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5.20 REPORT: SURVEY OF AVAILABLE COMPONENTS FOR CW RF TRANSMITTER FOR THE XFEL [1]

5.21 REPORT: ARCHITECTURE OF PREFERRED DESIGN

EUROFEL – DS5

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INTRODUCTION

These Reports are prepared in framework of the EUROFEL Design Study 5 (DS5). In the first stage of this study generic parameters for continuous wave (cw) or near-cw operation of a superconducting acceleration unit, were defined and reported in May 2005 (deliverable D19) [1]. The unit has been proposed as the "building block" of a superconducting linac driving a coherent light source. It consists of the TTF-type cryomodule, Inductive Output Tube (IOT) with a driving amplifier, a power supply and an RF-distribution system. In these reports we will overview IOTs available on the market at present and estimate costs of a preferred architecture of the RF distribution system.

ACCELERATING UNIT

The accelerating unit is shown schematically in Figure 1. It consists of: eight TESLA type cavities housed in one cryomodule, 120 kW IOT amplifier with power supply, a 760 W driving amplifier and the RF-power distribution system. The 120 kW IOT is not offered by vendors at present. Its technical feasibility will be examined in frame of the Industrial Studies which will be conducted in 2006 and 2007. Accordingly to the vendors' experience the cost of a 120 kW tube will be lower than cost of two 60 kW or four 30 kW tubes. The potential cost reduction is the motivation to conduct the Industrial Studies. On the other hand, the phase and amplitude stabilization is technically easier and higher final energy can be reached when a shorter chain of cavities (or single cavity only) is supplied by a single RF source. The optimal chain length should be investigated for each application individually and may change with progress in the phase-amplitude control systems development.

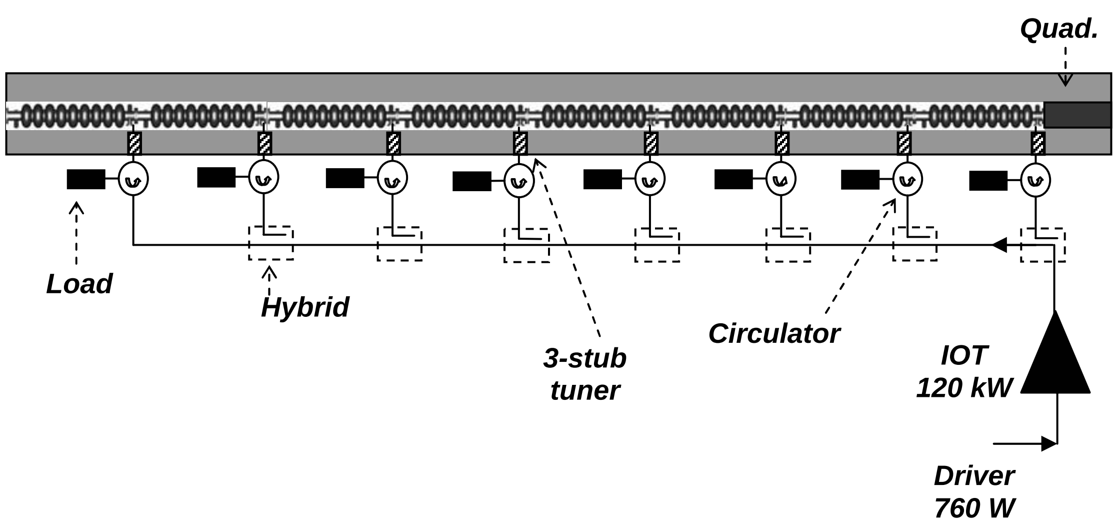

Figure 1. Accelerating unit consisting of: eight 9-cell cavities, 120 kW IOT, a driving amplifier and the power distribution system (eight circulators, eight loads, eight 3-stub tuners, seven directional couplers, waveguides, H-bends and E-bands).

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RF-SOURCE (REPORT 5.20)

INDUCTIVE OUTPUT TUBES

Inductive Output Tubes (IOTs) are very compact and robust microwave power amplifiers used commonly in terrestrial TV broadcast industry. Their potential application to cw or near-cw operating accelerators is the motivation for R&D programs at companies CPI, Thales and e2v which have many years of experience with the tubes for telecommunication. We will concentrate on performance of 1.3 GHz tubes only because those are applicable for 1.3 GHz TESLA cavities. At present the highest output power IOT is offered by CPI Company. The tube generates 30 kW power in cw mode and recently has been tested successfully in pulse mode up to 85 kW [2]. Its parameters for cw operation are shown in the second column of Table 1. The second vendor, Thales, offers tubes generating 15 kW power (third column in Table 1). The e2v announced R&D program towards 1.3 GHz tube in 2003 but progress has not been reported yet event in recently distributed catalogue of the e2v products.

Table 1 Parameters of cw operating 1.3 GHz IOTs.

	CPI	Thales TH713	e2v
P_{out} [kW]	30 (85 pulse)	15	Development in frame of Faraday Partnership, UK. Tube should be tested in April 2004?
Gain [dB]	21	21	
η [%]	> 60	> 60	

Figure 2. 30 kW cw IOT of CPI *(Courtesy Y. Li CPI/Eimac).*

The CPI Company has offered to examine technical feasibility of a cw operating 1.3 GHz tube providing output power of 60 and 120 kW. The very preliminary modeling shows no fundamental technical difficulty to build such a tube [3]. The computed tube parameters are listed in Table 2. For the computed efficiency and the gain of 22 dB the tube will require a 165 kW power supply and a 760 W driving input amplifier.

Table 2. Preliminary parameters of 120 kW IOT.

Parameter	Unit	P_{out}= 120 kW
Voltage	[kV]	46
Current	[A]	3.7
Gain	[dB]	22
Efficiency	[%]	72.8

POWER SUPPLY AND DRIVING AMPLIFIER

There are many companies worldwide offering power supplies for IOTs. Some of them are listed below:

1. IDX CORPORATION , Japan
2. ACRODYNE INDUSTRIES, INC., USA
3. CONTINENTAL ELECTRONICS CORPORATION, USA
4. ETM ELECTROMATIC INC., USA
5. CPI/BMD, USA
6. FuG, Germany.

A very rough cost estimate of a power supply is 0.8$ per 1W of the output DC power. Taking into account calculated efficiency of 120 kW tube the cost of power supply will be about 130 k€.

A driving amplifier for 120 kW IOT should deliver about 800 W input RF-power. Also here there are many vendors worldwide, but in contrary to the power supply market investigation showed that prices vary very strongly, from 47 k€ to 330 k€ for a comparable performing device [4].

The list of six companies offering driving amplifiers at 1300 MHz is given below:

1. Microwave Amplifier Ltd. , UK
2. R.F.P.A., France
3. AR Amplifier Research, USA
4. Bonn Elektronik, Germany
5. SSB Elektronik, Germany.
6. CPI, USA

ARCHITECTURE OF POWER DISTRIBUTION SYSTEM (REPORT 5.21)

The RF-power distribution system shown schematically in Fig.1 is similar to the system used for cryomodules in the TTF-2 linac at DESY [5] (Fig.3). Almost all components of the TTF-2 system, but circulator loads, are capable to carry RF power needed to drive the accelerating unit in the voltage range from 50 to 225 MV with the beam current range between 1.86 mA to 0.41 mA, as it has been proposed in [1]. The installed in TTF-2 circulator loads are specified for 4 kW of average power. They still can be used for the cw operation of the accelerating unit if a fast electronic protection circuit will be applied to switch off RF source in case of the beam loss. A safer solution requires 15 kW loads. Because the maximum power level for cw operation is much lower than for the TTF-2 pulse mode one can operate RF-system without filling it with the SF_6 gas, what simplifies design and reduces the costs. Prices of all components of the RF system and its total price are listed in Table 3.

Table 3. Components and estimated costs for 120 kW power RF distribution system.

Components	**Price / €**	**# per cryomodule**	**∑ Price / k€**
Straight waveguides:			
880 mm	323	7	2.26
200 mm	180	1	0.18
Flexible waveguides:			
300 mm	723	8	5.78
E bend	277	16	4.43
H bend	288	10	2.88
3-stub tuner	1000	8	8.00
Circulator with load (17 kW cw)	6000	8	48.00
Hybrid	1333	7	9.33
Load (20kW cw) estimated	1500	7	10.50
Directional coupler	700	1	0.70
Sum for one accelerating unit			**92.1**

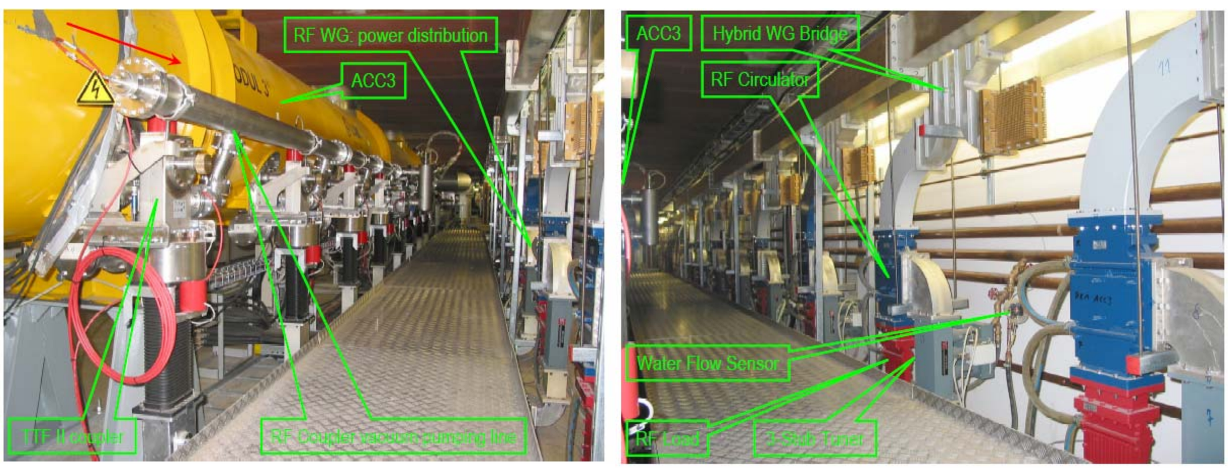

Figure 3. Photographs illustrate RF-power distribution system operating in the TTF-2 linac at DESY. The system has been designed to distribute 10 MW peak power over 32 cavities.

FINAL REMARKS

The Industrial Studies will show technical feasibility of the 120 kW IOT. In case of technical difficulties one may use 60 kW or even 30 kW tubes. This will change architecture and increase the cost of the RF distribution system. The driving amplifiers and power supplies are expensive but it is expected that ordering of a bigger quantity of these devices will reduce their price.

REFERENCES

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