Report on DELTA, One Year Before Routine Operation

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Abstract

A status report of the Dortmund ELectron Test Accelerator DELTA [1] in its final phase of construction is presented. DELTA is a 1.5 GeV 3^{rd} generation synchrotron light source designed for low emittance (10^{-8} m rad), high currents (500 mA for $\geq$ 12 bunches) and beam life times of $\geq$ 10 hours, which is dedicated to free-electron-laser (FEL) and accelerator-physics research and development. With the first FEL experiment [2], already funded and to be installed in one of the two long straight sections of the racetrack-shaped storage ring, DELTA represents a new Storage-Ring-FEL facility. After first oscillator operation in the visible (planned for end of 1994), FEL experiments in the VUV clearly below 100 nm are foreseen. In the second long straight section an asymmetric superconducting wiggler, providing 1 Angström radiation, will be installed in the future and used as wave-length shifter. A predesign study of this second insertion device has been performed already. Details of the construction of DELTA and present status of most hardware components of 100 MeV LINAC, booster synchrotron, storage ring, vacuum system, beam lines and first FEL experiment will be discussed.

1 INTRODUCTION

The high-brilliance 1.5 GeV synchrotron light source DELTA dedicated to FEL and accelerator-physics research has been described previously in a technical status report and several publications [1]. In contrast to most other synchrotron-radiation sources, DELTA will not be a user machine. Instead of being available for long-term research experiments and industrial applications, the purpose of DELTA is different. It represents a test facility for research in radiation and accelerator physics, for preparing and testing of experimental setups and for performing measurements with very special beam characteristics.

When designing the machine, it was noticed that a triplet focussing cell with strong bending fields (max. 1.5 T), as the reflection symmetric version of the FODO cell, represents optically the most flexible separated-function structure. Besides this triplet focussing, the DELTA lattice provides two long dispersion-free straight sections with nearly constant beta functions for magnetic insertions. Accordingly, the DELTA storage ring in conjunction with its FEL undulator devices [2] has been be optimized to provide radiation of unprecedented beam quality, concerning high intensity (0.1-0.5 A for 1 to 12 bunches), low emittance (10 nm rad), large coherence and short time structure. Other characteristics of this third-generation light source are its short damping time (about 4 msec) and bunch length (2 cm) and large energy spread ($< 10^{-3}$), qualities which are indispensible to obtain a large FEL gain. Moreover, the flexible optics with variable emittance and energy, the high beam stability due to its low impedance and the long lifetime (about 10-20 hours) due to optimum vacuum conditions, make DELTA an ideal test machine. Machine experiments are planned for investigating beam stability, machine-parameter dependencies and for developing all kinds of accelerator components and diagnostic tools. Accordingly, one aim is to develop a fully automatic diagnostic and computer-control system. A predesign study has been undertaken for constructing also an asymmetric superconducting wiggler, producing short-wavelength radiation with a high degree of polarization, suitable for a large variety of research applications [3]. As a university institute, the DELTA facility with its relatively small storage ring of 115 m circumference will serve as an ideal instrument for the education of students, technicians and physicists in accelerator technology.

2 STATUS OF THE PROJECT

-Building and Infrastructure-

After funding of the DELTA project has been approved end of 1989, work on the final design of the three machines, 100 MeV LINAC, booster synchrotron and storage ring, continued in 1990. Besides these design activities parts of an old LINAC from the University of Mainz were shipped to Dortmund and rebuilding of this machine has started for its use as preinjector. End of 1990 ground breaking of the laboratory site happened and from May 1991 till June 1992 construction of the laboratory building with its 40 m by 74 m large accelerator hall and its offices and laboratories was performed. Since moving into the new building trafo station, power-supply circuits, cabeling and many other parts

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of infrastructure have been installed, the concrete wall for radiation protection erected and the electronical and mechanical workshops and the vacuum lab equiped and put into operation. Radiation safety and interlock system is under design. Most parts of the cooling-water and heat-exchange system with cooling tower and tube circuits are mounted.

-Accelerator Components-

The components of the old Mainz LINAC are under test, in particular klystrons and accelerating structures (with 40 MeV/section particle energy at 20 MW pulsed RF-power and 2.9985 GHz operating frequency). A new design of the LINAC focussing system is completed, the buncher section, built by LAL in Orsay, was delivered, the 3 GHz RF-system is ready, PFN and klystron tanks are under construction, a new design of the LINAC modulator has been developed in cooperation with the University of Bonn and its construction has been ordered. A new pulsed triode gun with integrated pre-buncher cavity is under test.

The status concerning booster and storage ring is the following. Design work for beam transfer between the accelerators and the injection and ejection systems are finished. The corresponding beam lines, focussing elements and the various kicker magnets and septum tanks are under construction. A simple, new kicker design of very low impedance has been invented by DELTA (see fig. 1). Whereas the magnetic elements of LINAC and transfer channels are being built at Dortmund, the kicker and septa tanks will be built by the KFA-Jülich. Prototypes are expected to be ready in late summer of this year. The girders to support the magnets for all machines and transfer channels are installed. The series production of quadrupole and dipole magnets is in progress. More than one half of all magnets, which are identical for booster and storage ring, is already in house and has been mounted on the magnet girders. Field measurements were found to be well within the tolerances. Whereas the yokes of the sextupole magnets will be manufactured by the lab workshop, the coils will soon be ordered from a company. The correction coils will also be made by industry. Manufacturing of quadrupoles and dipoles of the transfer lines has started in house. Ion-clearing electrodes are designed and foreseen for the booster only. The main power supplies for the two dipole circuits and the two klystron amplifiers arrived early this year. The chopper power supplies for the quadrupoles and the power supplies for steering coils, LINAC beam transport etc. are ready.

The topology of the DELTA control system consists of the display level (HP grafic workstations), the control level (risc workstation as databases) and the process level (VME CPU's with VX-Works). For the field level an object oriented fieldbus system (CAN bus), nowadays widely spread as industrial standard, is foreseen because of its high functionality, data security, flexibility and easy programming and timing.

-UHV System-

The DELTA ultra-high-vacuum (UHV) system has to fulfill the following three basic requirements : (i) stored-beam lifetime of the order of 10 to 20 hours; (ii) smooth and uniform beam chambers along the circumference of the storage ring; (iii) short vacuum-conditioning times, which is indispensible for a test accelerator. In order to realize these particular features for a machine with closely arranged magnets of small apertures (50 mm) and vacuum vessels of low longitudinal conductance, a number of technical novelties were introduced at DELTA. For the first time a vacuum vessel of keyhole cross section, totally made of stainless steel (316 LN), with an antechamber all along the inner side of the ring circumference has been constructed and successfully manufactured. Inside of this chamber both types of distributed UHV pumps are mounted at some locations side by side, namely ion-getter pumps of the diode-noble-gas type and non-evaporable-getter pumps (St 707). External lumped ion-getter pumps (IP's) and titanium-sublimation pumps (TSP's) are additionally installed. The type of flanges and gaskets (VAT-SEAL) with their very particular keyhole aperture used at DELTA are other novel features. All these design criteria were described elsewhere [1]. The prototype hardware was tested in detail. The series production of UHV chambers and integrated pumps is well on the road and all chambers with these pumps will be ready before the end of this year.

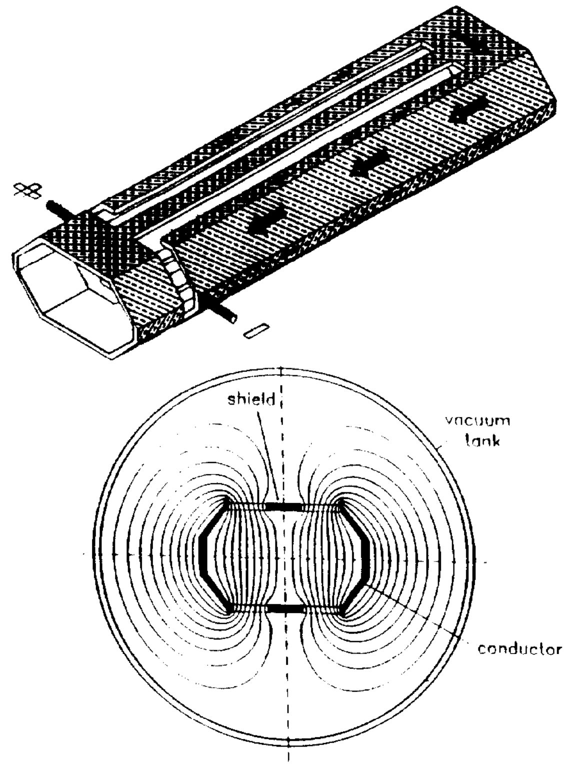

Figure 1: Sketch of the new kicker design showing the particular geometry of the 12 mm wide slit cut into the beam-chamber and the field distribution inside the vacuum tank of the kicker (below).

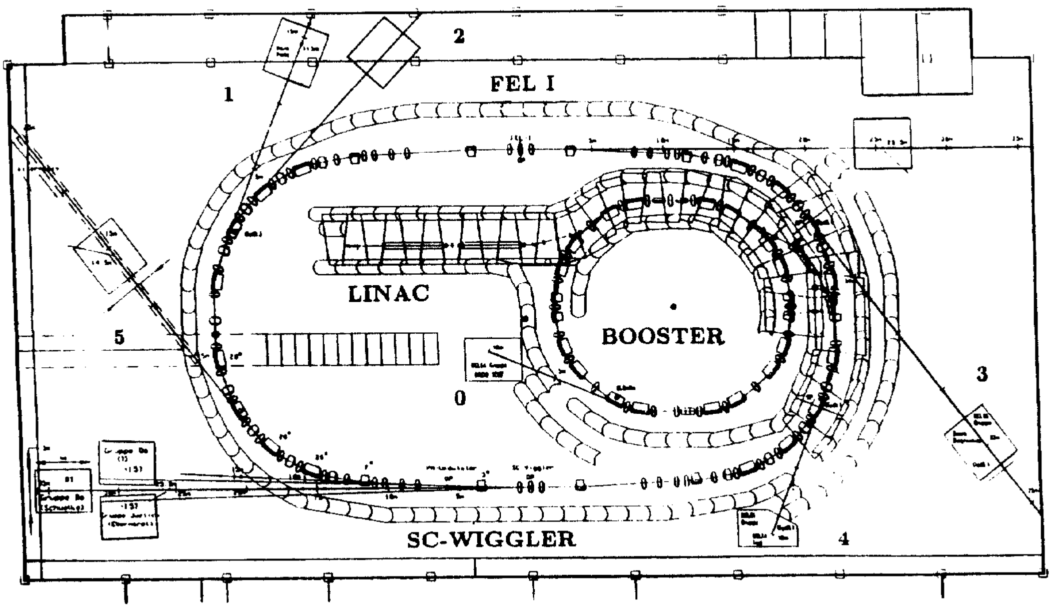

Figure 2: Floor plan of the accelerator hall with LINAC, booster and storage ring, together with radiation-protection wall and the various beam lines.

A new design of a very flexible compensator, made of a double-membrane bellow and a two-sided RF shield, has been developed to interconnect the vacuum vessels. All external pumps, IP's and TSP's, mounted in a common housing, were delivered already.

-SR Sources, Beamlines and Experiments-

Although DELTA will not be a user machine, a number of synchrotron-radiation (SR) beam lines will be provided for a variety of user experiments. Three sources of very different radiation characteristics will be available at DELTA, namely the photon flux from bending magnets ($E_c = 2.26keV; 2.5*10^{10}$ photons) and that from two different insertion devices, from the undulator [2] of the first FEL experiment (FELICITA I with $E_1 = 27eV; 2.5*10^{12}$ photons) and from the superconducting asymmetric multipole wiggler [3] or wavelength shifter ($E_c = 8.23keV; 1.2*10^{11}$ photons; circularly polarized X-rays). In total, 5 beam lines for radiation from the 1.5 T dipole magnets of the storage ring will be installed and one line from a dipole of the booster. Besides these conventional sources, the FEL undulator and the superconducting wiggler, mounted in the two long straights of the storage ring, will both produce radiation fans of quite different characteristics, which can be used by up to three experiments independently. Whereas till now only a predesign study of the superconducting wiggler has been carried out [3] and a feasibility study is ordered from industry, the electromagnetic undulator of the first FEL is already under construction. FEL undulator and optical cavity with its control units will be ready for experiments soon after routine operation of DELTA will start. In fig.2 a floor plan of the accelerator hall is exhibited, with the accelerators, the concrete wall for radiation protection and the various beam lines from bending magnets, FEL undulator and superconducting wiggler, respectively.

3 SUMMARY

A status report of the construction work at DELTA has been given. The project is on time. The first stored beam is expected to circulate in early summer of 1994.

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