4 kW, 25 keV Power Electron Source for Studies of Thermal Beam Effects

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Abstract

A power electron source assembly, with an average beam power of 4 kW and an output energy of 25 keV was designed and constructed during 1992 in the Department of Accelerator Physics of SINS [1]. After completion and preliminary measurements at Swierk, it was transported and installed at the "Sincrotrone Trieste" in Italy. The installation took place in the laboratory where various types of equipment, prepared for application in electron-synchrotron ring ELETTRA, were measured, modified and optimized. In this paper the main components of the system, and beam diagnostics methods are described.

1. Introduction

The principal destination of the low energy, power electron source was investigation of thermal effects equivalent to possible events which occur when high energy beam in the ring occasionally impinges on some devices located in the beam line. Use of low energy beam allows one to avoid high radiation background in experimental work. When designing the source it was necessary to match the geometrical configuration of the gun assembly to the experimental requirements of the Trieste Laboratory. The main parameters of a high power beam of variable current, the beam spot size, and the spot plane position were measured in a specially designed diagnostic vacuum chamber.

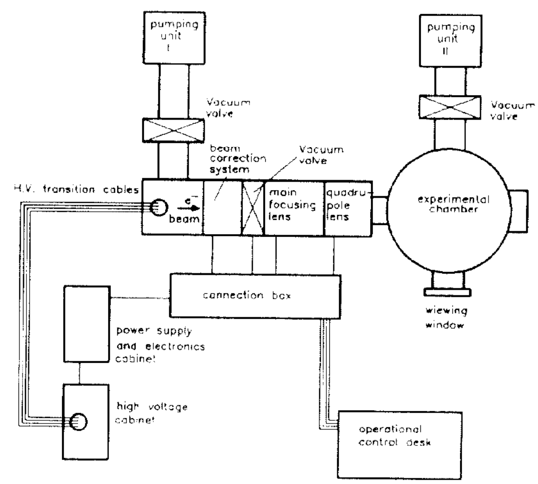
2. Design Parameters

The main parameters of the power electron source are listed below.

Energy of accelerated electrons	- 25 keV
Beam power	- 10 W - 4 kW
Ranges of beam current setting	- 0.1-2.0 mA, 2-20 mA, - 20-200 mA
Distance from the cathode to experimental plane	- 600 mm ± 50 mm
Diameter of beam spot at a focus plane	- 1 mm for 20 W - 3 mm for 4 kW
Variation of a focus position in the horizontal and vertical planes	- ±10 mm
Variation of beam dimensions	- max. 10 mm in hor. plane max. 3 mm in vert. plane
Stability of beam dimensions and position	- ±10% in one hour
Pressure in experimental chamber	- $<10^{-6}$Torr

3. General Description

Schematic diagram of the power electron source modules is presented in fig.1.



Power electron source — schematic diagram

Due to Coulomb forces, efficient transport of low energy, high space charge beam over a long distance is quite complicated and imposes stringent requirements on the beam optics as well as stability of high voltage, high power supply. All supplies necessary for operating of power electron source were installed in two cabinets. Steering electronics which controls current of a beam was located in a "high voltage" one. Control of a beam in a full operating range of 0 to 200 mA is achieved by variation of cathode-grid potential of a triode electron gun. In order to get high resistivity against poisoning during experiments with heating and melting of various materials, tungsten cathode is used. Its small - 1 mm diameter gave a point-like beam source. Approx. 20 mm long cathode rod is surrounded by a heater. Steering electronics was constructed in a way which gives maximum flexibility of choosing primary and secondary cathodes working point. Avoiding excessive heating of cathodes, during experiments with low currents of a beam, is very important as far as their life-times are concerned. The beam optics was simulated by a TRANSPORT computer code. Three coils magnetic system of the beam control was used. First, beam is steered by magnetic field of correction coils. These coils precisely localise a beam along the geometrical axis of the system. The main focusing action is provided by a solenoid-type second lens. Finally, at the entrance to experimental chamber, third - single quadrupole lens is installed. The lens enables variation of beam dimensions in horizontal or vertical planes. As a result of such arrangement of coils, one can get:

- a focused circular beam spot 1 to 3 mm in diameter,
- an elliptical-shape spot,

and also, can vary the position of the focal spot within 100 mm distance.

High vacuum is reached by implementing two turbo-molecular pump units, one at the electron gun chamber, and the other at the experimental chamber. The two chambers are interconnected with a vacuum valve which enables opening of either part without loosing vacuum in the other. Pumps are connected to the chambers with stainless steel flexible pipes to dump the transmission of mechanical vibrations toward very sensitive cathode assembly. To ensure a low residual gas pressure and cleanness of the system, very careful leak detection and thermal annealing of the vacuum chamber was necessary. It was heated approximately to 150^{0}C and pressure level as well as residual gases composition was continuously measured. This procedure was essential to avoid high voltage breakdowns. After the vacuum conditioning the following data were obtained:

- pressure - $2.5 \cdot 10^{-7}$ Tr
- total leak - $2 \cdot 10^{-6}$ Tr l/s
- spectrum - free of watervapour, free of hydrocarbons.

4. Diagnostics of Beam

Four main methods have been used for experiments with the beam: [2]

- observation of thermal heating of a tantalum plate,
- observation of luminosity of an alumina CHROMOX ceramic screen,
- holes formation in thin foils as a result of beam-foil interaction
- X-ray emission measurement

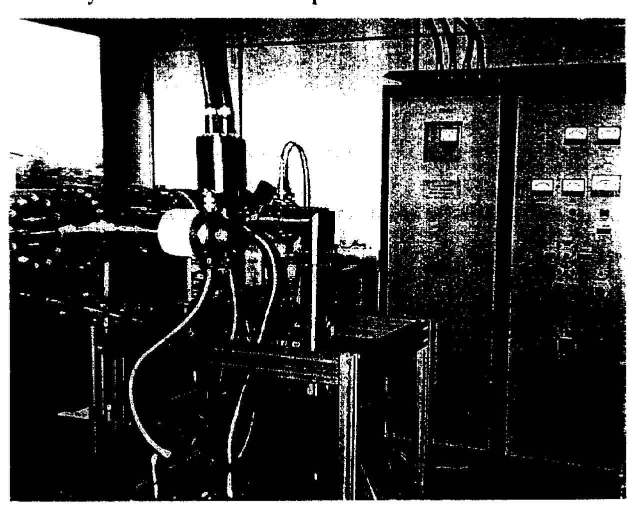
The first method, was very useful during preliminary experiments and was used to find optimal distribution of correction and focusing fields. In the second, the beam profile was derived from computer analysis of alumina ceramic luminance. The computer program was able to draw planar lines of equal luminosity as well as three-dimensional profiles. The results of experiments have been recorded on easily accessible files. While in the first method the power of a beam during observation was high, in the second it was limited to approx. 20 W due to high thermal sensitivity of ceramics. For beam power higher than 100 W we used the third method. Punctures made in tantalum and copper foils with thickness from 0.1 to 0.5 mm gave information of the real diameter of a beam and the shape of its spot. As an example, a hole of 1 mm diameter was burnt in a 0.15 mm thick tantalum plate during 3 sec. exposition to a 1500 W beam. In the last, radiographic method of beam dimension estimation, a thin conversion target was applied. When the examined electron beam struck the conversion target, bremsstralung X-rays were irradiating a radio-sensitive film through a special tester. The tester was built using 10x10 mm lead and mylar thin foils which formed a 10x10x10 mm box. Due to the tester, the film was irradiated by the X-ray beams, which were parallel to the electron beam, giving (after developing) easy visible white lines. The tester could be turned and thus both vertical and horizontal dimensions of the beam on a target foil were measured. The measured vertical and horizontal dimensions of the beam spot in our experiments were 0.8 mm and 1.1 mm respectively. These results were obtained with the output beam current of 0.4 mA. This method, similarly to the method with ceramics was limited to approx. 20 W of beam power.

5. Installation and Final Commissioning

After installation in Trieste the following tests on the power electron source were performed: [3]

- focusing the beam into a sharp point (1 mm in diameter) at a distance of 600 mm from cathode,
- shifting the focus position along the beam axis in a range of ± 50 mm,
- shifting the beam spot in the transversal plane ±10 mm from axis,
- elliptical beam profiles extension in horizontal or vertical directions.

The executed experimental tests proved the operational flexibility of the system. General view of the installed assembly can be seen in the picture below.



6. References

[1] "Power Electron Source 25 keV, 4 kW for Studies of Thermal Beam Effects, SINS Annual Report 1992, p.59.

[2] "Diagnostics of 25 keV/4 kW Beam in TRIESTE Electron Gun", SINS Annual Report 1992, p. 61.

[3] "Installation and Running-in of Low-Energy High-Power Electron Source in Sincrotrone Trieste Centre", SINS Annual Report 1993, p. 59-60.