DESIGN OF THE 100 KEV DC GUN TEST STAND

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In the scope of the LEG Project at PSI [1][2] a field emitter array (FEA) cathode is being considered as an electron source. In order to characterize the electron beam generated by pulsing a FEA cathode in vacuum under high voltage and to study emittance minimization by space charge compensation, it was decided to build a 100 keV DC gun test stand. The test stand will consist of a HV power supply deck, gate pulser, exchangeable in-vacuum electrodes, solenoid magnets, drift line, diagnostic module, ion pump, and a dedicated control system allowing remote control and data acquisition. Construction of the first vacuum sections began in 2004 and the test stand should be assembled by March 2005. Commissioning and first measurements are planned to start in April 2005.

OVERVIEW

The motivation behind building the 100 keV DC gun test stand is to deliver a characterization of the electron beam emerging from a pulsed FEA cathode and to investigate emittance minimization and space charge compensation schemes. Beam characterization includes reconstruction of the transverse phase space distribution, transverse emittance, energy spread, pulse time structure, pulse charge, etc.

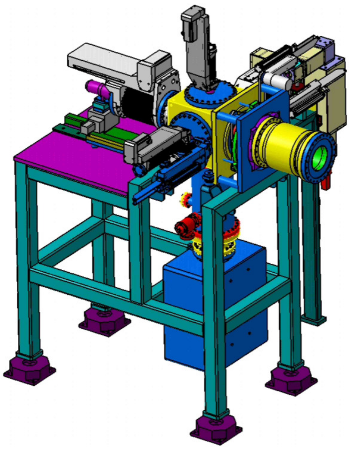

Fig. 1: Overview of the gun test stand: ion pump, ceramic isolating structure, 3D mover motors, center cube, and diagnostic equipment (slit arrays, Faraday cup, YAG screen, CCD camera).

In order to compare different anode/cathode designs and emittance minimization schemes the test stand is required to have a modular design. In the chosen design the test stand consists of a permanent part with the HV power supply, hot deck (containing the gate pulser), ceramic structure isolating the HV components from the grounded parts, 3D mover motors, ion pump, control system, and a 'flexible' part containing the removable gun electrodes, solenoid magnet, drift section and diagnostic devices. An overview of the test stand is given in Fig. 1.

GUN

The gun is a simple diode structure where the cathode electrode is on -100 kV potential with respect to the grounded anode. Fig. 2 shows an inside view of the gun electrodes and solenoid structure.

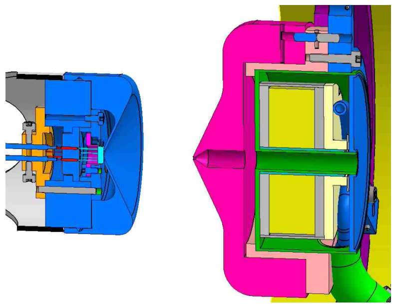

Fig. 2: Inside view of the test stand gun: cathode electrode with inserted FEA transistor, anode electrode with iris and recessed beam channel. Enclosed in the u-shaped yoke behind the anode are the solenoid windings.

The cathode electrode has at its center a 1.5 mm diameter insertion port for the transistor element holding the FEA which is expected to have a diameter of 200 μm. The FEA has a gate layer which is connected to the pulser in the hot deck; the pulser can deliver 300 V (with respect to the FEA potential) pulses with 5 ns minimum pulse length. A 500 l/h ion pump will maintain the UHV conditions required by the FEA.

The gun configuration, solenoid structure, drift beam line, and certain diagnostic components have been modeled in 2D with the code MAFIA and extensive parameter studies have been conducted [3] in order to specify initial design parameters. The gun geometry has been optimized for minimum emittance at its exit while keeping the accelerating gap large enough ($\approx$ 11 mm) to avoid peak electric field strength larger than 20 MV/m on the anode iris. Simulations showed that an anode radius of r_{iris} = 0.75 mm would allow the beam to pass without any particle loss. The minimum normalized transverse emittance at the end of this gun configuration (without solenoid focussing) was found to be $6{\cdot}10^{-8}$ m·rad.

In the future, we plan to improve the gun geometry in order to reach a lower emittance at the gun exit. The modular design of the test stand will allow us to exchange the anode and cathode electrodes without disassembling or redesigning the entire test stand. If vacuum and surface conditions allow, we would also like to reduce the gap between the electrodes in order to increase the accelerating field strength which should lead to less space charge blow-up and thus to lower emittance.

After assembly of the test stand and throughout future exchanges of gun components we need to retain proper alignment of the FEA with respect to the gun electrodes, solenoid and beam channel. This is accomplished by a set of 3D mover motors which will be installed between the center cube (holding the anode electrode and solenoid) and the ceramic structure to which the cathode electrode is attached. The motors will allow us to adjust the position and tilt of the FEA with respect to the design beam axis through the control system of the test stand.

SOLENOID

The designed in-vacuum solenoid structure is capable of delivering 200 mT of magnetic field strength on axis. It is cooled through a water pipe connected to an external water-air chiller capable of dissipating roughly 50W of heat. Through proper tuning of the solenoid current we expect to achieve beam foci at any location in the drift section behind the gun structure with a minimum normalized transverse emittance as low as $1.6{\cdot}10^{-8}$ m·rad.

Furthermore, the parameter studies show that proper adjusting of the solenoid current as well as simple changes to the gun geometry will allow the emittance to be optimized for different emitter radii, bunch charges, or bunch lengths. The obtained simulation results will be compared to experimental data when test stand construction is completed.

DIAGNOSTICS

The diagnostic module consists of a YAG screen, Faraday cup, slit arrays, pepper pot, phosphor screen, CCD camera, and a set of motors capable of driving these devices into their proper positions. The diagnostic devices are controlled and their data acquisition read out through the test stand control system. EPICS [4] was chosen as a control system because it is already successfully in use throughout the SLS; driver and software support will be supplied by the SLS Controls Group.

The YAG Screen inserted from the side will visualize the beam's transverse distribution; the screen's diameter is 30 mm. The coaxial Faraday cup will be inserted (from the side as well) right behind the solenoid magnet; it has a diameter of 20 mm and offers high bandwidth ($>$ 4 Ghz). We expect to measure the charge and time structure of the bunches emitted from the FEA by reading out the FC signal on a high bandwidth oscilloscope.

From the top and side two mask holders can be inserted in the beam path. Each holder carries three masks: a single slit, an array of slits, and a pepper pot. The slit width is 20 μm, the distance between slits is 170 μm; the pepper pot hole diameter is 50 μm, the distance between holes is 320 μm. The masks are laser eroded substrates of 100 μm tungsten. The position of the masks is measured by linear encoders with a resolution of 0.5 μm. In order to visualize the beamlets that pass the slit(s) or holes there is a phosphor screen inserted from the back and a CCD camera with variable zoom optics. The phosphor screen is optimized for 100 keV electrons; its thickness is 6–8 μm, the granularity is roughly 3 μm and the substrate is aluminized. The slit and pepper pot arrays will allow two principal measurement modes: without solenoid focussing the moveable pepper pot arrangement (300 mm travel) will allow imaging of diverging beamlets emerging from various longitudinal positions (onto the phosphor screen 300 mm downstream of the holes). With proper solenoid focussing a beam waist can be placed at the location of the slits or pepper pot holes. In this regime the phosphor screen can be moved (300 mm travel) with respect to the slits or holes in order to ensure proper resolution of each beamlet on the screen. Both modes should deliver spacial and angular dimensions of the beam at the location of the slits or holes and allow cross-checking of results. First simulations of phase space reconstruction show that this setup allows to measure transverse emittances in the order of 10^{-8} m·rad with a resolution of 10^{-9} m·rad.

ACKNOWLEDGMENTS

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REFERENCES

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[2] R. Ganter et al., *Status of the Low Emittance Gun Project*, this report.

[3] S. C. Leemann, *100 keV Gun Test Stand: Design and Parameter Study*, Internal Note SLS-TME-TA-2004-0244, http://slsbd.psi.ch/pub/slsnotes/

[4] EPICS: Experimental Physics and Industrial Control System, http://www.aps.anl.gov/epics