16 kW UPGRADE OF THE 1.3 GHz ELBE RF-SYSTEM WITH SOLID STATE AMPLIFIERS

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Abstract

The superconducting CW- LINAC (1.3 GHz) of the radiation source ELBE is in permanent operation since May 2001 [1]. In 2011 an upgrade program of ELBE is in progress to support additional applications. One part of the program is to double the RF-power per cavity to at least 16 kW. Since we started ELBE in May 2001 substantial progress was made in all fields contributing accelerator science. As far as RF-amplifier technology is concerned IOT-based and Solid State Amplifiers compete with klystrons. To prepare for the power upgrade of ELBE we developed a couple of activities, like:

-Test of the ELBE RF-couplers and waveguide windows

-Test of an available 30 kW IOT amplifier with beam

-Test of a 10 kW solid state amplifier (SSPA) with beam

-Test of two 10 kW SSPA with beam

-Redesign of the Low level RF controller

-Redesign of the technical water cooling

TEST OF THE RF COUPLERS AND WG-WINDOWS

A new coupler test bench based on a resonant ring has been built at ELBE in Dresden-Rossendorf to run window as well as coupler tests with RF power up to 100 kW.

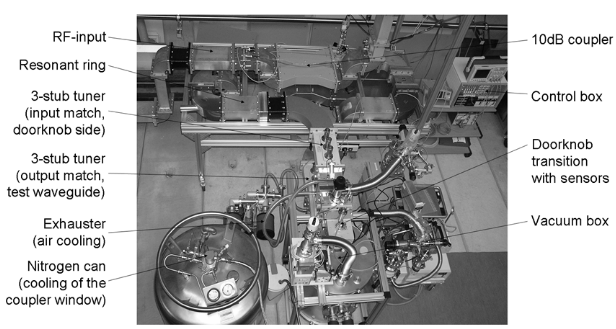

Figure 1: Layout of the resonant ring

The ring is driven by a 10 kW klystron. This test bench includes also liquid nitrogen cooling of the ceramic cold window of the RF-coupler which allows testing under almost real conditions. A special waveguide was designed to match couplers with different antenna tips. In a first step the waveguide window has been equipped with additional air-cooling.

The design of the test bench and the gained experience with warm window tests at the resonant ring as far as it could be collected within a short time of operation were reported in [2].

Summary: The experiments with the resonant ring confirmed that the ELBE RF-couplers as well as the "Rexolite"-waveguide windows could be used in a future 16 kW RF-system.

TEST OF AN IOT POWER AMPLIFIER AT ELBE

The "idea" came from the senior scientist Heinz Bohlen (CPI), well known in the "RF-power community", when he asked for a possibility to test a new IOT transmitter with one of our superconducting cavities with beam. The prototype was developed in close collaboration between BRUKER BIOSPIN and CPI. We were glad about the proposal because we were searching for a bigger RF-power source to replace the 10 kW VKL7811St klystrons.

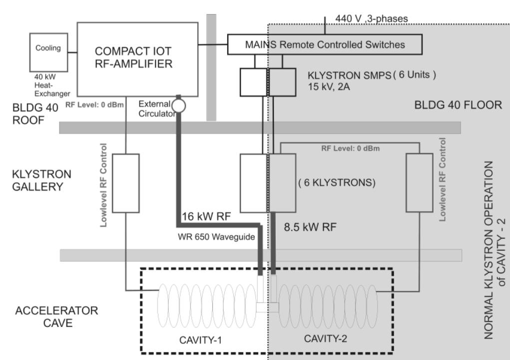

Figure 2: Block diagram of the IOT operation

Figure 3: 30 kW IOT based transmitter

The setup was several weeks in routine operation at ELBE without mentionable difficulties. Especially the (in our experience sensible) operation of the Infrared Free Electron Lasers was comparable with the klystron routine operation [3].

In the RF power range below 30 kW klystrons like the 10 kW VKL7811St (CPI) and compatibles take advantage of permanent magnet focusing systems, they are very compact and require very low drive power because of their high gain. Unlike to a 10 kW klystron a comparable IOT need additional power sources on HV-level and 16…20 dB more drive power. In the power range above 20….30 kW IOT-based RF amplifiers could be a good choice because of their higher efficiency and lower costs of an complete system

Summary: The IOT-based amplifier behaved well at ELBE but was not our first choice because of the reasons mentioned above.

TEST OF THE 1.3 GHZ 10 KW CW SOLID STATE POWER AMPLIFIER (SSPA)

During the experiments with the IOT transmitter the idea was born to test a solid state amplifier at a superconducting cavity. The IOT transmitter was equipped with very compact solid state drivers from BRUKER. We asked for a possibility to build a setup with at least 4 kW to test it at ELBE. BRUKER developed within only 9 months a complete 10 kW CW transmitter build in a standard 19-inch rack (fig.4, block diagram fig.5)[4].

Extensive tests demonstrated the good performance of this 1.3 GHz 10 kW CW transmitter (figures 6 to 10). The prototype is in permanent operation at ELBE since summer 2010, a second one since March 2011, both without any failures so far. The following curves demonstrate the performance.

Figure 4: 10 kW SSPA (BRUKER)
Two SSPA at ELBE, left rack: 10kW klystron amplifier

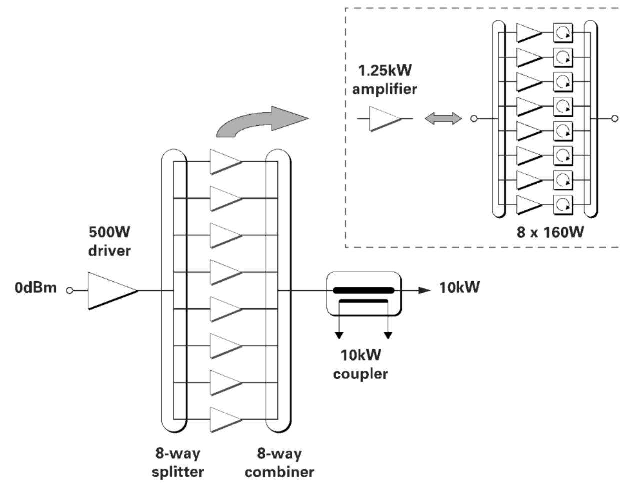

Figure 5: Block diagram of the RF-part

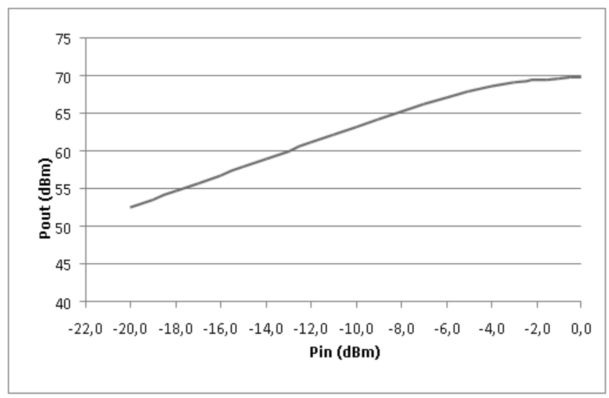

Figure 6: Gain response of the SSPA

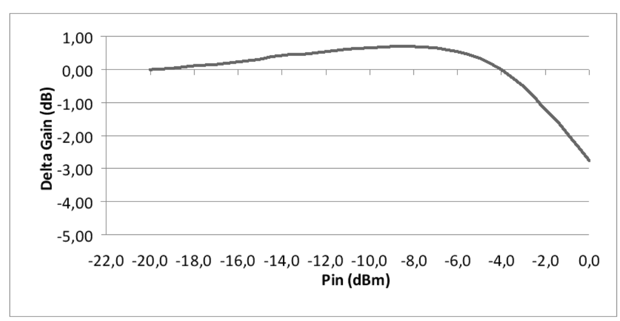

Figure 7: Gain deviation of the SSPA

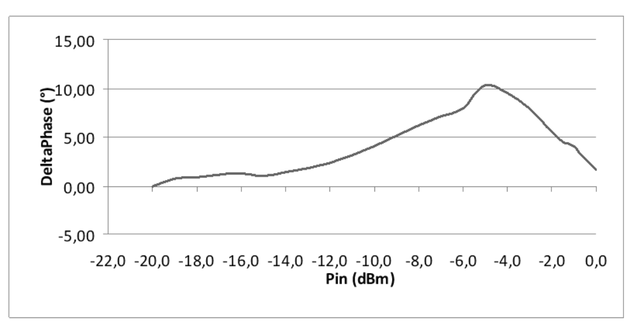

Figure 8: Phase deviation of the SSPA

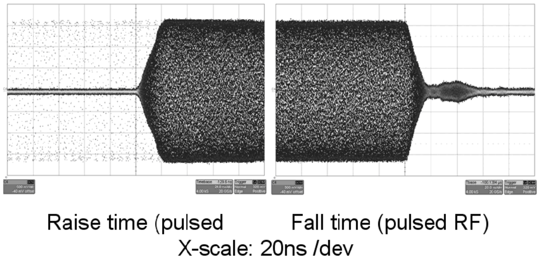

Figure 9: Raise time (using pulsed operation) (rise time 20ns, fall time 60ns resp.)

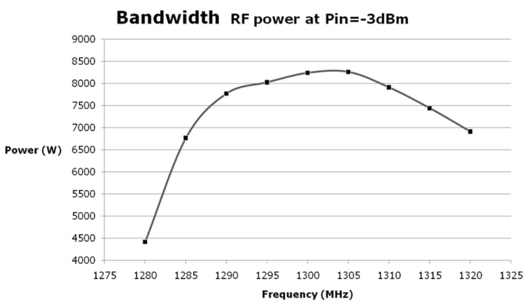

Figure 10: Bandwidth of the SSPA

OPERATION OF TWO 10 KW SSPA IN PARALLEL

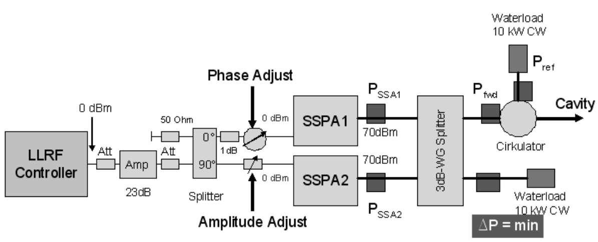

Figure 11: Setup to operate two SSPA in parallel

The coupling was made using 90-deg hybrids, amplitude and phase had to be matched carefully at about 2/3 of the output power (+/-20%) depending on the s21-characteristics of both amplifiers (Fig.12). Matching criterion is minimum differential RF-power at the insulation port of the 3dB waveguide coupler (Fig.14). Typical curves characterizing the setup are presented in figures 12 to 15:

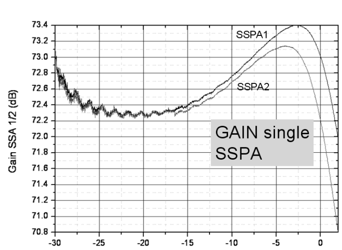

Figure 12: Individual gain curves of both SSPA

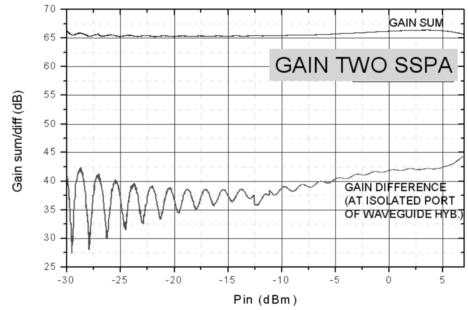

Figure 14: Combined gain response

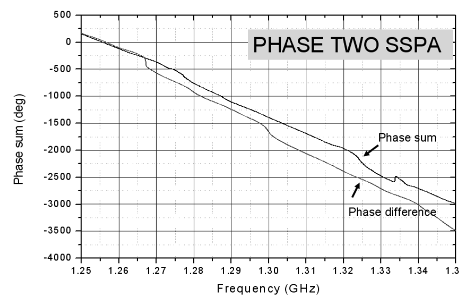

Figure 15: Combined phase response

OUTLOOK

It is planned to install five 20 kW RF-amplifier blocks during the winter shutdown 2011 / 2012 at ELBE.

ACKNOWLEDGEMENT

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[2] H.Büttig et.al.: Study of the ELBE RF-couplers with a new 1.3 GHz RF- coupler test bench driven by a resonant ring , NIM-A A 612(2010), 427-437

[3] H.Büttig et.al.: First Test of a Turnkey 1.3 Ghz 30 kW IOT - Based Power Amplifier at ELBE , 24. Linear Acc. Conference, 2008, Victoria, Canada

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