HIGHLY STABLE IOT BASED 1.3 GHz / 16 KW RF POWER SOURCE FOR CW OPERATED SC LINACS

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Abstract

Most proposals of fourth generation light sources are based on CW operated sc linacs used in a FEL or ERL [1], [2], [3], [4], [5]. The requirements for the stability of the RF field in the cavities are better than 0.1 deg phase and better than 0.1% amplitude. The required RF power is strongly amplitude modulated due to the fact, that microphonic effects in the sc cavities play an important role. At the HZB a modular RF transmitter was developed with FuG, that can be used for IOT tubes for different power levels and frequencies. Attention was taken to the stability in the case of AM modulation.

AIM

The RF plant is designed, that the cavity voltage amplitude and phase noise of the transmitter match the requirements of the sc linacs. This stability of the RF power is reached without the need for RF control loops.

Requirements for the RF Power Source

To achieve this aim, the RF power source has to fulfil the following requirements:

- 16 kW CW RF Output Power (minimum).
- RF output power ripple $< 2*10^{-4}$ peak-peak for ripple below 10 kHz and $< 2*10^{-3}$ above 10 kHz.
- RF transmission phase ripple $< 0,1°$ peak-peak for ripple below 10 kHz and $< 1°$ above 10 kHz.

SPECIFICATIONS

Prior to the development of the first 1.3 GHz IOT in 2003 CPI provides us with the estimated data of the sensitivity of the RF output power to changes in IOT operating voltages [Table 1].

With this information the IOT power supplies have been specified [Table 2], [Table 3].

Fig. 1 shows the block diagram of the arrangement of the power supplies.

Table 1: Sensitivity of the RF output power to changes in IOT operating voltages

IOT Supply	RF	Value
Beam voltage	Phase	about $-2*10^{-4}$ rad/V peak-peak
	Amplitude	about $1*10^{-4}$ /V peak-peak
Bias Voltage	Phase	about $95*10^{-4}$ rad/V peak-peak
	Amplitude	about $-320*10^{-4}$ /V peak-peak

Table 2: Specifications of the IOT beam voltage supply

Beam voltage	0.. 31 kV / max. 1,3 A
Voltage ripple	below 10 kHz: < 0,1 ‰ (peak-peak) above 10 kHz: < 1 ‰ (peak-peak) to be followed up to max load changes
Stored energy	< 10 J
Max. ΔU	± 0,5 kV @ current jump < 1,3 A

Table 3: Specifications of the IOT bias voltage supply

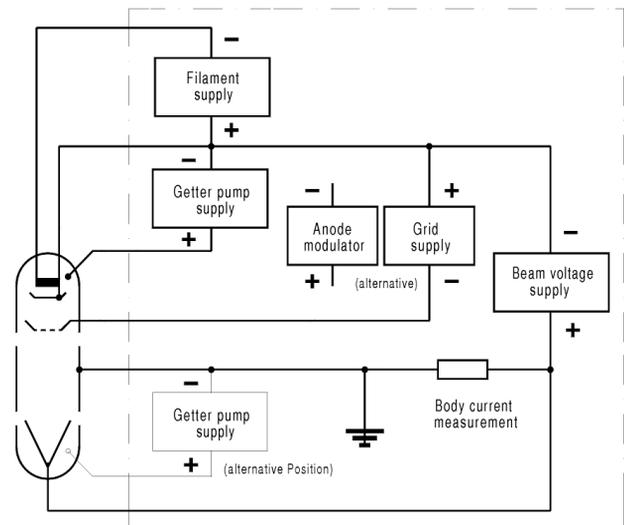| Bias voltage	0.. 150 V / max. ± 300 mA
Voltage ripple	below 10 kHz: < 0,2 ‰ (peak-peak) above 10 kHz: < 2 ‰ (peak-peak) to be followed up to max load changes
Stored energy	< 10 J
Max. ΔU	± 2 V @ current jump < 300 mA

Figure 1: Block diagram of the transmitter

REACHED STABILITIES

Switching power supply design has been chosen for those supplies, which are responsible for the stability of the RF output power.

To check the stability of the power supplies the response to a dynamic load has been measured by changing the load current at a defined slew rate.

Fig. 1 to Fig. 7 shows, that the measured stabilities meet the requirements:

Beam Voltage Supply

This supply has been realized by two driver units, 20 kW each, water cooled and IGBT equipped. Fig. 15 shows one of the driver units.
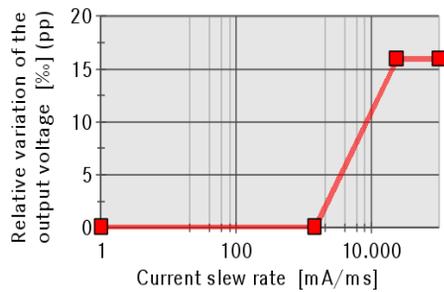

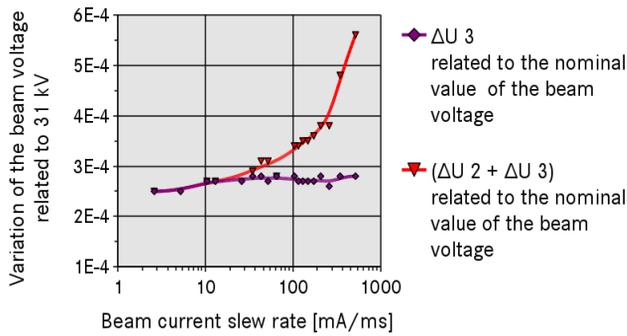Figure 2: Voltage variations due to a dynamic load – specified maximum values for $\Delta I \leq 1,2$ A.

Figure 3: Measured beam voltage response to a dynamic load (Δ I-beam ~ 0.5 A). Values $\Delta U 2$ and $\Delta U 3$ are explained in Fig. 4.
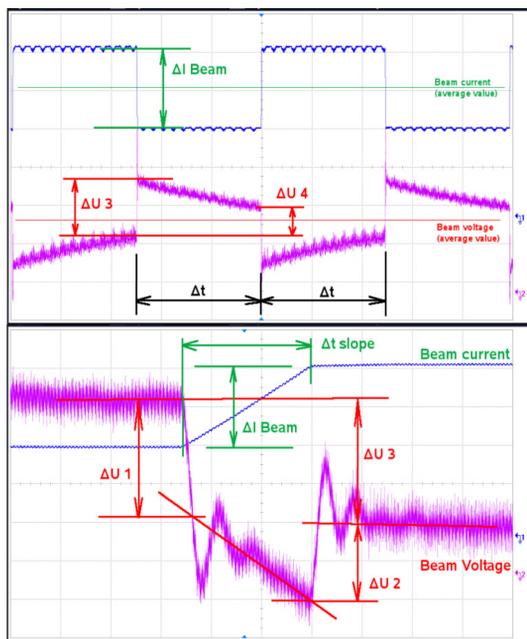

Figure 4: Explanation of the values measured. First figure shows step response of the power supply in 100 ms range. Second figure shows the response of the beam voltage to

the rising slope of the beam current in 0,5 ms range. Blue curve is the beam current, red curve is the beam voltage.

Bias Voltage Supply

This supply is realized in a small plug-in module. Fig. 14 shows how it is housed on the HV deck.
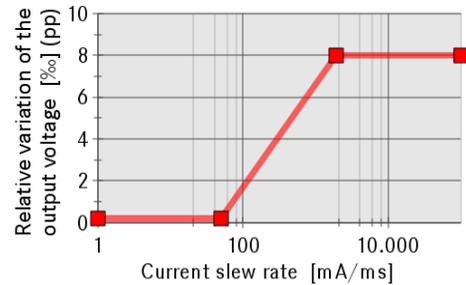

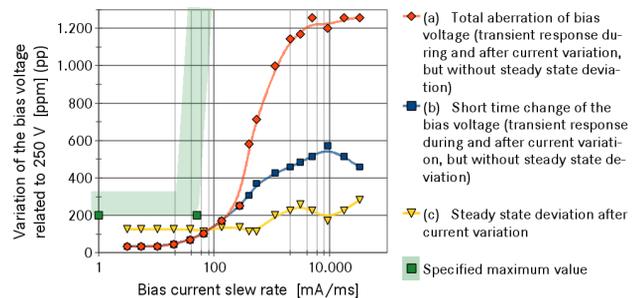Figure 5: Voltage variations due to a dynamic load – specified maximum values for $\Delta I \leq 300$ mA

Figure 6: Measured beam voltage response to a dynamic load (Δ I-beam ~ 300 mA) . Values (a), (b) and (c) are explained in Fig. 7.
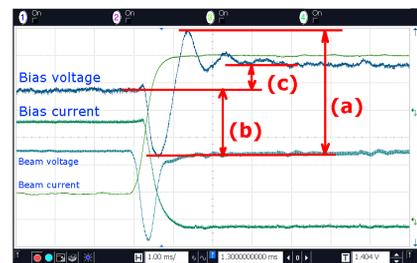

Figure 7: Explanation of the values measured. Shown is the step response of the bias voltage supply in 1 ms range. Value (a) shows the total aberration of the bias voltage as a response of a bias current variation. Value (a) includes the amplitude of the transient oscillation to reach the new steady state value of the bias voltage. Value (b) shows only the portion caused during the current variation. Value (c) shows the steady state deviation after the current variation.

It is essential to avoid ringing of the IOT beam current caused by ringing of the bias voltage at the tube socket in consequence of a bias current step. Fig. 8 and Fig. 9 show that damping the cable between the bias supply and the

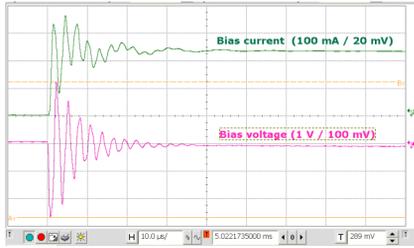tube is essential to avoid instabilities on the IOT beam current:

Figure 8: Step response measured with 10,0 µs/Div at the tube socket without damping the cable.

Figure 9: Cable resonances damped with a 5 Ohm series resistor and additional 1µF foil capacitor integrated into the tube socket. Step response measured with 20,0 µs/Div at the tube socket.

APPLICATIONS

Due to the high stability of the IOT power supplies and the high stability of the preamplifier, effects produced by the behaviour of the electron beam inside the IOT could be observed.

As an example Fig. 10 to Fig. 12 show instabilities in gain and transient phase against focussing current observed on the 1.3 GHz tube IOT116LS (Ser.No:18) manufactured by E2V:
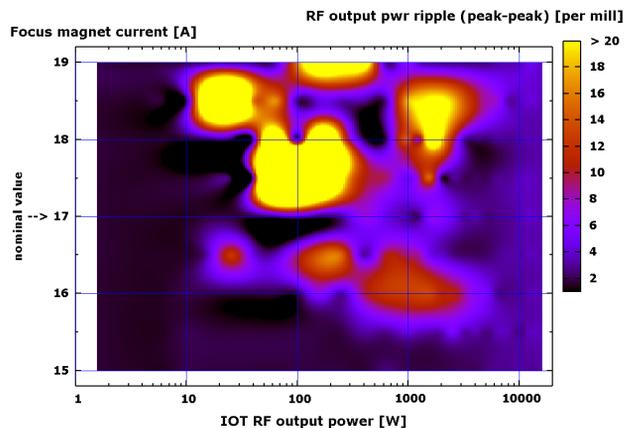

Figure 10: RF gain ripple (observed on the 1.3 GHz tube IOT116LS, Ser.No:18, RF input power without any ripple). The focus current is plotted in linear scale versus the log. scaled output power. There are areas, where the gain ripple exceeds a level of 1%
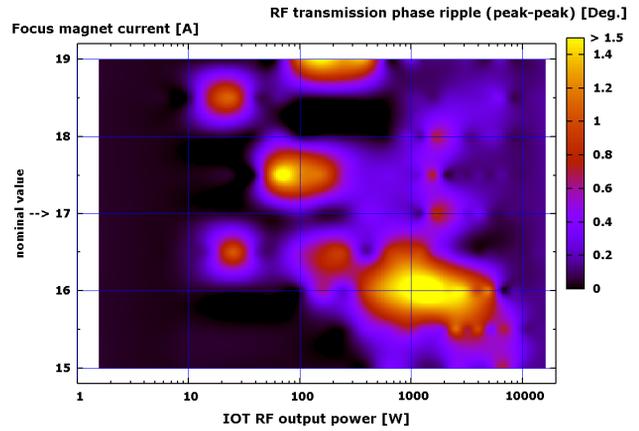

Figure 11: RF transient phase ripple (observed on the 1.3 GHz tube IOT116LS, Ser.No:18). The focus current is plotted in linear scale versus the log. scaled output power. There are areas, where the phase ripple exceeds a level of 1 Degree.

Figure 12: Typical time structure of the observed instability (IOT RF output power near 51 dBm, Focus current: 16,5 A). Green curve is the phase difference between IOT RF input and IOT RF output with 0,5 Deg/Div. Red curve is the AC component of the IOT RF input power with 0,02 dB/Div. Blue curve is the AC component of the IOT RF output power with 0,02 dB/Div. Grey curve is the DC component of the IOT RF output power with 50 dBm/Div.

THE PLANT

The RF plant contains a set of power supplies located in three cabinets also housing the pre-amplifier (Fig. 13 and Fig. 14). The IOT is placed next to the cabinets.

The transmitter is controlled by a SIMATIC S7 PLC. Remote control of the plant is done via EPICS.

Figure 13: Three cabinets containing operating panel, interlock, all power supplies and the mains distribution. On the left the 1,3 GHz CPI IOT CHK5-1320W operating at a dummy load.

Figure 14: Arrangement of the IOT power supplies on the HV deck.

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Figure 15: One of the two 20 kW driver units of the switching power supply of the beam voltage.

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