>5</td>
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<tr>
<td>Dimensional control place</td>
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<td>5</td>
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<tr>
<td>Metal working station</td>
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<tr>
<td>BCP barrel</td>
<td>2</td>
<td>5</td>
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<tr>
<td>Degreasing bath (clean room)</td>
<td>2</td>
<td>5</td>
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<tr>
<td>EB welding machines</td>
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<td>5</td>
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<tr>
<td>Leak checker</td>
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<td>5</td>
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<tr>
<td>RF control</td>
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<tr>
<td>Grinding place</td>
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<td>Press</td>
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<table>
<thead>
<tr>
<th>Resources (preparation)</th>
<th>XFEL</th>
<th>post XFEL</th>
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<tbody>
<tr>
<td>Degreasing bath</td>
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<tr>
<td>Ethanol rinse</td>
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<td>BCP outside bath</td>
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<tr>
<td>Leak check station, clean room</td>
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<tr>
<td>Tuning machine</td>
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<tr>
<td>Clean room assembly</td>
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<tr>
<td>EP station</td>
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<tr>
<td>800 °C oven (4 cavities per run)</td>
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<tr>
<td>HPR</td>
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<td>5</td>
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<tr>
<td>Drying places</td>
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<td>5</td>
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<tr>
<td>EB welding</td>
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<td>5</td>
</tr>
<tr>
<td>120°C Oven</td>
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<td>7</td>
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<tr>
<td>Leak check, pressure check</td>
<td>2</td>
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<tr>
<td>TIG welding</td>
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Basis: 75% on time
## 500 MHz accelerator modules

Technology transfer from Cornell University, USA

<table>
<thead>
<tr>
<th>Year</th>
<th>Modules</th>
<th>Location</th>
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<tbody>
<tr>
<td>2000</td>
<td>2 SRF</td>
<td>Taiwan</td>
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<tr>
<td>2000</td>
<td>2 SRF</td>
<td>USA</td>
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<tr>
<td>2000</td>
<td>2 SRF</td>
<td>Canada</td>
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<tr>
<td>2003</td>
<td>3 SRF</td>
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<tr>
<td>2005</td>
<td>3 SRF</td>
<td>PR China</td>
</tr>
<tr>
<td>2010</td>
<td>3 SRF</td>
<td>Korea</td>
</tr>
<tr>
<td>2012</td>
<td>1 SRF</td>
<td>Great Britain</td>
</tr>
</tbody>
</table>

- Cavity production
- Cavity surface preparation
- Cavity vertical test
- Coupler production
- Coupler conditioning
- Ferrite style HOM loads
- Module assembly,
- Installation on customer site
- Commissioning, **performance guarantee on cavity voltage and Q**
- Valve boxes and transfer lines
- SRF Electronics
- Interlock and data acquisition system
Cavity preparation and test
Factory testing, shipping, installation
Twin TESLA Cavity Accelerator Module as Turn-Key System for FEL and ERL Application

Order from 4GLS (Daresbury in 04/2004) 2 modules delivered in January and June 2006

New order from Ankara University received in August 2012

Target Values cw:
Eacc > 15 MV/m @ Cavity Q > 1 E10
Prf > 8 kW per Coupler

TESLA Technology Transfer from e.g. DESY, JLAB, Cornell,
License Agreement on the Twin Cavity Module with FZ Rossendorf
RI Research Instruments GmbH

- Advanced technologies, turnkey systems
- Project management, engineering and manufacturing
- Integrated system control, software
- Highly motivated, qualified people
- Project oriented, integrative, flexible
- Intensive, multinational cooperation's
- Global player in an expanding worldwide business