

# STRATEGY OF TECHNOLOGY TRANSFER OF EXFEL PREPARATION TECHNOLOGY TO INDUSTRY

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## *Abstract*

For the XFEL a specification for the cavity preparation procedures was set up and handed to the industrial companies. Basing on this specification, companies' hardware as well as process flows were set up. Beside this specified part of the preparation technique the companies personnel needed to be educated and the processes ramped up. To check the quality of the infrastructure, status of education of personnel and correct set up of process flows, so called Dummy cavities (DCV), Reference Cavities (RCV) and Pre-series cavities (PCV) were assigned. We report on the general strategy applied for the XFEL technology transfer on cavity preparation and the results obtained on the cavities for qualification.

## INTRODUCTION

A total of 800 s.c. cavities have to be fabricated and prepared for vertical acceptance test by industry. It's the first time in super conducting (s.c.) Cavity area that industry takes over the complete responsibility from semi-finished products to the completed resonators, housed in Helium tanks, applying Pressure Equipment Directives (PED) and handed over in "ready for strings assembly" condition for 2 K acceptance test at DESY. The baseline for cavity production and preparation is fixed in the specifications for series mechanical fabrication, Series Surface and acceptance test preparation of superconducting cavities for the European XFEL (XFEL).

The development of superconducting resonator technology for the XFEL treatment was done in the collaboration between DESY and INFN. It was taken into account that this technology could be used in future for other projects in this area, first of all for ILC.

## PREPARATION OF SERIAL PRODUCTION

In preparation of the XFEL fraction of the fabrication and surface treatment sequences, foreseen for industrial production, are studied together with industry from 2006 to 2010. First experiences on process flow are collected and the methodology of surface treatment is checked on 30 prototype resonators. For these resonators it was decided that Main Electropolishing (EP) is contracted to industry and the final preparation sequences (BCP flash and final EP) should be done and studied at DESY [1].

A call for tenders and contracts were launched to industry for industrial studies of cavity production, Helium Vessel production as well as Main EP, (removal

of the up to 140 µm by electropolishing). It was shown that these technologies, developed over the last decade at DESY, could be transferred to industry successfully and that resonators performances well above 25MV/m with both preparation methods [2].

After successfully completion of this R&D phase the XFEL specifications on series mechanical fabrication and surface preparation of superconducting cavities for the European XFEL is set up. Technical details of DESY infrastructure and process parameters in use at DESY are collected in Appendix to the XFEL Cavity Specification.

## *Vendor Selection and Qualification of Vendors*

At an early phase and in preparation of the XFEL, industry was involved by international call for tenders for industrial studies where industry was asked for analysis of processes, proposal for large scale production and prototyping.

Industry could qualify itself here as possible vendor for helium tank, super conduction resonators, manufacturer for semi-finished products (SFP). In addition industries had to show that they can fulfil PED regulation if their production is related to pressure loaded parts for pressure equipment. Within those studies they had to deliver prototypes for qualification, hand out cost estimations and proposals for industrial improvements of specific parts of the project and time schedules for production. The prototypes delivered by the selected companies were tested at DESY in individual tests and in combination in modules. The modules have undergone intensive test on the test bench (CMTB) and in the FLASH linac.

The companies Research Instruments (RI) and Ettore Zanon (EZ) were qualified for the cavity production and preparation. RI and Henkel Lohnelektropolitur in Neustadt Gleve Germany were qualified for Main EP. Ningxia OTIC, Toyko Denkay, Plansee, and Heraeus were qualified as supplier of SFP made of Niobium and NbTi alloy. For the fabrication of Helium tanks and the tank accessories, CSC and EZ both companies located at Schio Italy, together with Graeven Metalltechnik in Germany, were qualified. HOM coupler antennas, Pick Up antennas, power couplers and accessories are qualified by the responsible work packages of the cold linac consortium..

## *Documentation and Contracting*

Documentations to be handed to vendors for quotation and design of serial production have to well define the process and requirements for the EXFEL production. These documents, set up in 2009, are reviewed by invited

international experts in a Production Readiness Review (PRR) meeting in summer 2009.

After review, the specification documents were permitted to be handed out to industry and used for the final call for quotations and contracting to the qualified vendors.

This call for tender asked for a quotation of 800 XFEL and 24 High Grade (HG) resonators as well as fractions of that amount. Parts of the quotation are optional resonators. In order to inspire the competition between the companies 240 cavities were foreseen to be order at a late phase of production [2]. This option should be contracted only after start-up of production and verification that companies met time schedule as proposed. Also set up of adequate infrastructure in time was one part of the selection criteria for contracting the optional cavities. Companies also should demonstrate a scenario and time schedule for production rates of up to 4 cavities per week.

Together with the quotation, companies had to hand out a scenario for set up production lines, time schedules and cost break down for the delivery rate of 3.5 to 4 Cavities per week.

After hand out of documents, companies had a chance to visit the DESY infrastructure and exchange information with the experts on place to complete all information needed.

In a kick-off meeting companies (Figure 1) had to explain in detail their scenarios for production, time schedules and cost breakdowns to the responsible persons of the XFEL project.



Figure 1: Kick off meeting by TÜV, DESY + INFN Experts and one vendor for XFEL cavity fabrication.

Basing on the offers and on the result of that review meeting, the contract and the amount of cavities contracted per vendor had been fixed. RI and EZ Company are contracted to deliver each 280 XFEL and 12 high grade resonators, four dummy and four reference cavities. The option was contracted end of 2012-beginning of 2013 to both companies in equal amounts after successful set up and qualification of infrastructure.

In the DESY specifications quality control documents are defined that had to be handed out in accordance to the fabrication status of each individual cavity.

The EDMS system of DESY is in use for storage and managing of all these documents [3], starting from SFP, cavity fabrication processes and preparation. EDMS is collecting all documents from the companies and guarantees the full traceability of cavities history. Moreover it transfers data for analysis to the XFEL database.

## START-UP PHASE OF CAVITY FABRICATION

A team of experts from DESY and INFN Milano is selected as contact person to the industry. This team, named WP 4 cavity team, took over the responsibility in the framework of the DESY INFN collaboration for the technology transfer and the production control. In addition teams of experts were named for each field of technological changes. They are the companies' contact persons that can be contacted in case of technical questions.

For the general planning and tracking of the project monthly reports are handed over from the companies to the WP 4 team, that allow tracking of the materials, status of infrastructure, production sequence and time schedules. During regular Project Meetings (PM) these information's are baseline for the controls on company's site and future planning. Deviation from proposed schedules and problems found during start-up are discussed and solution for recovery of time slip are outlined in this meetings as well.

Weekly video and telephone conferences between WP 4 team members as well with the companies are set up for fast information flow and in time reaction on problems influencing the time schedule.

### *Detail Technology Transfer*

Quality control plans, work instructions and workflow schemes are set up by the companies and are reviewed by DESY/ INFN team members. Intensive exchange of information on the DESY hardware and processing steps took place right after signature of contracts.

The start-up of individual infrastructure at each company is accompanied by DESY/ INFN experts. The quality control of major infrastructure like cleanroom air flow conditions, the ultra-pure water and vacuum plants were accompanied by experts and test equipment form DESY/INFN as well.

Each company had to adapt the XFEL cavity fabrication to the existing infrastructure and boundary conditions of space or personnel. In some details the XFEL specification could not be transferred in direct line to the process flow. Here so called change requests are emitted. After experts review and verification, the change requests became part of the EXFEL project specification documents.



Figure 2: View on stock of dumb bells during cavity production.

Besides the general planning at the regular PM detailed transfer of surface preparation technique is done in five major steps by experts' team (Table 1).

Table 1: Transfer scenario for the cavity preparation technology from Institutes to industry for the XFEL

PED request	DESY/INFN team	Company
<b>Contract placed</b>		
<b>1) Preparation phase</b>		
Design approval Module B1	Training of key personal at DESY	Consultancy on DESY infrastructure and design
<b>2) Installation phase</b>		
Manufacture test piece for parameter approval	Training of key personal at Industry Consultancy on ramp up of infrastructure	Set up and commissioning
<b>3) Qualification phase</b>		
Approve and fix fabrication parameters	Consultancy on Cavity preparation	Preparation of reference cavities
<b>4) Production ramp up</b>		
TÜV Witness of production of 8 series cavities (PED module B)	Consultancy and service by experts on place and on call	Preparation of pre-series cavities
<b>5) Production phase</b>		
TÜV Witness of individual pressure test of cavities PED Module F	Inspection visits and service by hot line to experts	Preparation of 4 cavities per week

### Training of Personnel

One major parts of the quality of cavity preparation are the operators in charge for installation of parts and handling of cavities inside the clean rooms.

Training of team members of the companies took place in four phases.

### 09 Cavity preparation and production

#### K. Technical R&D - Large scale fabrication

Phase 1: One week's intensive training at DESY for key personnel and designers in charge. All step of cavity handling, assembly of accessories, tuning and RF checks as well as processing of cavities and hardware were covered in that a one week intensive course.

Phase 2: At ramp up of infrastructure at industry new team members, especially the once working inside the cleanrooms, are trained at the companies' infrastructure by WP 4 experts.

Phase 3: Witness of preparation of reference cavities (RCV) (Figure 2), cross check of education status of operators dedicated for a second shift of production.

Phase 4: Non regular visits during production of SCV, witness of production, recheck of qualification of infrastructure and personnel.

### VERIFICATION OF INFRASTRUCTURE

PED regulations to be applied for the XFEL cavities require prove of all pressure bearing welds and materials. So called test pieces are fabricated and check by TÜV [4] before start of cavity manufacturing.

Moreover four resonators produced by each company are dedicated to ramp up the production. These are the so called dummy cavities (DCV) and they are in use to parameterize BCP and EP infrastructure; 800 °C annealing oven, ethanol rinsing set up, alignment and parameter studies of the HPR systems and parameter check of the 120 °C baking oven.

Qualification of the cavity processing and infrastructure is done by referencing (RCV) resonators. Four RCV produced by each company are processed and successfully RF tested at DESY. For EZ they are processed according to BCP flash sequence, for RI they passed the final EP process.

Release of infrastructure is given after retreatment of the RCV at the companies and successful retest at DESY. Six referencing treatment steps [5, 6] had to be passed successfully before permission is given to start treatment of XFEL cavities in the new infrastructures.

### Start-up of Production

The first eight serial resonators from each company are named pre series cavities (PCV). They are used to ramp up the production of cavities fully equipped. They pass the first time the complete cavity preparation process and they are equipped with all XFEL accessories. These cavities are handed to DESY in status "ready for string assembly and test". To fulfil the PED Module B (EC type-examination, category IV of PED annex II regulations) the production of the PCV is witnessed by a notified body on place.

After successful test of the PCV, the serial production for XFEL Cavities is released and production ramped up (Figure 3) to the contracted delivery rates.



Figure 3: View on stock of cavities during production phase ready for surface treatments.

## SUMMARY

The technology of fabrication and surface preparation of superconducting cavities for the XFEL accelerator is transferred to industry. The industrial production of 800 superconducting resonators for the EXFEL project is contracted to industry.

A set of documents, specifying the processes and technology developed at DESY is set up and reviewed by experts during a production readiness review.

Vendors are pre-qualified by industrial studies and prototype productions during the preparation phase of the XFEL project.

Work out of production schedules with completion date of the project, control plans, work instructions and workflow schemes is done. Regular reporting, project- and experts meetings are installed to review and control the project in regular sequences.

Serial production at the two suppliers for s.c. cavities has started at beginning of 2013. Until KW 37/13 one hundred and six XFEL cavities are handed to DESY for acceptance test. From the seventy nine resonators tested so far 50 passed as received all acceptance criteria and reached average max gradient of  $28.1 \pm 7.8$  MV/m.

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