FIRST EXPERIENCE AT ELBE WITH THE NEW 1.3 GHz CWRF-POWER SYSTEM EQUIPPED WITH 10 kW SOLID STATE AMPLIFIERS (SSPA)

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Abstract

With the expansion of the radiation source ELBE, a centre for high power radiation sources is being built until 2014 at the Helmholtz Zentrum Dresden Rossendorf. One part of this program is to double the electron beam current of the ELBE LINAC. In January 2012 each of the 10 kW CW klystrons, used to operate the superconducting cavities of ELBE since 2001, had been replaced by a pair of 10 kW solid state amplifiers. The paper gives an overview on the activities around this project and the first experience with the new RF system.

THE NEW CENTER OF HIGH POWER RADIATION SOURCES

Between 2009 and 2014 the Radiation Source ELBE is under reconstruction to become a Centre of High Power Radiation Sources. ELBE is in routine operation since 2001 and provides electromagnetic radiation, infrared light, bremsstrahlung, neutrons and positrons. New applications are terahertz radiation, CBS X-rays, electron wake field acceleration and ion wake field acceleration. Fig.1 illustrates the new layout.

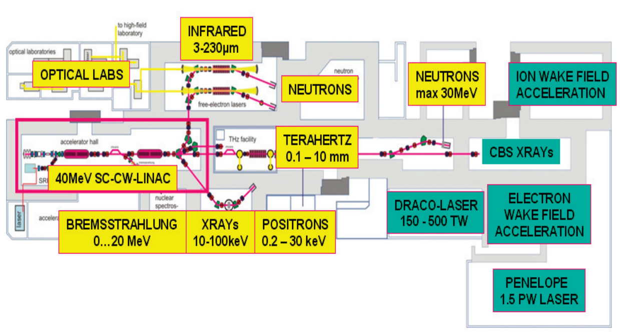

Figure1: Layout of the enlarged ELBE facility.

ELBE RF UPGRADE

The intension of the RF-upgrade is to double the accelerated electron current. The ELBE CW-LINAC, equipped with four superconducting TESLA cavities was designed to accelerate an electron current of 850 µA CW, at a favourite repetition rate of 13 MHz because of the resonance frequency of the two free electron lasers. The maximum bunch charge is 77 pC. The typical energy gain per cavity is 10 MV/m the overall energy gain of the LINAC is 40 MeV. The limit is set due to the capacity of the helium liquefier and due to the radiation safety design of the building. The RF-system is a modular design, e.g. each cavity was driven by a 10 kW CW klystron VKL7811St (CPI) [1]. On the way to double the RF-power per cavity different activities during the past four years were targeted to check system components, like couplers and waveguide windows [2]. The early idea to substitute the 10 kW CW klystron by a 16 kW or a 30 kW IOT was cancelled because of the rapid development of competitive solid state amplifiers by BRUKER BioSpin [3].

THE FIRST 8.5 KW SSPA - PROTOTYPE

The prototype amplifier is built in a 19” (42units) rack, size 600 x 1000 x 2200 mm^3. In the block diagram are shown eight water-cooled chassis, each equipped with eight LDMOS transistors (PTF141501E) delivering 8.5 kW of RF power per rack (Fig.2). Each LDMOS transistor is protected with an individual drop-in circulator.

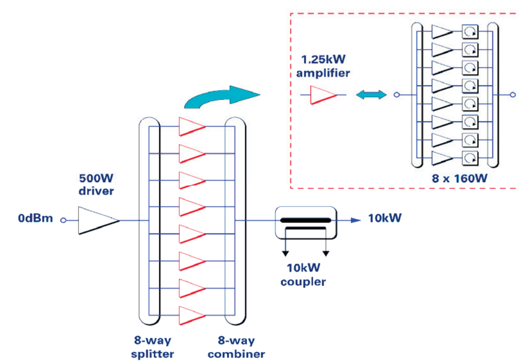

Figure 2: Block diagram of the 8.5 kW SSPA module.

The WR650 wave guide output is on top of the rack, as well as all RF and control inputs. The water connection (1 ½-inch, 6 Bar, 35 l/min) and the 400 V mains connection (56 A 3-phases) are on the backside (bottom). In the middle of the front side is the chassis with the driver and the controller. The amplifier can be controlled remotely by SPS 24V pulsed signals or locally by a touch screen. Bruker provides service and remote diagnosis via Internet using allocated IP addresses.

TEST OF THE PROTOTYPE

The transfer function of the 8.5 kW prototype SSPA is shown in Fig.3. The 1 dB compression point is at 8.5 kW; 2 dB at 9.1 kW. The bandwidth of the SSPA is given in Fig.4. The 3-dB bandwidth of the VKL7811St klystron used before was 4 MHz. The gain and phase variation over the dynamic range of the prototype is shown in Fig.5. It is seen that when overdriving the SSPA above the 1 dB compression point (ref. Fig.5, above the input level of -5 dBm) the phase changes drastically.

ISBN 978-3-95450-115-1

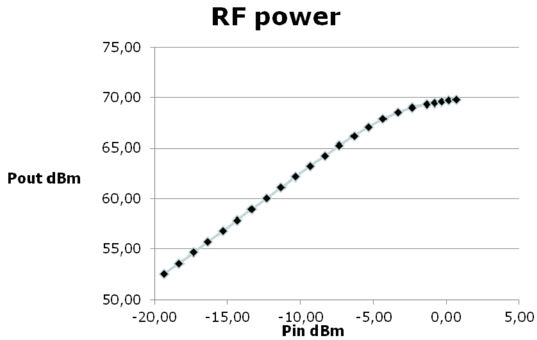

Figure 3: Transfer function of the prototype SSPA.

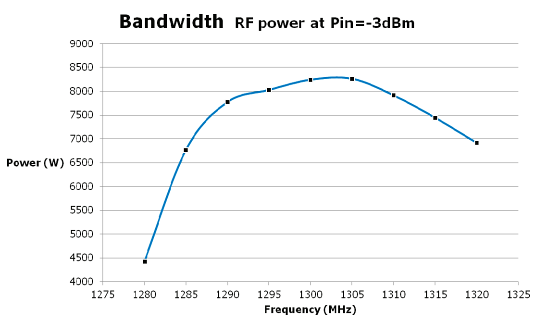

Figure 4: Bandwidth curve of the SSPA.

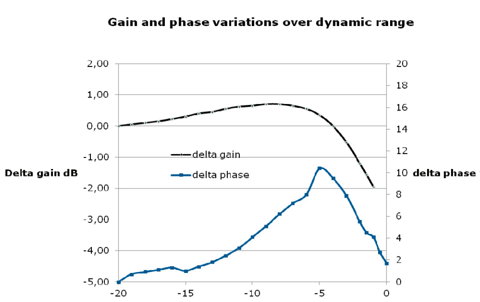

Figure 5: Gain and Phase characteristic of the prototype.

Figure 6 shows the rise- and fall time of the output RF-signal when pulsed measured at 8 kW output power.

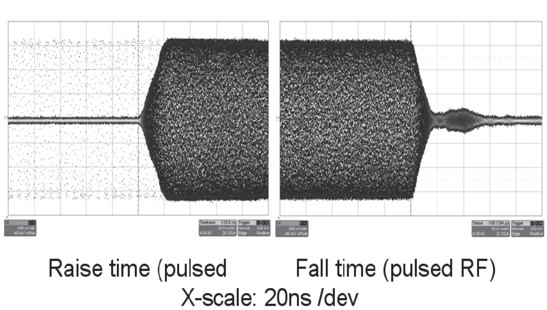

Figure 6: Behaviour of the pulsed SSPA.

SSPA amplifiers show a significant dependence between output power and the temperature of the coolant (Fig.7).

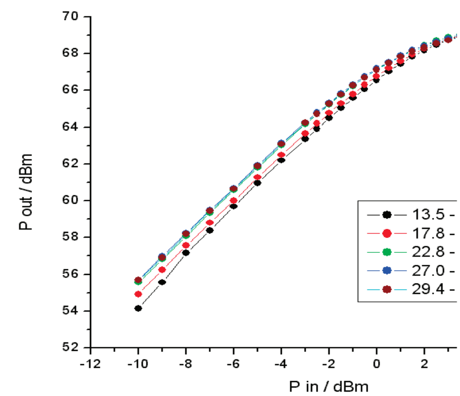

Figure 7: Transfer curve versus temperature of the coolant (Temperature: T=13.5 C to T=29.4 C).

During the ELBE shutdown in Jan. 2010 the prototype of the SSPA was implemented into the ELBE klystron gallery to run long time tests with beam under regular operation conditions. Whilst the cavity driven by the SSPA was properly tuned, the operation was smooth and stable. When we started the superconducting LINAC after a warm-up period and the cavities were completely detuned, we observed excitations at the cavity pickup signal (Fig. 8).

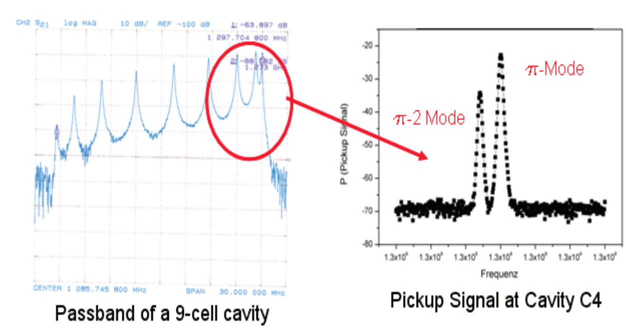

Figure 8: Excitation of the unwanted mode Pi-2 when cavity detuned.

These excitations could be reproducible generated by detuning the cavity. The reason for the observed effect is the ten- times higher bandwidth of the SSPA in ref. to the klystrons used before. The gain and phase settings of the lowlevel controller were matched to the klystron used before. Due to the smaller bandwidth (only 4 MHz) of the klystron the filter characteristic of the controller could be realized using simple active low pass filters with operational amplifiers. The dilemma was solved by a redesign of the lowlevel RF-controller (Fig.9). The characteristic of the new introduced low pass filters with carefully tuned notches is given in Fig.10.

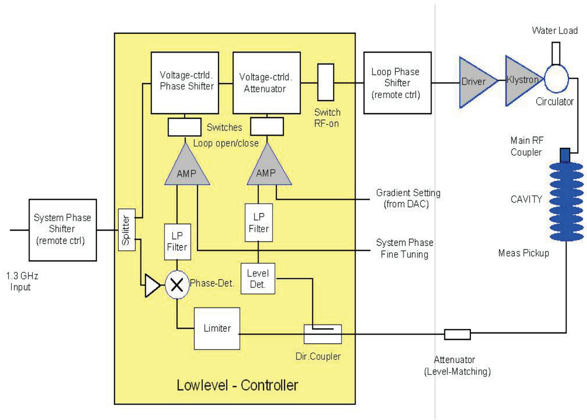

Figure 9: Direct converting (1.3GHz to DC) ELBE low level RF-controller with low-pass filters (LP-Filter) used in the amplitude and phase loop of the LLRF controller.

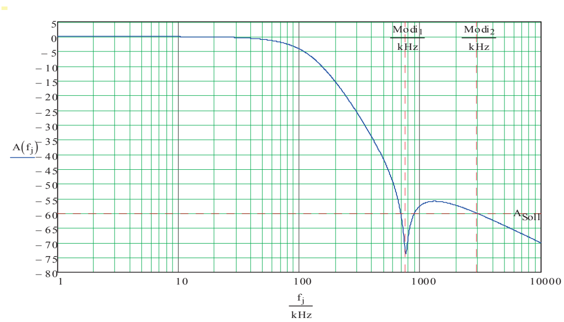

Figure 10: Transfer function of the redesigned low pass filters.

The prototype was in permanent operation at a superconducting ELBE- cavity for more than one year without any failures. After that we ordered a second one to operate the SRF Gun and to test the operation of two SSPA in parallel. The test of a 2 x 8.5 kW block with beam was done before the winter shutdown in 2010. In spring 2011 we ordered eight improved SSPA, each equipped with nine transistor banks to provide 10 kW of RF at 1 dB compression and a modified control to implement the units into the ELBE PLC control system (SIMATIC S7).The delivery was in time in December 2011. During the winter shutdown in January 2012 the four klystrons were substituted by a pair of 10 kW SSPA. The enlarged cooling system for 10 SSPA (four cavities and the SRF GUN) had been installed in 2011.

THE 20 KW RF POWER BLOCKS AT ELBE

The new ELBE RF-cabinet is shown in Fig. 11. Two of 10 kW SSPA are switched in parallel using 90-deg 3dB couplers (Fig.12). Since February 2012 ELBE is in permanent operation with eight SSPA driving four cavities of ELBE. Two SSPA of the 8.5 kW SSPA are used for the SRF Gun. The ELBE operation is much smoother than with klystrons used before.

Figure 11: The new SSPA Cabinet at ELBE.

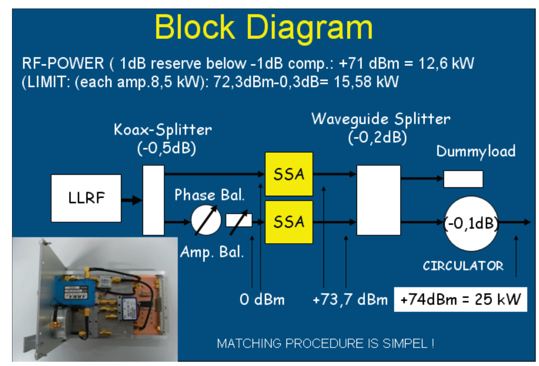

Figure 12: Block diagram of the 20 kW SSPA Block.

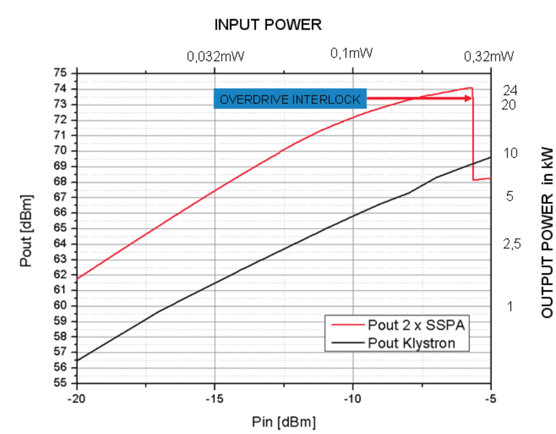

Figure 13: Gain characteristic of the 20 kW SSPA block compared to the klystron used before.

REFERENCES

[1] H.Büttig et.al., Proceedings 5th CWRF Workshop 2008, CERN, Geneva.

[2] H.Büttig et.al., 6th CWRF Workshop 2010, Barcelona.

[3] H.Büttig. et.al., Proc.7th CWRF Workshop 2012, Port Jefferson, NY.

ISBN 978-3-95450-115-1