Ground Vibration Measurements at DESY

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motivation

magnet vibration could have a significant effect on the beam quality of particle accelerators

- betatron oscillation + decoherence -> emittance
- aberration effects -> emittance
- pointing stability (light sources)
- displacement at the IP (collider)

the beam quality requirements are increasing

- synchrotron light sources, third generation, fourth generation, ...
- linear collider
our consequence

- study the impact of „cultural noise“ at several accelerator laboratories
- site comparison for future accelerators
  (in particular for ILC)

our approach: measurements using always the same equipment and data analysis technique

- comparable data sets for all sites
- creation of a public data base
equipment

- **broadband seismometers (GÜRALP)**
  - measurement of acceleration, output signal: velocity
  - three components: vertical, 2x horizontal
  - integrated 24bit ADC, 200Hz sampling rate
  - data acquisition via notebook / PC
  - frequency ranges: 360s – 80Hz CMG-3T (old)
    - 120s – 80Hz CMG-3T (new)
    - 60s – 80Hz CMG-6T

- **geophone system (KEBE)**
  - SENSOR SM-6 geophones with nonlinear high gain amplifier
  - measurement of velocity, output signal: velocity
  - separate sensors for vertical or horizontal
  - 16bit USB-ADC, 500Hz sampling
  - data acquisition via notebook / PC
  - frequency range: 3Hz – 250Hz
data taking and analysis

- continuous data acquisition for 24h or more
- one dataset per minute
  - -> 700MB per day and sensor
- “FFT” based on this file structure
  - -> 1/60Hz lower frequency limit
    - usually without windowing
- integration (velocity -> motion)
  - -> power spectral density (PSD) of motion
- integration above cut frequency
  - -> rms-value of motion (in nm) versus f

- interactive Visual Basic programs
- automated online analysis
  - focus on: vertical component
typical PSD

- $1/\omega^4$ drop $\rightarrow$ random walk noise
- microseismic peak (seven second hum) at 0.1-0.2Hz
- $f > 1$Hz: cultural noise $\rightarrow$ uncorrelated
typical PSD + integrated view

- $1/\omega^4$ drop $\rightarrow$ random walk noise
- microseismic peak (seven second hum) at 0.1-0.2Hz
- $f > 1$Hz: cultural noise $\rightarrow$ uncorrelated
site comparison

Example: Saltmine “Asse” (900m below surface) in comparison to CERN, Fermilab, TESLA and DESY

-> large difference in cultural noise

-> rms values (f>1Hz between 1nm and 100nm)
single events: earthquakes

2.5h raw data, taken at DESY

10min raw data, taken at DESY

-> magnitude 8.7 earthquake in Indonesia causes gigantic ground motion signals in Germany, but:
-> very low frequency => well below 1Hz
single events: street traffic

raw data (velocity)

-> nearby street traffic causes signals in the frequency range between 1Hz and 10Hz
modelling of cultural noise

- numerical ground mechanical model for street or rail traffic
  - inputs: number of cars, trucks …, masses, damper characteristics, unevenness of street/rail, distance to the street/rail, soil parameters
  - in cooperation with TU HH (Hamburg University of Technology)

preliminary result:

street (rail) traffic seems to be the main reason for “cultural noise”
rms values vs. time

- day-night variation
- working day < > weekend difference

=> for site characterisation it’s important to take data for long periods

example: XFEL synchronous measurement with three sensors along the foreseen XFEL site close to DESY
rms value distribution

distribution of the rms values of vertical motion (f>1Hz) for complete data taking periods

• usually no gaussian distribution
• two maxima
  -> quiet times during the night, busy times during the working hours
=> typical distribution for different sites
peak to peak value distribution

another characterisation technique:

• numerical integration of velocity raw data for 1s periods -> displacement (implied 1Hz frequency cut)

• peak to peak value analysis

• sensitive to short events (1s time scale, no averaging over 1min)

• worst cases included

=> maxima and width characteristic for different sites
SSRF site measurements

- Data taking at the SSRF site in southeast Shanghai during ongoing construction work
- Construction works stopped for 24 h

- Four sensors used:
  - “S4” and “S5” (CMG-6T) on the concrete foundation of the foreseen experimental area
  - “S3” (CMG-3T) on a much thinner concrete foundation outside the foreseen buildings
  - “S2” outside the temporary office building

- Data taking for about 48h
- GPS synchronization
results from SSRF site (1)

PSD comparison for *vertical motion*, experimental area foundation, average of 1h quiet versus 1h noisy time

- strong influence of cultural noise above 1.5Hz
- clear microseismic peak at 0.23Hz
- clear second microseismic peak at 0.64Hz
- typical sharp peaks around 1.3Hz (one or two) (frequency not constant!)
- good “correlation” for 30m distance up to about 2Hz
- 50Hz signal (unimportant)

- **rms values for f>1Hz:**
  - quiet: 102nm
  - noisy: 444nm
results from SSRF site (2)

PSD comparison for horizontal motion, experimental area foundation, average of 1h quiet versus 1h noisy time

- similar
- also microseismic peaks at 0.23Hz and 0.64Hz
- good “correlation” also for frequencies above 2Hz

rms values for f>1Hz:
- quiet: 127nm
- noisy: 354nm
results from SSRF site (3)

PSD comparison for **vertical motion**, outside the experimental area, average of 1h quiet versus 1h noisy time

- **strong events**
- much larger amplitudes

- **rms values for f>1Hz:**
  - quiet: 202nm
  - noisy: 1510nm

=> experimental area foundation substantially improves the vibration situation!
results from SSRF site (4)

rms values of vertical motion (f>1Hz) versus time

SSRF Shanghai 2005: rms values of vertical motion (f>1Hz) in nm, sensors S4 and S5 on the experimental area foundation, S3 outside

“quiet” during the night
maximum in the morning
large fluctuations during noisy times

stop of construction works

experimental area outside

19
results from SSRF site (5)

peak to peak distribution

broad distributions
highest maximum value

=> noisiest site we measured up to now
microseismic signal versus time

- tidal behaviour of second hum \(\rightarrow\) maxima at flood time?
- is also the sharp signal at around 1.3Hz correlated to water waves on the river?
## status of our site comparison

### Peak to Peak distribution

<table>
<thead>
<tr>
<th>Location</th>
<th>Maximum pp (nm)</th>
<th>FWHM (nm)</th>
<th>Average RMS (nm)</th>
<th>SD σ (nm)</th>
<th>Selected Data Quiet RMS (nm)</th>
<th>Noisy RMS (nm)</th>
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<td>3.3</td>
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<td>1000</td>
<td>292</td>
<td>164</td>
<td>102</td>
<td>444</td>
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</table>
http://vibration.desy.de

our data is available for everyone
• live data from DESY
• direct download
  • all raw data
  • selected data
  • spectra, results
  • software
software download

interactive visual basic application for
• PSD display
• integrated view
• zoom etc.
• averaging
• back FFT
• ...
The measurements were done with the help of:

- David Carles from ALBA, Cerdanyola
- Louis Emery from APS, Argonne
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- Thorsten Bierer and Jürgen Grabe from TUHH, Hamburg
“seismic station”

rms value of vertical motion (nm) for f>1Hz vs. time, HERA tunnel at WL745m, calendar week 13 (2004)

- permanent data acquisition
- permanent data transfer to the University of Hamburg -> geophysics
- online data available for everybody worldwide (on request) -> SCREAM
**TESLA module vibration** inside the TTF tunnel

**rms value of motion for f>3Hz versus time**

⇒ strong module vibration  
⇒ vacuum installation?  
⇒ module installation itself?  
⇒ further investigation is necessary
... in action