PULSED RF SYSTEM FOR THE ELBE SUPERCONDUCTING ACCELERATOR

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Abstract

The RF system for the ELBE accelerator was originally designed for CW mode. Although this works problem-free tests have shown that it is possible to reach higher gradients in the TESLA cavities with a pulsed RF system. The new RF system is presented together with measurements of the achievable gradients. Roughly 30% higher gradients could now be used in pulsed mode. As positive side effects the radiation by field emission is reduced by the duty cycle and an easy in situ RF conditioning of cavities and coupler windows is possible .

RF SYSTEM AT ELBE

From the beginning the ELBE superconducting accelerator was designed as a CW machine [1]. This works problem-free. In practice the machine is operated both in CW beam mode and in macropulse beam mode. The RF system was always operated in CW mode.

At ELBE the TESLA-cavities are used. They have been tested with much higher gradients than 15 MV/m at the vertical test stand at DESY. From the operational experience at ELBE it is difficult to use them in CW mode with much higher gradients than 10 MV/m. Initial tests with a pulsed RF have shown that it is possible to reach higher gradients in this mode.

To increase the versatility of ELBE the RF system was modified to operate not only in CW mode but in pulsed mode too. The RF system at ELBE uses analogue amplitude and phase control [2].

MODIFICATIONS

With a pulsed mode RF system an easy in situ conditioning of cavities and coupler windows is possible. So the system was designed for 4 operating modes:

- CW mode
- pulsed mode

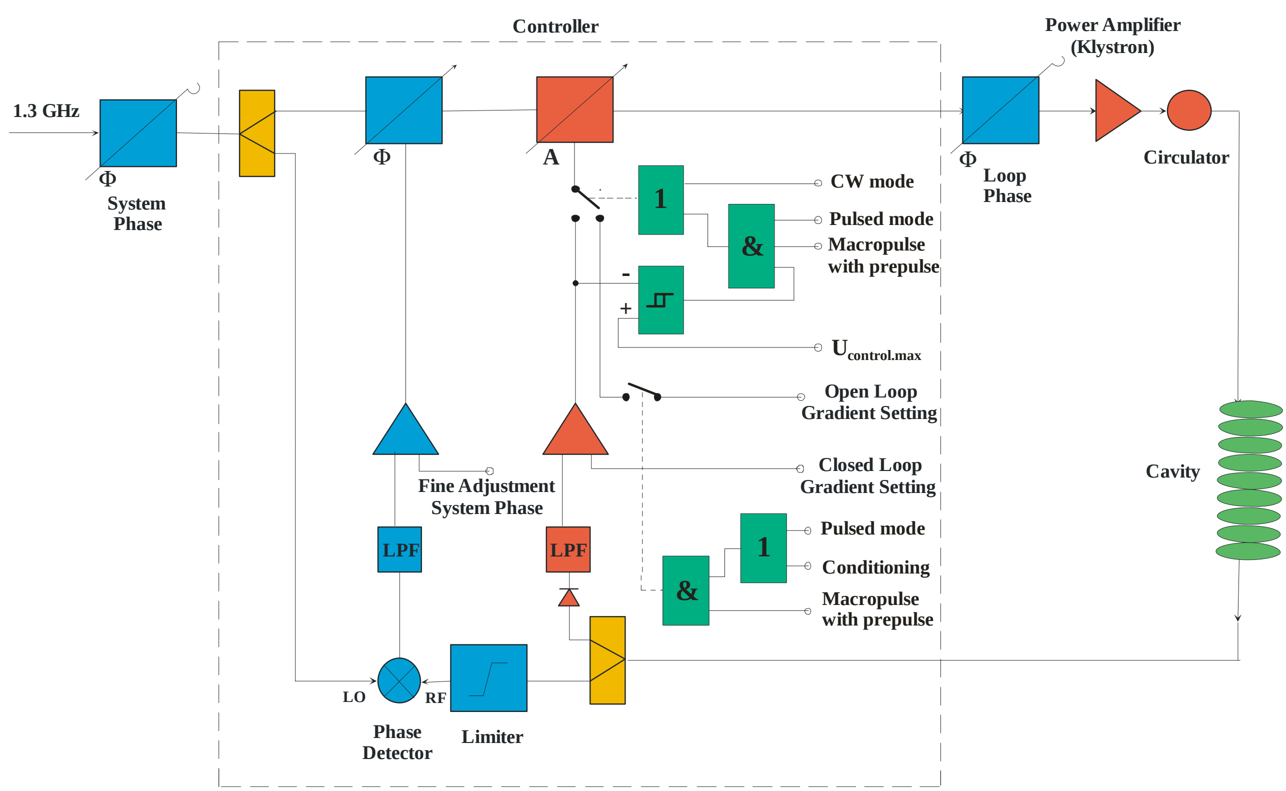

Figure 1: Block diagram of the modified RF system.

- conditioning mode
- manual test mode.

For simplification the manual test mode will be omitted in the following.

To use this modes the RF system, the macropulser and the control system software were changed.

Principle of Operation for Pulsed Mode

The block diagram of the modified RF system is shown in Figure 1. The added parts in the controller are shown in green colour.

It is necessary to switch the RF on before the beam is switched on. The macropulser has to deliver an extra pulse which starts before the beam macropulse to give the RF system enough time to settle. With the beginning of this pulse a fixed amount of RF power (determined by the open loop gradient setting) is sent to the cavity and the system works open loop. When the gradient in the cavity gets near his final value (determined by the closed loop gradient setting) the control voltage in the amplitude loop comes into the working range of the loop. This is detected by a trigger which closes the loop. At the end of the macropulse the RF is turned off again.

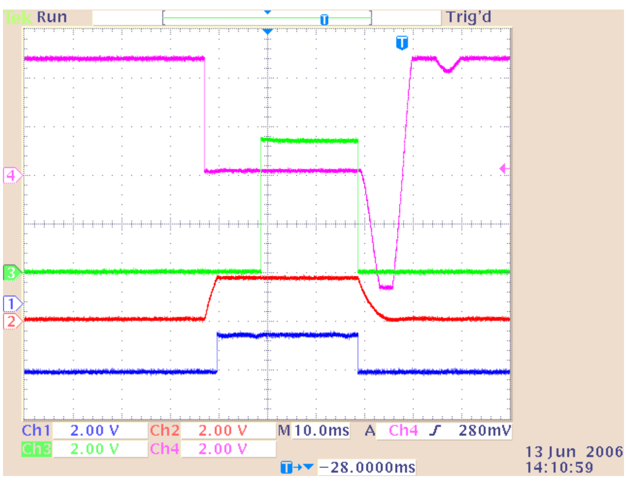

Figure 2: Signals in the control loop:
Blue: amplitude control signal
Red: measured gradient
Green: beam macropulse
Pink: measured phase signal

The design bandwidth for the ELBE system is 114 Hz so a settling time of roughly 15 ms is needed to guarantee settling. The maximum klystron power of 10 kW is used till settling. The minimum macropulser period is 40 ms given by the camera synchronisation for the beam diagnostics.

Principle of Operation for Conditioning Mode

In this case the RF system operates all time open loop. For ease the macropulse with prepulse is used for conditioning with roughly 20 ms duration and 280 ms period. After every 2 minutes the RF power is slightly increased by the control system till the maximum value of 10 kW when no interlocks occur. The control system checks for light, vacuum and temperature interlocks at the windows. If an interlock occurs the system continues conditioning after the interlock with the same power until no events are observed for 2 minutes.

In case of windows conditioning the cavity is completely detuned by the control system. So almost no gradient develops in the cavity and the power system works all time with full reflection.

In case of cavity conditioning the operator has to tune the cavity by hand to the maximum gradient. Because of the nonlinearity caused by Lorentz force detuning this gets a delicate task at high gradients.

RESULTS

The modified system is used till now for the third and the fourth cavity of the ELBE accelerator. For the first and the second cavity it will be applied after the next machine shut down.

Although the windows and the couplers were conditioned before they were installed [3] an additional in situ check is useful because it is inevitable to contact them with air during assembling. The windows for the third cavity showed clearly problems which will be solved at the next warm up of the accelerator. Cavity processing was possible till 15 MV/m. This was mainly limited by the klystron power. For this gradient the effect of Lorentz force detuning comes in the range of 2 times the bandwidth. Operation at these gradients requires a very stable helium pressure and tuning becomes more difficult. No attempts were made to change the bandwidth of the system which is possible by the 3-stub tuner.

Till now both cavities were operated in CW with beam at 10 MV/m maximum. In pulsed mode stable accelerator operation was possible with 14 MV/m for both cavities. A beam duty cycle of 2.5% was used. No significant increase of the beam energy spread was observed.

REFERENCES

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