CERN Accelerator School
"SYNCHROTRON RADIATION &
FREE-ELECTRON LASERS"
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Mechanical Engineering Aspects - the SLS Experience

Saša Zelenika for the SLS ME team
(with the generous support of other SLS groups and the whole PSI staff)

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General Requirements on Mechanical Engineering at the Light Sources

- precision machining (μm) and positioning (nm, μrad);
- high heat load problems (10^8 W/m^2; Sun surface: $7{\cdot}10^7$ W/m^2);
- vibration measurement and suppression (ampl. in nm range);
- high and ultra-high vacuum issues ($<10^{-8}$ mbar);
- radiation compatibility (materials selection)
- experimental techniques;
- new analytical and numerical methods;
- computer aided engineering systems (CAD, FEM and DB management)

Outline of the Presentation

- SLS: 1st medium energy range machine which entered the hard X-ray region by using the higher spectral harmonics of undulators with short periods and small gaps
- Main goal: high quality source (brightness) -> mainly determined by electron beam quality (low emittance and increased lifetime) => severe challenges in terms of stability and reproducibility of the stored beam
- Room left for lattices optimisation is very limited -> increasing positioning, re-positioning and alignment precisions of the magnets becomes a must to reach small emittances and reduce orbit distortions before switching on correctors
- Provisions for accurate positioning and dynamic minimisation of ground motion and thermal effects have been foreseen from the beginning of the SLS design

Aims of the Work

Support the storage ring magnets, vac. chambers, diagnostics and position monitoring systems (Horizontal positioning system - HPS, and Hydrostatic Levelling System - HLS)

Obtain **one large rigid pre-assembled item** not necessitating fiducialization of individual magnets or items other than the support itself

Provide high precision **reference surfaces** both in horizontal and in vertical

Provide a **simple and reliable** mechanical **design** allowing **easy mounting and alignment**

Kinematic support: number of constrains balances the number of needed

Compensate for thermal and geological horizontal and vertical disturbances with large time constants

Provide **smooth, hysteresis-free** and **remotely controllable** motion at **micrometric levels**

Stiffness (dynamic stability) such that the residual rms beam jitter – including optics amplification – remains smaller than 10% of the beam sigmas (i.e. with a 1% emittance coupling: 1 μm vertically and 10 μm horizontally)

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Support System

Individual stands:

- used when components are spread out
- simplest: pipe with plates welded on both ends
- granite epoxy (Anocast): better damping, bigger thermal inertia, cost comparable to steel, but: cast structures -> machinability (precision) & long term stability???

Girders

-> stress relieved **steel boxes** or **concrete beams** (cheaper but creep + cracking);

- a set of components is mounted on a common platform (no ground settlement of individual components)
- random displacements of girders with magnets mounted onto them are generating a far smaller impact on orbit distortions than individually supported quadrupoles
- support also the vacuum chambers -> one reference for a generally overconstrained system; guarantees the needed tolerances between magnet poles and vacuum chambers
- can be pre-assembled
- can be filled with H_20 to increase thermal capacity

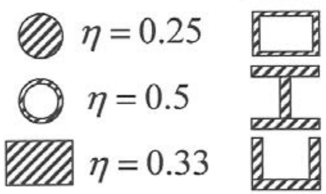
Bending

$$\sigma = \frac{M_x}{I_x} y \qquad W_x \geq \frac{I_x}{y_{max}}$$ - elastic section modulus

$$W_{opt} = A \cdot y_{max}$$

$$\eta = \frac{W_x}{W_{opt}}$$

$$W_x = \frac{1}{2} A h \eta$$



Torsion

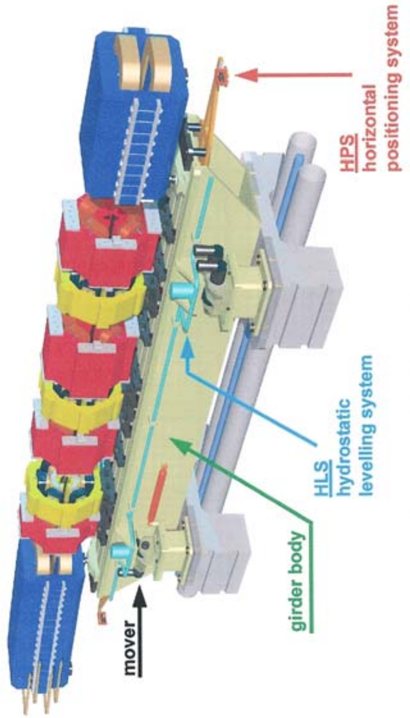
Closed forms are better than opened; ribs help

$$\tau = \frac{M_t}{W_t}$$ Goal: min area for a given stress, i.e. for a given W_t

$\frac{A_{○}}{A_{▨}} \leq 0.815 \Rightarrow$ ○ is better than ▨

$\frac{A_{○}}{A_{●}} \leq 1 \Rightarrow$ ○ is better than ●

$\frac{A_{□}}{A_{▨}} \leq 0.374 \Rightarrow$ □ is better than ▨



Basic support unit:
welded, stress-relieved (annealed), hollow square girder structure with internal ribs

- An extensive optimisation process based on numerical sensitivity analysis was performed so as to maximise the static and dynamic stiffness while minimising the costs
- 48 girders are finally used (30 with a 4.5 m and 18 with a 3.7 m length). Four girders are placed in each of the 12 TBAs of the SLS storage ring
- Kinematically supported dipoles (flat-V-cone kinematic mount) overlap adjacent girders establishing, together with the HPS and HLS, a virtual "train link" with joints near the centres of the dipoles

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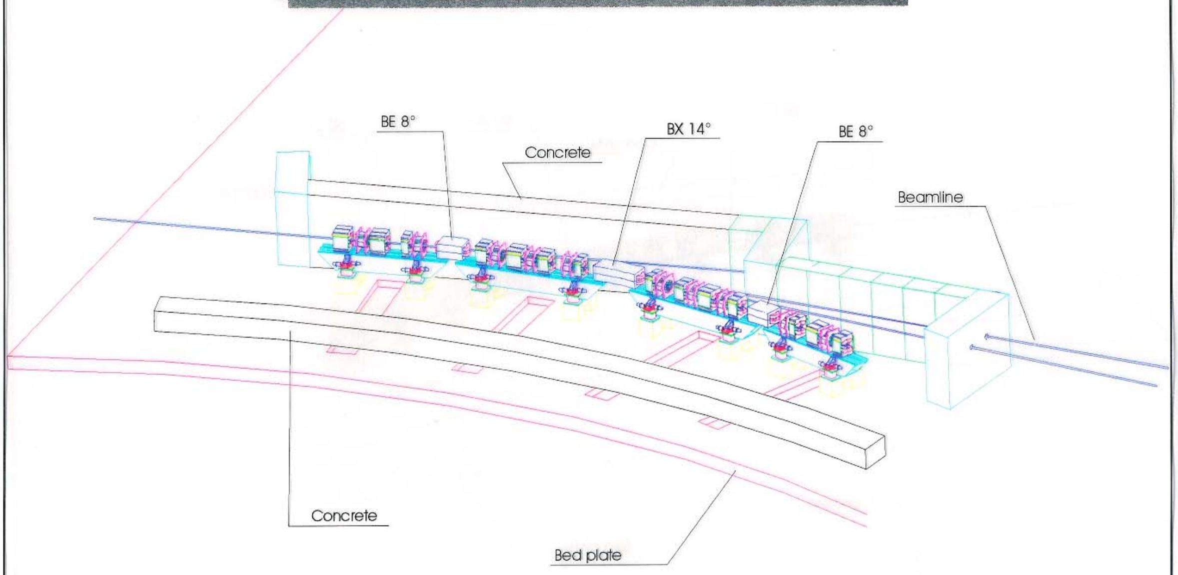
A 30° Sector of the Storage Ring



Max element vs. girder misalignment ± 50 μm

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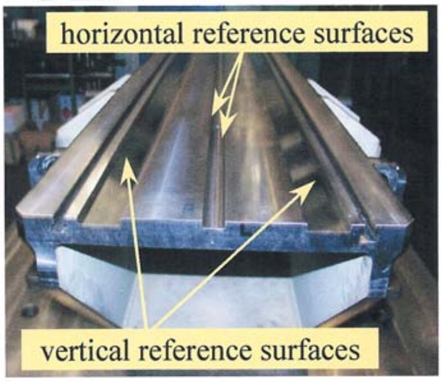
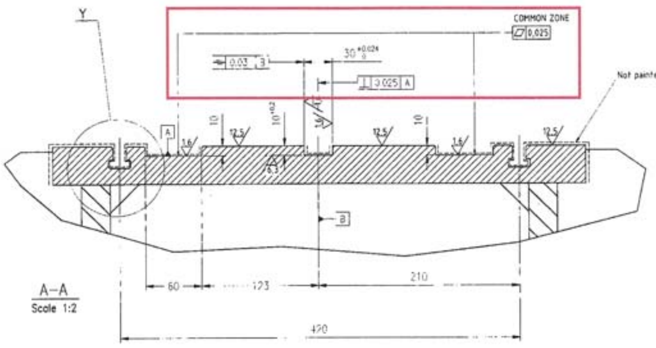
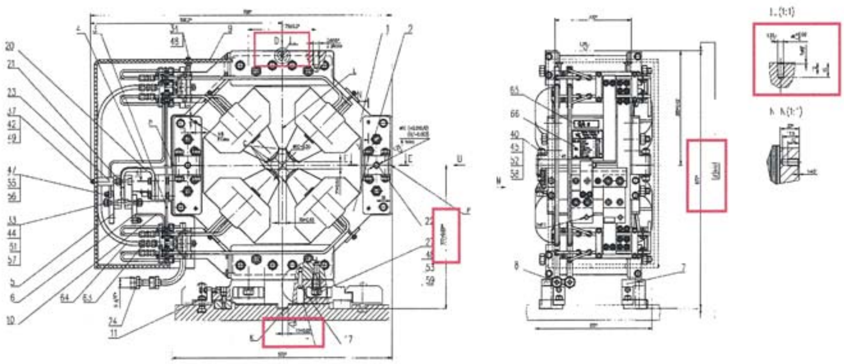




Upper part of the girders: ground reference surfaces with a precision of < ± 15 μm onto which the magnets are laid and fixed via suitably designed clamps



Positioning System

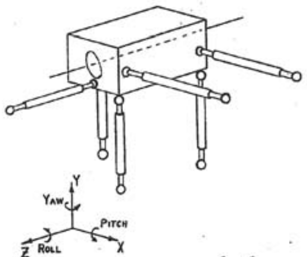
Goal: alignment and compensation of girder misalignments due to geological and thermal drifts

Separate horizontal and vertical adjustment:

Vertical: 3 standoffs to adjust heave, roll & pitch -> shim stacks (iterative procedure), threaded rods, wedge jacks (limited range) or screw jacks (ESRF)

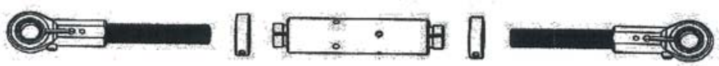
Horizontal: adjustment of sway, surge and yaw; 1 (coupled motion in 2 directions) or 2 sliding plates with push-push screw or turnbuckle push-pull/rail-slide systems (CERN, SLAC, DESY, …)

6 strut system (ALS): length-adjustable bars with spherical joints at ends: 3 vertical (heave, roll, pitch) & 3 horizontal struts (1 ⊥ to other 2 -> sway, surge, yaw)



Both strut ends are threaded but one coarse and the other fine -> high resolutions (10 μm)

Disadvantages: limited loading capacity; coupling of DOFs because of cosine effect; backlash at joints (tight tolerances), at threads (special collars with accurately tuned break-away torques) and at joint-to-component coupling



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Motorized systems (SLAC, Gordon Bowden):

Kinematic support (Kelvin clamp principle) on eccentric roller cam-shafts ('MOVERS')

Driven via *stepping motors* with an *LVDT* feedback system

Gravity-constrained in vertical direction

Remotely controllable

Smooth, hysteresis free motion with minimized friction

Pure rolling motion bounded by design geometry

Range limited to ± 2 mm, loading to ~ 1 t

SLS:

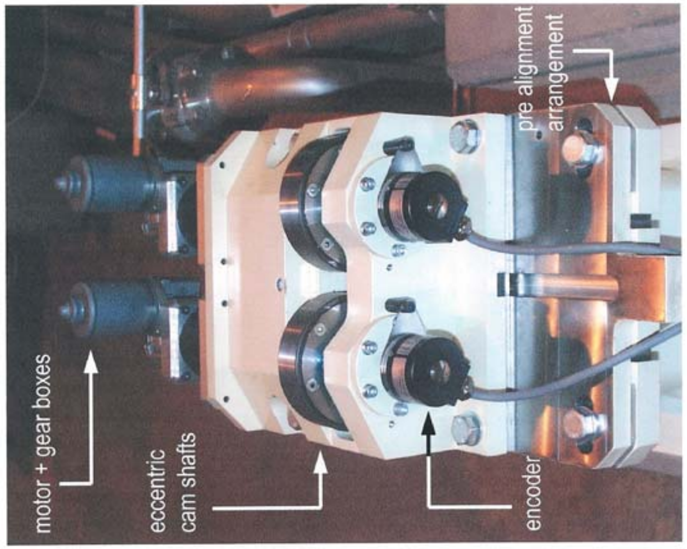
Driving side: low cost DC motor + worm & planetary gearboxes

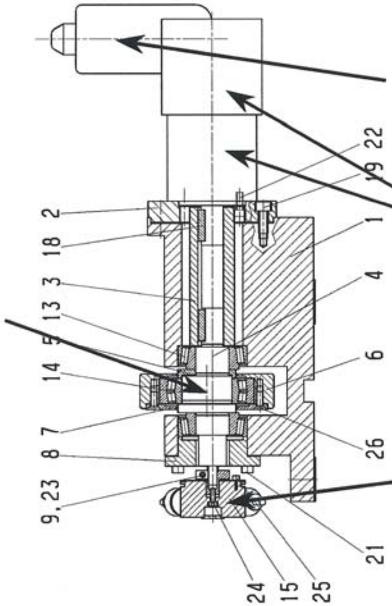
Feedback: BFA series BAUMER absolute rotary encoders -> resolution enhanced to 17 bit by in-house developed interpolation module interfaces

Fully integrated into the SLS EPICS-based control system which allows to perform simultaneous 5 DOF movements

⇒ Pseudo stepper motors with resolutions better than 2 μm

Arrangement includes motion bounding via Baumer Electric My-Com based limit switches





eccentric cam shaft with spherical roller bearing -> adaptation to misalignments + increased loading capacity and stiffness

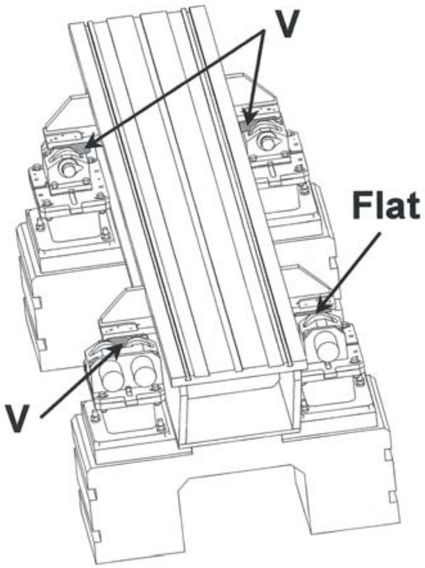
DC motor -> low cost

gearboxes worm (1:78) + planetary (1:40)

absolute rotary encoder -> easier mounting & calibration

RANGE: ± 5 mm

RESOLUTION: < 2 µm



Kinematic girder support: 1 flat + 2 V seats balance the needed 5 DOFs (sway, heave, pitch, yaw and roll) - the surge, given its smaller relevance, is left to a simple strut system

Advantages:

- self-locating, free from backlash -> alignment (and re-positioning) repeatabilities in the µm or even sub-µm range
- probability of foreign matter contaminating the interface is minimized
- no overconstrain (deterministic) -> behaviour can be represented in a closed form solution
- no clamping forces can distort the shape (no overconstrain induced stresses)
- thermal expansions are allowed keeping the resulting mechanical stresses to a minimum

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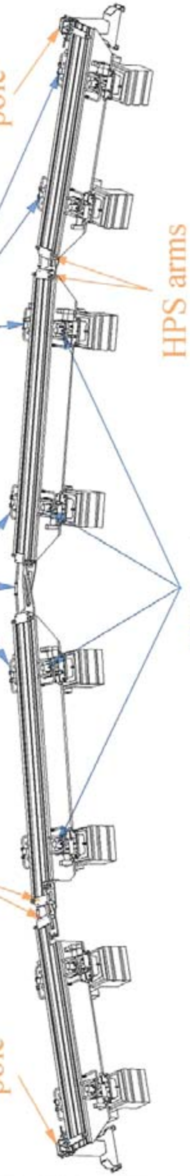
Position Monitoring Systems

Purpose: continuous monitoring of girders positioning stability i.e. long time deterioration of their initially aligned location => use of the Hydrostatic Levelling System (HLS) and the Horizontal Positioning System (HPS), both having micrometric range accuracies



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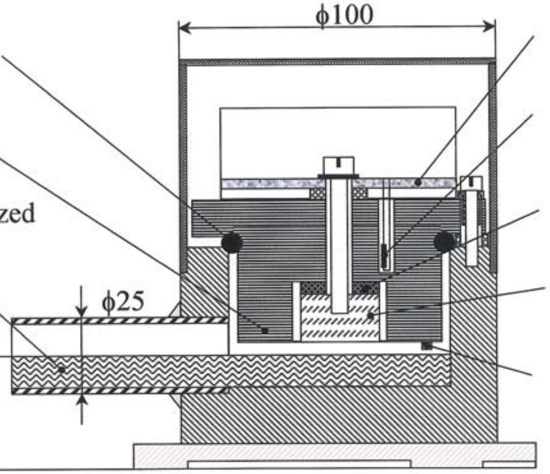
Hydrostatic Levelling System

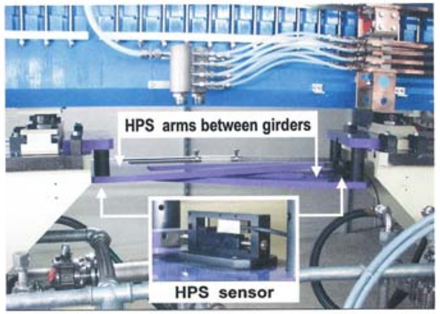


ϕ = 10 cm stainless steel pots connected by a half filled stainless steel pipe (OD 25 mm) around the ring => single absolute reference altimetric level

Fluid: originally de-mineralised H_2O
Sensing elements: capacitive proximity gauges -> non-contact measurements
Resolution: < 2 µm; accuracy and repeatability: ± 10 µm; working range: ± 2.5 mm

4 pots per girder: measure of heave, pitch and roll

Horizontal Positioning System

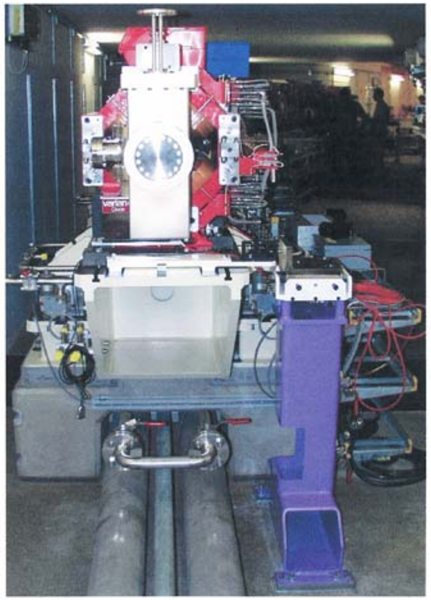


Monitors horizontal girder movements (sways + yaws)

Constituted by pairs of lever arms under the girders surfaces equipped with absolute linear encoders (0.5 µm resolution, ± 2.5 mm range)

The HPS extends in a "train link" scheme -> relative horizontal displacements of adjacent girders are correlated to artificially created reference poles at TBAs ends

Using these artificial references as starting points, any motion of girders can be detected and traced back via a 2N dimensional system of equations (N - no. of girders taken into consideration)



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Beam Based Alignment

Beam trajectory is measured by 72 BPMs; encoders monitor the positions of BPMs with respect to adjacent quadrupoles

Resulting data can be used to remotely align the girders via the mover system obtaining closed orbit and even coupling correction (achieving, in principle, the same functionality of the corrector magnets)

By using the conceived systems, **beam-based alignment is hence obtained**

Beam tracing simulations: all static vertical closed orbit corrections can be covered by girder alignment; horizontally: a proper selection of girders to be re-positioned allows to reduce corrector magnet strengths by a factor 4 => corrector strengths can be used for dynamic correction (active orbit feedback) and local bump creation for matching the beamline acceptances or for machine studies

Beam-based girder alignment is a dynamic method and may be done on-line with the stored beam: it appears to be a superior substitute for magnet sorting

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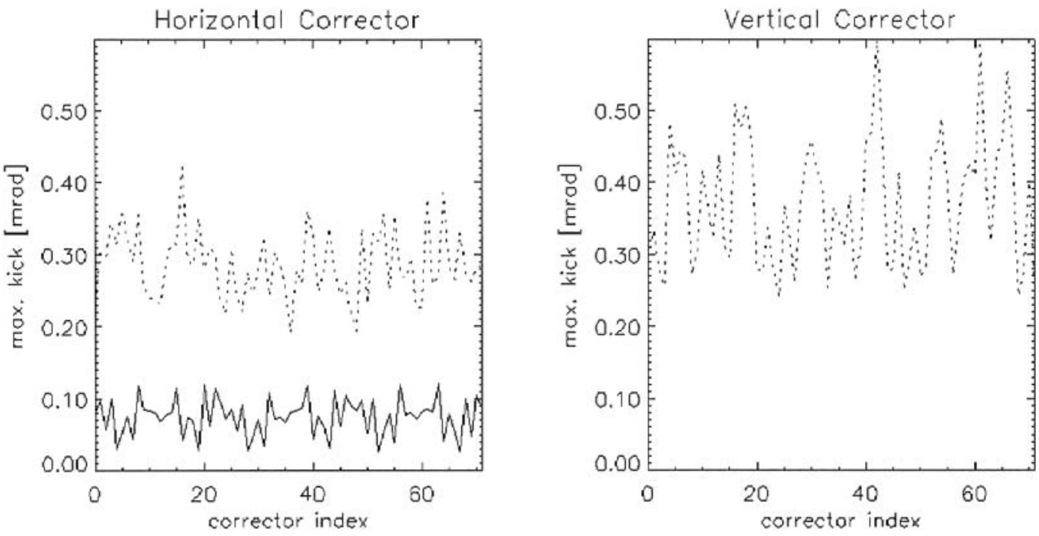

rms corrector magnet strengths before (dashed) and after (full line) closed orbit correction through girder alignment. 200 random misalignments seeds were generated and corrected. The random errors assumed partial train links over four girders with rms (2σ cut) displacement errors of 300 μm for the (virtual) girder joints, 100 μm for the joint play (i.e. errors in the HPS and HLS readings) and 50 μm for magnets and BPMs positioning tolerances relative to the surfaces of the girders

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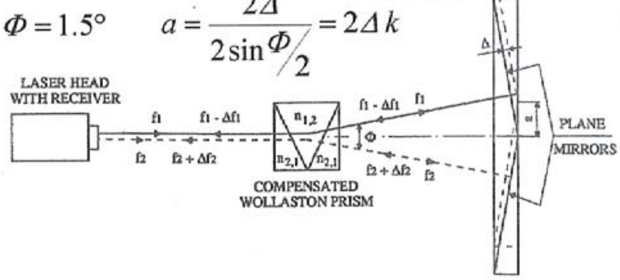
Tests on Prototypes

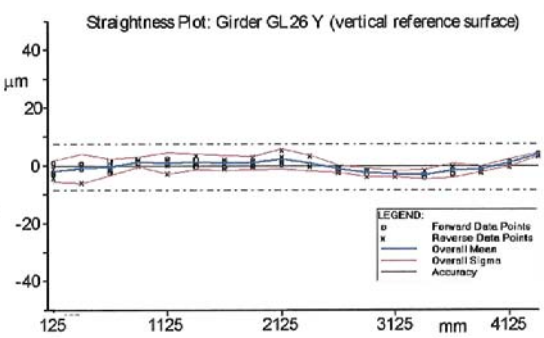
Girders:

Straightness accuracy of girders reference surfaces was checked by using the HP5529A Michelson-type heterodyne laser interferometer in an optical configuration with a Wollaston prism (resol.: 100 nm) -> it was proved that the very tight tolerances (± 15 μm) have been met

$2\Delta \propto (\Delta f_1 + \Delta f_2)$

$\Phi = 1.5°$ $\quad a = \dfrac{2\Delta}{2\sin\Phi/2} = 2\Delta k$





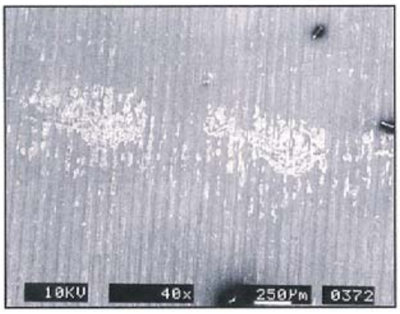
Dimensional checks of main components performed on a 3D coordinate measuring machine -> proof that design tolerances have been met

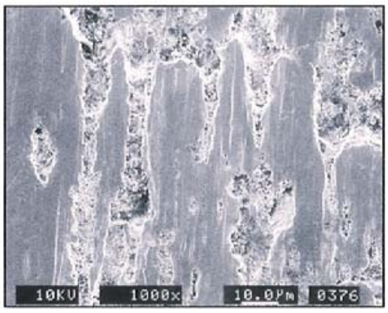
Mounting and alignment procedures reviewed

Mover System:

Functionality test: OK

85'000 cycles fatigue test: fretting of the surface => material & hardness changed





Resolution and repeatability of single mover: better than ± 2 μm; resolution of whole girder: ± 3÷5 μm; positioning repeatability of girder: better than ± 10 μm

Control SW (including inverse algorithm) optimised and tested; 5 DOF common working window established: ± 1.4 mm for linear displacements, ± 1÷1.5 mrad for angular motions (for 1 DOF motions the limits are ± 5÷7 mm and ± 3.5÷7.5 mrad)

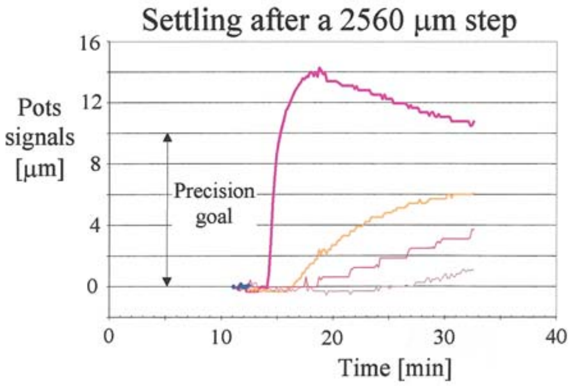
HLS:

Repeatability on girders (including thus movers inaccuracies) -> for long range motions (> 1mm): better than ± 10 μm, for motions < 100 μm: better than ± 3 μm

Settling times on a 100 m piping network: even with extreme perturbations (2.5 mm lifting of one pot) do not exceed ~ 1/2 h

Vibrations influence on measurements is negligible => no need for mechanical or SW vibrations filtering

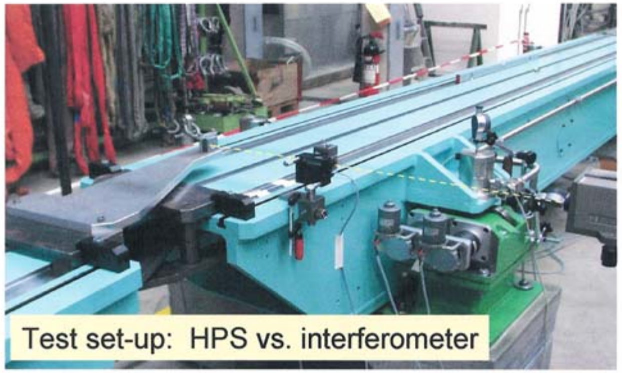
Temperature variation of ± 2 °C of one pot: negligible (± 1 μm) difference in the readings



HPS:

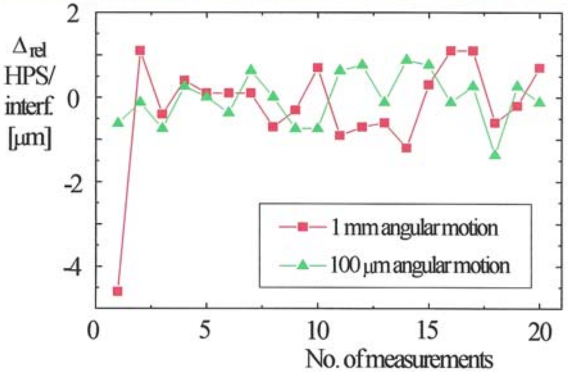
Preliminary tests performed on HPS prototypes mounted on girders

Laser interferometric measurements used as reference



Test set-up: HPS vs. interferometer

Relative errors of HPS do not exceed ± 1 μm with a repeatability also in the ± 1 μm range => comparable to the resolution of the HPS sensors



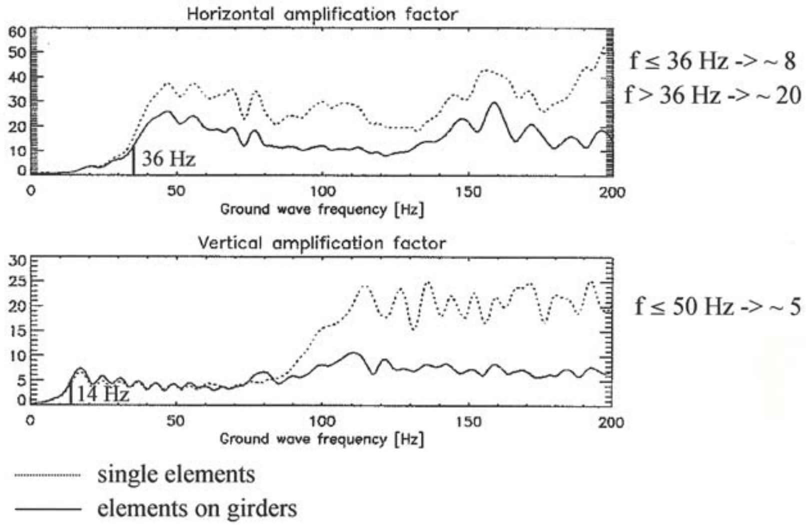
Dynamic Stability

Vibrations displace the magnetic elements and generate time-dependent closed orbit distorsions

Experiments at SLS require a highly stabilised photon beam below 100 Hz (effects of slow motion neglected since λ far grater than the SLS $\lambda_{betatron}$)

Goal: reduce residual rms beam jitter (i.e. stabilize "golden orbit") to 1/10 of e^- beam sigmas

With an emittance coupling of 1% and an optics amplification of ~ 8 horizontally and ~ 5 vertically => max mechanical vibration amplitudes of 0.2 μm in the vertical and 1.25 μm in the horizontal plane

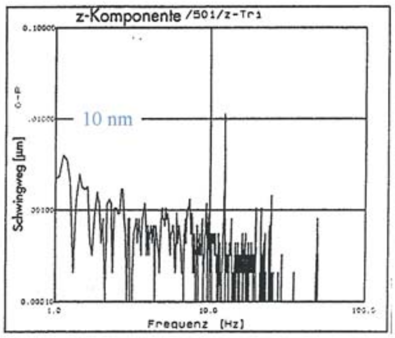


Increase of ampl. factor @ λ = betatron wavelength (assuming v_{sand} = 500 m/s)

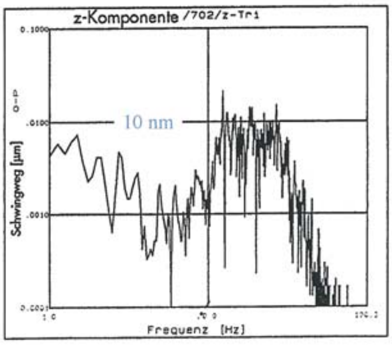
Need to evaluate: incoming ground noise spectrum and transmissibility of girder/magnet assemblies

Design goal: no coupling of eigenfrequencies with ground motion noise

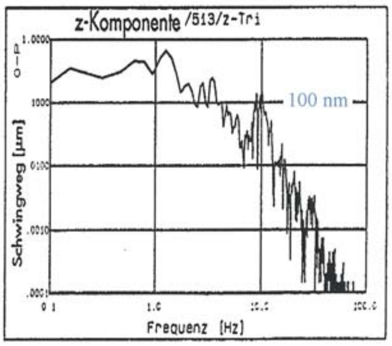
1997 measurement campaign of SLS site spectrum: due to nearby road and machinery installed at PSI (especially a nearby compressor working at a 12.3 Hz frequency) => significant ground noise in 5-40 Hz region



Ground w/o excitation



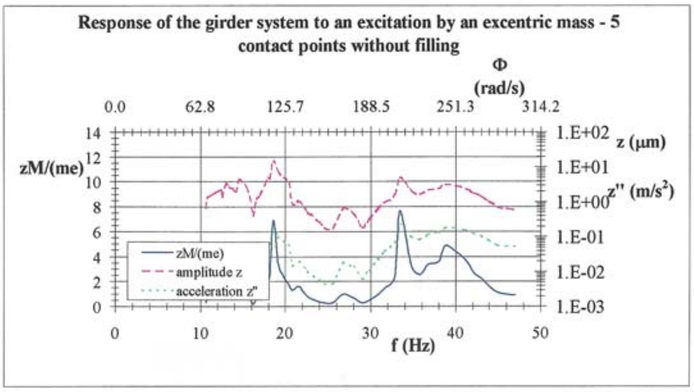
Truck on road

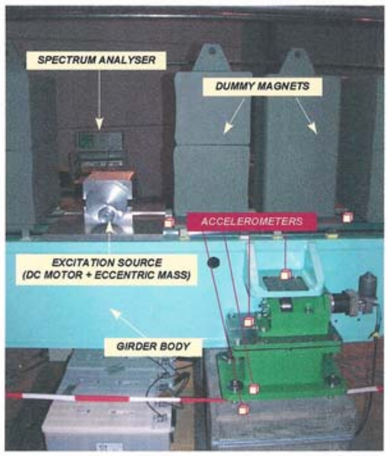


Explosion in a quarry 1 km away

Concurrently: extensive numerical design optimization to validate the needed stiffness of the girder body, the location (both longitudinal and vertical) and number of girder support points, …

1999: measurements on girder prototypes under natural and induced (eccentric mass) excitations -> preliminary analysis via simplified mono-dimensional models: some eigenfrequencies in the ground noise frequency range are present but the ground-to-girder transmissibility is < 10 so that the resulting amplitudes under natural excitation should remain in the acceptable range





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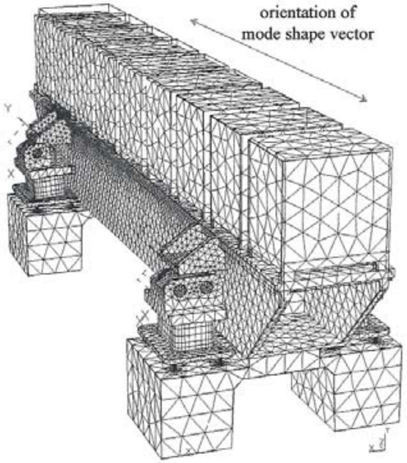
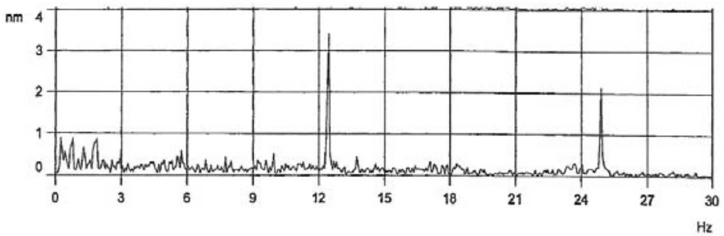
Based on the experimental results: the parameters of a FEM modal model were tuned and further design variables (screw types at the concrete-to-metal interface, grouting of the supports, ribs in the girder body, fixation of the magnets onto the girders, …) could be optimized



Summer 1999: measurement campaign of newly built SLS building => ground motion amplitudes under natural excitations are < 10 nm



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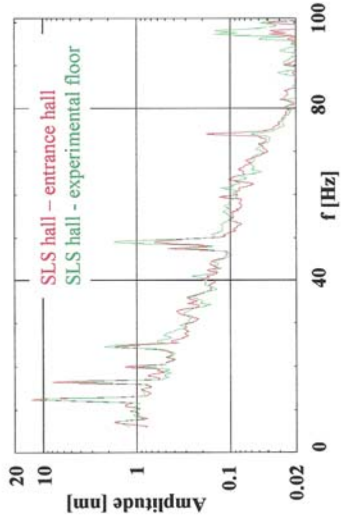
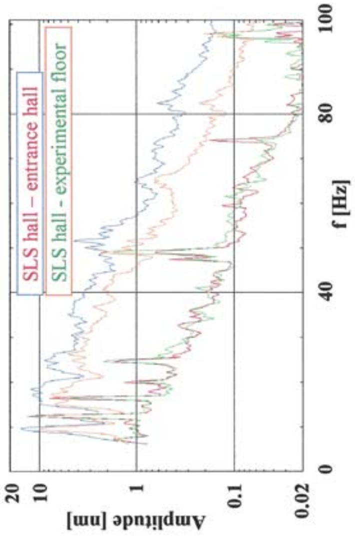
Subsequent measurements of SLS building vibrations -> confirmation of very quiet conditions (except 12 Hz peak) on machine and experimental floor => levels suitable for TEM & SEM equipment; visible influence of crane; influence of infrastructure equipment low



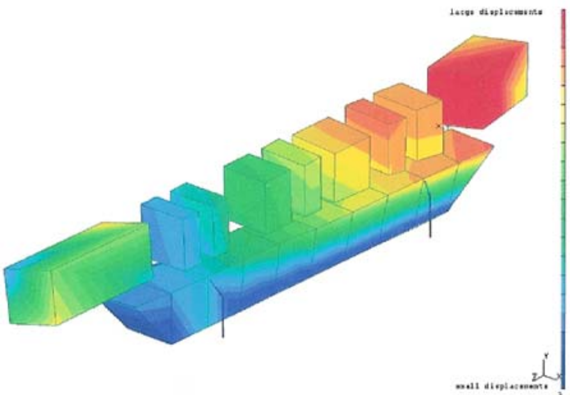


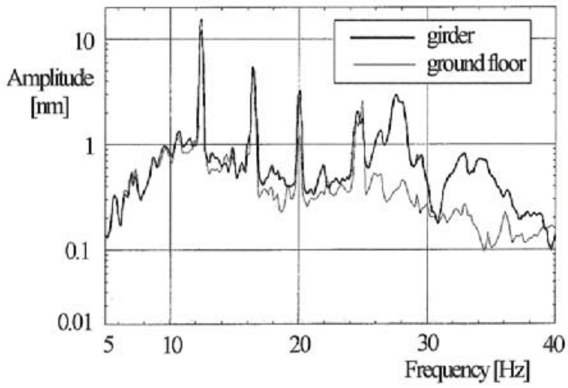
Comparison of ground noise with and w/o crane operation

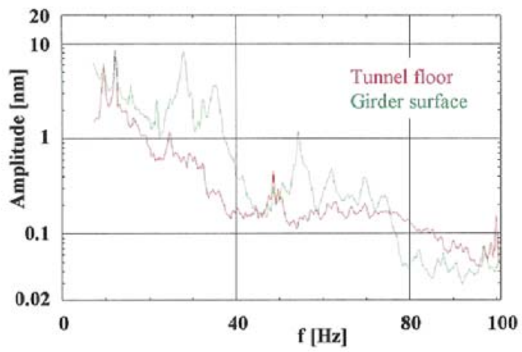
Early 2000: measurement campaign to establish the response of the girder system under natural excitation and real operating conditions (cooling/conditioning units, crane, machinery in experimental hall, …)

Girder excited by impulse hammer -> eigenfrequencies and resulting mode shapes => transmissibility of girder/magnet assembly indeed ≤ 10; dynamics influenced by dipoles ("cross-talk" between girders)

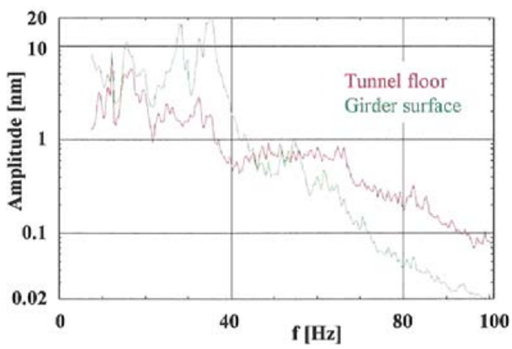
Some eigenfrequencies are in the range of excitations of technical devices (especially 25÷40 Hz range), but resulting amplitudes are still, even in the worse conditions, in the 10÷30 nm range, i.e. an order of magnitude lower than those which would produce significant perturbations of storage ring performances





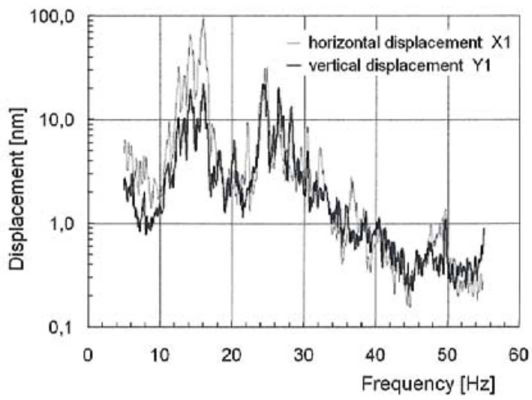


Influence of cooling water circulation



Influence of crane – worse case

In the horizontal direction the amplitudes can be quite higher (e.g. measurement on dipole with cooling water circulating), but still an order of magnitude lower than required



Installation in the Storage Ring

Based on tests -> design optimization -> approval for serial production
During productive cycles: thorough quality control
Reference surfaces of each girder measured via HP laser interferometer -> some girders re-ground to meet the tolerances
Inspection records accompanying every girder obtained from manufacturer; on ~ 10% of critical components a double check performed at PSI
All the girder and mover pieces delivered to PSI according to schedule or even before it

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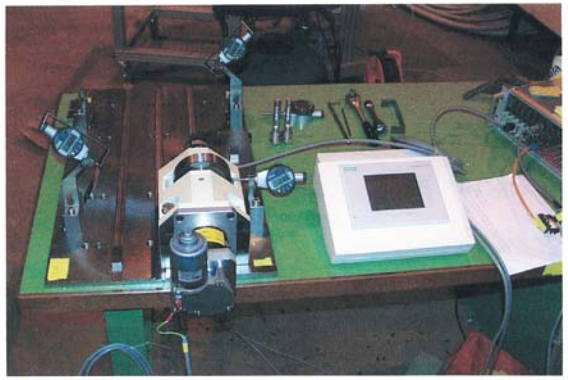
-> Assembly of the motor-gearboxes units and encoders onto movers
-> Determination of movers' zero positions (μm accuracy required)



-> Girder steel pedestals mounted and grouted onto concrete blocks
-> Movers mounted onto the pedestals; cabling performed

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Magnets delivery: 36 dipoles, 174 quadrupoles, 120 sextupoles (72 sextupoles have additional horizontal and vertical dipole windings for closed-orbit correction)
Dipoles: measured by using a Hall probe
Multipoles: each magnet measured at the factory via a rotating coil -> where needed, feet re-machined to bring the magnetic axes positions within the specified tolerances (± 30 µm)
-> After delivery to PSI: new measurements following the same procedure

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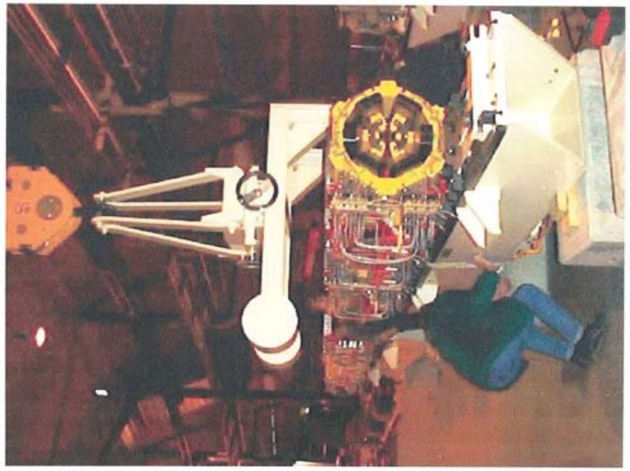
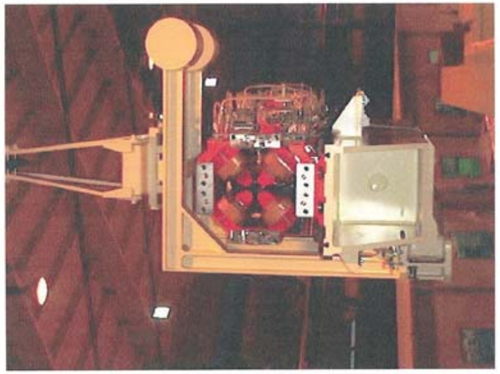
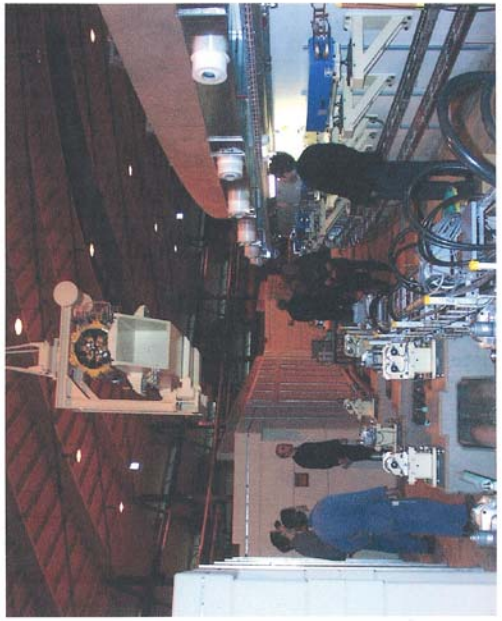
At completion of the magnetic measurements, the magnets have been mounted onto the girders



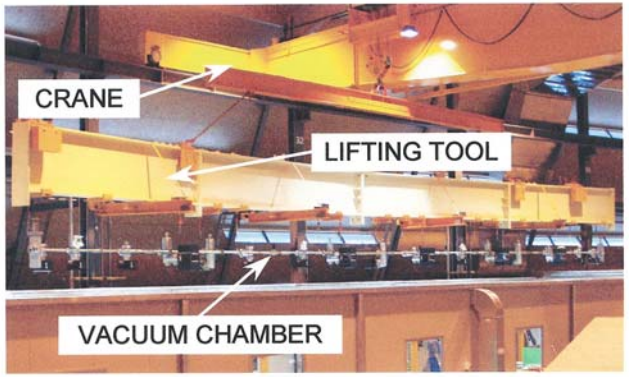
A specially designed lifting tool was then used to transport via a crane the girder/magnet assemblies into the storage ring tunnel

The first TBA was thus installed into the SLS storage ring on December 9th, 1999





Network-based (in total in the SLS building there are 312 (+BLs) network reference points, 155 of which are in the storage ring tunnel) pre-alignment of girder/magnet (including dipoles) assemblies was then carried out by using the Leica laser tracker



-> Removal of upper parts of yokes

-> Installation of the first 18 m stainless steel vacuum chamber (corresponding to one TBA) whose components were previously vacuum fired up to 950 °C, assembled in a clean room, and baked-out at 250 °C

Installation of all storage ring girder/magnet assemblies (with respective water and electrical connections) was completed in early summer 2000, with the last vacuum chamber installed shortly thereafter. In parallel: assembly, mounting and cabling/piping of the elements of the HPS and HLS

Operational Experience

Girder & mover systems:

The originally foreseen strut-based longitudinal girder fixation did not allow the desired positioning accuracies to be attained and maintained because of breakage of frictional contacts => new roller-bearing-based backlash-free mounts have been developed -> simple and repeatable positioning of the 9 t girders on the micrometric scale

The noise generated in the mover cables by the adopted pulse-width-modulated motor power supplies hindered their functionality => adoption of stabilised DC power supplies

The final alignment of the storage ring allowed the positioning of whole TBAs (4 girders with up to 28 magnets mounted onto them) with micrometric accuracies within 1÷2 days

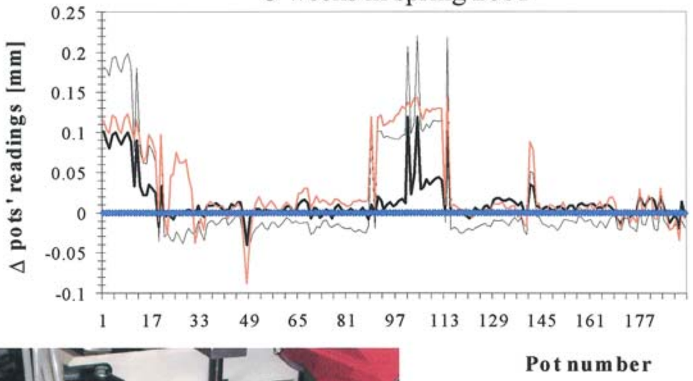
Performed beam-based measurements allowed the achievement of the required machining (± 50 μm) and alignment tolerances (first turn with all correctors off!) to be confirmed

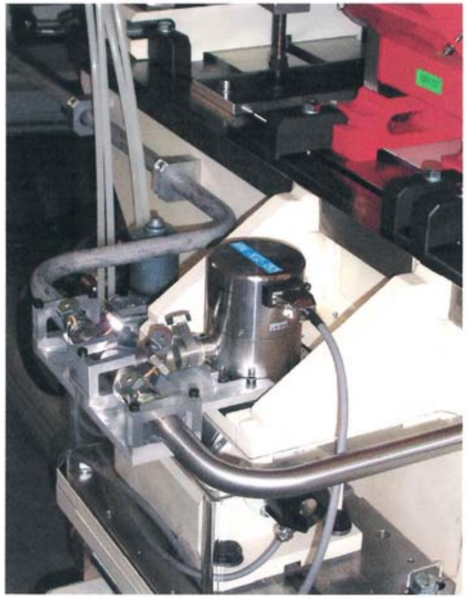
HPS:

Has worked reliably ever since the commissioning

HLS:

Excellent short-term behavior (relative errors in 1% range), but drifts of up to 1-2 mm on the longer time scale





Some drifts due to misalignments of the HLS pipe (Bernoulli tube effect)

Other completely randomly distributed in space and time and not related to temperature or pressure

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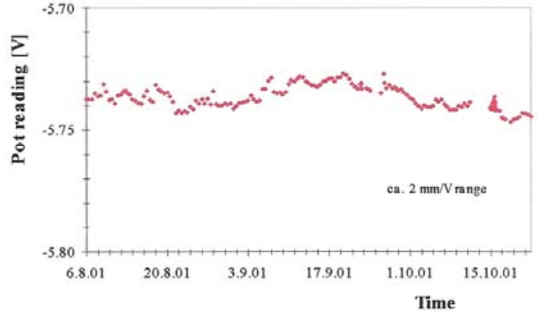
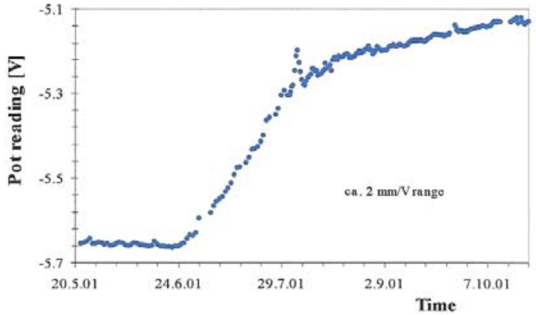
A humidity build-up at the guard-to-sensor interface (=> parasitic capacitance) was postulated

The change of the material of the insulator plate and an electronic compensation of drifts were unsuccessful

The introduction of an O-ring between the guard and the sensor led to encouraging results (± 10 μm stability over several weeks)



However, after several months, some (ca. ½) of the pots started drifted again



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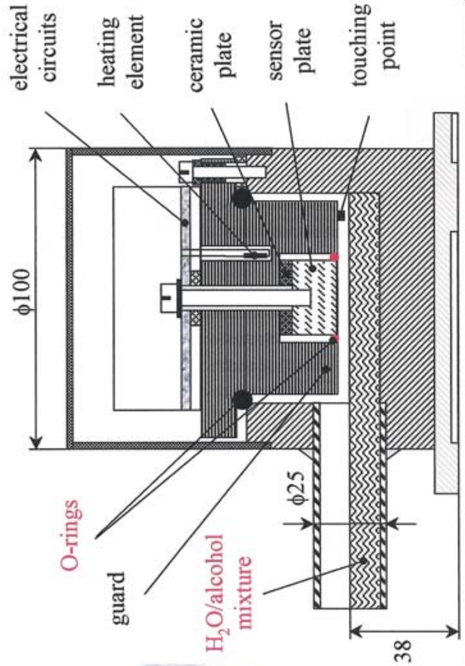
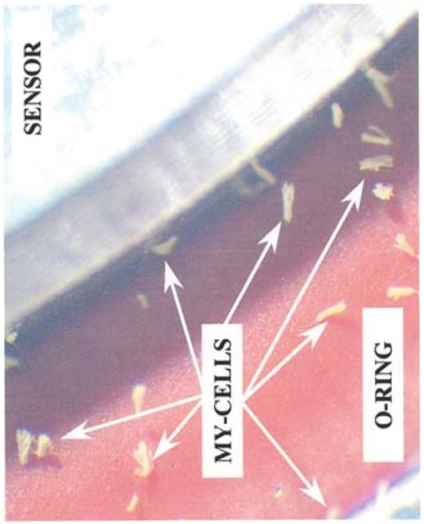
The problem could eventually be solved by adding 30% of an antibacterial fluid + alcohol solution to the working fluid; the theory of killing in such a way the build-up of the observed my-cells cannot explain all the observed phenomena





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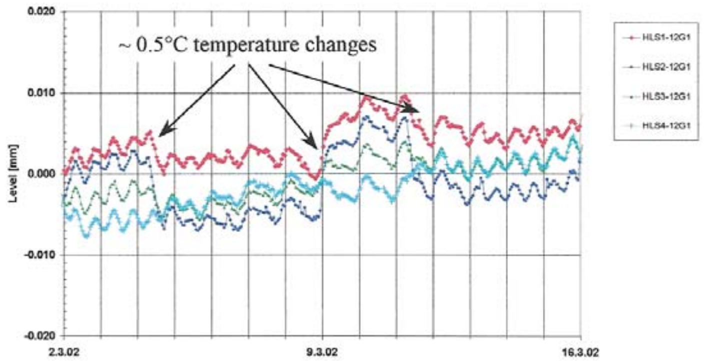
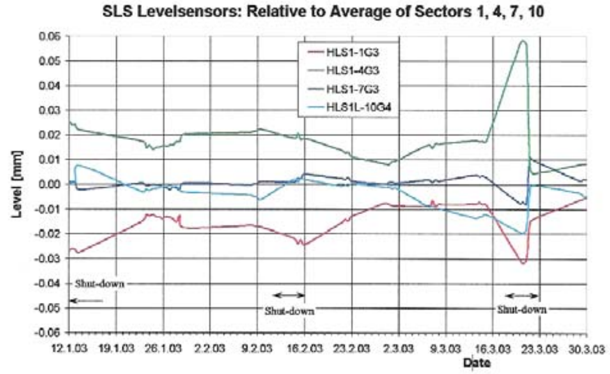
Ever since 01/2002 the HLS is stable to a level at which earth tides can be observed, with a small temperature effect on its behavior; shut-downs introduce larger perturbations



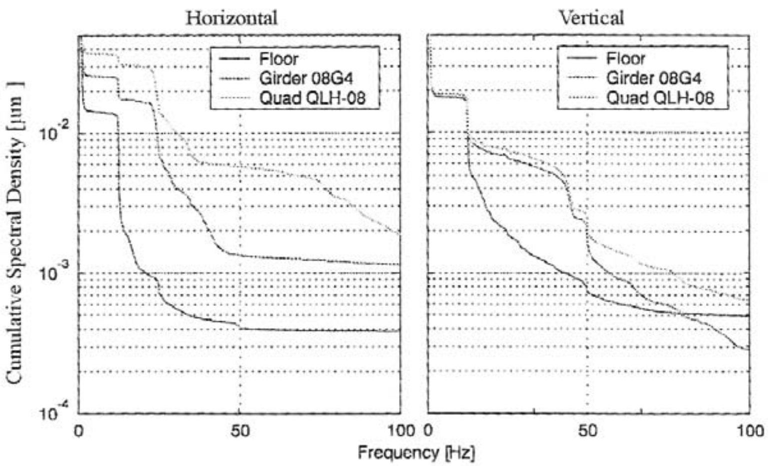


The full integration into the Epics control system will now allow to study the eventual residual “parasitic” effects, the correspondence with long-term survey data, …

Dynamic Stability:

Beam measurements via digital BPMs confirmed earlier girder eigenfrequency and corresponding amplitude measurements [cf. PAC'01]

11/2002 measurements performed in the framework of a CERN PhD thesis have further confirmed these data. It was also shown that the installation of new BL equipment (including additional excitation sources), thank to the low transmissibility of the girder structures (TR < 10 in the vertical and < 20 in the horizontal direction), does not induce significant perturbations of the storage ring optics nor of the photon beam itself



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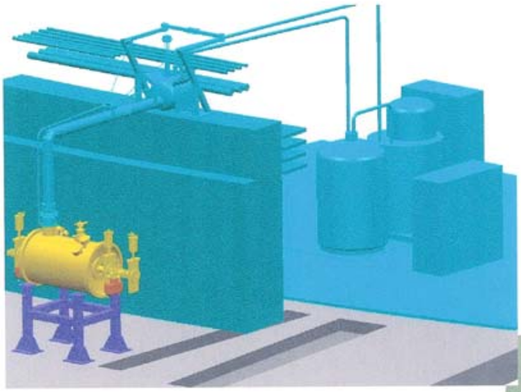
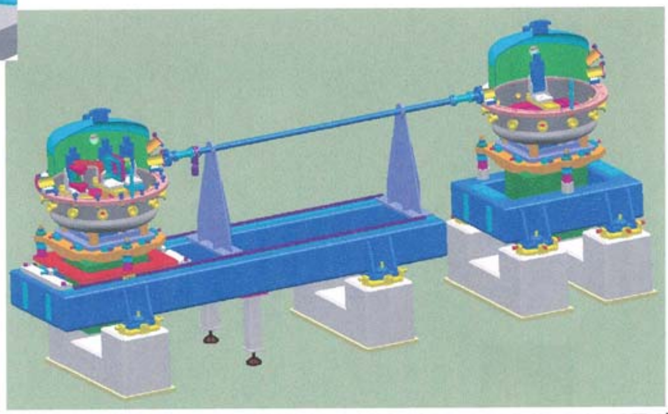
Although some upgrades have been necessary, the storage ring support, positioning and position monitoring systems have been successfully installed and commissioned

Their effectiveness and sophisticated designed are proven not only by the excellent results achieved at the SLS, but also by the high degree of interest shown by other synchrotron radiation facilities (SLAC, DIAMOND, CLS, APS, ELISA, …) to adopt similar solutions

Other ME Tasks at the SLS

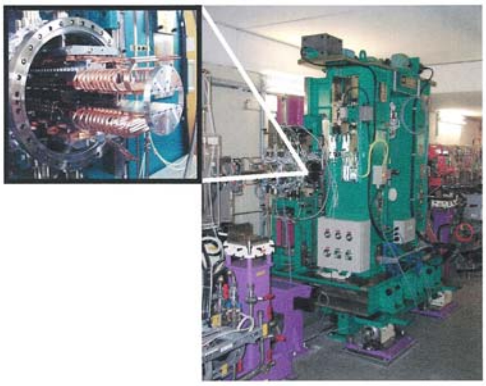


3rd HARMONIC SUPER-CONDUCTING RF SYSTEM: DESIGN AND PRODUCTION FOLLOW-UP; INTERFACES TO VACUUM SYSTEMS, CRYO SYSTEM AND GROUND



DIAGNOSTIC BEAMLINE: COMPLETE DESIGN OF BEAMLINE AND RESPECTIVE HUTCHES; RAY TRACING CALCULATIONS

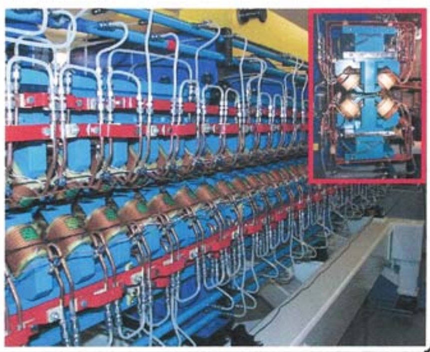
INSERTION DEVICES



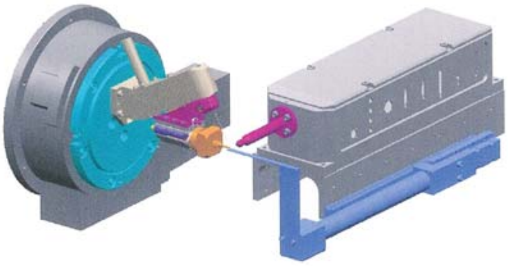
U24 IN-VACUUM ID: SUPPORT AND ALIGNMENT SYSTEMS; TAPERS

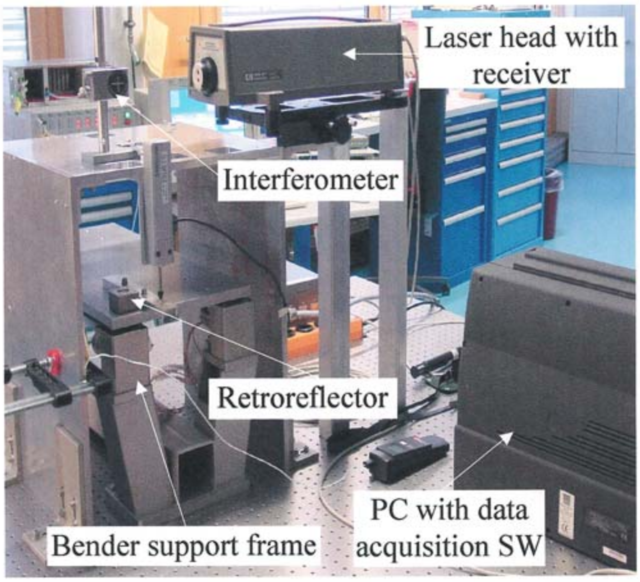
UE56: NUMERICAL OPTIMIZATION

W61: DESIGN REVIEWS

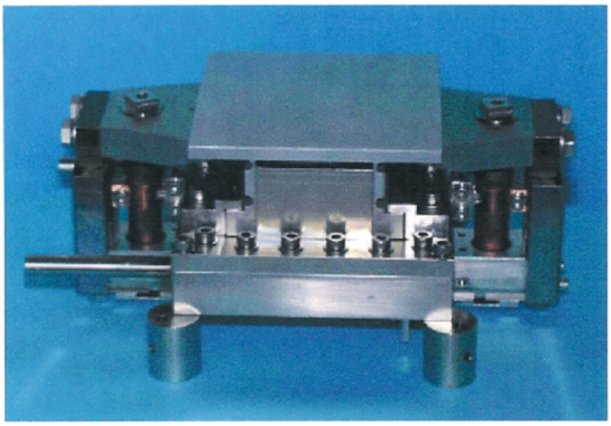


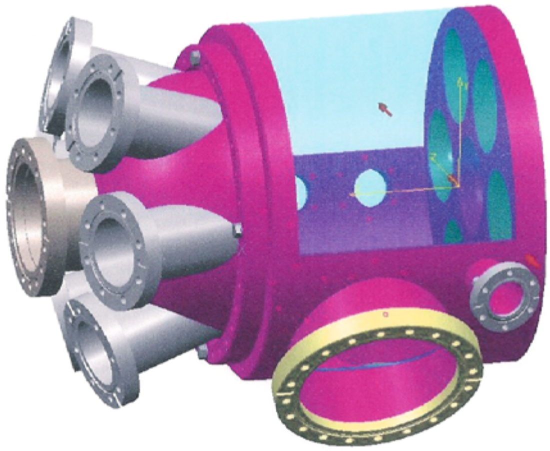
UE212: NUMERICAL OPTIMIZATION AND DESIGN OF SUPPORT; QUALITY ASSESSMENT OF POLES' TOLERANCES



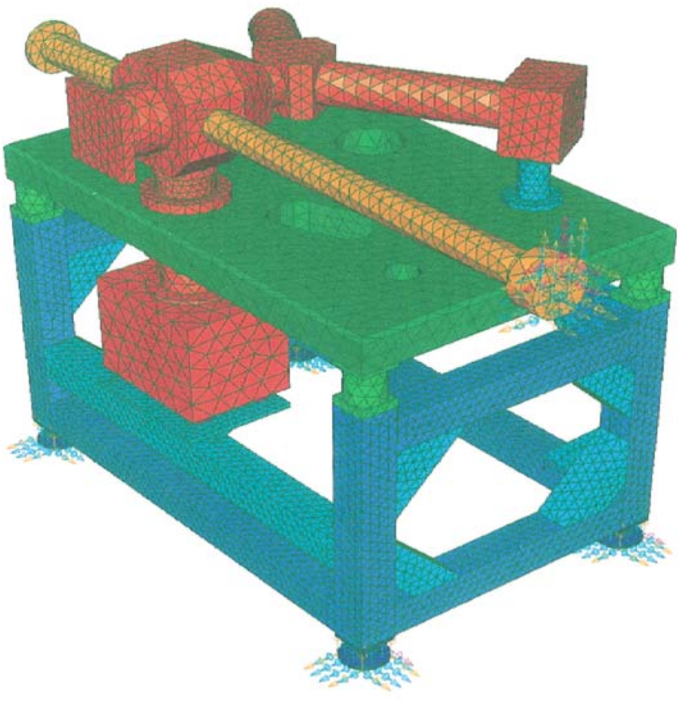


PROTEIN CRYSTALLOGRAPHY BEAMLINE: DESIGN OF THE DYNAMIC MIRROR BENDER, THE EXPOSURE BOX, THE DIFFRACTOMETER TABLE, THE DETECTOR POSITIONING SYSTEM, THE K GONIOMETER, …; QUALITY ASSESSMENT OF CRITICAL COMPONENTS



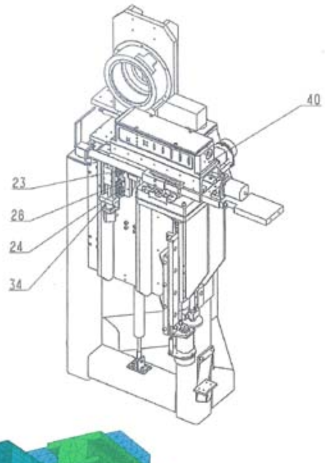


MATERIALS SCIENCE BEAMLINE: 1st MONOCHROMATOR CRYSTAL MOUNT; IN-SITU PULSED LASER DEPOSITION CHAMBER; DESIGN FOLLOW-UPS; FACTORY INSPECTIONS; ACCEPTANCE TESTS; …

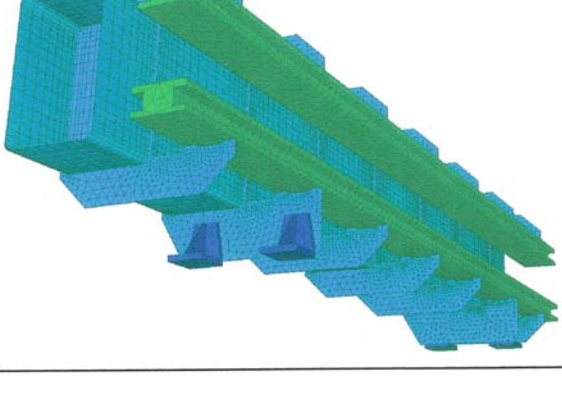


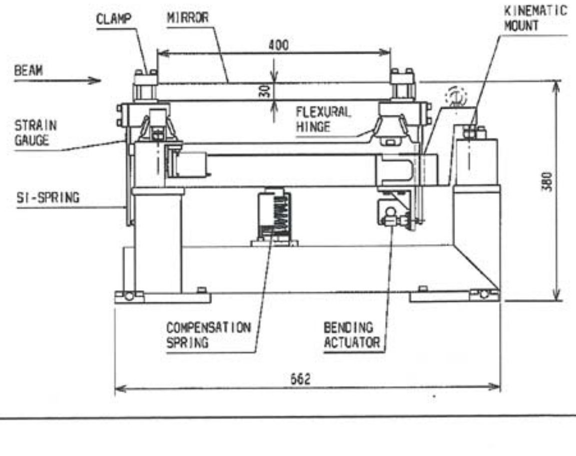
SURFACES AND INTERFACES SPECTROSCOPY & MICROSCOPY BEAMLINES: NUMERICAL OPTIMIZATION OF CRITICAL COMPONENTS; SUPPORT AND POSITIONING STRUCTURES; MATHEMATICAL MODEL OF OPTICS' MOTIONS; ACCEPTANCE TESTS; ...

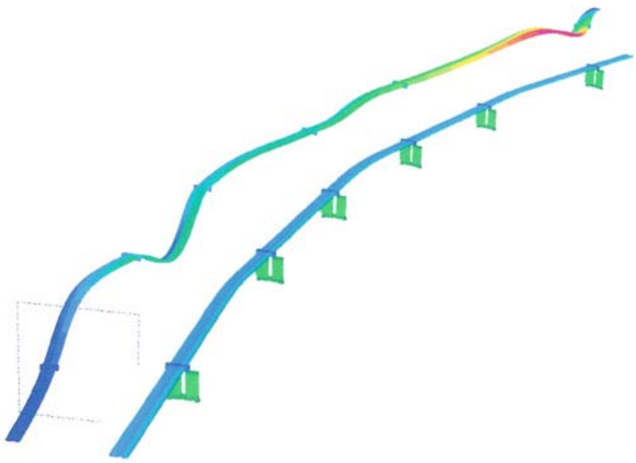
SKILLS

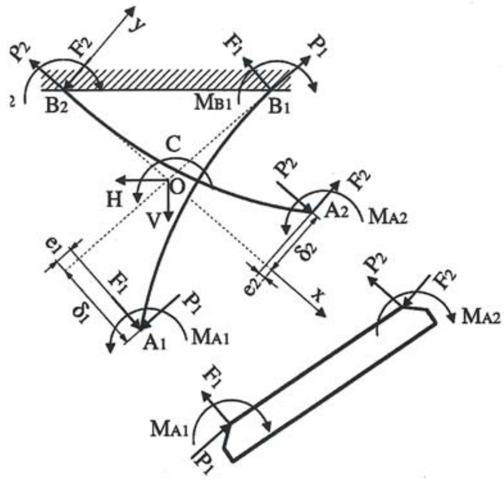


ADVANCED DESIGN OF UHV & RADIATION COMPATIBLE, HIGH-HEAT LOAD, HIGH-PRECISION AND OTHER COMPLEX ACCELERATOR AND BEAMLINE EQUIPMENT

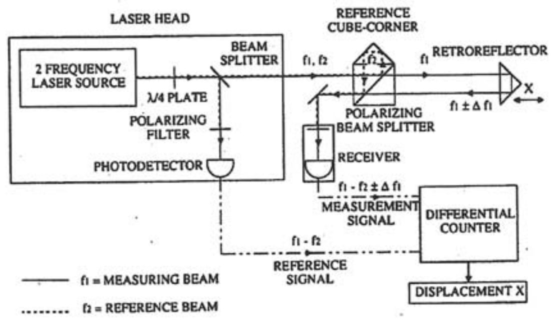


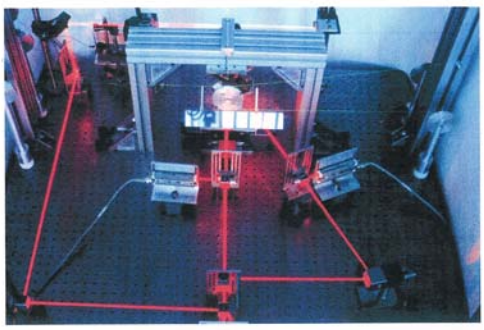




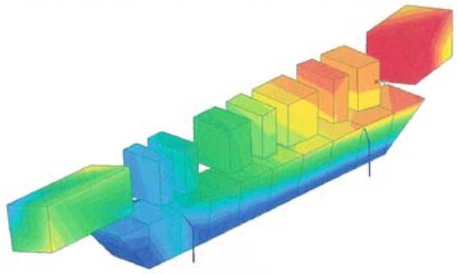


ANALYTICAL AND NUMERICAL (FEM) MODELING OF STRUCTURAL (STATIC & DYNAMIC + MODAL), THERMAL, NON-LINEAR (BUCKLING, CONTACT, LARGE DISPLACEMENTS, …), TRANSIENT … PROBLEMS

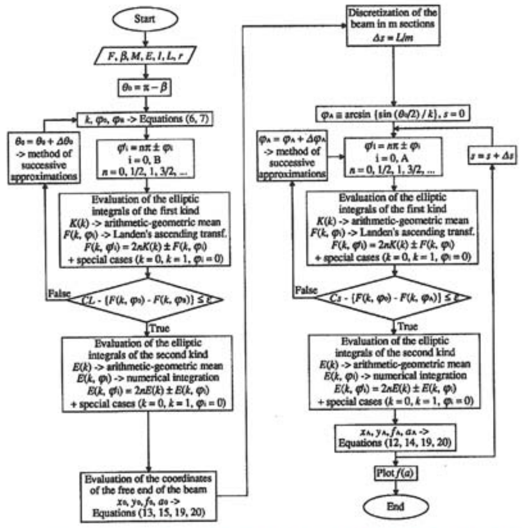


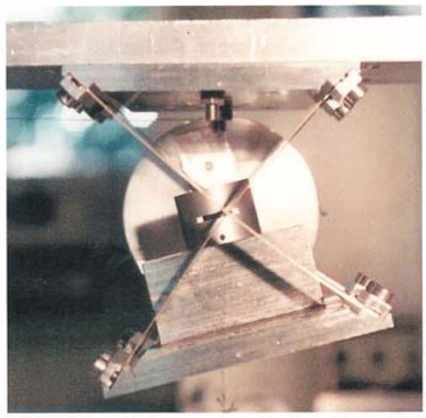


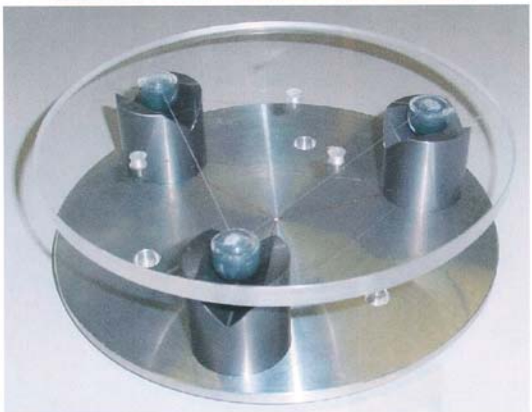
MICHELSON-TYPE HETERODYNE LASER INTERFEROMETRIC MEASUREMENTS: LINEAR (resol.: 10nm), ANGULAR (0.05") & STRAIGHTNESS (10 nm) MEASUREMENTS OF GIRDERS, INSERTION DEVICES' POLES, BEAMLINE COMPONENTS, …



VIBRATION MEASUREMENTS ON MACHINE AND BEAMLINE COMPONENTS (INCLUDING OPTICS) AS WELL AS ON INFRASTRUCTURE EQUIPMENT







ORIGINAL APPROACHES TO THE ANALYTICAL MODELING AND EXPERIMENTAL ASSESSMENT OF THE PERFORMANCES OF UHV-COMPATIBLE ULTRA-HIGH PRECISION DEVICES

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ORGANIZATION OF THE "1st International Workshop on Mechanical Engineering Design of Synchrotron Radiation Equipment and Instrumentation" (MEDSI 2000)

2nd edition: APS, 2002
3rd edition: ESRF, May 2004

Current Status

On July 1st 2002 the SLS ME Group has been merged with the Division of Mechanical Engineering Sciences of the PSI LOG Department

The current tasks for the SLS include:

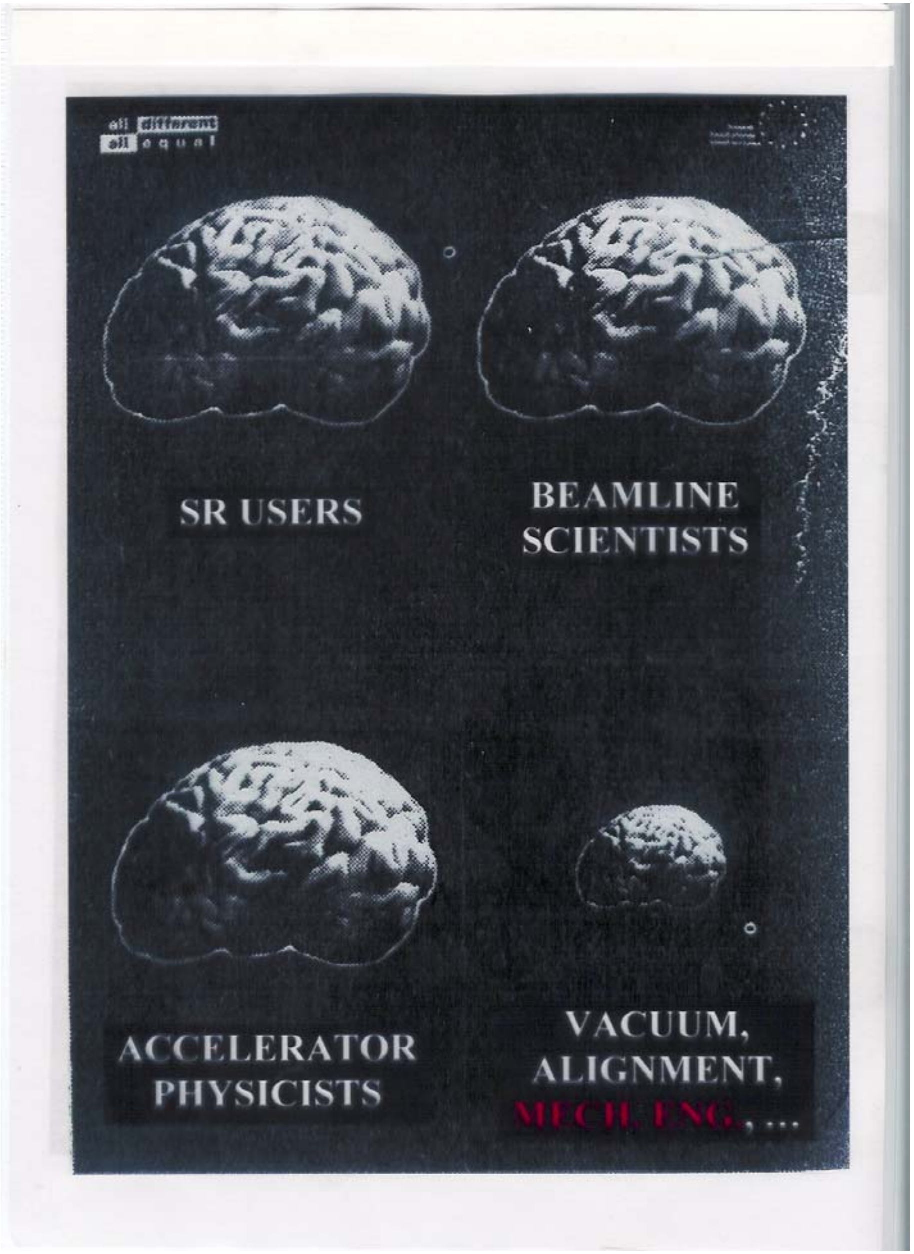
- Design and production of components for the fs project
- Conceptual design, design reviews and production follow-up of 3 U19 in-vacuum insertion devices and the UE54 device
- Design of support components for the Superbends
- Design of front-end components
- Design and production of optical components for the PX II beamline
- Design and production of critical beamline components (e.g. innovative diamond vacuum window)
- Updates of the global SLS reference model
- …

INSTEAD OF A CONCLUSION

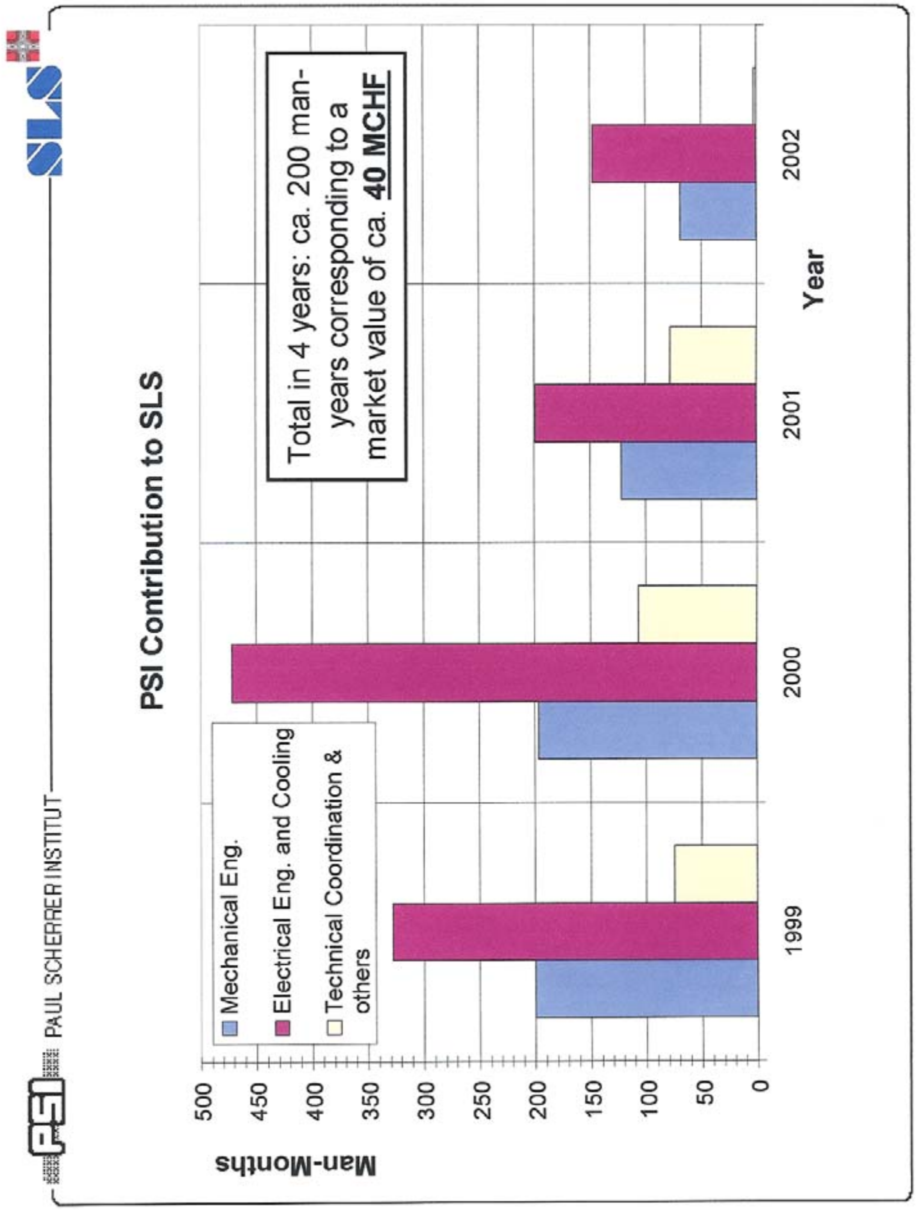
The SLS experience proves that such complex projects can be dealt with only via an interdisciplinary approach

Generally the role of vacuum experts, alignment crews, mechanical and electrical engineers, technicians, … is considered of lower relevance

I do hope that this presentation could help in illustrating the importance of our contribution to this joint effort



all different
all equal
SR USERS
BEAMLINE SCIENTISTS
ACCELERATOR PHYSICISTS
VACUUM, ALIGNMENT, MECH. ENG., ...



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SLS
PSI Contribution to SLS
Mechanical Eng.
Electrical Eng. and Cooling
Technical Coordination & others
Total in 4 years: ca. 200 man-years corresponding to a market value of ca. 40 MCHF
Man-Months
500
450
400
350
300
250
200
150
100
50
0
1999
2000
2001
2002
Year

Engineering is not a science. Science studies particular events to find general laws. Engineering design makes use of these laws to solve particular problems. In this it is more closely related to art or craft; as in art, its problems are under-defined, there are many solutions, good, bad, or indifferent. The art is, by a synthesis of ends and means, to arrive at a good solution. This is a creative activity, involving imagination, intuition and deliberate choice.

Ove Arup

"In educating engineers, we probably have the largest challenge of any educational component because we expect them to be technically competent, good managers, good economists, good businesspeople, good communicators, good citizens and international leaders. Other than that the job is easy."

Winfred M. Philips
Dean of engineering
University of Florida in Gainesville