SALOME: AN ACCELERATOR FOR THE PRACTICAL COURSE IN ACCELERATOR PHYSICS

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Abstract

SALOME (Simple Accelerator for Learning Optics and the Manipulation of Electrons) is a short low energy linear electron accelerator built by the University of Hamburg. The goal of this project is to give students the possibility to obtain hands-on experience with the basics of accelerator physics. In this contribution the layout of the device will be presented. The most important components of the accelerator will be discussed and an overview of the planned demonstration experiments will be given.

INTRODUCTION

At the present time the particle accelerators have become an important instrument in many areas of the physics research. For example in the field of high energy physics, beams of accelerated particles collide and provide an insight into the structure of the matter. In photon science, third and fourth generation light sources generate intense synchrotron or FEL radiation, which is used to study the x-ray matter interactions. In addition to the scientific applications particle accelerators are used in many other different areas, for example in radiation therapy for medical cancer treatment. This large variety of possible applications sets higher

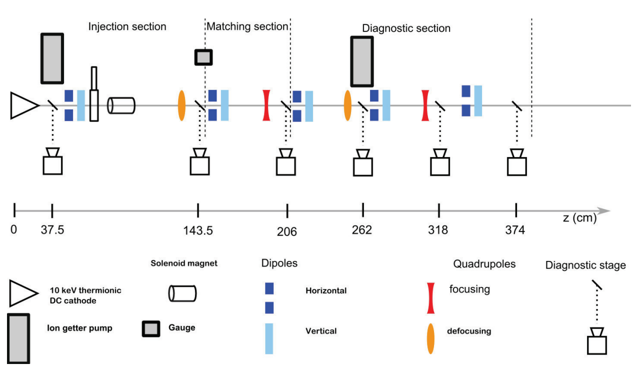

Figure 1: Schematic layout of SALOME.

requirements to the academical education of the future accelerator physicists. Nowadays already during the bachelor and master courses they have to show not only good knowledge in the theory of the accelerator physics but also comprehensive practical experience in the operation of the modern machines. The SALOME accelerator has been designed and built to serve this mission.

The accelerator was built by the University of Hamburg at the site of the Deutsches Elektronen-Synchrotron (DESY) in Hamburg. The goal of the project is to provide a platform for young accelerator physicists to learn and to extend their knowledge of the basics of accelerator physics during their practical courses. SALOME is designed as a stand-alone machine. Therefore the students are free to work with the device without disturbing the normal accelerator operations at DESY. The design of the accelerator, as shown in the sketch

Table 1: Main Parameters of SALOME

Particles type	electrons
Particles source	thermionic cathode
Maximal beam energy	12 keV
Energy spread σ_E/E	10^{-5} – 10^{-4}
Normalized transverse emittance	0.5 mm · mrad
Maximal beamline length	6.5 m

in Fig. 1, provides maximal flexibility and gives a possibility not only to perform experiments with the existing setup but also to modify and upgrade the accelerator for additional studies. Available are experiments cover both the introductory and the advanced level of the accelerator physics course, such as beam orbit adjustment through the beamline, dispersion measurement and correction, beam-based quadrupole alignment, transverse phase space characterization using quadrupole scan or multiple screen technique as well as phase space thomography.

DESCRIPTION OF THE MAIN COMPONENTS

Cathode System

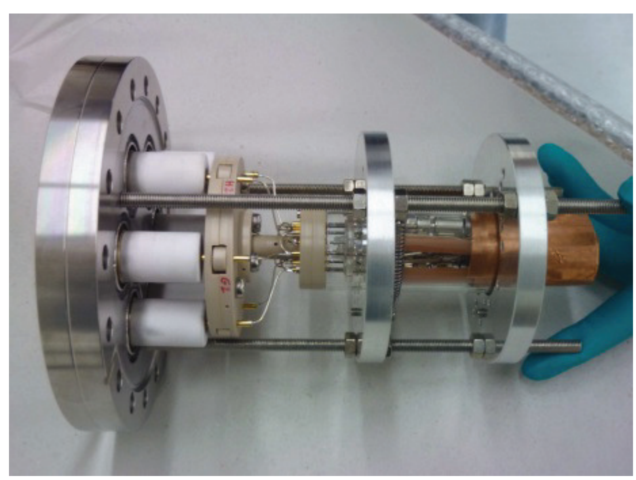

Figure 2: Thermionic cathode assembly together with high voltage feedthrougs inside the cathode holder.

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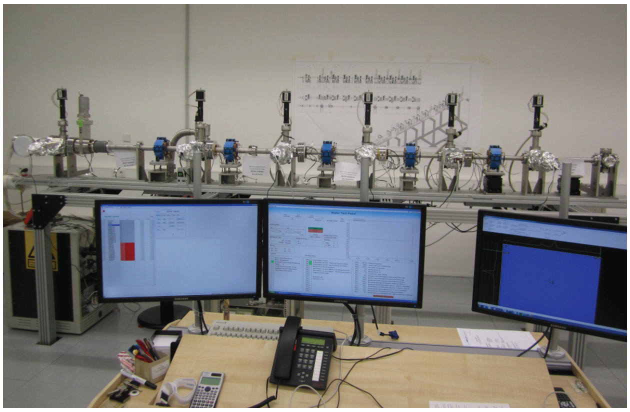

Figure 3: A side view of the accelerator with the control console.

One of the most important components of SALOME is the cathode system setup. The system has to fulfill several requirements. Ideally to minimize the costs and to increase the reliability it should be made of commercially available parts. It should also be taken into account that the maximum electron energy should be in the order of ten keV for to avoid radiation protection issues due to bremsstrahlung. The most obvious choice in such a case are the cathode ray tubes (CRT) which were extensively used in the TV-technology in the near past. Unfortunately since the advent of the LCD and LED technology the manufacturers have phased out the production of CRTs. This makes it difficult to find a vendor for the cathode assembly which is the main part of the cathode system. After several tests it was decided to use cathode assemblies which were originally designed for a color-TV-tube. These cathodes provide continuous electron beam with an energy that fits the SALOME requirements. The cathode assembly contains besides the cathode additional grid electrodes which can be used for adjusting the electron beam current and for initial focusing of the beam. The cathode assembly together with high voltage feedthroughs inside the cathode holder is shown in Fig. 2. By the means of an 'off the shelf ' HV-power supply the energy of the electrons is limited to maximal 12 keV . This low electron energy allows to setup the accelerator in the same room where the control console is situated without further radiation protection as illustrated in Fig. 3.

Magnets

The guideline throughout the entire design of SALOME was to build a device of the same "look and feel" as the accelerators that are already used in the research. Thus SALOME will not only visually resemble the bigger machines, but will also give the future machine physicists a more pragmatic introduction to the commissioning and the everyday operation of the real accelerators. The lattice of SALOME consists of the following types of magnets: dipoles, quadrupoles and a solenoid. The design of the quadrupoles was custom made by the DESY MEA group. The main parameters of the quadrupoles are listed in table 2. In order to minimize the hysteris effects of the iron yokes, iron of the type PERMENORM 5000 H2 was used for the SALOME quadrupoles. To estimate the hysteresis effects of the magnets the integrated magnet field has been measured from -10 A to +10 A and from +10 A to -10 A. The resulting data is shown in Fig.4. The field errors due to hysteresis effects are in the order of 10^{-4} T i.e. at least an order of magnitude smaller than the typical fields during operation. Currently two types of quadrupole holders are being used - the standard fixed ones and a remote-controlled motorized version with two degrees of freedom allowing positioning in the transverse plane with micrometer precision. The control system of the magnet power supplies and the micro-movers is based on the same networking environment, which is adopted at many of the accelerators at DESY [2].

Table 2: Parameters of SALOME Quadrupoles

Gap	40.0 mm
Yoke length	60.0 mm
Effective length	78.8 mm
Total width	120.0 mm
Iron type	PERMENORM 5000 H2

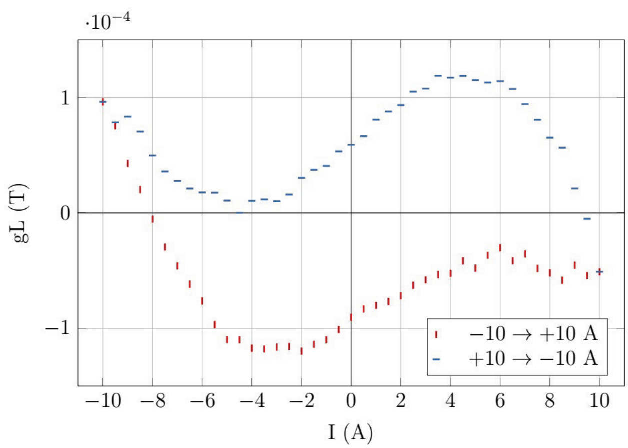

Figure 4: Hysteresis effects of the quadrupole after subtraction of the linear term [3].

The dipoles with an iron yoke are much too strong for the low energy beam at SALOME. The deflection even for small currents is too large and in addition due to hysteresis effects of the iron core the reproducibility of the magnet settings is not fully satisfactory. Therefore instead of iron yoke steerers air coils were used. These air coils are of the same type which where constructed for the FLASH accelerator to steer the beam right after the FLASH gun [1]. These air coils have several benefits for SALOME. First they work without an integrated iron yoke which eliminates hysteresis effects so the measurements are more precise and the magnet power settings for beam guidance are reproducible. Second they can steer simultaneously in both the horizontal and the vertical plane which reduces the used length on the beam pipe.

Diagnostics

The diagnostics is realized using YAG-coated aluminum screens mounted on remotely controlled movable actuators. Each YAG-screen together with the stepper motor for the actuator, the Prosilica Ethernet CCD-camera and the corresponding optical setup is forming a diagnostic station. At present there are in total six such stations. However, thanks to the flexible design of the beamline and because all of the components are commercially available even more diagnostic stations can be added at any time if needed. Except the hardware briefly discussed above, the imaging software is the other major part of the diagnostics at SALOME. The TINE-based video system originally developed at PITZ and later on exported to various accelerators at DESY [5] was found to be particularly suitable for an university laboratory such as SALOME. Besides the server components, the system comes along with client software which calculates beam spot rms size, position, region of interest and saving images for later analysis. Furthermore, thanks to the provided Matlab interface, the students have the option to develop own routines for more advanced data processing or to automatize the measurements.

COMMISSIONING RESULTS

Since the first beam in 2013 a number of master and bachelor theses have been already finished ([3, 4]) or are currently under preparation. SALOME has also welcomed the first groups of students attending the advanced laboratory course at the University of Hamburg. It is worth to note that the students showed great interest in the accelerator physics and technology and participated enthusiastically in the experiments. As mentioned above, the laboratory

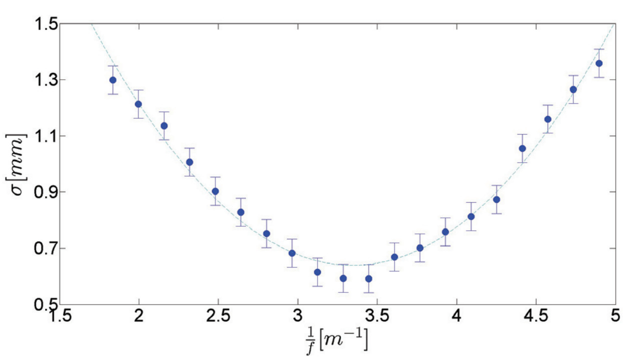

Figure 5: Example of transverse emittance measurement at SALOME. The rms size of the beam spot is shown as a function of the strength of a quadrupole. The analysis yields a normalized emittance $\epsilon_n = 0.50 \pm 0.01$ mm · mrad.

course offers a large variety of different measurements. The quadrupole scan transverse emittance measurement (as shown in Fig. 5) is an example, which needs relatively simple hardware. In the same time this experiment has a great didactic value because it requires a deep knowledge on the underlying physics as well as good understanding of the mechanisms of the transverse particle motion and focusing. Last but not least, a certain degree of mastery in the processing and the analysis of the experimental data is also needed.

OUTLOOK

Except a part of the advanced laboratory course at the University of Hamburg, SALOME is an ideal platform for stand-alone bachelor-, master- or PhD studies. Such studies might include for exmaple:

- ’Thick-lens’ modification of the novel symmetric quadrupole scan method [6].
- Tomography of the electron beam transverse phase space
- 4D emittance measurements
- Development of an UV photo-cathode, which is to replace the present thermionic cathode.
- Velocity bunching investigations - requires the development, installation and the commissioning of a suitable buncher cavity.

These are just a few of the long list of ideas that are being considered for the future upgrades of SALOME.

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