INDUSTRIAL RF LINAC EXPERIENCES AND LABORATORY INTERACTIONS *

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Abstract

For more than two decades ACCEL Instruments GmbH at Bergisch Gladbach (formerly Siemens/ Interatom) has supplied accelerator labs worldwide with key components like rf cavities and power couplers, s.c. magnets, insertion devices, vacuum chambers and x-ray beamline equipment. Starting with the design and production of turn key SRF accelerating modules in the late 80th, meanwhile ACCEL is now engineering, manufacturing, on site commissioning and servicing complete accelerators with guaranteed beam performance. Today, with a staff of more than 100 physicists and engineers and about the same number of manufacturing specialists in our dedicated production facilities, ACCEL's know how and sales volume in this field has accumulated to more than 2000 man years and several hundred Mio €, respectively. Basis of our steady development is a cooperative partnership with the world's leading research labs in the respective fields. To give an example, we established a very fruitful partnership with DESY for the supply of a turn key 100 MeV injector linac for the Swiss Light Source, and meanwhile also for the Diamond Light Source as well as for the Australian Synchrotron Project.

INTRODUCTION

In the last years there have been different talks by people from industry [1], [2] or labs [3] on international accelerator conferences concerning the relation between the labs and the supplying industry for this worldwide research market. The scope of industrial supplies and services ranges from job shop and build to print work over standard and special equipment to turn-key systems. The lab's choice of type of relation is generally depending on their individual capabilities and strategies. While there exist a broad range of companies for performing work on a job shop/build to print level or supplying standard and special equipment there exist only very few companies worldwide with the know-how and capabilities for supplying complete accelerator systems or subsystems with guaranteed beam performance.

ACCEL Instruments GmbH is supplying advanced technology special equipment as well as turn-key linear and circular accelerators for research, industry and medical purposes worldwide. In the following I will try to give a picture on ACCEL's experiences and interactions with the international accelerator labs in the field of rf linac components and complete systems within the last years.

SRF CAVITIES AND MODULES

Within the last two decades ACCEL has manufactured more than 600 superconducting rf cavities out of bulk niobium, by Nb sputter coating of copper cavities or by Nb/Cu explosion bonding techniques. As examples we built all the 360 niobium cavities for CEBAF, the 109 medium and high ß cavities for SNS/ORNL (fig. 1) [4] and in the meantime more than 50 TESLA type cavities (fig. 1) for DESY, Stanford University, FZ Rossendorf and BESSY [5]. Our production know-how for these key components is based on a very intense, long term co-operation especially with DESY, CERN, JLAB, Cornell and Wuppertal University.

Figure 1: SNS (upper) und TESLA (lower) Cavity.

While in the past the cavity production was performed more or less on best effort basis, today customers are asking more and more on a performance guarantee especially for the accelerating field (E) and the cavity Q of the naked cavity, sometimes including the LHe vessel.

For BESSY we have been contracted for manufacturing, chemically treating (BCP) and high pressure rinsing (HPR, fig. 2) two TESLA type cavities [5]. The 800 °C heat treatment (fig. 2) and the vertical cold test have been performed at DESY with the help of DESY personnel. In fig. 3, the resulting Q versus E curves are shown in comparison with results of TESLA cavities manufactured by us but finally treated by and at DESY. We think these first results of accelerating fields above 20 MV/m at a Q of 1 E10 are very promising.

For future projects upon customer's request we plan to perform all preparation steps on TESLA type cavities under full responsibility of ACCEL, using DESY Nb material inspection, furnace and test infrastructure under service contract.

Figure 2: TESLA Cavities for BESSY during HPR at ACCEL (left) and vertical testing at DESY (right).

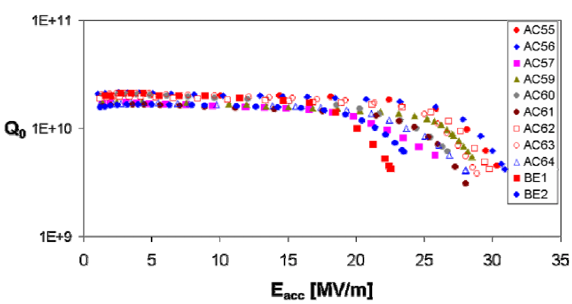

Figure 3: Q versus E curves of the two TESLA type cavities for BESSY (BE1, BE2) in comparison with those finally prepared by DESY (ref. TESLA TDR, DESY 2001). Most of the AC cavities have been titanium heat treated at 1400 °C, while the BE cavities did undergo only the standard 800 °C annealing process.

For an increasing number of labs, like CERN (LEP200), JAERI (FEL), LANL (pion momentum compaction), FZJ (ESS prototyping), BESSY, Cornell University (CESR), NSRRC, CLS, DLS (all synchrotron light sources) and Daresbury lab (4GLS prototype) we have delivered or are supplying complete SRF modules with guaranteed performance.

In figure 4 a complete LEP 200 module with four 352 MHz 4 cell Nb sputter coated copper cavities is shown together with 3 more cavity/LHe tank/tuner assemblies in front of our class 10 clean room. After a very intense technology transfer from CERN, which took about half a year, we were able to accomplish the manufacture, sputter coating and final preparation of the huge 352 MHz cavities. Before module assembly on our site all of the 88 cavities had been cold tested at CERN. This quality assurance step basically allowed us to issue guarantee for the performance of the modules.

Figure 4: LEP 200 module and 3 single cavity/LHe tank assemblies in our assembly hall. In the back is a 15 m long clean room, the quality of which has since been improved from class 100/10 to class 10/1.

The design of the four 500 MHz SRF modules for the JAERI free electron laser (FEL) and for FZ Jülich (for ESS prototyping [6]) was based on a DESY layout and then completely engineered by ACCEL. For the worldwide supply of the CESR type 500 MHz single cell modules, including valve-box, instrumentation and system control [7] (see figure 5), we concluded a technology transfer agreement with Cornell University which also regulates the use of university infrastructure for testing cavities and higher order mode absorbers as well as conditioning the high power rf windows.

Figure 5: Cornell type module with electronics and valve-box delivered to NSRRC and CLS.

Meanwhile this design has also been further engineered especially to stay in line with the European pressure vessel regulations. The status of the projects with Cornell, NSRRC/Taiwan, CLS/Canada and DLS/UK is given elsewhere [8].

The 1.5 GHz third harmonic Landau module for BESSY [9](fig. 6) is completely based on our own design. The required very short flange to flange distance made a rather complex cryostat design and cryogenic loss simulation necessary.

Figure 6: Turnkey 1.5 GHz SRF Landau module for BESSY.

Generally transportation to the final destination takes place in specially designed shock absorbing frames by trucks (in Europe) and/or by plane (intercontinental). Up to now the overall cavity and module transportation distance has exceeded 200.000 km and in all cases of proper transportation, no deterioration in cavity Q and maximum acceleration field has been observed. This documents that SRF cavity and module transportation should not be a technical issue especially when considering possible world spanning projects like an international linear collider (ILC).

In the beginning of 2004 we settled a license agreement with FZ Rossendorf for the production and worldwide sale of the twin TESLA cavity modules (fig. 7). The design is based on the technology developed by the world spanning TESLA collaboration and optimised by FZR in cooperation with Stanford University for cw operation for the FEL project ELBE. Meanwhile we have been contracted by Daresbury lab for supplying two such modules on a turn-key basis with guaranteed performance for the 4GLS prototype project in UK.

Our future goal is to also build and sale turn-key TESLA/XFEL type modules with guaranteed performance for worldwide FEL and energy recovery linac (ERL) applications.

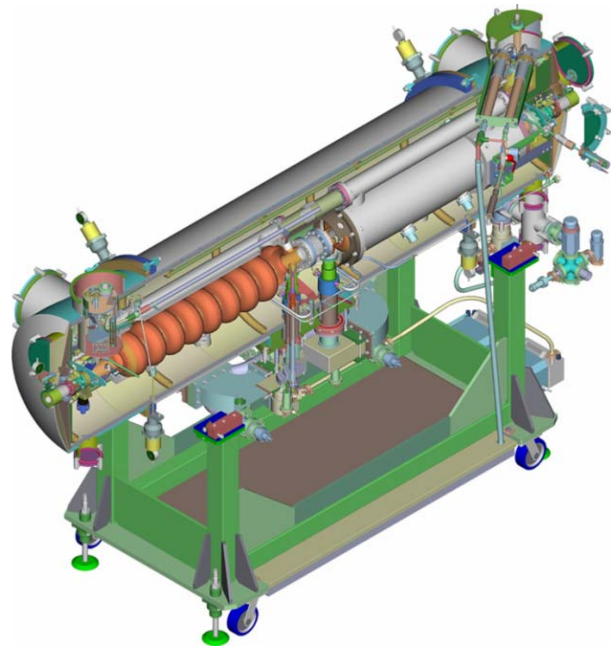

Figure 7: Twin cavity accelerator module, designed by FZR for cw operation in the ELBE FEL on the basis of TESLA module technology.

CU CAVITIES AND MODULES

In parallel to our SRF activities more than 200 normal conducting rf structures, couplers and modules in the frequency range between 52 MHz and 4.9 GHz have been manufactured for accelerator labs like CERN (LEP, CLIC), ESRF, ANL, LBL, BNL, DESY, SLAC, ORNL/SNS, SLS, CLS, DLS, ASP and Mainz University.

To give an actual example, for the SNS project we manufactured, assembled, aligned and rf tuned all the 4 CCL modules (fig. 8). Here we had a very intense technology and know-how exchange with LANL e.g. on the brazing technique and on the rf tuning procedures.

Figure 8: Completely aligned CCL module for SNS during rf test at ACCEL.

LINACS WITH GUARANTEED BEAM PERFORMANCE

Some years ago, a further step into systems technology was accomplished by developing, constructing, on site assembling and commissioning a complete 100 MeV S-Band electron injector linac for the Swiss Light Source at PSI (fig. 9) [10]. The settlement of a license agreement with DESY on the S-Band accelerating structures and electron gun, developed for linear collider applications at that time, together with a very fruitful co-operation with DESY and Dortmund university, made it possible to put the complete linac into operation with guaranteed beam performance on schedule. As of today three more such types of linacs are in production for DLS, ASP, and PTB, respectively [11].

Figure 9: Turn-key S-Band injector linac for SLS at PSI.

Two years ago, after a very thorough assessment study, we have been contracted to design, build and install a turn-key proton/deuteron linac injector for SARAF/Israel (fig. 10) for cw operation with a beam current of up to 2-4 mA [12]. Key subsystem of the accelerator is a prototype SRF module with 6 half wave resonators (HWR, fig.11) with a frequency of 176 MHz. The assessment study included beam dynamic simulations as well as error analysis. Since then the first prototype HWR (fig. 12) has been fabricated and first cold tests are expected soon. After a successful run of this injector the energy is foreseen to be upgraded to 40 MeV by means of an adequate number of additional superconducting modules. ACCEL is chosen to supply the complete accelerator including all the rf supply.

In order to satisfy these requirements we have defined - as we do for all contracted projects - a project team, consisting of project managers and engineers, several rf, srf and beam dynamics experts as well as manufacturing and assembly specialists. An intense inhouse R&D effort has been combined with a very strong cooperation with the world's leading accelerator labs in this field like INFN LNL, Frankfurt University, FZ Jülich, ANL, MSU; LANL, ORNL; PSI and AECL.

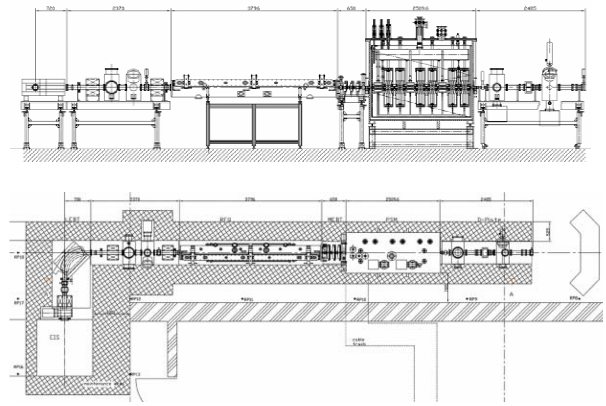

Figure 10: Scheme of the proton/deuteron injector linac for SARAF/Israel.

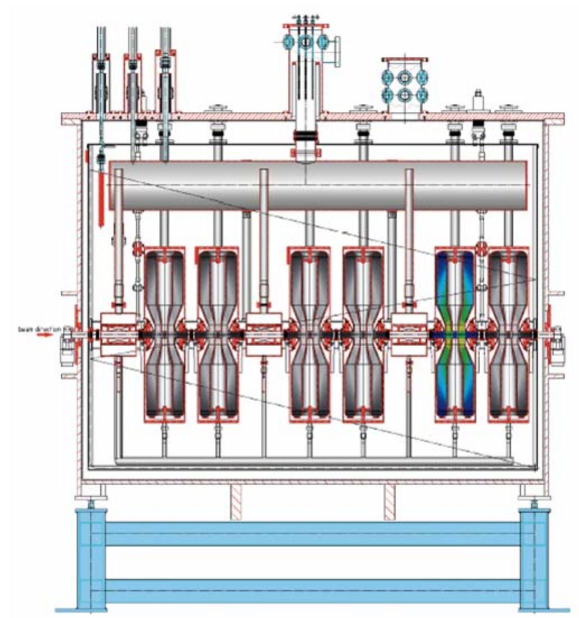

Figure 11: Scheme of the prototype SRF module for SARAF with 6 bulk niobium HWR and 3 superconducting solenoids. The beam vacuum is separated from the cryostat vacuum.

CONCLUSIONS

ACCEL's mission is to serve as an industrial partner for the worldwide labs on supplying advanced technology equipment and turn-key systems with guaranteed performance as well as co-operating with the labs on rf accelerators and its respective technologies. Therefore ACCEL is investing substantially in specialised production capabilities and in human resources.

Figure 12: Bulk niobium 176 MHz half wave resonator for the prototype superconducting module for SARAF.

We are observing that an increasing number of young and motivated lab physicists and engineers are deciding to join ACCEL for working as accelerator specialists or project managers, thus combining their individual know-how with the company's experience and capabilities.

Baseline of our technological development is an intense co-operation with the world's leading labs in the respective fields. This allows us to evaluate and compare the different experiences of those labs for gaining best solutions on running and future projects.

It is our impression that an increasing number of labs and people accept the role of the specialised industry and take advantage of a partnership under flexible but well defined conditions. This gives us – the industry – the necessary basis to stabilize and continuously expand our activities.

Our long term experience with the research organisations of the different countries shows us in view of both technical/operational and legal/administrative aspects, that all the different contractual systems give enough room for a flexible handling of the project, but it is up to the individual people on both sides to use and take advantage of it.

Successful partnership can only be accomplished by human beings on both sides with mutual respect and understanding. A growing acceptance of a dependence on each other and a common understanding of the benefits from the synergies within the partnership can even create more in the future.

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