

The Challenge and Realization of the Cavity Production and Treatment in Industry for the European XFEL

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on behalf of the European XFEL cavity team







Industrialization of fabrication and surface treatment of 800 Cavities for European XFEL is the larges action in the history of SC Cavities



Outlook

- Preparation phase (2006-2010) Production phase (2011-2015)
- Procurement strategy
- Strategy of supervision and quality management
- Material for SC cavities
- PED (Pressure Equipment Directive) activities
- Qualification of new infrastructure at industry
- Current status and time schedule

Appendix: Images of new infrastructure at Industry.





Preparation phase 2006-2010. Construction phase 2010-2015.



Main issues of the preparation phase

- Define final cavity design (TESLA design minor design changes)
 Establishing the XFEL treatment recipe on base of ca. 50 prototype cavities (reached ca. 90% yield of EXFEL spec. requirement)
 Industrialization of the main EP treatment (set up of EP at RI, Henkel)
 Single cell cavity R&D program (several aims)
 Work out of detailed specifications for mechanical fabrication, treatment, HT integration, assembly for shipment
 Work out a concept for documentation and data transfer
- Material for XFEL Cavities. Qualification of new companies (2 new companies, decisive for cavity production)
- Work out Pulse Acceptance RF Test for XFEL Cavities
- R&D on Large Grain cavities

Large Grain LG cavity R&D: 11 LG 9-cell cavities from HERAEUS material fabricated at RI

Development of LG disc production was done within the framework of the XFEL R&D program of DESY and the W. C. HERAEUS.

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Fabrication similar to fine grain cavities: Deep drawing, Machining, EB welding

Very smooth (shiny) surface in grain areas after BCP

The steps at grain boundaries are more pronounced as in polycrystalline material. More in **TUP041**, **X**. **Singer et al**.



European XFEL Large Grain Cavities (or LG advertisement for future projects)





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 E_{acc} performance of LG cavities in EXFEL cryomodule XM-3.
 The cryomodule has ca. 60% lower cryogenic losses in CW, compared to all 4 previously tested cryomodules (J. Sekutowicz).
 For details see presentation of C. Madec THIOA02

Comparison of Q_0 at 2 K for 11 EP-treated LG cavities (red) with Q_0 at 2 K of XFEL prototype cavities (AC115–AC129, best result) treated according to XFEL recipe (blue).



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EuropeanProduction Phase: started by CavityXFELProduction Readiness Review (PRR) mid 2009



Procurement strategy

Three alternatives:

- Build in house
- Ask industry to design, develop and produce the product
- Industry build the product that was developed during R&D program at the laboratory (build to print)

The **build to print** strategy was chosen for procurements of European XFEL SC cavities. Production has to follow precisely the in detail worked out specifications which also include the exact definition of infrastructure to be used. **No performance guaranty by the vendors** (possibly retreatment at DESY)

Goal: Average usable gradient Eacc=23.6 MV/m (Qo=1x10¹⁰, X-Rays< <1x10⁻² mGy/min)



Status EXFEL cavities production contracts

Research Instruments (RI) and E. Zanon (EZ) were contracted without performance guarantee.

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- 560 series cavities (280 cavities per company) allocated end 2010 at RI and E. Zanon.
- 240 cavities as additional option (120 at EZ and 120 at RI have been allocated end 2012 - beginning 2013)
- 24 ILC HiGrade cavities (12 per company) allocated end 2010. For XFEL used as a tool for QC (poster MOP043).
- Material for cavities Nb / NbTi provided by DESY.

This was the beginning (E. Zanon)



Kick off meeting with RI



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Strategy of supervision and quality management

Vacuum

Jointly supervision of DESY and **INFN (Milano): created structure of** expert teams for:

- General coordination
- Material
- Mechanical fabrication
- Treatment
- **PED** Issue
- QM and Documentation
- RF

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Vacuum

No steadily presence at the companies, but regularly visits. Hard to find one expert that could cover all fields





Arne Brinkmann /

Paolo Michelato



- Main technical documents for contract are WP04 -S.C. Cavities Technical Specifications + Change Reports
- Quality Process based on Quality Control Plan (also for PED)
- Company internal QA, QM system
- Non Conformity Reports NCR: If the required property of a component is not provided, a nonconformity report must be prepared in which the correction procedure is proposed by the contractor and has to be confirmed by orderer.
- **Regularly expert visits** to the company by members of expert teams.
- Regularly meetings "Project Meeting" (coordinators of expert teams) on the company location (ca. one time every 2 months, issues depending)
- Quarantine zone for "non conform" parts (not epidemic!)
- Monthly progress report of the company
- Microsoft Project Plan based on companies and DESY Time Schedules (use the plan for tracking the progress, tracking of the time schedule)



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QM and Documentation : EDMS, Data Bank for statistic. Automated transfer of documents/data from System to System. Paperless documentation





All XFEL SC cavity documents (specifications, protocols, PED data etc.) recorded in EDMS. RI and E. Zanon have an access (to relevant data only). For more see poster MOP035, J. Iversen et al.



XFEL

Cavity

Bank for

statistical

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analysis

Data



Current status material for XFEL cavities. For more see poster MOP050, MOP032

In total 24420 pieces has to be build according Pressure Equipment Directive PED/97/23/EC and delivered after QC at DESY to RI and EZ

Contracted January 31st, 2011 to previously qualified and certified companies:

- Heraeus (ca. 95% SFP for end groups)
- Tokyo Denkai (52% sheets)
- Ningxia OTIC (30% sheets, 100% NbTi,..)
 PLANSEE (18% sheets, ..)









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DESY responsibility for material procurement

- certification of the material producers for PED
- procurement procedure
- incoming visual control
- independent QC for required
- parameter (RRR, interstitial impurity (H, N, O, C), metallic impurities, metallography, tensile test, hardness, HV, surface roughness)
- Eddy-Current scanning of sheets
- documentation using the DESY EDMS (guarantee of traceability for pressure bearing parts)
- marking and delivery to cavity producers







Infrastructure and QC of the Cavity Material (SFP) at DESY







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Details in Posters MOP050: X. Singer et al, MOP032: A. Brinkmann et al





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One example of foreign material inclusion (Ta) in the Nb sheets. For details see MOP050, MOP032



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Example: Eddy-Current scan, 3D -Microscope image and element analysis





Pressure Equipment Directive PED activities for cavity production. For more see poster

Module B (EC type-examination), contracted by DESY

- examination of design, FEM calculation
- qualification of welding processes (welding parameters, welders)
- qualification of another relevant processes (annealing, deep drawing)
- production of test pieces 2 pieces/company (qualification of each EBW machine) and destructive tests
- supervising the production qualification of the each company (Dummy cavities DCVs and Reference cavities RCVs)
- Supervising the production on first 8 cavities per company (pre-series cavities PCVs).

Module F (product verification), contracted by RI and EZ

visual inspections and control of documents pressure test for each cavity



Notified body is TÜV NORD (location in Germany and Italy)



And all this fight for the stamp





Test piece represents all pressure bearing parts: Destructive notified body analysis. MOP048

Test piece (TP) is composed by 2 cell with helium vessel, representing all pressure bearing parts and welding seams.

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- It is built using the same welding parameters that will be used in the series production.
- Two EBW machines/company. Consequently two test pieces had been built per company and destructively tested by TUEV NORD.
- Previously DESY has done similar tests on real cavities and gave the feed back to companies



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Cavity burst test. LG Cavity and Fine Grain Cavity. Poster MOP048, A. Schmidt et al



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LG cavity after burst test. How painful for us was to look on this.











Burst happened at the connection of stiffening ring to half cell

The burst test on a Fine Grain and Large Grain cavity could approve the sufficient stability of both types for European XFEL Linac



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Challenge of technology (know-how) transfer to industry. MOP038, MOP037, TUP054, MOP050.



Availability of infrastructure	DESY-INFN	Industry
Electron beam welding EBW equipment	yes	partly
ISO 7 and ISO 4 clean rooms with cleaning, rinsing and BCP	yes	no
Ultra-pure water (UPW) systems, clean nitrogen and other gases	yes	no
High pressure water rinsing equipment HPR	yes	no
Electropolishing EP facility	yes	partially
800°C annealing furnaces	yes	no
120°C final baking oven (3-4 per company)	yes	no
Tools for mech. measurement, cavity welding, integration in HT, pressure test equipment	partly	partly
Slow pumping slow venting vacuum system (SPSV)	yes	no
Systems for visual inspection of cavity internal surface	yes	partly
Machine for cavity tuning at room temperature (CTM)	yes	no
Equipment for RF measurement of dumb bells and end groups	yes	no
Qualified and trained personnel for surface cavity surface treatment	yes	no

We uncovered for companies everything up to last product of the mind



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Treatment: European XFEL treatment recipe was worked out on prototype cavities



Prior surface treatment. EP 110-140 μm (main EP), outside BCP, ethanol rinse, 800° C annealing, tuning Final surface treatment - two alternative options 1. Final EP of 40 μm, ethanol rinse, high pressure water rinsing (HPR) and 120° C bake 2. Final BCP of 10 μm (BCP Flash), HPR and 120° C bake.





Integration of the helium tank, assembly of HOM, pick up and high Q antennas and shipment to DESY for 2K RF acceptance test







DESY developed, build and installed at both companies the Cavity Tuning Machine CTM and Equipment for RF measurement of half-cells, dumb-bells and end-groups HAZEMEMA



Service is in DESY responsibility. Equipment has to be robust, required trained personal that has special background. MOP051, MOP052, MOP053 A. Sulimov et al



Cavity Tuning Machine CTM installed at RI

HAZEMEMA installed at EZ

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DCV / RCV: strategy for qualification of the surface treatment infrastructure at RI and EZ



Each company produced 8 "special" cavities

4 dummy cavities (DCV).

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DCV has to be used at the company for operator training, mechanical test of devices, infrastructure set up and ramp-up, final treatments test, tuning test etc. (not treated at DESY).

 4 reference cavities (RCV)
 After treatment at DESY the RCVs have to be used for stepwise qualification of surface treatment infrastructure (after infrastructure set-up using DCV has been done)





4 RCVs of RI and 4 RCVs of E. Zanon: acceptance test successful













- Mechanical fabrication of series cavities is going on. More as 220 CAVs in total fabricated
- Delivering of completely prepared series cavities started end 2012 - beginning 2013. 111 CAVs in total delivered.
- All 800 series cavities planned to be delivered till mid of 2015 (production rate: ca. 4 CAV/week)
 Cavity performance is encouraging: Average usable E_{acc} for all cavities taking into account the second pass is 29 MV/m (23.6 MV/m is required)
 For more details see presentation
- of **D. Reschke THIOA01**)









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RI: Status September 10th. Delivered 42 CAVs. More details in Talk **THIOA01**



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Experiences of the European XFEL demonstrate that industry is in position not only mechanically produce SC Cavities, but also do the complete cavity preparation up to vertical RF test









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Appendix: Photos to Infrastructure for European XFEL Cavity Production at RI and E. Zanon





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Furnaces for annealing at 800°C and baking at 120°C. Equipment for EP treatment (courtesy of RI)

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Clean room ISO 4. Refurbished EBW equipment (courtesy of RI)



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Ethanol rinsing, Ultrasonic rinsing and HPR at RI. (courtesy of RI)

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EP facility, EB welding and 3D-measurement equipment (courtesy of E. Zanon)

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Helium Tanks Fabrication (courtesy of E. Zanon)











Cleaning, Rinsing, BCP and HPR at E. Zanon (courtesy of E. Zanon)









120 °C and 800 °C Oven at Zanon (courtesy of E. Zanon)



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