EUROPEAN INDUSTRIES POTENTIAL CAPABILITIES ON SUPERCONDUCTING RF ACCELERATOR MODULES

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Abstract

European Industry has been supporting accelerator projects in the past and will be supporting future projects. Larger numbers of superconducting accelerator modules with guaranteed performance parameters have been supplied for example for LEP at CERN and superconducting cavities have been supplied also with guarantees for CEBAF at Jefferson Lab, the proton linear accelerator for the Spallation Neutron Source, Oak Ridge, and for the rf system for LHC. A significant number of cavities have been supplied in support of the TTF/ILC activities. With a view to the future European X-FEL linear accelerator it is expected that turn-key accelerator modules will be requested from industry. A review of the European Industries supplies in the past and present will be given to show their capabilities for the future ILC.

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SUPERCONDUCTING ACCELERATING MODULES

Within this paper a superconducting accelerator module is defined as the turn-key assembly of superconducting rf cavities with all their auxiliaries like power-couplers, HOM couplers, tuners, and the helium-vessel, heat-shields, vacuum vessels etc.

REVIEW OF INDUSTRIAL SUPPLIES FROM 1985 TO TODAY

Cavities for CEBAF

Starting with prototype cavities Interatom was contracted for the production of 360 1.5GHz cavities for the Continuous Electron Beam Accelerator Facility (CEBAF). The cavities were delivered in a 37 months time exceeding the guaranteed values of Q = 2.4 * 10^9 and Eacc = 5 MV/m [1].

LEP Modules for CERN

From 1990 on superconducting 352 MHz modules each housing 4 4cell cavities were supplied by three European industries (ACCEL, Ansaldo, CERCA). The cavity-production was based on the CERN developed coating technology of sputtering niobium on the inner surface of a copper cavity. During the development of this technology CERN showed that specific parameters for the cavity and module performance could be achieved on a regular basis and the contractual performance was set at of Q = 3.4 * 10^9 and Eacc = 6 MV/m [2].

Figure 1: LEP module housing 4 4cell cavities.

Nb-coated Cavities for LHC

For the RF systems of LHC CERN choose the well established Nb coating technology for the 400 MHz single cell caveties. 20 cavities were order from ACCEL, whereas the modules were completed at CERN. The specification for this contract was Q = 2.0 * 10^9 and Eacc = 5 MV/m [3].

Cavities for SNS

The Spallation Neutron Source (SNS) project includes a superconducting linac in the energy range from 186 MeV to 1 GeV. Two types of 805 MHz 6cell cavities with geometrical beta values of beta=0.61 and beta=0.81 have been ordered at ACCEL. The cavities have been accepted after passing a cold test (2 K) with of Q = 5.0 * 10^9 and Eacc = 10.1 MV/m for the medium beta cavities and of Q = 5.0 * 10^9 and Eacc = 12.5 MV/m for the high beta cavities.

These parameters were agreed based on the prototype cavity performances of of Q > 2..0 * 10^{10} and Eacc exceeding 14 MV/m for the medium beta cavities and a Q = about 2.0 * 10^{10} and Eacc exceeding 15 MV/m for the high beta cavities[4]

Figure 2: Niobium cavities for SNS (above) and X-FEL (below).

X-FEL cavities for DESY

During the past years more than 120 cavities have been supplied by Zanon and ACCEL. These cavities have been prepared by either buffered chemical polishing or

1-4244-0917-9/07/$25.00

electropolishing at DESY. Typical test results of one of the latest production batches are shown in figurre 6 [7]

CORNELL Modules for Synchrotron Light Sources

500 MHz srf modules based on the CORNELL CESR design have been supplied turn-key with guaranteed performance to CORNELL, Taiwan Light Source, CLS, DLS, and are under delivery to the Shanghai Light Source.

X-FEL cavities for BESSY

BESSY is proposing a 2,3 GeV linear accelerator using X-FEL type cavities operated in cw mode at operating gradients of 16 MV/m and related Q > $1.3 * 10^{10}$ [5]
Based on proven manufacturing and in house surface preparation technologies (buffered chemical polishing, BCP) and high pressure water rinsing (HPWR) for the X-FEL cavities ACCEL supplied the cavities with guaranteed accelerating field parameters and quality factor to BESSY.

Figure 3 (left): X-FEL cavity under High Pressure Rinsing.
Figure 4 (right upper): Turn-key srf module based on X-FEL cavity design.
Figure 5 (right bottom): Power coupler for X-FEL accelerating modules.

Project	**scope**	**Average Q_0 at operating E_{acc} [MV/m]**	**E_{acc} max [MV/m]**	**E_{acc}/Q_0 [MV/m]** Contractually agreed	**Industry's Obligation**
CEBAF	360 cavities	6.0 to 10.0 * 10^9 at 5 MV/m	10.0 to 15.0	$2.4*10^9$ at 5.0	Best workmanship
LEP Modules	~ 80 modules	4.2 * 10^9 at fields of 6.0 at 4.0 to	9.0 to 10.0	$3.4*10^9$ at 6.0	Best workmanship
Cavities for LHC	20 Nb coated cavities	$2.5*10^9$ at 5.0	7,0 to 9,0	$2*10^9$5at 5.0	Best workmanship
Cavities for SNS	35 cavities (MB)	$2.0*10^{10}$ at 10.0	> 14.0	$5*10^9$ at 10.1	Best workmanship
	74 cavities (HB)	$2.0*10^{10}$ at 12.5	> 16.0	$5*10^9$ at 12.5	
X-FEL	Tbd.	$1.0*10^{10}$ min. at 23.4	25.0 to about 30.0	Tbd.	Tbd.
500 MHz Modules for Synchrotrons	Turn-key srf modules	$1.0*10^9$ at 5.0	10.0 to 11.0	$5*10^8$ at 6.5 to 8.5	Guarantee for Module performance
BESSY FEL	X-FEL cavities operating at $1.3*10^{10}$ at 16.0 MV/m	See X-FEL	See X-FEL	$*10^{10}$ at 16.0 and 20.0	Guarantee for Cavity performance
4GLS	2 SRF Modules with 2 X-FEL cavities each operating at $3.3*10^9$ at 12.5 MV/m	See X-FEL	See X-FEL	$3.3*10^9$ at 12.5	Guarantee for Module performance

SRF Modules with X-FEL cavities for 4GLS

Based on the X-FEL cavity and coupler design Forschungszentrum Rossendorf has developed a srf accelerating module with two cavities for cw operation. ACCEL has provided two such modules to the 4GLS project at Daresbury. The surface preparation (BCP, HPWR) has been performed at ACCEL. Proof of performance has been given by cavity cold tests at DESY before integration of the accelerating module.

Power Couplers for SRF Modules

Power couplers (figure 3) represent another key component for srf modules besides the cavities. The development of the power coupler for the X-FEL accelerating module has been driven by DESY and is supported through the supply of prototypes and batches of couplers by industry. Furthermore, in preparation of the production of about 800 to 1000 couplers for the X-FEL linac modules 3 industrial companies (E2V, Toshiba, ACCEL) are performing design and industrialisation studies in 2006 and 2007[6].

GUARANTEED PARAMETERS OR BEST WORKMANSHIP FOR CAVITY PERFORMANCE

The difference between turn-key delivery with guaranteed parameters and contracts with “best workmanship” shall be discussed as follows.

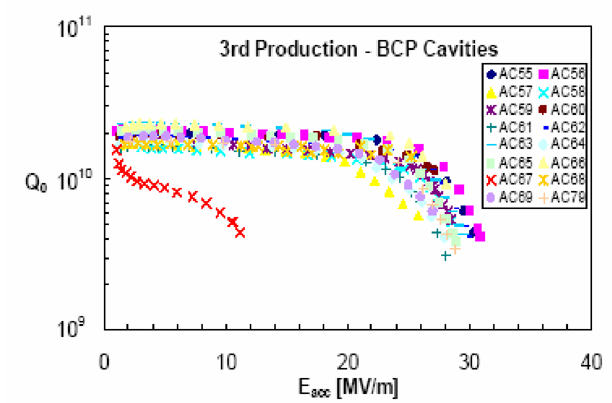
In projects with guarantees industry takes responsibility for the delivery of a functional srf module or operating cavity. In this case of guaranteed performance the company will review the state of the art performance for the particular case, review its own manufacturing technology and propose a set of parameters to the customer. If, in such agreement parameters are not met after delivery, industry will perform improvements, repairs, or additional cavity preparations until contractual performances are met.

In projects based on a “best workmanship” approach industrial companies supply cavities by following and repeating precisely production procedures developed and detailed by the laboratory. The agreement on performance parameters is based on the evidence shown by the laboratory that the performance can be achieved reliably. In general this evidence is given by a series of results that have safely surpassed the minimum specification. In cases where performance specifications are not met, a detailed common analysis of the laboratory and the company has to be made to investigate if the failure is due to the procedure itself or errors made during the production.

In the above shown table an overview of successful projects with their specified/guaranteed parameters is given. The third column shows the mean value for the quality factors achieved on a regular basis at the operating field of the project, the forth column shows maximum achieved gradients, and the fifth column shows the contractually agreed values for the industrial supplies. It can be seen that usually the operating gradient is guaranteed with somehow lower quality factor

OUTLOOK FOR X-FEL

Cavity and module performances achieved at the laboratories in a reliable manner have been reproduced and delivered by industry in the past as can be seen from several successful projects. In preparation for the X-FEL project DESY showed for a batch of cavities manufactured in industry during the past production the results shown in figure 1. [7].



These results show that a mean value of 23 MV/m with a quality factor of above $1.0*10^{10}$ can be achieved with industrially consolidated cavity manufacturing procedures and the surface preparation sequence developed at DESY. Based on these results European industry is ready to provide cavities as well as complete modules following the DESY established procedures with guaranteed parameters.

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