EUROPEAN INDUSTRY'S POTENTIAL CAPABILITIES FOR HIGH POWER RF SYSTEMS FOR THE FUTURE ILC

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Abstract

The ILC Baseline Design identifies presently available technology that could in principle be used for its construction. But, to be viable, the associated cost must be greatly reduced and predicted performance, reliability and life improved. This applies equally to its RF systems. A brief view of European competence is presented in terms of new RF systems developments, available products and overall capability. Europe has a strong industrial base that can accept the challenges set by the ILC but it can only be engaged if the ILC is seen to be a good business prospect. Industry must be involved from an early stage, and its involvement based on risk sharing. Technical and commercial information should be readily available and there needs to be adequate funding.

INTRODUCTION

ILC is deemed to be technically feasible based on using existing technology but it is unaffordable without major cost reductions. Europe has been active over several decades in building accelerators for many different applications and as a result now has a broad manufacturing base. It is therefore ideally positioned to take a very active role in reducing component costs and in particular those of the RF system. Examples of relevant European capability are presented below. It will be noted that RF power couplers are given only brief attention and superconducting RF modules are not considered at all as both are the subjects of other papers in this conference.

RF SYSTEM

Power conditioning and modulators

The modulator designed by the Fermi Laboratory and adopted by the TESLA project has been further developed for use on XFEL. Several of these have already been supplied by European industry, and a modulator test facility has been constructed at DESY to support the construction of XFEL. The modulator has several years' track record and is the baseline choice for the ILC. The modulator includes some massive components and occupies a large footprint but it is highly likely that its cost and size can be reduced within the ILC lead time.

An alternative technology similar to that used by LANL for SNS is being further developed in the UK [2,3]. Technical issues that characterised the SNS modulator that have now been solved include the achievement of soft-switching throughout the entire pulse duration, the development of a control philosophy that can deal with unbalance between the 3-phase tanks and the achievement of a closed loop control for pulse generation. This work owes much to techniques and understanding developed for the traction and power transmission industries.

A prototype modulator has been constructed that has delivered 1.5ms pulses of 312kW peak power at 25kV with a mean power of 25 kW. Both pulse-width and pulse-frequency variation are exploited within the converter in order to produce soft switching and simultaneous pulse flatness despite the large voltage droop of the power source. Figure 1 shows the converter power circuit and Figure 2 some performance results. The good output pulse shape has been achieved despite a droop of over 25% on the source voltage although the rise time needs to be reduced somewhat.

More work is needed but this is a very promising start.

Figure 1: Experimental Multi-Phase Resonant Converter Power Circuit [2,3].

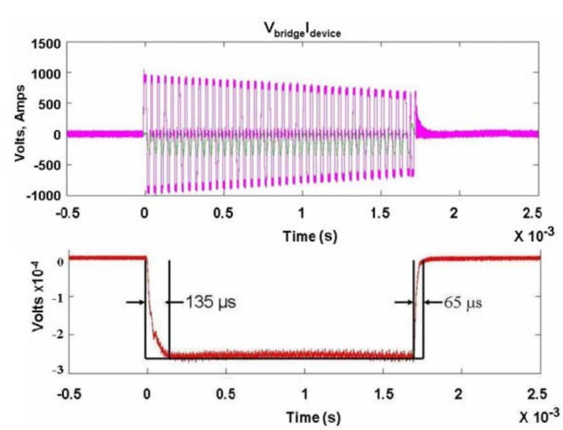

Figure 2: Top:– magenta - voltage applied by one of (three) H-bridges to one of three resonant tanks; green - current in one leg of an H-bridge. Bottom:- the output pulse profile [2], [3].

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RF power amplifier klystron

Two European tube companies are active in the accelerator market: e2v Ltd [3]who has not indicated that it will make multibeam klystrons or any other equivalent devices for XFEL or ILC, and Thales [4]. Thales has been the major European supplier to the accelerator community for decades and its manufacturing and test capability for large devices has recently been further expanded. The Company was the first to develop and manufacture the multibeam klystron for the TESLA project and today there are 5 of these tubes operating at DESY where they have accumulated more than 30,000 operating hours. It is now being developed into a device, the TH 1802, that will be used in the construction of XFEL. It is a horizontally mounted version of the original klystron that can be installed inside the XFEL tunnel. Figure 3 is a visualization of the TH 1802.

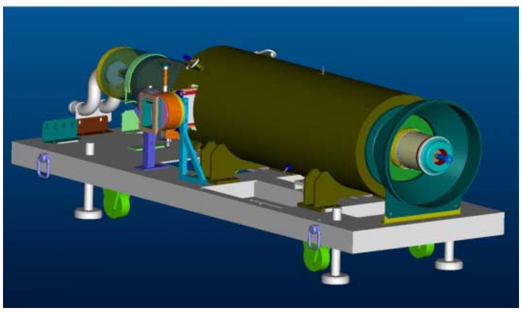

Figure 3: Schematic view of Thales TH1802 in horizontal format to facilitate placing in a tunnel [4].

This device will not necessarily be the one offered by Thales for ILC because technical specifications and the time schedule for ILC have not been finally settled. Specific technical and/or industrial actions which could be carried out for ILC cannot be specified for the time being. However, there is no doubt that Thales possesses demonstrated capability to design a specific product for the ILC.

Klystron Drivers

Figure 4: 650 watt driver developed for XFEL by Microwave Amplifiers Ltd [5].

There are several companies in Europe capable of building L-band drive amplifiers. Figure 4 illustrates an amplifier developed by Microwave Amplifiers Ltd [5] for XFEL. It incorporates the latest GaAs device technology and is capable of further development to higher power if needed.

Passive waveguide components

Cables, connectors etc. – The TESLA programme included a significant project for prototyping cable to transmit DC power to the klystrons. More than eighteen kilometres have been supplied to DESY for extended tests. The cable is manufactured by Dielectric Sciences Inc [6] (USA) and its performance meets European 12kV distribution standards for Category A fire-test and water tightness in the event of mechanical damage. The terminations and splices are made on site by Essex X-Ray and Medical Equipment Ltd (UK) [7]. Both companies are divisions of the HVT Group.

Waveguide components – Circulators and loads continue to be developed for use with high power pulsed klystrons such as those developed for the Tesla Test Facility and XFEL. Figure 5 shows an example of such a device developed by the company AFT Microwave GmbH [8].

Figure 5: Circulator type CPR 650 manufactured by AFT Microwave GmbH [8].

The assembly of many kilometres of guide incorporating thousands of standard flanges suggests an opportunity to reduce parts count and more particularly to re-think the connection method. Each pair of flanges needs ten sets of fasteners. Between 1 and 2 million individual operations are needed to position and tighten all these fasteners. Innovation would pay dividends here particularly in terms of assembly time.

Couplers – Continuous evolution of RF coupler design has been a long-running part of the TESLA project and this continues into the XFEL programme. Industry has been closely involved and currently there are three industrialization contracts running with the task of reducing the cost. ACCEL [9] (now a subsidiary of Varian Medical Systems Inc) and e2v Ltd [3] are simplifying the construction by using techniques suitable for medium volume production and fewer parts. The use of optimised process parameters, tight process control and precision jigging will increase yield and minimise rework. For example, both companies are evaluating advanced TIG welding equipment in the search for an effective, clean and low cost joining method. Figure 6 shows images of weld samples from each company.

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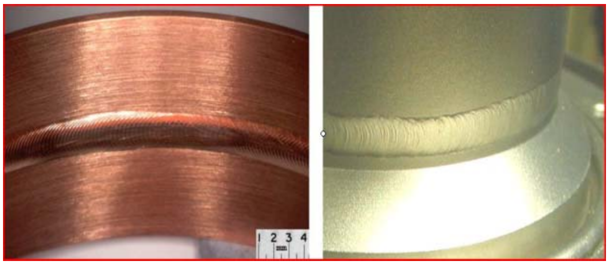

Figure 6: Examples of TIG welding on coupler components. Left: e2v Ltd [3] and right: ACCEL Instruments GmbH [9].

ENGAGEMENT OF EUROPEAN INDUSTRY

The development of several European laboratories, in particular CERN and DESY, as sites for major accelerator construction has resulted in groups of European companies having learnt how to work together to deliver and install the hardware. This legacy remains as a major strength and several European contractors are able and willing to take the role of prime contractor supported by others who play roles as secondary suppliers. Although these teams are reformed on infrequent occasions, their ability to do so at short notice is of considerable benefit to complex projects. The construction of XFEL will see this in action once more over the next year or so.

It is clear from the foregoing that Europe has an industrial resource that can provide the whole range of RF components and complete RF systems as may be required for the ILC. In addition, several major companies that are accustomed to taking on the task of prime contractor could fully support the tasks of their integration, installation and commissioning.

The challenge is to convince industry that the ILC represents a worthwhile business opportunity. A clear message that emerged from the XFEL Industry Workshop in May 2007 was that companies need and want to be involved at the earliest stages of design when there is ample opportunity for them to inject their own ingenuity and manufacturing expertise. It is here where cost can be avoided at the outset. Going through an "industrialization" process is itself costly and may be avoided altogether if the design is developed in close collaboration with industry.

It is now accepted in Europe that although the design, prototyping and type approval may be done there, much of the actual manufacture may well be carried out in lower cost economies. Companies are developing close collaborations with suppliers in these countries so that strict standards and quality control is ensured. Working with a European supplier therefore does not necessarily imply traditional European prices.

However, the key to industrial engagement is for a company's commercial risks in preparing for (i.e. supporting) ILC to be shared equitably (and affordably) between the company and the ILC project. Ideally, this needs visibility and stability in both timescales and target specifications and, most importantly, it needs money.

CONCLUSIONS

European industry has a long history of engagement in accelerator construction largely due to the many projects that have been completed in this region over the last half century. This remains the situation today and with the formal approval of XFEL earlier this month a major opportunity for the field testing of many technologies that lie at the heart of the ILC has arisen. The TESLA project provided the opportunity for European companies to acquire the competencies needed to produce many critical items required by XFEL. This was facilitated by placing development contracts with industry enabling them to work with the TESLA team. ILC is, for the moment, recognisable as an extension of TESLA/XFEL technology and so the European RF equipment industry can be expected to be very active in its support as the design develops. But it is vital that the ILC project management office/GDE engages industry early on as part of the wider team so that industrial design and manufacturing expertise can be incorporated. To play its part to the full, not only does industry need the exchange of knowledge to be maintained, but it also needs access to suitable funding commensurate with its task. If this can be assured, European industry will be eager to support the ILC team over the coming years.

REFERENCES

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