Installation of the Optical Replica Synthesizer (ORS) at FLASH

Who and What ?

G. Angelova, V. Ziemann- Task: Modulator and radiator undulators, participating in the Theoretical simulations with Genesis

P. van der Meulen, N. Javahiraly, M. Larsson, Task: The Seed laser, and the Diagnostic devices in the tunnel downstream of the modulator undulator

H. Schlarb, M. Yurkov, E. Schneidmiller, E. Saldin, Task: Responsible for the dipole magnets of the chicane, Support structures for all magnets and general construction work such as the building of the laser laboratory where the seed laser will be placed as well as. Theoretical simulations

S. Khan, Joern Bodewadt, Task: Design and construction of the laser transport line from the seed laser to the injection of the seed pulse the accelerator vacuum vessel at the vacuum window at the 'dog leg' of FLASH

Atoosa Meseck, Task: Theoretical simulations with MAD and Genesis

Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Nuclear Instruments and Methods in Physics Research A 539 (2005) 499–526
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

A simple method for the determination of the structure of ultrashort relativistic electron bunches

E.L. Saldin, E.A. Schneidmiller, M.V. Yurkov*

Deutsches Elektronen-Synchrotron (DESY), Notkestrasse 85, Hamburg 22607, Germany

Received 3 August 2004; received in revised form 2 November 2004; accepted 2 November 2004
Available online 2 December 2004

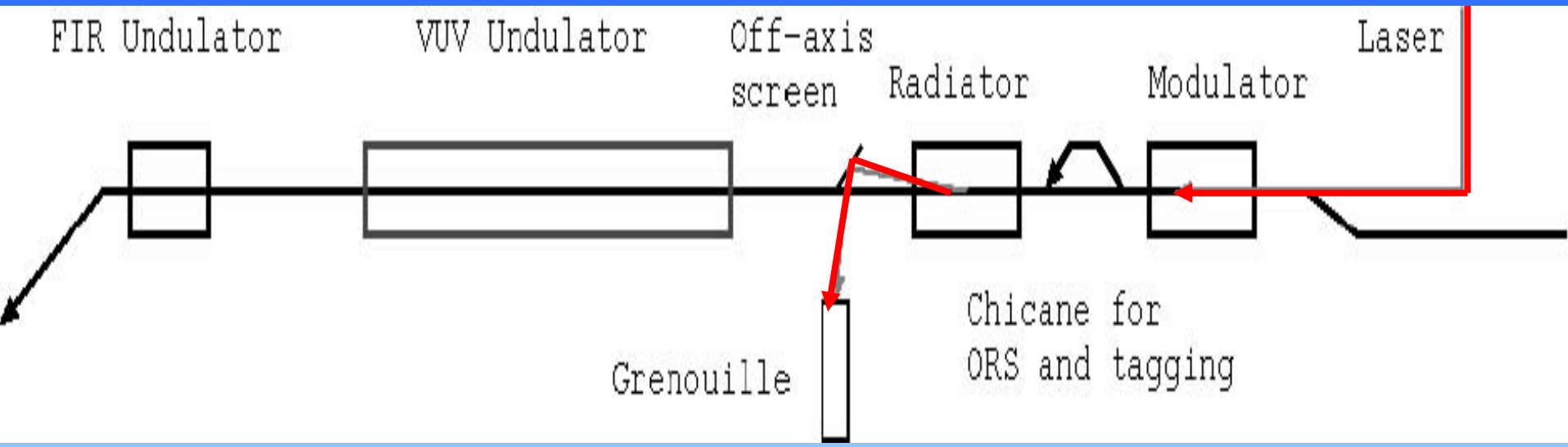
Abstract

In this paper we propose a new method for measurements of the longitudinal profile of 100 fs electron bunches for X-ray Free Electron Lasers (XFELs). The method is simply the combination of two well-known techniques, which where not previously combined to our knowledge. We use seed 10-ps 1047 nm quantum laser to produce exact optical replica of ultrafast electron bunches. The replica is generated in an apparatus which consists of an input undulator (energy modulator), and the short output undulator (radiator) separated by a dispersion section. The radiation in the output undulator is excited by the electron bunch modulated at the optical wavelength and rapidly reaches 100 MW-level peak power. We then use the now-standard method of ultrashort laser pulse-shape measurement, a tandem combination of autocorrelator and spectrum (FROG—frequency resolved optical gating). The FROG trace of the optical replica of electron bunch gives accurate and rapid electron bunch shape measurements in a way similar to a femtosecond oscilloscope. Real-time single-shot measurements of the electron bunch structure could provide significant information about physical mechanisms responsible for generation ultrashort electron bunches in bunch compressors. The big advantage of proposed technique is that it can be used to determine the slice energy spread and emittance in multishot measurements. It is possible to measure bunch structure completely, that is to measure current, energy spread and transverse emittance as a function of time. We illustrate with numerical examples the potential of the proposed method for electron beam diagnostics at the European XFEL.

PACS: 41.60.Cr; 42.55.Vc; 41.75.Ht; 41.85.Ew

Keywords: Free electron lasers; X-ray lasers; Relativistic electron beams

Why?

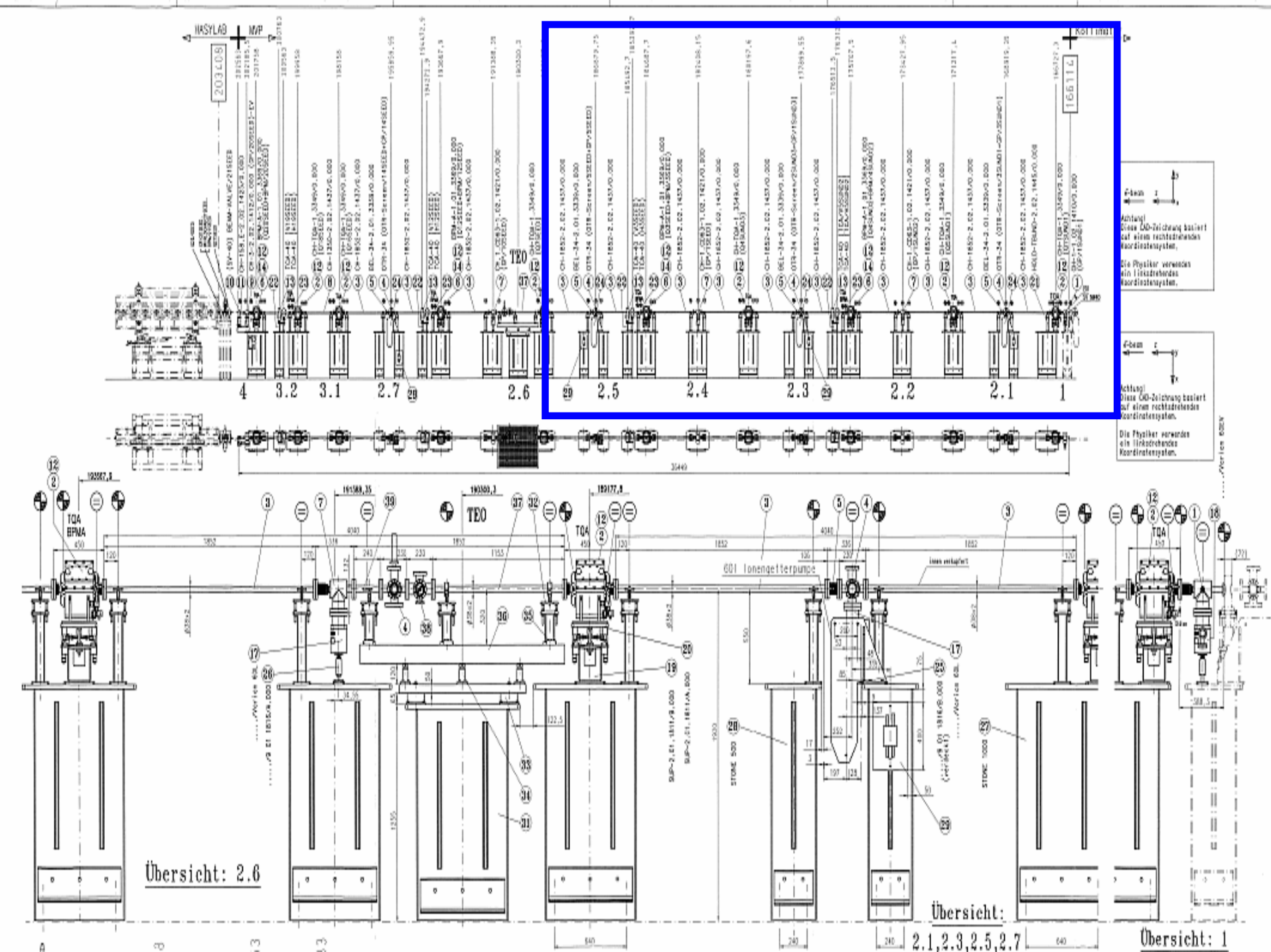


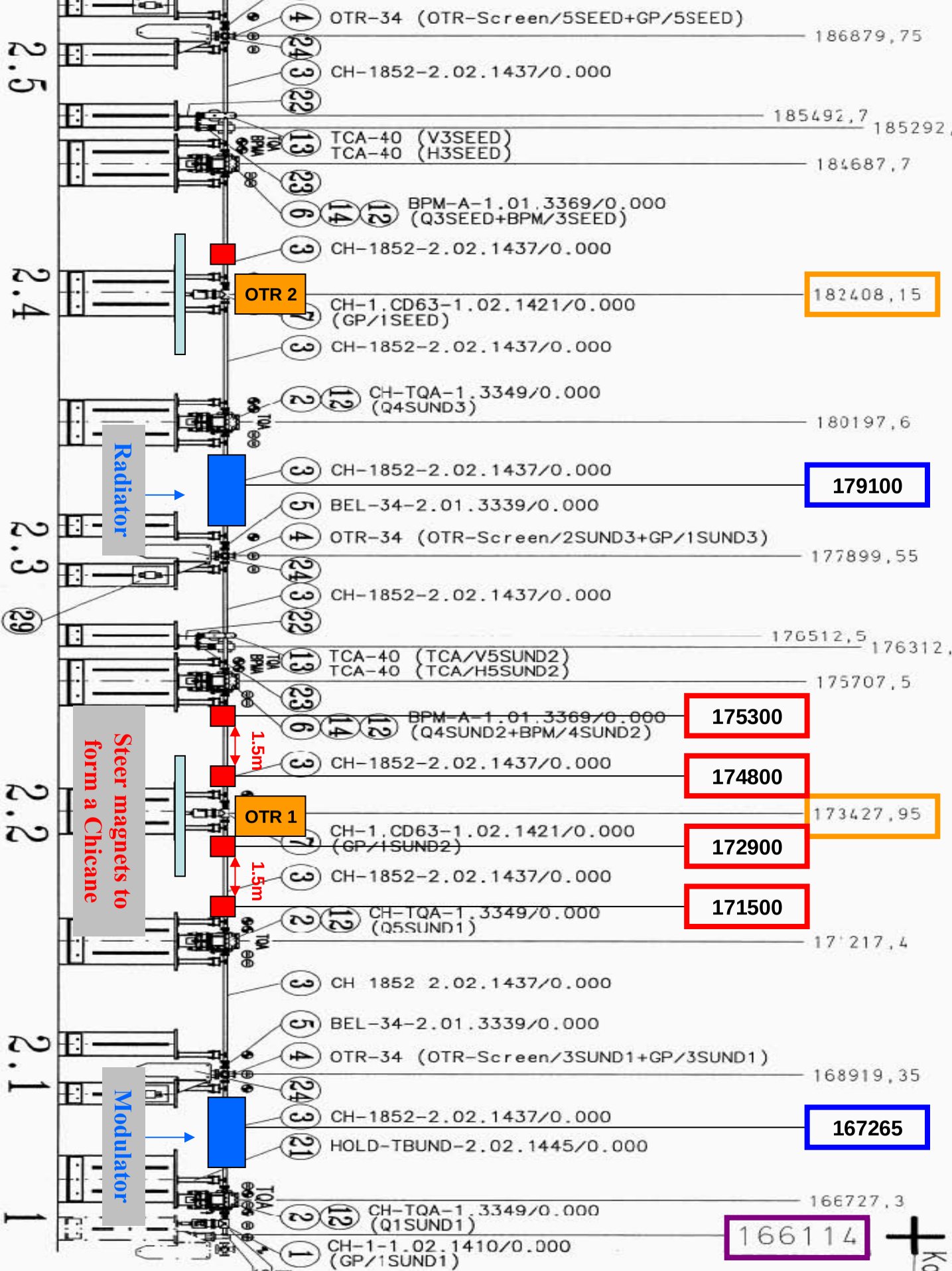
• Measure the longitudinal bunch profile of the femtosecond long electron bunches (Saldin, Schneidmiller, Yurkov: NIM A 539 (2005) 499.)

• Energy modulation via (v.E) coupling

• Longitudinal density modulation in chicane

• Cause coherent emission of light pulse in radiator that mimics the longitudinal shape of the electron bunch (optical replica).


HASYLAB
MVP
KOTTMAT
TEO
TQA
BPM4
601 Ionengetterpumpe
STOKE 500
STOKE 1000
Übersicht: 2.6
Übersicht:
2.1,2.3,2.5,2.7
Übersicht: 1


OTR-34 (OTR-Screen/5SEED+GP/5SEED)
186879,75
CH-1852-2.02.1437/0.000
185492,7
185292,
TCA-40 (V3SEED)
TCA-40 (H3SEED)
184687,7
BPM-A-1.01.3369/0.000
(Q3SEED+BPM/3SEED)
CH-1852-2.02.1437/0.000
OTR 2
182408,15
CH-1.CD63-1.02.1421/0.000
(GP/1SEED)
CH-1852-2.02.1437/0.000
CH-TQA-1.3349/0.000
(Q4SUND3)
180197,6
Radiator
CH-1852-2.02.1437/0.000
179100
BEL-34-2.01.3339/0.000
OTR-34 (OTR-Screen/2SUND3+GP/1SUND3)
177899,55
CH-1852-2.02.1437/0.000
176512,5
176312,
TCA-40 (TCA/V5SUND2)
TCA-40 (TCA/H5SUND2)
175707,5
BPM-A-1.01.3369/0.000
(Q4SUND2+BPM/4SUND2)
175300
1.5m
CH-1852-2.02.1437/0.000
174800
Steer magnets to form a Chicane
OTR 1
173427,95
CH-1.CD63-1.02.1421/0.000
(GP/1SUND2)
172900
1.5m
CH-1852-2.02.1437/0.000
171500
CH-TQA-1.3349/0.000
(Q5SUND1)
17'217,4
CH 1852 2.02.1437/0.000
BEL-34-2.01.3339/0.000
OTR-34 (OTR-Screen/3SUND1+GP/3SUND1)
168919,35
Modulator
CH-1852-2.02.1437/0.000
167265
HOLD-TBUND-2.02.1445/0.000
166727,3
CH-TQA-1.3349/0.000
(Q1SUND1)
166114
CH-1-1.02.1410/0.000
(GP/1SUND1)
2.5
2.4
2.3
2.2
2.1
1

Component List

- Two undulators and power supplies
- Chicane
- Optical stations I and II
- Laser Transfer Line

In the Tunnel

- Seed Laser, Hutch

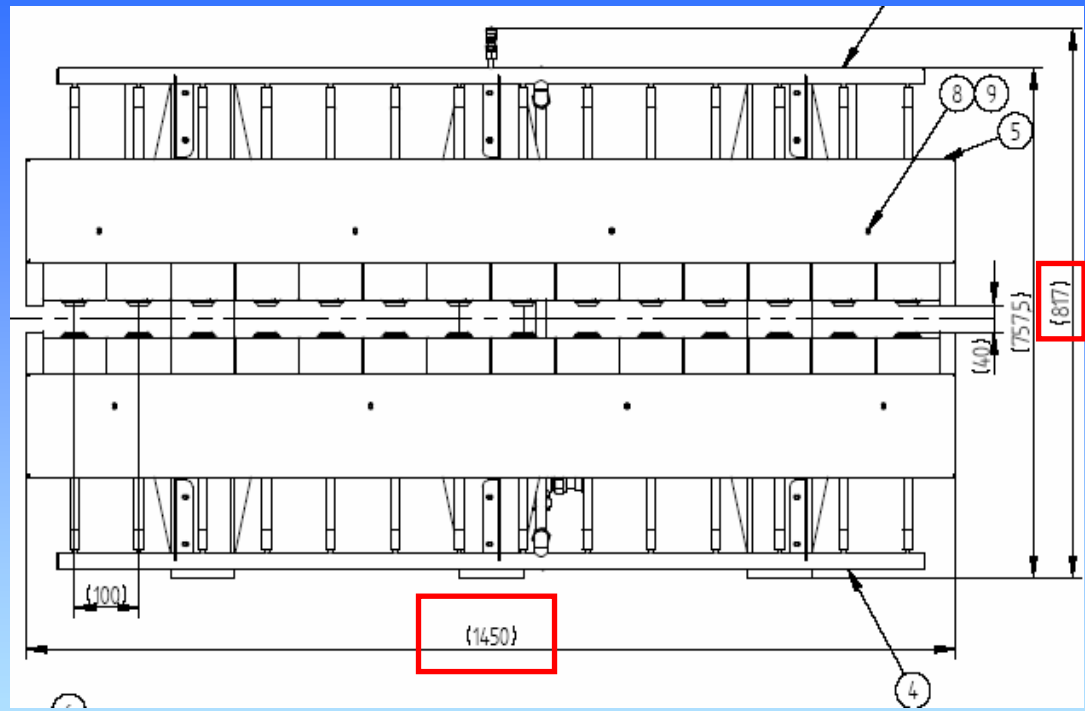
Out of the Tunnel

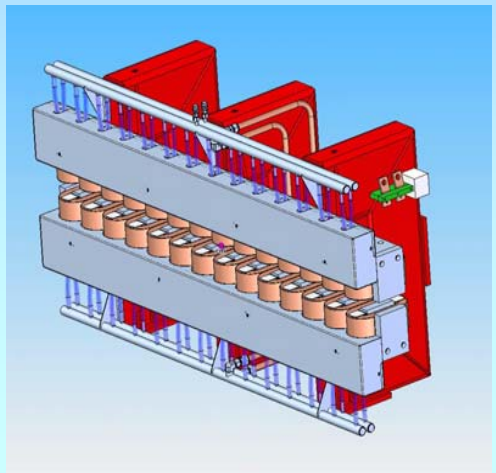
- Person-power
- Good-will

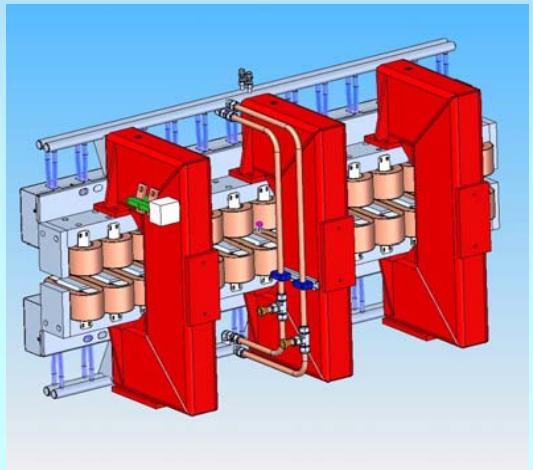
Undulators

Delivery –first week of March 2007

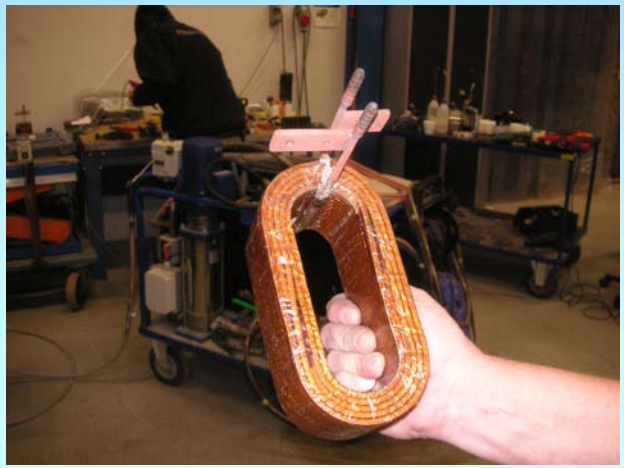
Parameter	Value
Type	Electromagnetic
Number of undulator	1-2 (vert + horiz)
Gap	40 mm
Period length	200 mm
Pole length/width	50/100 mm
Number of full periods	5
Number of poles	14
Nominal field	0.31 T
Nominal K-Value	5.7
Maximal field	0.42 T
Maximum K-Value	7.7
Iron yoke length	1400 mm
Overall length incl. coils	< 1500 mm
Ampere-turns per coil	to be decided
Number of turns	to be decided
Maximal current	< 400 A, better < 100 A
Number of basic / end coils	10 main, 4 end coils
Vacuum chamber diameter	35 mm
First field integral	5×10^{-5} Tm
Second field integral	2×10^{-4} Tm^2



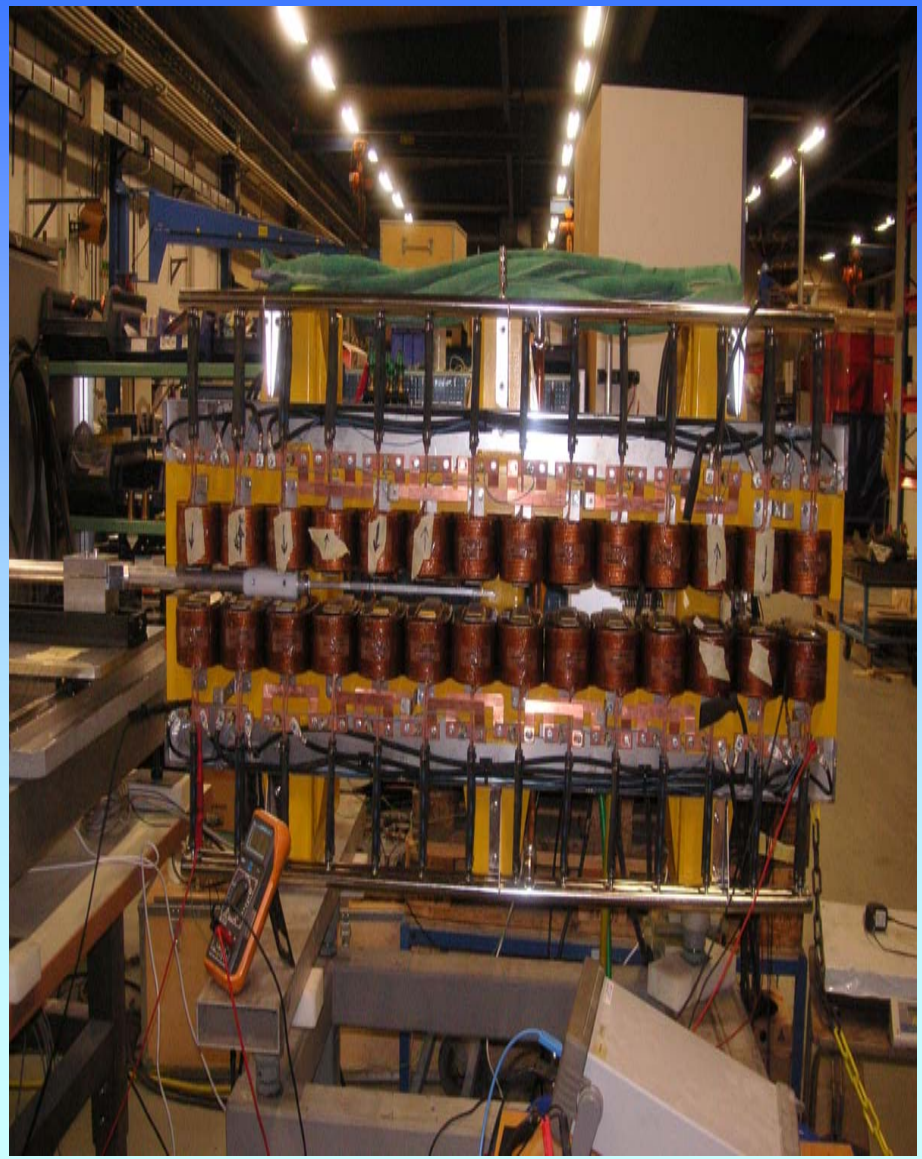




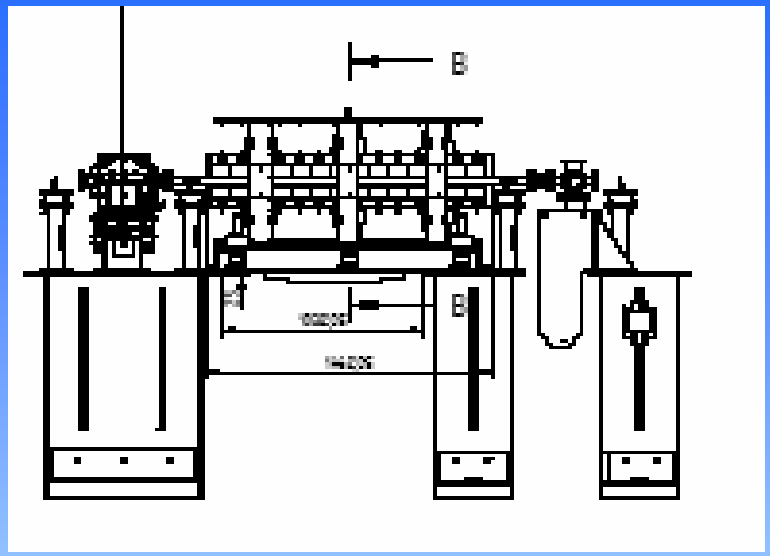
“HILDA”

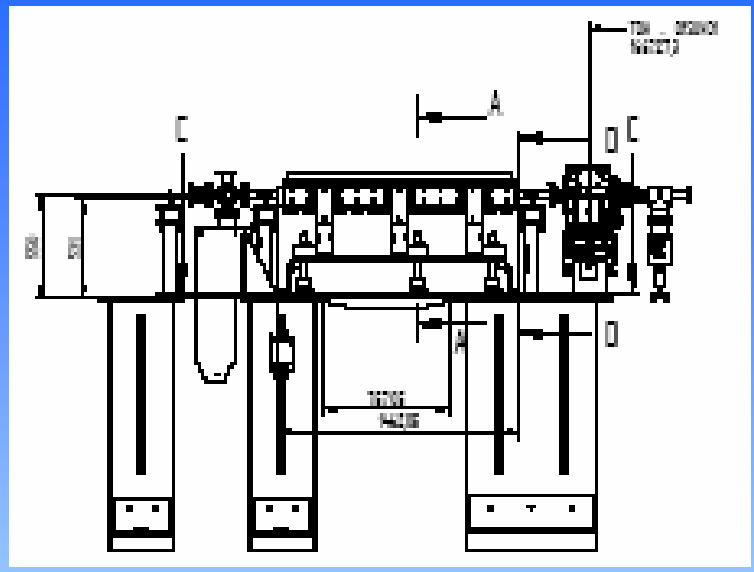


“VERONICA”

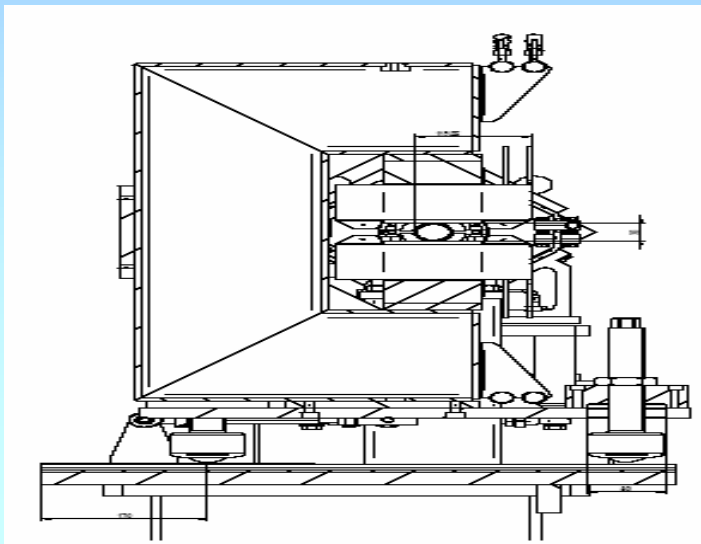


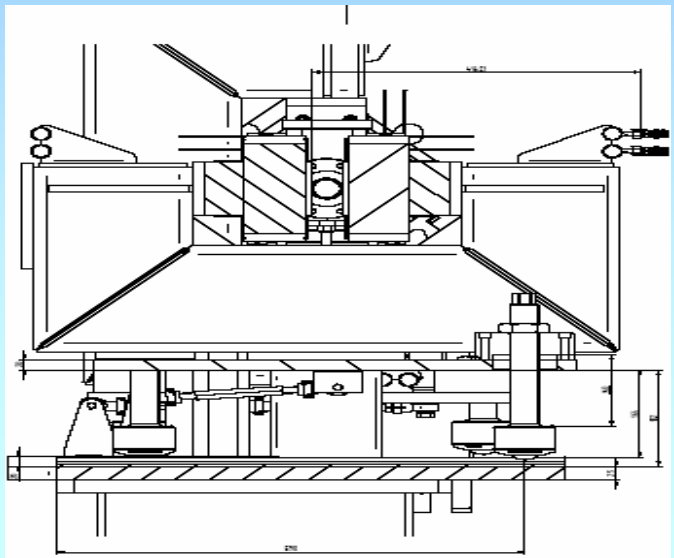
Mechanical Support



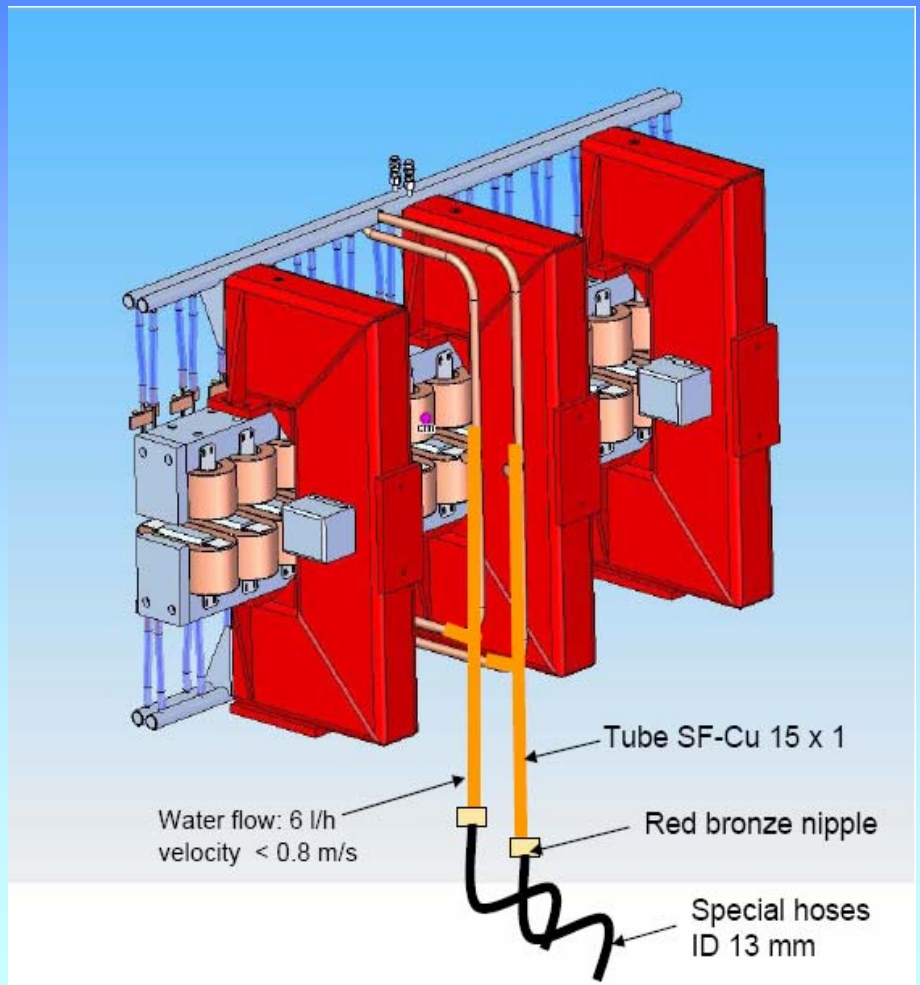


In progress- ready middle of March 2007



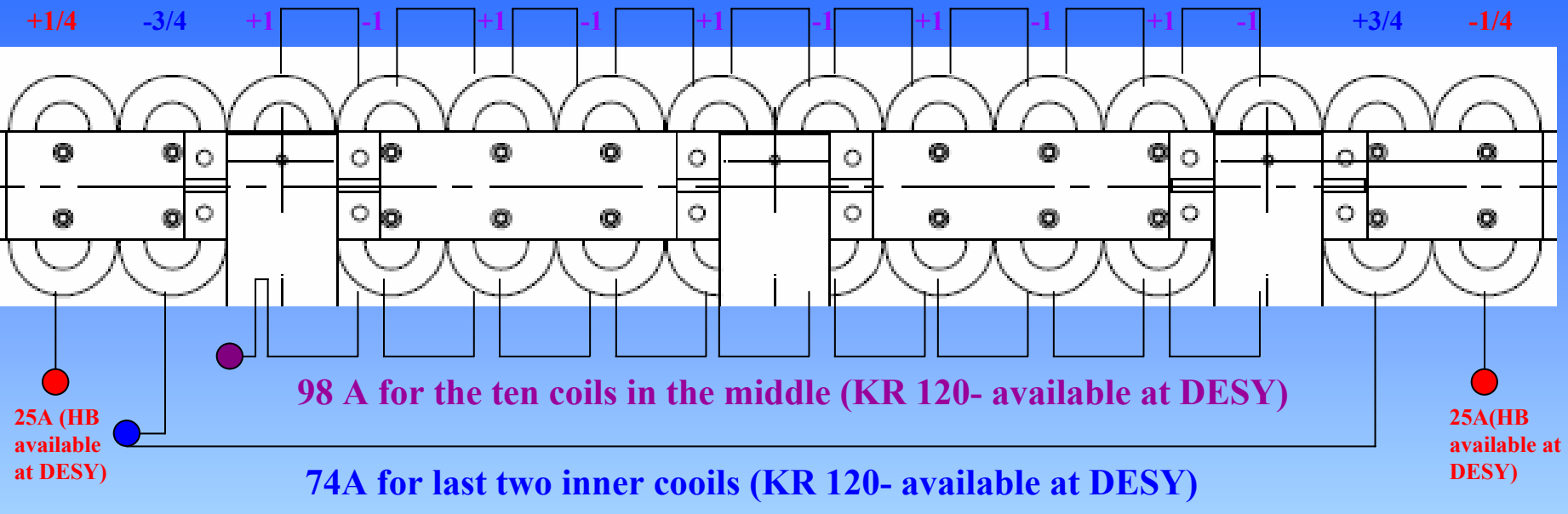


Water cooling of the Undulators



- The coil will be cooled with demineralised water
- The maximum available pressure drop in the magnet is 3.7 bar.
- The inlet temperature of the cooling water is 30°C
- The temperature increase in the undulator should be at least 10 ° C.
- The maximum flow velocity of the water must be below 2 m/s.

Power supply connections for the undulators



Task Name	Duration	Start	Finish	Resource Names
UNDULATORS				
Design and production of Mechanical Support for the Undulators	44 days	Thu 28.12.06	Mon 26.02.07	External Company- Mr. Demker
Sending power supplies from DESY to SCANDITRONIX for field tests of the undulators	6 days	Fri 12.01.07	Fri 19.01.07	Gergana Angelova
Delivering the Undulators from SWEDEN to DESY	5 days	Sun 25.02.07	Thu 01.03.07	SCANDITRONIX, Sweden
Field Tests of the Undulators at DESY	16 days	Mon 19.03.07	Mon 09.04.07	Mr. York Holler
Electronics for thermoswitches for the undulators - 4 sicuits per undulator	0 days	Tue 09.01.07	Tue 09.01.07	Mr. Mattias Steckel
Installation of Radiator Undulator z= 179.1m	2 days	Mon 14.05.07	Tue 15.05.07	Mr.Sparr, Mr. Damker
Installation of Modulation Undulator z= 167.8m	2 days	Thu 17.05.07	Fri 18.05.07	Mr.Sparr, Mr. Damker
Connecting the Water cooling system of the Undulators	3 days	Mon 21.05.07	Wed 23.05.07	Frank-Reinhard Ullrich
Power Supply cabling of the Undulators	2 days	Mon 28.05.07	Tue 29.05.07	Hans-Joerg Eckoldt
Testing the power supply for the Undulators	2 days	Mon 18.06.07	Tue 19.06.07	Hans-Joerg Eckoldt

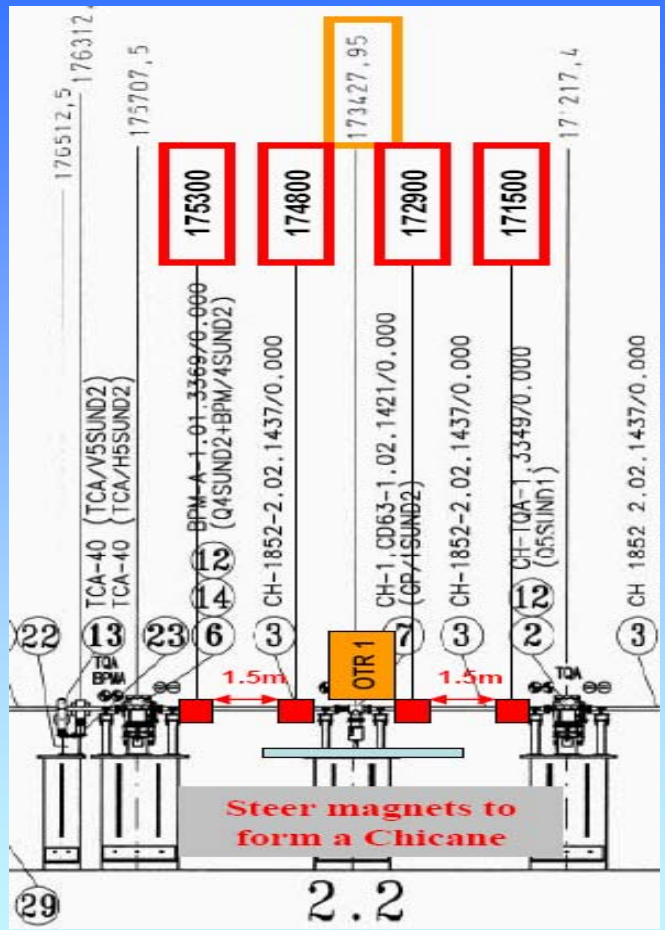
Chicane

Purpose :

•Transform energy- into density modulation at the laser wavelength

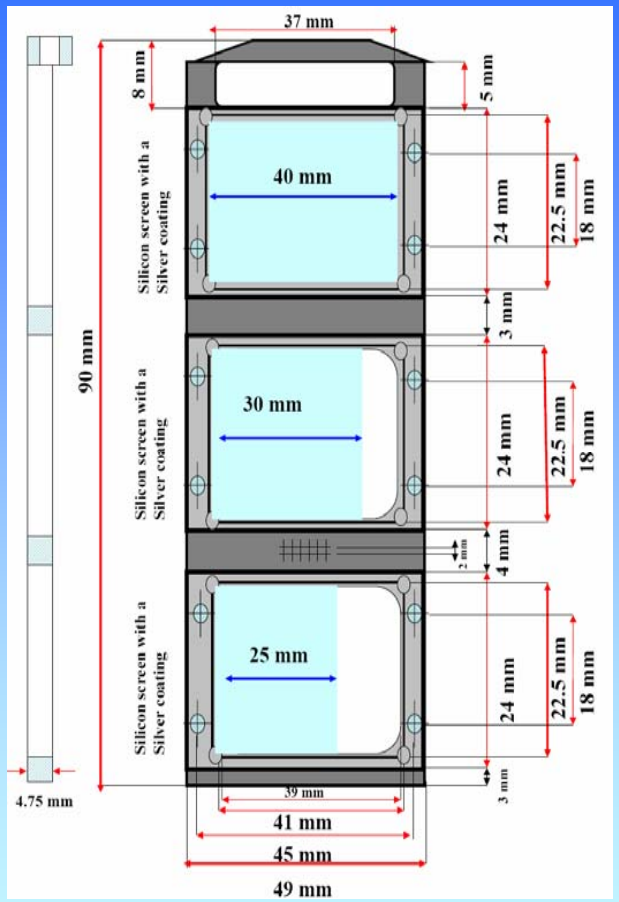
Hardware:

- Steerer magnets at 171.5, 172.9, 174.8, 175.3m
- Girders for 4 steerer (to form a chicane)
- 1.5 m between dipoles
- Power supplies



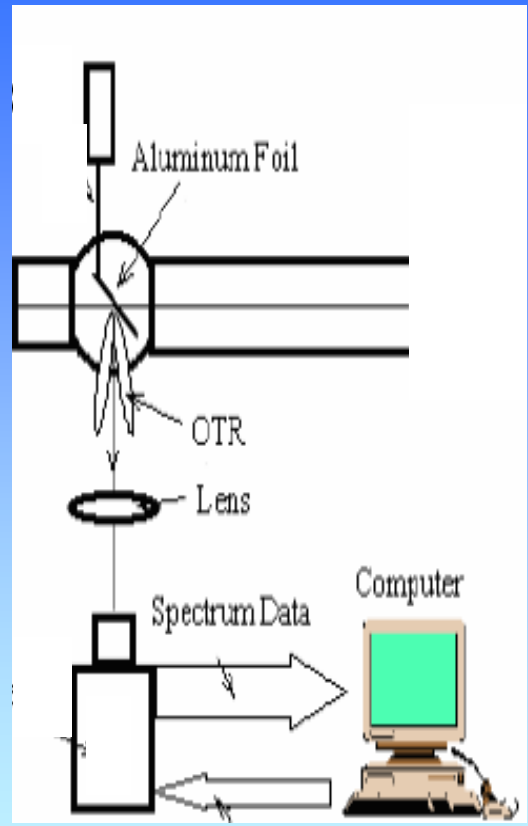
Instalation of HV correctors on the optical table I and II	2 days	Mon 14.05.07	Tue 15.05.07	Mr. Kai Ludvig
Instalation of two HV correctors at z= 171m and 175m	2 days	Tue 15.05.07	Wed 16.05.07	Mr. Kai Ludvig
Connection of the HV correctors	3 days	Mon 21.05.07	Wed 23.05.07	Mr. Kai Ludvig

2 OTR station



To analyze the beam profile and the OTR distribution we will have:

- OTR chambers + window: CF63, CF16
- OTR mover,cabling, interlock
- OTR frame
- Silicon wafers + Ag coating (extra pair with Al coating)

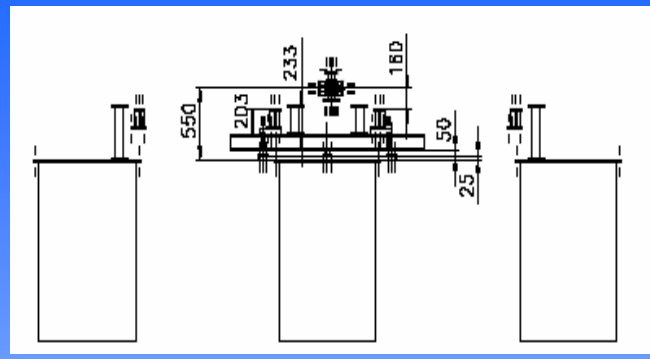


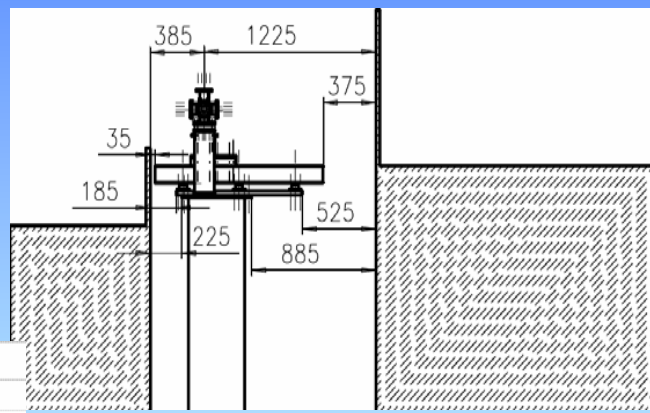
OTR stations				
Delivering of the OTR movers from Italy to DESY	10 days	Tue 09.01.07	Mon 22.01.07	Mr. Remde
Design and building of OTR frame for wafers	50 days	Tue 23.01.07	Fri 30.03.07	?
Ordering of Wavers for the two Optical Stations (installed into the OTR tube)	43 days	Thu 25.01.07	Fri 23.03.07	??????????????
Delivery of view ports CF 63 and CF 16 for OTR station	35 days	Mon 18.12.06	Mon 05.02.07	Mr. van der Meulen
Leak tests of windows	4 days	Tue 06.02.07	Fri 09.02.07	Mr.Remde
Construction of the screen holder metal frame attached to acuator for OTR I and II	45 days	Mon 29.01.07	Fri 30.03.07	External Company-???????
Installation of screens and view ports to OTRs from Seeding section	7 days	Tue 17.04.07	Wed 25.04.07	Mr. Remde

Optical Station I and II

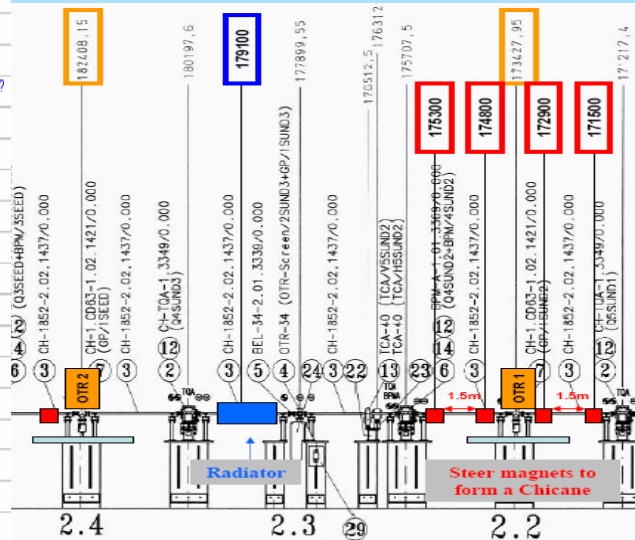
Hardware:

- Optical table *(one per station)*
- Mechanical support for the optical table
- Optical components on the optical table
- OTR chamber *(one per station)* + window, frame, screens, interlock
- Laser shielding

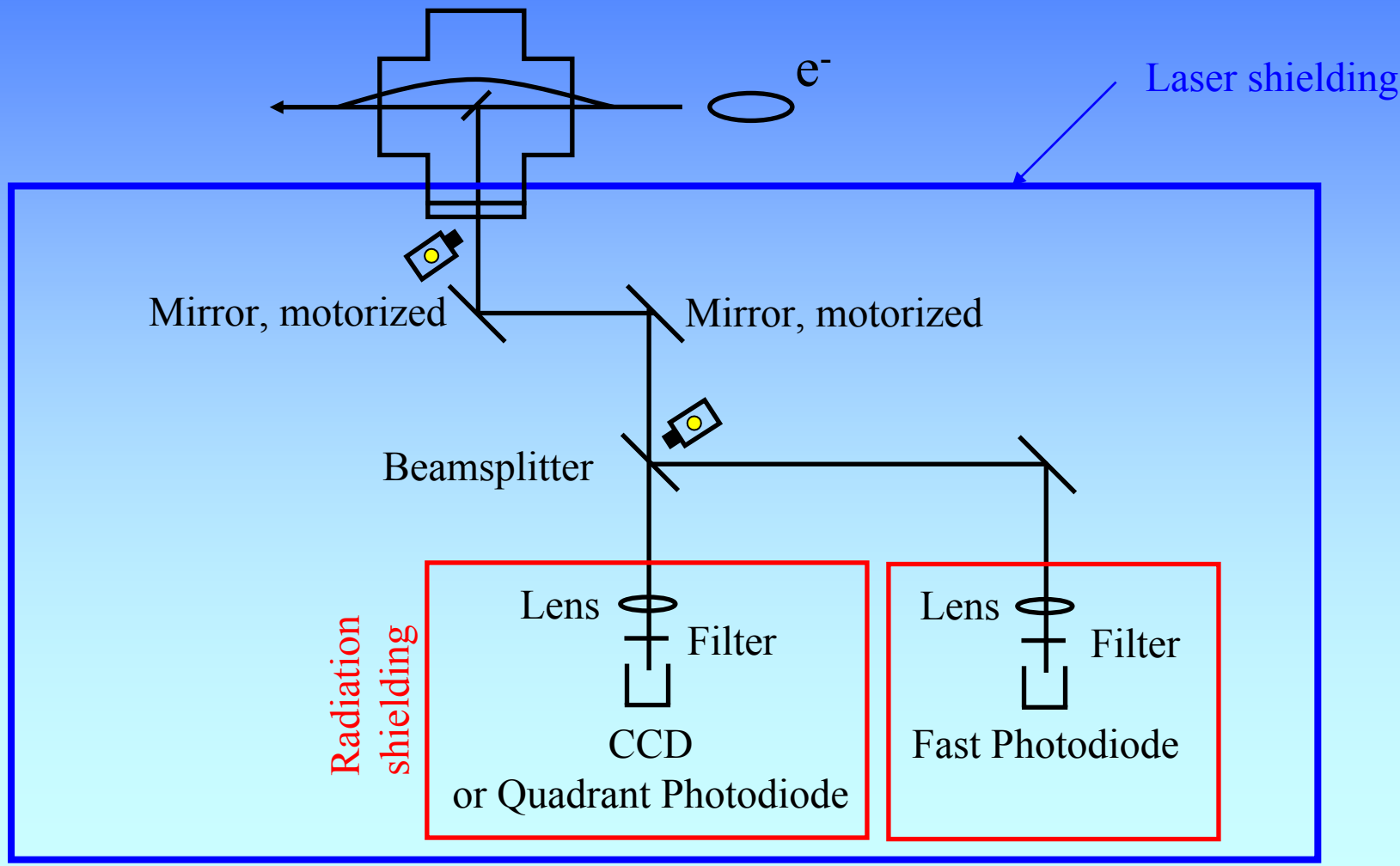




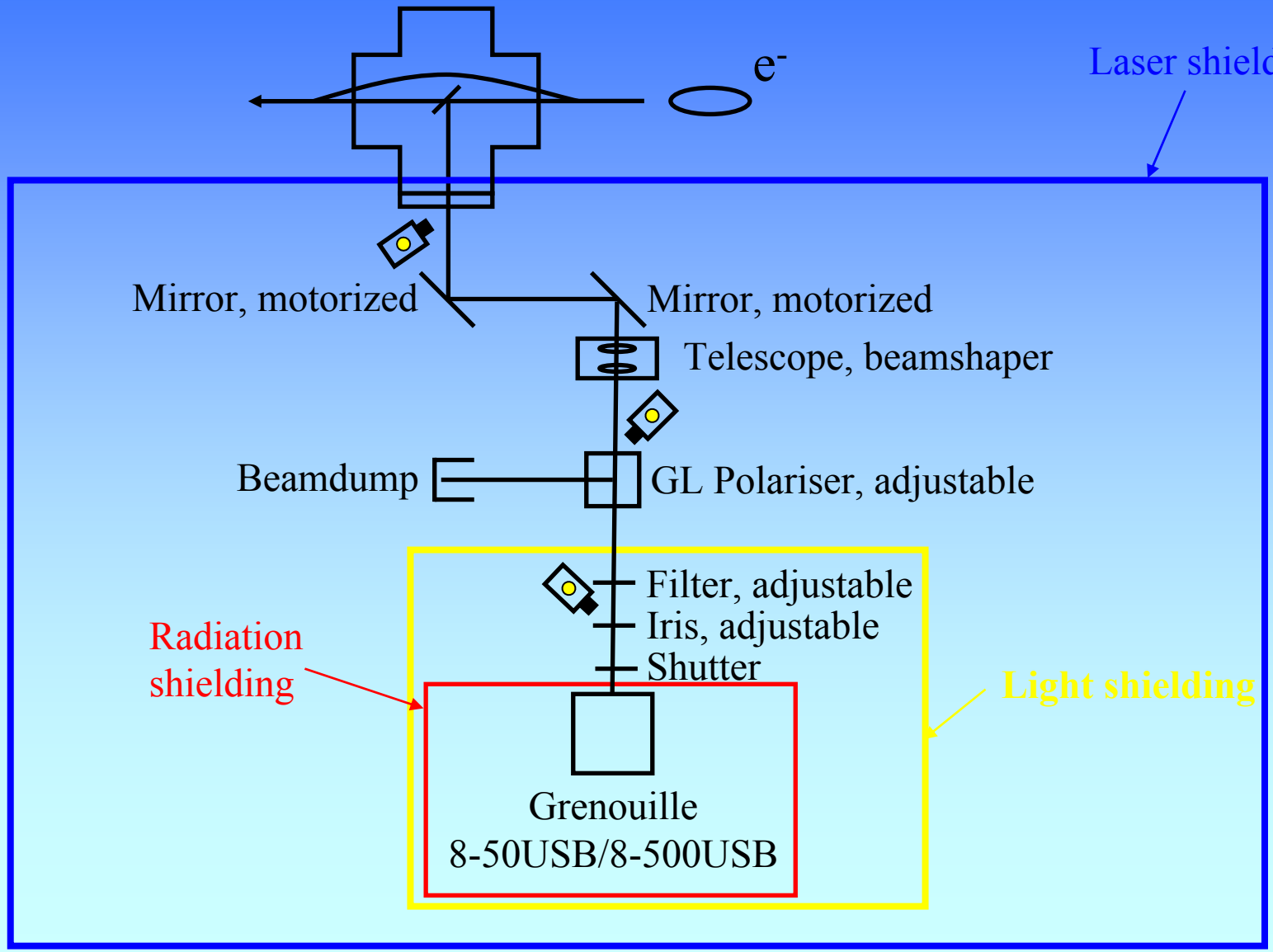
Optical Station I and II				
Delivering of the Optical tables I and II	45 days	Mon 15.01.07	Thu 15.03.07	
Design and building of the Mechanical Support for the optical tables	51 days	Tue 23.01.07	Mon 02.04.07	External Company- ??????
Design and building of the mechanical support for the stereer magnets on the optical table	49 days	Tue 23.01.07	Thu 29.03.07	External company?????
Design and building of the mechanical support for the 2 other stereer magnets on the beam line with out optical table table	64 days	Tue 23.01.07	Thu 19.04.07	External company ?????
Design and building of the mechanical support for the OTR's and vacuum beam pipes	56 days	Tue 23.01.07	Mon 09.04.07	Externbal compoany ?????
Removing of vacuum parts in Seeding section at 173m and 182m (everything should be removed between the quads)	**14 days**	**Tue 27.03.07**	**Fri 13.04.07**	**Mr. Remde**
Instalation of Optical Tables I and II	6 days	Tue 10.04.07	Tue 17.04.07	Mr. Kai Ludvig
Instalation of girders for OTR and vacuum beam pipes	6 days	Wed 18.04.07	Wed 25.04.07	Mr. Kai Ludvig
Instalation of OTR I and II on the beam line	10 days	Mon 30.04.07	Fri 11.05.07	Mr. Kai Ludvig
Leak tests of Optical section I and II	**3 days**	**Fri 11.05.07**	**Tue 15.05.07**	**Mr. Remde**
Instalation of HV correctors on the optical table I and II	2 days	Mon 14.05.07	Tue 15.05.07	Mr. Kai Ludvig
Instalation of two HV correctors at z= 171m and 175m	2 days	Tue 15.05.07	Wed 16.05.07	Mr. Kai Ludvig
Connection of the HV correctors	3 days	Mon 21.05.07	Wed 23.05.07	Mr. Kai Ludvig
Cabling of the OTRs and Commisioning	6 days	Mon 23.04.07	Mon 30.04.07	
Instalation of Safety Tents around Optical Station I and II	11 days	Mon 28.05.07	Mon 11.06.07	Mr. Helmut Remde
Laser interlock Instalation	5 days	Tue 12.06.07	Mon 18.06.07	?
Instalation of laser components and motors	20 days	Mon 04.06.07	Fri 29.06.07	Mr.van der Meulen
Laser interlock tests	**1 day**	**Mon 18.06.07**	**Mon 18.06.07**	**?**
Laser Alignment	9 days	Tue 19.06.07	Fri 29.06.07	Mr.van der Meulen



Optics Station I ORS Chicane @ 173.43m Seed Laser and OTR



Optics Station II **ORS analysis @ 182.41m ORS and coherent OTR**



Laser Hutch- To be or not to be

November 2006

23 February 2007

End of work scheduled for March 2007 !!!

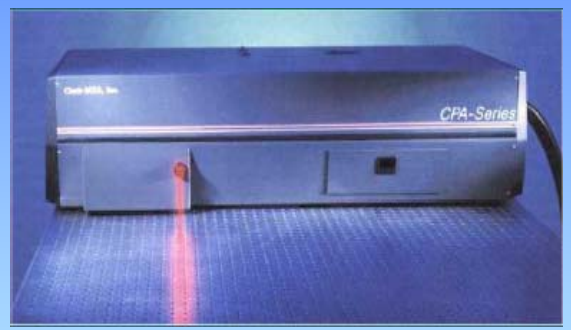
The Enigma

Seed laser

- Peter van der Meulen, N. Javahiraly (SU) and Axel Winter (DESY).
- The Seed laser will be based on **1550nm Er-fiber oscillator** with frequency doubler from DESY

- As an amplifier we will use **CPA2001 Ti: Sapph amplifier from Stockholm University**.

- Wavelength : 800 nm
- Pulse duration : 150 fs
- Pump:YAG Laser operating at 10W of 532 nm



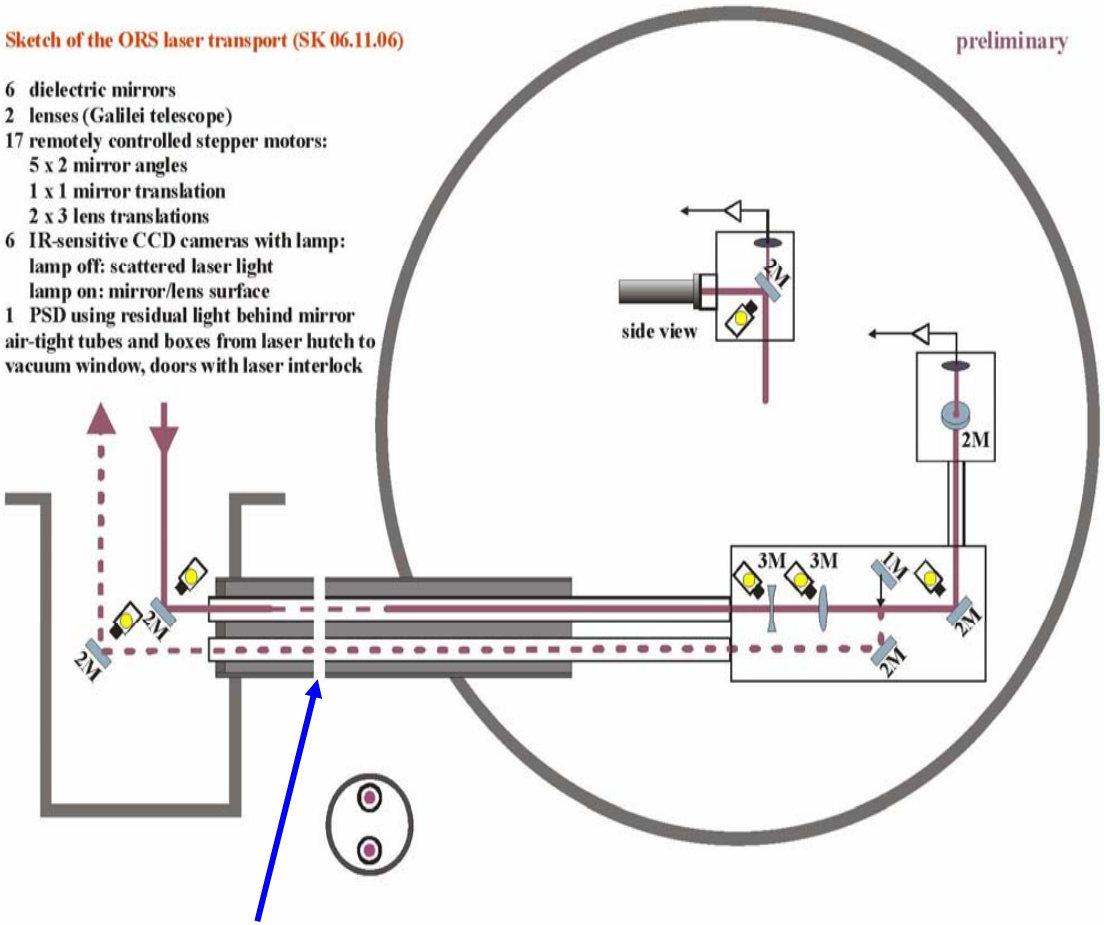
- **Seed Laser** with:

– Length = 2 ps (for stable overlap between the el bunch and laser pulse)
– Energy/pulse=0.25 mJ, Peak field = 1.8 108 V/m
– Width = 0.75 mm (FWHM)

Schedule:

1) Building seed laser and oscillator, shipping the oscillator and testing it- Ready 13/03/07
2) Interfacing the Oscillator- Ready 13/04/07, Transportation of the Seed laser- 20/04.07
3) Work in Laser hutch including Laser tests (optical tables, water connections etc.) – Ready 04/05/07

Laser Transfer Line



Additional tunnel into the beam tunnel will be drilled near the dogleg

1. Ordering of mirror, lenses, cameras, laser spot position control and virtual beam waist

2. Design, ordering parts, assembly and cabling of motorized mirror holders

3. Design, assembly and installation of the telescope

4. Design and installation of tables and transport tubes

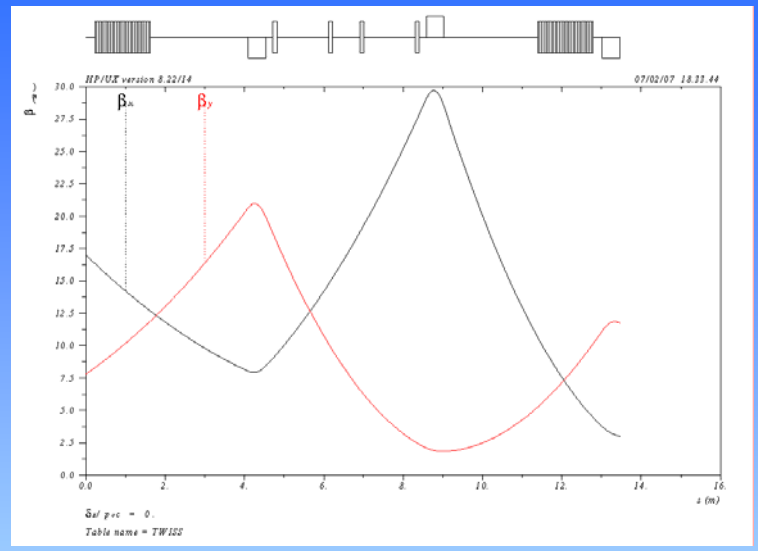
The influence of the el. beam properties on the ORS- output

Simulation:

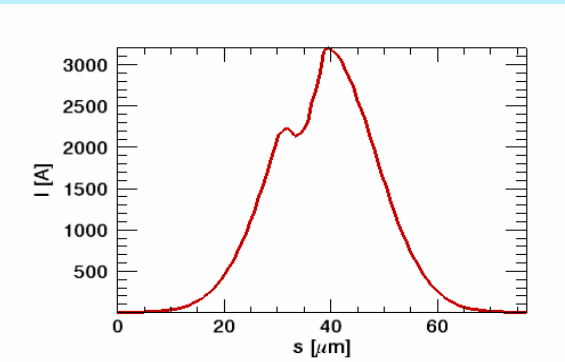
- **Comparison between ideal bunch** (constant parameter along the bunch) **and the more realistic bunch** (variation of the beam properties along the bunch).

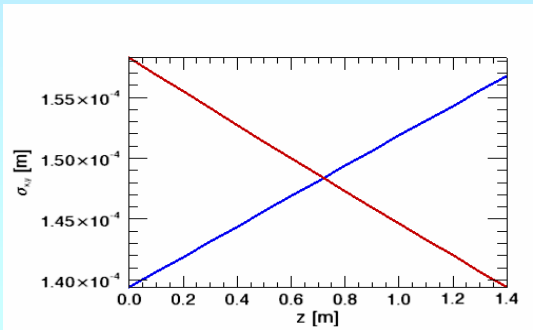
- **What are the tolerance limits** (which beta-amplitude, energy chirp and so on, breaks the process?

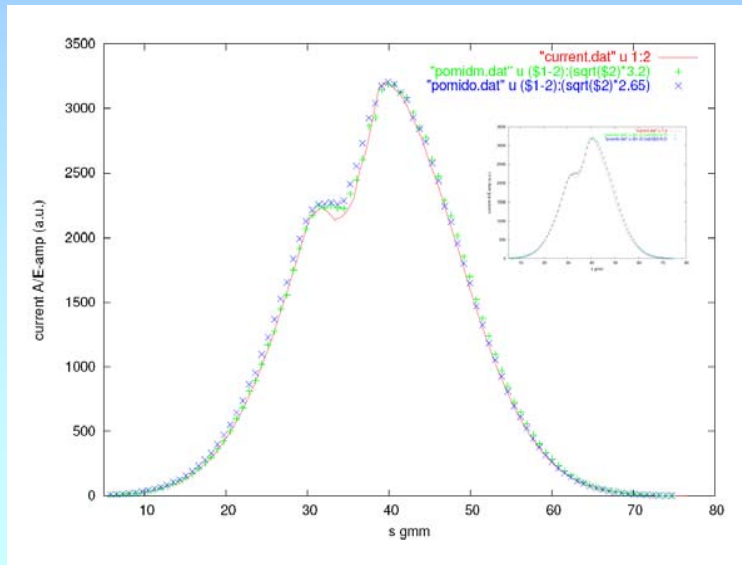
- **Can we implement an additional angle in the dispersive section** to separate the seeding radiation.



Electron beam properties







Additional info: Atoosa Meseck- BESSY

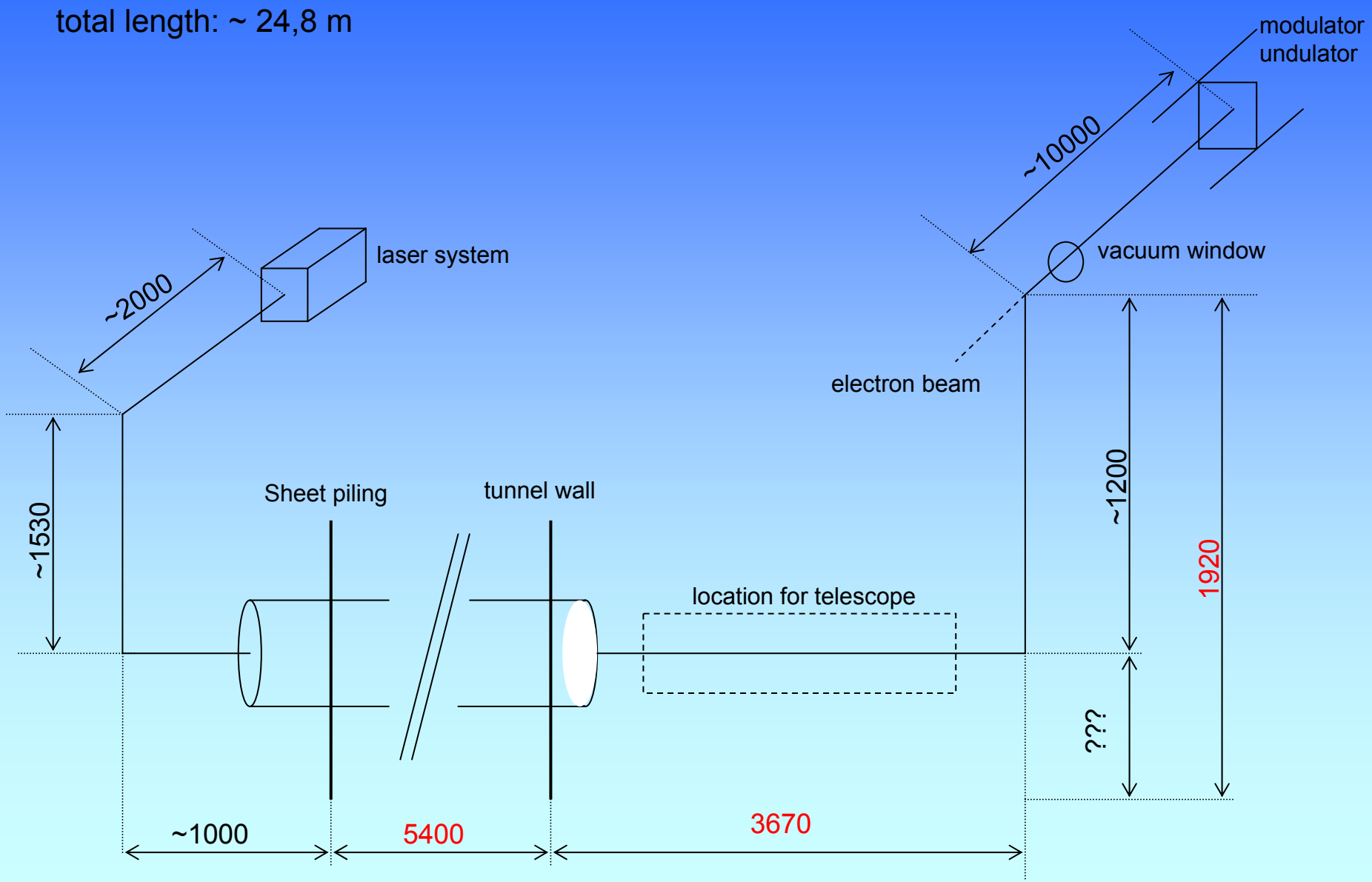
Conclusions

1. Undulators- Arrive at DESY 06/03/07, Installation- Ready 19/06/07
2. Mechanical support – Ready 15/04/07,
3. OTR station elements- Ready 30/03/07, Installation- Ready 25/04/07
4. Optical Stations elements - Ready 09/04/07, Installation- Ready 30/04/07
5. Stereer magnets for Chicane- Prepared, Installation- Ready 23/05/07
6. Laser Building- Ready 30/03/07
7. Seed laser, oscilloscope, tests- Ready 04/05/07
8. Laser Transfer line- Ready 30/05/07
9. Theoretical simulations- In progress
10. Commissioning - July-August 2007

Position of interest, approximately

- Vacuum window 158.2
- Modulator start 167.0
- Chicane 171.5, 172.9, 174.8, 175.3
- Radiator start 178.2
- Existing OTR screens
  - 7match 165.8 (overlap)
  - 3sund1 168.9 (overlap)
  - 2sund3 177.9 (CTR)
  - 5seed 186.9 (extract)
  - 14seed 195.8
- Existing BPM
  - 2match 161.2
  - 6match 164.7 (modulator)
  - Q4sund2 175.7
  - Q3seed 184.7
  - Q12seed 193.
  - Q20seed 201.7
- Existing steering magnets
  - 3match 161.5 (modulator)
  - 6match 165.0 (into modulator)
  - 5sund2 176.3 (into radiator)
  - 3seed 185.3 (out radiator)
  - 12seed 194.3
  - 19seed 200.6

Sketch of the seed laser beamline (length in mm)



Separating the (strong, mJ) seed laser from the (weak, tens of μJ) replica pulse

- Orthogonal polarization from crossed undulators.
- Modulator vertically polarized. (Separation of the spontaneous radiation from dog-leg dipole with horizontal polarization)
- Radiator horizontally polarized.
- Absorb the seed laser in the chicane.
- Higher harmonics problematic: The TiSa 800 nm has 2nd harmonic 400 nm, which cannot be phasematched in the BBO.