STATUS REPORT ON SURVEY AND ALIGNMENT EFFORTS AT DESY

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Abstract

This report presents major projects and activities of the survey and alignment group at the Deutsches Elektonen-Synchrotron during the period of 2002 to 2004. It focuses on the construction and alignment of the new TESLA TEST FACILITY with its VUV-FEL beamline. Besides that it describes some newly installed monitoring systems in the HERA tunnel.

1. INTRODUCTION

The research activities of DESY today are based on three topics: High energy physics with HERA II, the development of new accelerators such as TTF/ILC and the research with photons. The last run of HERA will end in 2007, so the focus in the near future is shifting towards synchrotron radiation sources. According to these guidelines the main activities of the DESY alignment group in the past two years were to help HERA reach its high luminosity goals, assist the construction of the VUV-FEL formerly known as TTF II and attend the preparation work of the planned light sources PETRA III and XFEL. Together with the existing DORIS ring there will be a unique ensemble of synchrotron light sources on the DESY site (Fig. 1).

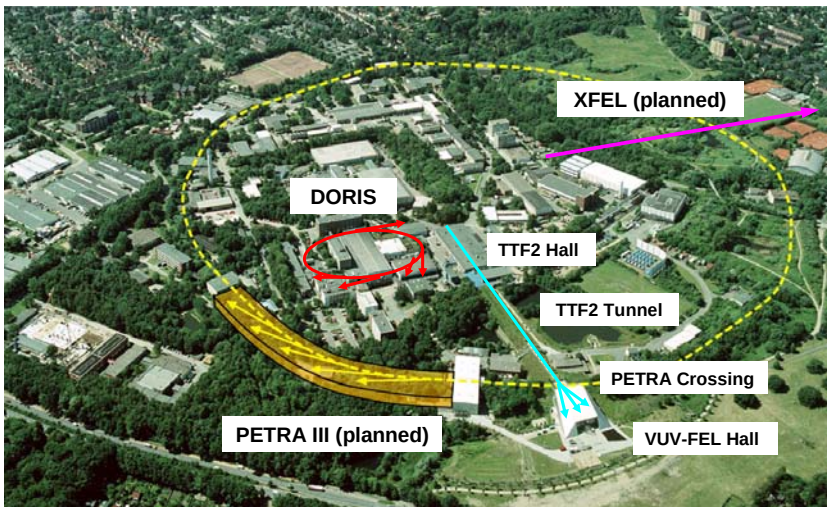

Fig. 1 Light Sources at DESY

Nevertheless the TESLA project is postponed until an international agreement on technology and site, research activities concerning the extraordinary recommendations in tolerance are going on. Methods and prototypes of new alignment techniques are currently being tested in existing accelerators and hopefully will improve alignment work for smaller accelerators too.

2. RECENT ACCELERATORS

2.1. HERA

Most of the HERA ring lies outside the DESY site. So some impacts of civil construction activities which were not under DESY control could not be avoided. A typical example is the construction of the “Color Line Arena”, a multipurpose hall situated directly on top of the HERA tunnel (Fig.2, Fig.3). Vertical movements during construction occurred in both directions, so the HERA machines had to be monitored during the whole construction phase. First during the excavation the machines were going up roughly 7mm. To make running of the machine easier the electron machine was lowered half of this amount. The proton machine was not touched because of the delicate vacuum connectors. After construction work was finished the situation was as shown in the picture (Fig. 4). The proton machine nearly reaches its original state but the electron machine had a sag of 3.5 mm on a length of 200 metres which has to be realigned again.

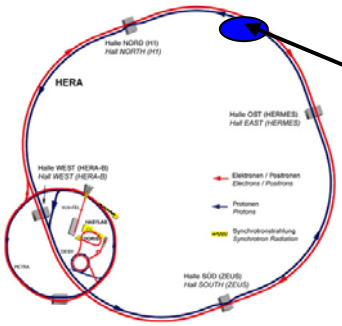

Fig. 2 HERA Ring

Fig. 3 Color Line Arena

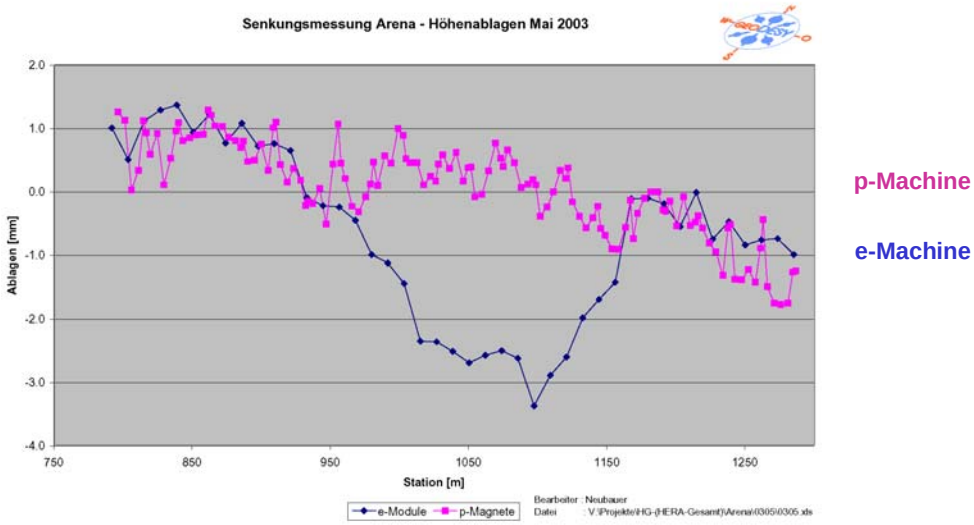

Fig. 4 Height Deviations after Completion of Construction Work

2.2. Research Activities at HERA

2.2.1. HLS Test

To fulfil the high alignment requirements for a linear collider at the TeV range a free surface hydrostatic levelling system with in situ calibration has been developed in cooperation with the Bauhaus-University Weimar. First tests of this system have taken place in a water adit near Katzhütte in the Thuringian Forest [1]. For a test under real accelerator conditions with ground motion and vibrations two of these systems were mounted in the HERA tunnel (Fig.5). One at the highest place under a road with heavy traffic the other at the lowest part under the groundwater level in a quiet place. No significant movements have been seen yet (Fig. 6).

Fig. 5 HLS Sensor in HERA

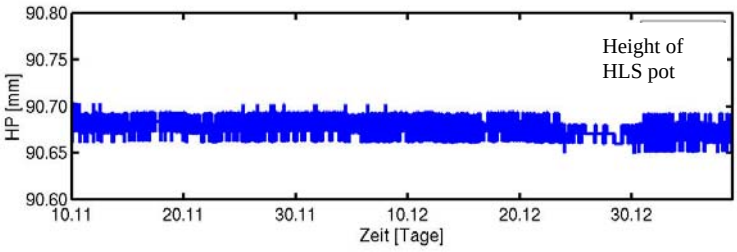

Fig. 6 First HLS Results at HERA

2.2.2. Floor ceiling measurements

During the TESLA planning process it was already decided to mount the superconducting modules at the tunnel ceiling in order to get more space on the tunnel floor for electric devices like klystrons. Some calculations by a civil engineering bureau indicate that the influence of changes of the groundwater level on the tunnel ceiling is bigger than that on the tunnel floor. In order to verify these theoretical effects three invar rods with electronic gauges were mounted in the HERA tunnel near a ground water measurement station (Fig. 7). This is nearly the same place where one of the HLS systems is mounted. First results show no correlation between the groundwater level and the tunnel diameter but between the temperature and the tunnel diameter (Fig.8).

Fig. 7 Invar Rod in HERA

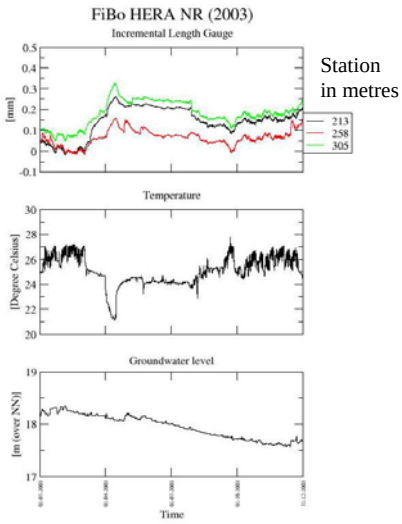

Fig. 8 First Results

2.3. VUV-FEL

2.3.1. Planning and civil construction

In November 2002 the TTF1 linac was switched off. The goals of this project were the test of the TESLA superconducting cavities and a proof of principle of the SASE undulator system as a free electron laser. As a next step it was decided to improve the machine towards a user facility reaching the vacuum ultraviolet range. So VUV-FEL was chosen as the new name of this facility. The machine has to be extended to 260m [2] and to reach the new experimental hall on a former parking ground outside the site used by DESY so far the PETRA tunnel has to be crossed. In order to test the installation work in the TESLA tunnel planned at the same time a round tunnel with the same diameter as the TESLA (and the HERA) tunnel was constructed (Fig. 9). The other parts of the building complex are the existing former assembly hall III with a tunnel made of shielding blocks in it, the PETRA crossing (Fig. 10) made by micro tunnelling and the experimental hall (Fig. 11). The geodetic connection between these independent buildings has to be done by an extension of the surface network of DESY.

Fig. 9 Tunnel without Components

Fig. 10 Crossing the PETRA Tunnel

Fig. 11 FEL Experimental Hall

2.3.2. Reference System

In the new part of the tunnel there is no possibility for fix standpoints on the floor. For this reason all reference marks have to be mounted at the tunnel wall. Two different types of reference marks are used: The Taylor-Hobson system (Fig. 12) which is used in nearly all existing accelerators so far and the PLX system (Fig. 13) coming up with the laser tracker. For the PLX system are not only available corner cube mirrors but also visual targets so we can use this system with classic instruments like Leica TC or TDA too. The targets are mounted at different heights on both sides of the tunnel for reason of a more stable geodetic network (Fig. 14).

Fig. 12 Taylor Hobson Sphere

Fig. 13 PLX Sphere

There exist two types of carriages for different instruments which are moved along a rail mounted on the tunnel wall. There is one for the laser tracker (Fig. 17) with an additional wagon for the electronics and one for optical instruments (Fig. 18) which has to be bigger because one has to place the head behind the telescope.

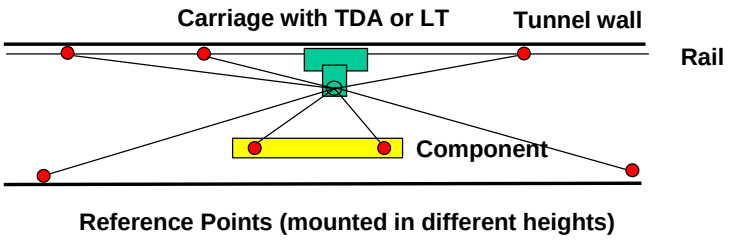

Fig. 14 TTF Measurement Scheme

In the old (TTF-Hall) part of the machine the reference system is made of removable HERA pillars mounted on the floor (Fig. 15). At the end of the tunnel near the PETRA crossing fix consoles are mounted at the (here rectangular) tunnel walls (Fig. 16). The connection to the experimental hall is done by a sight tube some 300mm in diameter.

Fig. 15 Measurement in the Former TTF1 Part

Fig. 16 Measurement in the New TTF2 Part

2.3.3. Alignment of the machine

After complete disassembling the TTF1 machine the shielding between the old and the new part of the tunnel was removed and it was possible to measure the complete geodetic network. Based on this coordinates the whole machine could be aligned for the first time. After connecting the vacuum tubes the machine has been measured and aligned again.

Fig. 17 Alignment with Laser Tracker

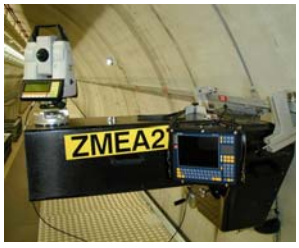

Fig. 18 Stake Out and Alignment with TDA (TTF2 Tunnel)

Fig. 19 Components (TTF1Tunnel)

Fig. 20 Aligning Components (TTF2 Tunnel)

2.3.4. Wire measurement system

The SASE undulator is made of six undulator sections with two quadrupoles between each other and one at the beginning and the end of the complete undulator (Fig. 23). These quadrupoles are mounted on granite plates (Fig 21, Fig. 24). Because of the high accuracy required (<0.01mm) a stretched wire is used as reference. The initial alignment was done by a wire finder developed by SLAC for the VISA project [3][4]. The reference sockets (Fig. 22) have been redesigned in order to allow fiducialisation with respect to the quadrupoles by laser tracker measurements. The first height alignment was done with a levelling instrument. During machine operation the movements of the granite plates are monitored by Fogale wire position sensors. Active steering of the plates is possible.

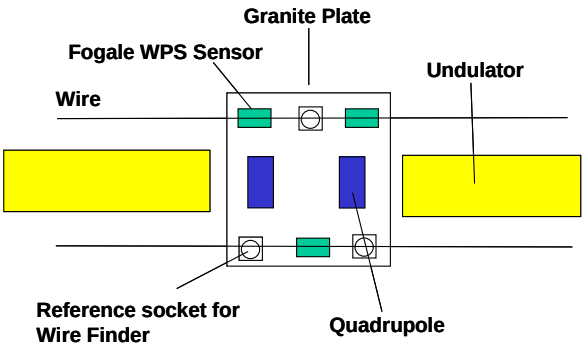

Fig. 21 Concept of the TTF Wire Measurement System

Fig. 22 Reference Socket and Wire Finder

Fig. 23 Undulator Section with Quadrupoles

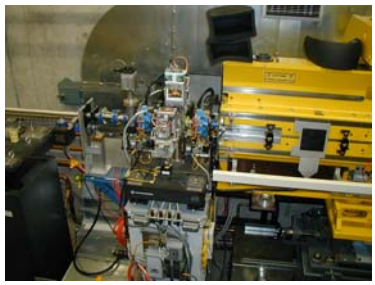

Fig. 24 Granite Plate with Quadrupoles

Fig. 25 Granite Plate with Fogale System

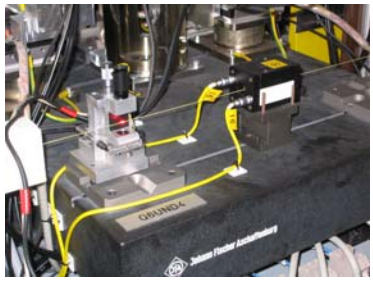

Fig. 26 Wire Finder and Fogale Sensor

3. FUTURE PROJECTS

3.1. PETRA III

3.1.1. Overall concept

In 2002 the design phase for an upgrade of the PETRA ring towards a 3rd generation synchrotron radiation source started. Today PETRA II is mainly used as a pre-accelerator for HERA so as a consequence with the beginning of construction in 2007 HERA will do its last run. One section of the PETRA ring (1/8) will get completely new components while the rest of the ring gets some improvements like damping wigglers and separate sockets for the sextupoles. Besides this an ESRF-type experimental hall will be constructed with 11 new photon beamlines (Fig. 27). Every wiggler section is followed by 12 magnets mounted on 4 girders each with 3 magnets (Fig. 28, Fig.29).

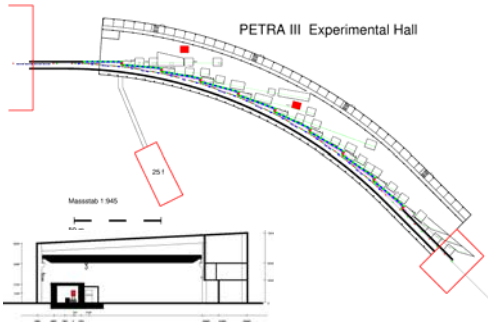

Fig. 27 PETRA III Overview

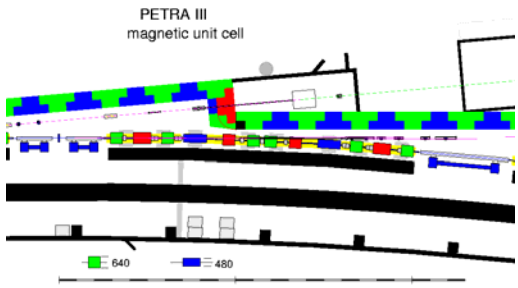

Fig. 28 Machine Layout

3.1.2. Girder test

The magnets on the girders shall be pre-aligned with a tolerance of ±50µm with respect to the girder. The girders itself have an alignment tolerance of ±100µm [5].

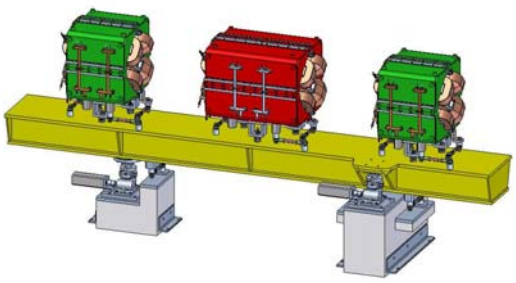

Fig. 29 Girder Concept

Fig. 30 Girder Test Assembly

In order to verify the alignment principle a test assembly was set up with old PETRA magnets (Fig. 30), aligned with a laser tracker, then transported to a different location and checked again with the laser tracker. The result was that without special fixation the magnets move by ±100µm and with fixation by ±50µm. So some improvements have to be done in order to reach the recommended accuracy.

3.1.3. Geodetic tasks

Before assembling the new PETRA III machine the PETRA II ring will be completely dismantled. This is necessary because all old magnets will get new coils. So for our work it is like a completely new machine. Following tasks are lying ahead:

- Re-measure the existing overground reference system by GPS and transfer is coordinates by plumbing to the existing bolts in the tunnel floor (Fig. 31)

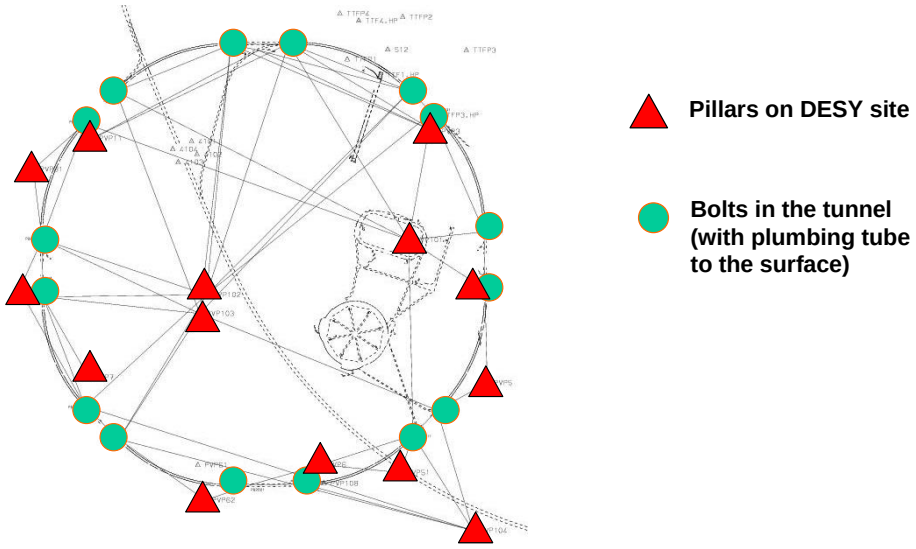

Fig. 31 Existing PETRA Reference System

- Enhance the reference frame in the tunnel by new monuments in the floor and at the tunnel wall in order to use modern alignment tools like laser trackers.
- Fiducialise all new and existing magnets by new fix reference marks (ca. 750).
- Stake out positions for new magnet sockets
- Align all old and new components (ca. 800).

Construction work will begin in 2007 and the operation of the facility will begin 2009. The total costs are 192 M€ in year 2003 prices.

3.2. XFEL

3.2.1. Political decision

In February 2003 the German ministry of education and research decided on future big scientific facilities [6]. The DESY related part of this decision says:

- Germany is willing to fund 50% of the XFEL project which formerly has been a part of TESLA [7].
- There will be no decision of a site for TESLA until an international committee has made its recommendations on technology.

In August 2004 the International Technology Recommendation Panel (ITRP) recommended the superconducting rf technology as technology for a future linear collider [8].

3.2.2. Site decision and overall layout

Under these circumstances for the FEL the Ellerhoop site as described in [9] is no longer the best solution. So after investigating many possible sites the DESY directorate decided in October 2003 to propose the “Schenefeld” site for the European XFEL project. The linac will start on the existing DESY site and the photon beamlines will end in an experimental hall in an open country area near Schenefeld big enough for future extension plans (Fig. 32). Some other advantages are:

- The injector on the DESY site allows direct connection to the DESY infrastructure
- The undulators are located in an area with relatively low vibration
- Small interference with DESY experimental operations and present plans for the TESLA (now ILC) route.

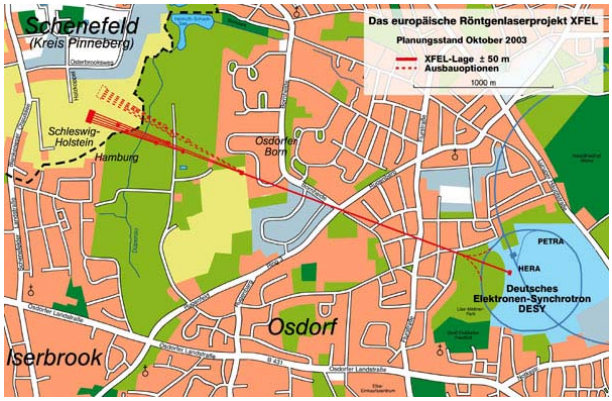

Fig. 32 XFEL Basic Layout

For the gradient the constraints were to build the undulator sections and the photon beamlines in a straight line and to have no inclination of the experiments with respect to the equipotential surface. Because of the cryogenic operation the distances of the linac to the equipotential surface shall be minimized. The solution was to have two straight lines as shown in Fig. 33. The disadvantage of this layout is to have a relatively deep shaft at the beginning of the linac.

Approx. 30m deep

Fig. 33 XFEL Gradient

For the tunnel layout a solution with a hanging machine was chosen because the klystrons and other devices should be easily to maintain (Fig. 34).

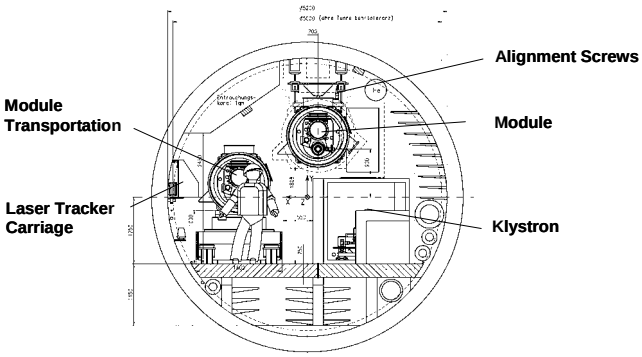

Fig. 34 XFEL Tunnel Layout

3.2.3. The geodetic approach

The required accuracy for aligning the linac components is much less then that foreseen for TESLA. It will be ±0.3mm with respect to 150m length. So a TTF like concept with laser tracker measurements seems suitable for the tunnel sections. Connecting the tunnels in the separation shafts will be done by a laser system in a vacuum pipe because of the expected temperature gradients in these areas. As an alternative a wire measurement system combined with a HLS is taken into account. Possible high temperature gradients in the undulator sections and the requirement of aligning the monochromators by ±0.5mm with respect to the undulators some 1000m away can make it necessary to have a complete laser system in each distribution tunnel.

References

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