FIRST TESTS AT INJECTOR FOR THE S-BAND TEST FACILITY AT DESY

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The s-Band Test Facility currently under construction at DESY requires 2µs long macropulses with 8ns, 16ns or 24ns interbunch spacing at an average current of 300mA in each case and a maximum repetition frequency of 50Hz. The injector design is based on a conventional scheme using a pulsed thermionic gun, two subharmonic bunchers (125MHz and 500MHz) and two travelling wave bunchers (β=0.6 and β=0.95). Together with a high power gunpulser and adequate triggering, the gun is expected to generate a 2µs long train of pulses with less than 2.5ns FWHM-pulsewidth and a peak current of up to 6A. The first 50cm of the injector beamline equipped with a wall current monitor, a button type position monitor and a faraday-cup at the end were built up in order to commission the gun and its pulser. First results of the gun and pulser operation are presented here and compared with calculated performance.

I. INTRODUCTION

The s-Band Test Facility at DESY will be constructed in order to study the feasibility of a large s-Band Linear Collider project. The Test Facility consists of an injector followed by 4 (β=1, 17MV/m) accelerating structures of 6m length each, intersected by quadrupole tripletts. Before being dumped the beam passes through a spectrometer arm and other diagnostics to analyze the beam quality.

Based on a 50Hz repetition rate the testlinac requires 2µs long bunchtrains with the possibility of switching between 3 different modes of time structure, while keeping the average current within the bunchtrain constant at 300mA, i.e.:

1. 250 bunches with 8ns bunch to bunch spacing and 2.4nC/bunch ⇔ $1.5 \cdot 10^{10}$ e^-/bunch
2. 125 bunches with 16ns bunch to bunch spacing and 4.8nC/bunch ⇔ $3.0 \cdot 10^{10}$ e^-/bunch
3. 83 bunches with 24ns bunch to bunch spacing and 7.2nC/bunch ⇔ $4.5 \cdot 10^{10}$ e^-/bunch

The injector which should deliver these bunchtrains was designed on a conventional scheme [1], where the pulses are generated at the thermionic gun and compressed by means of two subharmonic (125MHz and 500MHz) and two travelling wave bunchers (β=0.6, 6.7MV/m and β=0.95, 14MV/m). To avoid deflecting systems such as choppers, the gun uses a gridded cathode in order to produce the desired bunchtrain right at the beginning. The generation of short electron pulses (FWHM-pulselength ≤ 2.5ns) with high bunchcharge of up to 12nC (60% safety margin included) in combination with 3 modes of multibunch operation is quite a challenging task for the gunpulser, especially in terms of amplitude and time jitter stability.

Since the generation of the pulsetrain at the gun is one essentiell part of the injector, only the very first part of the injector beamline was built up in order to be independant of commissioning all the other components of the injector at the same time. This setup, as shown in figure 1, is instrumented with a wall-current monitor (CM1) at z=31.6cm, a button-type position monitor (BPM1) at z=36.4cm and a faraday cup at the end of the beamline, i.e. 46.1cm downstream of the gun anode which is at z=0. The whole system has an aperture of 34mm in diameter, except the hole in the anode of the gun which has a diameter of 20mm. Pumping is done directly at the gun via a short pumping port by means of a 400l/s getterpump.

For transverse focussing two solenoids AF2 (5.6cm long, 320 turns) and AF3 (8.7cm long, 500 turns) are centered around z=12.2cm and z=24.3cm respectively. With the same inner radius of 4.5cm and an outer radius of 6.4cm

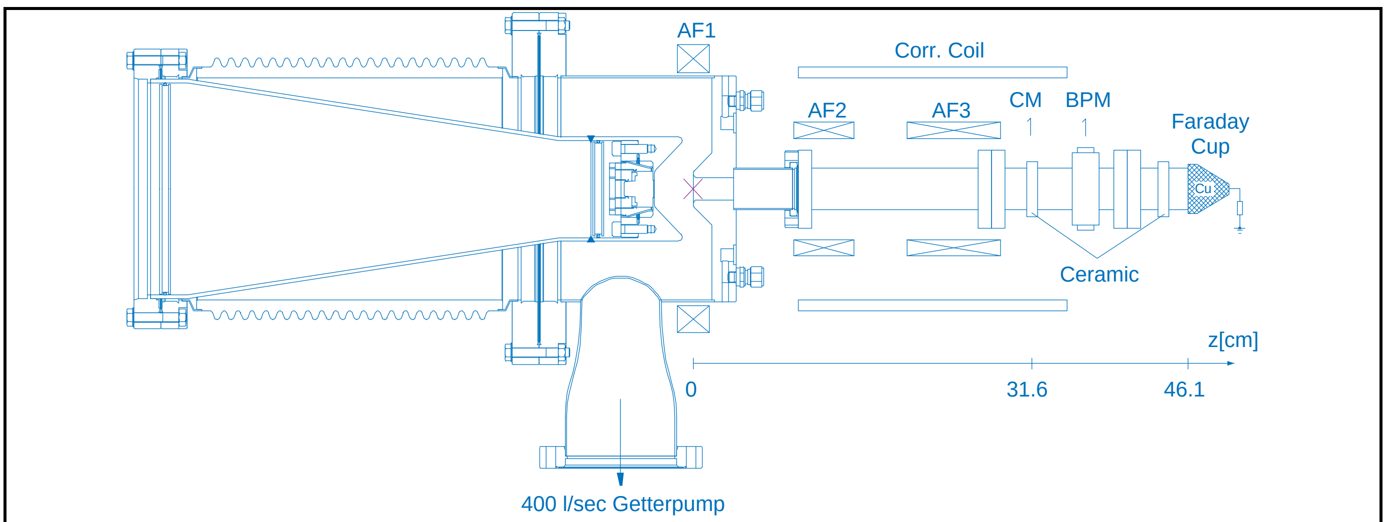

Figure 1: Setup for commissioning the gun and measuring the performance of the gunpulser

the magnetic fieldstrength in the center of each solenoid reaches 35 Gauss/A for AF2 and 45 Gauss/A for AF3. A third solenoid AF1 centered at z=0 is used for compensation purposes to keep the cathode free from magnetic field. With a length of 2.3cm, 100 windings, an inner radius of 10.4cm and an outer radius of 12.5cm, AF1 produces roughly 5 Gauss/A in its center.

In the first phase of commissioning the gun was operated by a testpulser, which supplies the cathode with single pulses of 3µs length and variable amplitude at 50Hz repetition rate. Results of this operation mode, in which the current capability of the gun and the beam transport to the faraday cup were investigated, are described in section III. During this operation the gun was conditioned and the vacuum improved. Thus the setup was well prepared, when the shortpuls gunpulser was delivered by HERMOSA Electronics. Its performance in combination with the gun during the first week of operation is presented in section IV. Before dealing with the experimental results the following section reviews the design of the gun.

II. GUN DESIGN

For clean capture by the first subharmonic buncher (125MHz) the FWHM-length of the gunpulse should be in the order of 90° of 125MHz, i.e. 2ns. The maximum charge which is required in that pulse is given for the 24ns interbunch spacing operation by 7.2nC. Including a 60% safety margin the gun has to deliver about 12nC in a pulse of about 2ns length. Thus the gun has to be designed for a current capability of approximately 6A.

In order to relax the requirements on the SHB amplitudes and to simplify the process of bunching the gunvoltage of 90kV has been chosen as low as possible. On the other hand PARMELA simulations show that this value is high enough to keep space charge effects (bunchlenghtening and energy modulation) in the 75cm long drift between gun and first SHB still acceptable.

Based on the EIMAC Y796 cathode-grid assembly the gun geometry as it can be seen in figure 1 was modelled with the EGUN code. With a 34mm anode cathode gap this gun has a calculated perveance of $0.22\mu A/V^{1.5}$, i.e. at 90kV it delivers the desired 6A of space charge limited current. Due to EIMAC fabrication tolerances the exact position of the cathode relative to the cathode-electrode has an accuracy of ±0.4mm. EGUN simulations show that this affects the perveance in the order of ±10%, since the electrical fieldstrength at the surface of the cathode is quite sensitive on its position.

At 90kV a maximum electrical fieldstrength of 81kV/cm appears at the surface of the anode “nose”. The normalized and absolut emittances at the gun exit are $\varepsilon_{n,100\%}=9.3\pi mm\cdot mrad$ and $\varepsilon_{abs,100\%}=15.0\pi mm\cdot mrad$ respectively.

The gun is operated at air and a 240mm long ceramic with an inner diameter of 200mm insulates anode from cathode potential. The cathode itself is carried by a conical metallic tube, that runs through the ceramic and is flanged on to the high voltage end of the isolator. At the same time this tube serves as a coaxial housing for the gunpulser, which uses a three stage triode tube circuit. Short current pathes and coaxial setup provides a low impedance arrangement, which bring up the short pulses to the cathode.

Pulsing the cathode by a resonant amplifier is not applicable. On the one hand each of the 3 time structures would require an extra amplifier (125MHz, 62.5MHz and 41.6MHz) and on the other hand the bias voltage in order to produce only 2ns long pulses would exceed the EIMAC specification, especially in the 24ns (41.6MHz) case. A linear broadband amplifier with a bandwidth in the order of 1GHz could be used. Since it has to deliver 6A at a forward voltage (net drive) of about 150V, the output peak power has to be at least 1kW. In this combination of bandwidth and power, such an amplifier is not available right off from the shelf. That’s why the nonlinear pulser based on triode tube technology is used.

III. GUN-OPERATION WITH TESTPULSER

In order to get experienced with the new hard- and software setup, the gun was driven by a testpulser. It delivers single pulses of 1-3µs length and variable amplitude to the cathode. The gunbias was fixed to 60V. Driven by this testpulser the maximum current which was measured at the faraday cup saturated at about 5.2A at 90kV independant of increasing the gunheater (7.5V) or the netdrive (175V). The vacuum was about $2\cdot 10^{-8}$Torr at this time. This perveance limit of $0.19\mu A/V^{1.5}$ corresponds to 87% of the EGUN predicted value.

The current settings of AF2(5A) and AF3(4A) for maximum transmission agreed well with PARMELA predictions. The impact of AF1 on the transmission is negligible in a wide range of ±3A, but it should deteriorate the emittance which could not be measured so far.

By means of this operation the vacuum quality improved automatically. With high voltage and gunheater on but beam off the vacuum is now at a level of $3\cdot 10^{-9}$Torr. During beam operation the average current and transmission losses determine the rise of the vacuum pressure.

IV. PERFORMANCE OF GUNPULSER

For the production of multibunchtrains with the time structure mentioned in section I a special gunpulser was used. It consists of 3 triode tube stages (2*EIMAC 8755 and 1*EIMAC 8940), with the last one acting as a perveance limited current source, which can be varied by setting its anode voltage (0-3kV) in order to determine the current that drives the guncathode. At a 20Ω dummy load the maximum current at the output of the pulser was measured to be 8.8A. Since the gunpulser input with an impedance of ≈50Ω requires 2ns wide pulses of about 60V peak, a very broadband high gain system is needed to produce the pulsetrains at the pulserinput.

Produced by a tektronix stimulus triggergenerator the desired triggerchains are brought up into the high voltage deck of the gun with a 3GHz bandwidth laser driven optical transmission system. The 500mV output of the receiver is fed into an 1GHz bandwidth A-type amplifier made by Amplifier Research to produce 60V level pulsetrains, which it did very clean even for the 8ns spacing.

At first we checked the single pulse performance of the gunpulser by feeding it with a 60V pulse from an avalanche pulser. This pulse had a FWHM-length of 2.1ns, a FW of 3.5ns and a risetime of 1.2ns. The corresponding beampulse measured at CM1 showed a length of FWHM=2.4ns resp. FW=3.5ns, a risetime of 0.9ns and a peakcurrent of 2.3A.

The faraday cup, which has a slower response due to capacitive effects showed a peakcurrent of 1.7A and a FWHM of 3.3ns. Nevertheless the product of both values, which is a rough estimate on the pulsecharge, gives the same result of 5.6nC for both measurements. During this test the gun ran at 60kV (heater 7.5V, bias 60V, vacuum $6 \cdot 10^{-9}$Torr) and the 8940 anode voltage in the gunpulser was set to 800V.

By the time the 1GHz bandwidth amplifier was delivered, the avalanche pulser was replaced by this device. Triggered with single pulses the beamresults, as can be seen in figure 2 were similar to the tests with the avalanche pulser, except that without changing the peakcurrent even shorter bunches down to FWHM=2ns could be produced by decreasing the low level trigger pulsewidth down to 1.25ns instead of 1.5ns. At the first time operating with multibunches a strong amplitude droop of the beampulses along the train occured. Caused by saturation of the interstage transformer cores in the gunpulser this was cured by some inductances to reset the core bias between two micropulses.

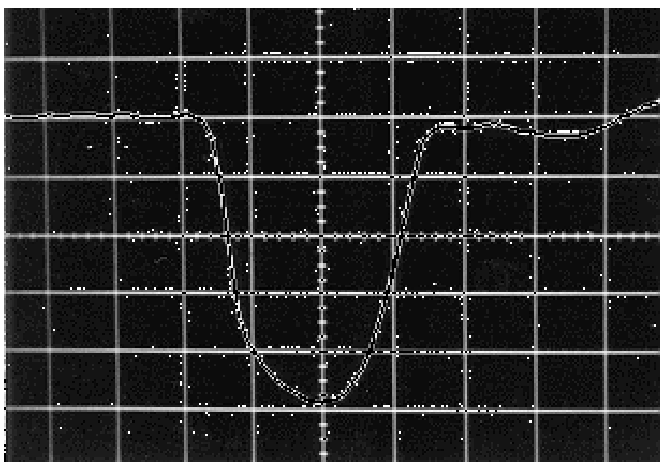

Figure 2: The first of 250 bunches with 8ns spacing measured at CM1, (1ns/div, FWHM=2.35ns, risetime=0.8ns)

After that the multibunch performance of the gunpulser was quite impressive. In all the 3 time modes (see section I) the pulseshape of each micropulse in the train has the same characteristics as the single pulse, i.e. a FWHM-length ≤2.5ns and FW≤3.5ns as specified. Concerning the amplitude stability one has to distinguish between the 3 modes. For the 24ns spacing only the first pulse is about 10% less in amplitude, while all the rest of the train is flat within 4% as it was guaranteed. At the 16ns mode we observed a resonance effect, which causes to start with a 20% higher amplitude decreasing within the first 5 pulses down to the level of all following bunches. In addition this resonance creates parasitic pulses ≈7ns after each main pulse. They can be suppressed by reducing the 8940 plate voltage. When the origin of this oscillation is understood it can be eliminated or shifted to a frequency where it does not interfere with our time modes. Although it was not guaranteed even the 8ns mode showed good performance. Some kind of a sawthooth amplitude modulation of ≤15% happens for the first 10 pulses, before coming to an equilibrium as can be seen in figure 3. In addition a continuous slow amplitude droop over the 2µs train of about 10% in total was observed. One reason might be that the 3x0.5nF HV-capacitors, which are located directly around the ceramic of the gun are not coupled low inductive enough to keep up the gunvoltage over the bunchtrain.

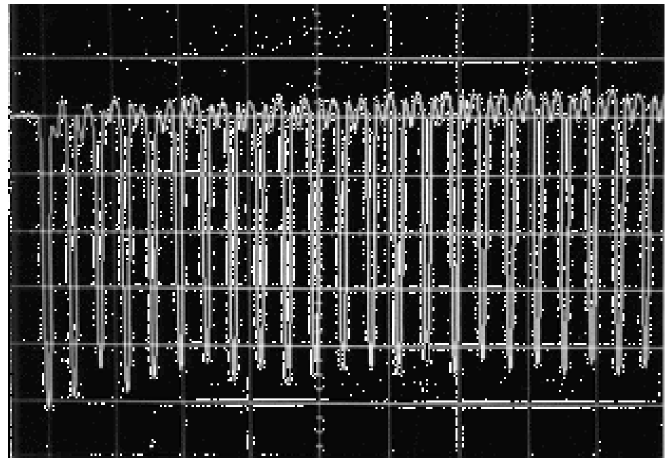

Figure 3: The 1. to 23rd of 250 bunches with 8ns spacing measured at CM1, (20ns/div)

The maximum bunchcurrent was about 3.2A at 80kV. Since this it not the perveance limit of the gun (see section III) it has to be investigated in more detail what is limiting this value. The pulse jitter observed on a 8GSa/s scope in a 100ps/div scale was less than 50ps which still includes the trigger jitter as well.

V. SUMMARY

The 90kV thermionic gun for the s-Band Test Facility at DESY was commissioned. With µs long single pulses 87% of the EGUN predicted perveance was measured. For the production of multibunchtrains a high gain high bandwidth system was built up for pulsing the gun. In a short beamline behind the gun the beamquality was measured. Bunchtrains of up to 250 bunches with 8ns, 16ns or 24ns bunch to bunch spacing , a non perveance limited peak current of up to 3.2A and an amplitude stability wihin less than 5% except from the first few pulses were produced. The micropulses had a FWHM-length of typically 2.3ns and a subnanosecond risetime.

VI. REFERENCES

[1] The Injector for the s-Band Test Linac at DESY, M. Schmitz, A.D. Yeremian, Proceedings of the 1994 International Linac Conference, p71-73, Tsukuba, Japan