FLASH Upgrade

FLASH.
Free-Electron Laser
in Hamburg

FLASH free-electron laser user facility at DESY

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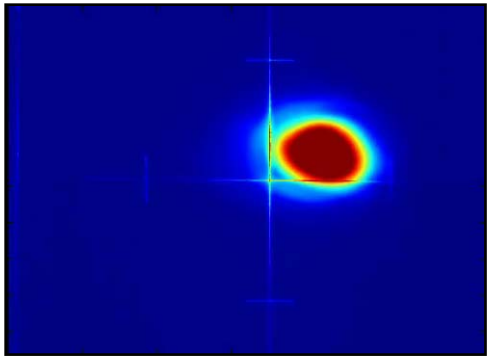
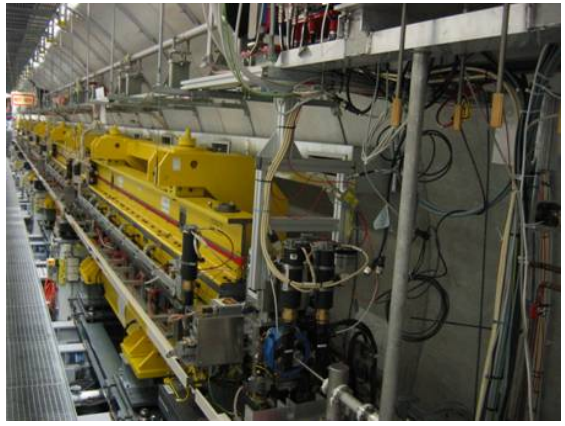
DESY

IPAC 2010
Kyoto, Japan
May 23-28, 2010





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FLASH at DESY in Hamburg

FLASH.
Free-Electron Laser in Hamburg

- single-pass high-gain SASE FEL
  - **SASE = self-amplified spontaneous emission**
- photon wavelength range from vacuum ultraviolet to soft x-rays
- free-electron laser user facility since summer 2005
  - 1st period: Jun 2005 – Mar 2007
  - 2nd period: Nov 2007 – Aug 2009
  - 3rd period: starting late summer 2010
- FLASH is also a test bench for the European XFEL and the International Linear Collider (ILC)

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FLASH layout before upgrade (Sep-2007 – Sep-2009)

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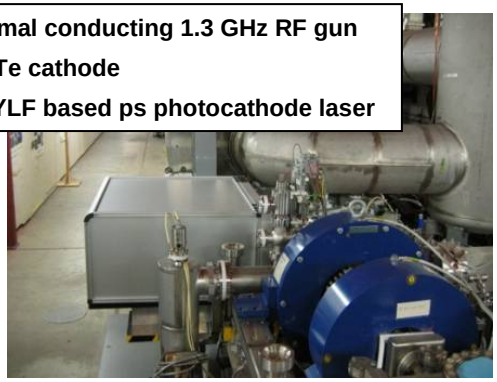
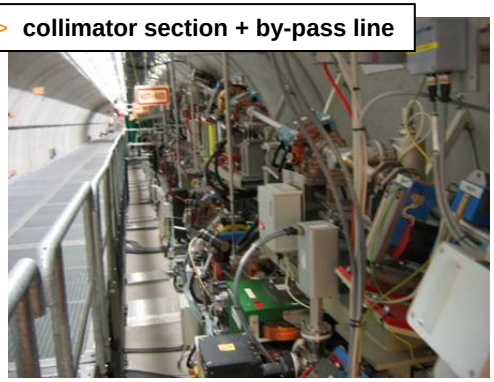
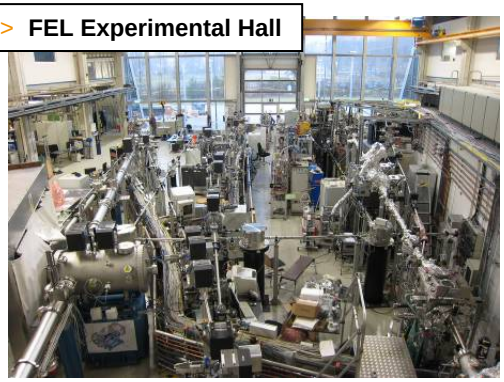
> normal conducting 1.3 GHz RF gun
> Ce_2Te cathode
> Nd:YLF based ps photocathode laser

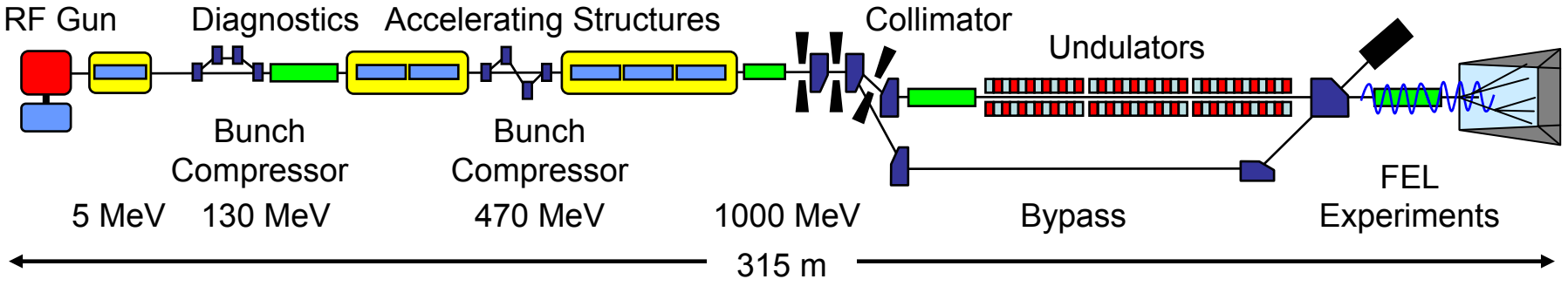


> collimator section + by-pass line



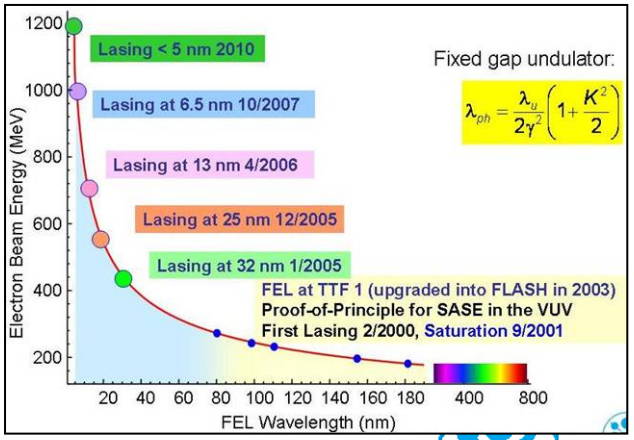
> FEL Experimental Hall





> TESLA type superconducting accelerating modules
> each module has eight 9-cell Nb cavities
> operated at 1.3 GHz

> fixed gap undulator
> total magnetic length ~ 27 m
> permanent NdFeB magnets



Poster TUPE004

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FEL performance

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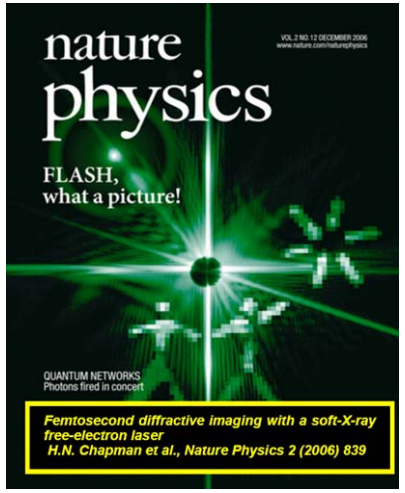
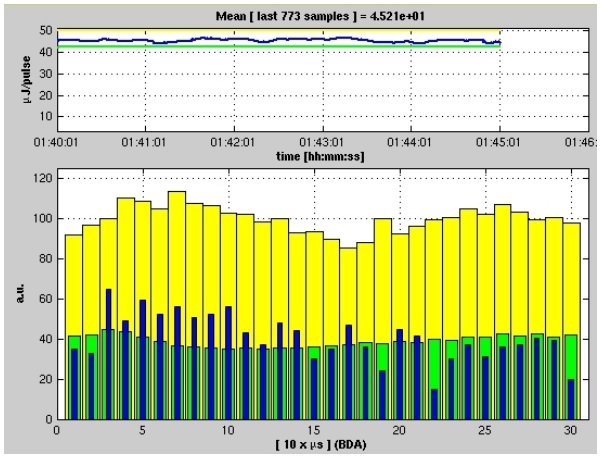
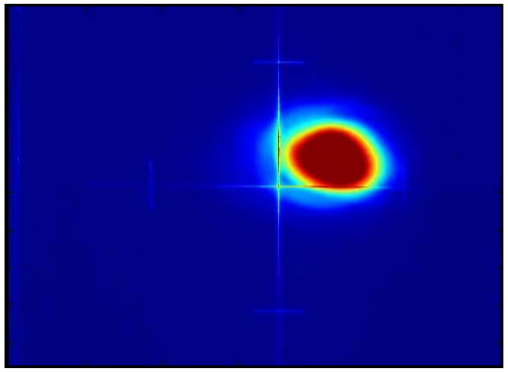
Typical user operation parameters (second user period)

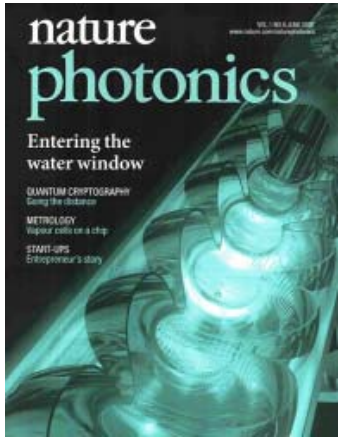
Wavelength range (fundamental)	6.8 – 40.5 nm
Average single pulse energy	10 – 100 µJ
Pulse duration (FWHM)	10 – 70 fs
Peak power (from av.)	1 – 5 GW
Average power (example for 500 pulses/sec)	~ 15 mW
Spectral width (FWHM)	~ 1 %
Peak Brilliance	$10^{29} – 10^{30}$ *

* photons/s/mrad^2/mm^2/0.1%bw









> more than 100 publications on photon science at FLASH in high impact journals
  - http://hasylab.desy.de/facilities/flash/publications/selected_publications

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Upgrade 2009 / 2010

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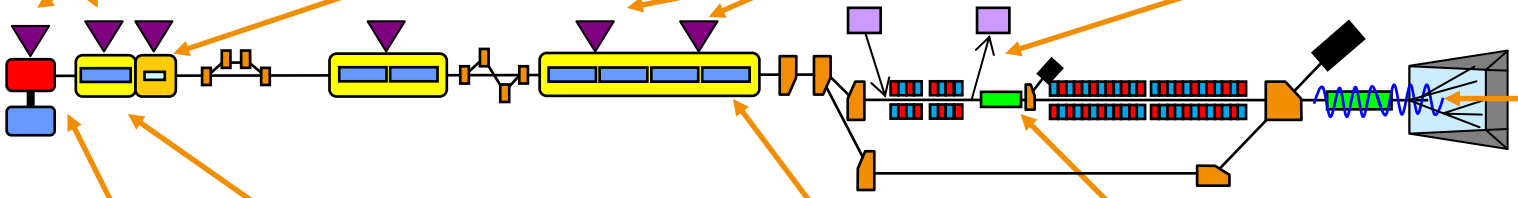
> upgrade shutdown: end September 2009 – mid February 2010



exchanged RF stations

3rd harmonic module + RF station

additional RF station + exchanged RF station

seeding experiment sFLASH + redesigned electron beamline

upgraded photon diagnostics and beamlines

new RF gun

exchanged 1st accelerating module

7th accelerating module

transverse deflecting cavity + spectrometer arm / tuning dump

new diode pumped photocathode laser; upgraded old laser system

exchanged injector corrector magnets

upgraded magnet controls

maintenance of infrastructure: water supplies, cryogenics

new synchronization and feedback systems

optimized llrf controls

improved survey and alignment of accelerator components (incl. SASE undulators)

new cabling/layout injector llrf electronics

upgraded and optimized waveguide distribution

upgraded personnel interlock und radiation safety systems

installation of a second master oscillator (as backup)

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RF gun and 1st accelerating module

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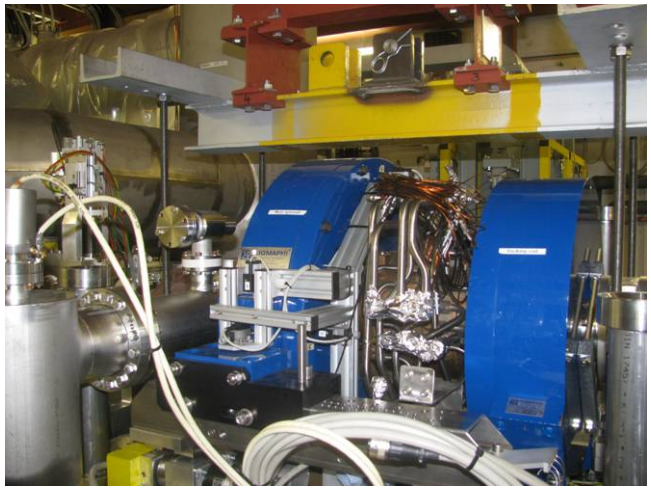
- RF gun replaced by a new gun tested and commissioned at PITZ (DESY-Zeuthen)
  - low darkcurrent
    - reduced by a factor of 10 **Poster TUPE006**
  - installations allowing a 10 MW operation in the mid-term future
    - higher accelerating gradient at the photocathode → improved electron beam quality
- 1st accelerating module replaced
  - new high performance cavities
  - with piezo tuners



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Bunch compression and third harmonic cavities

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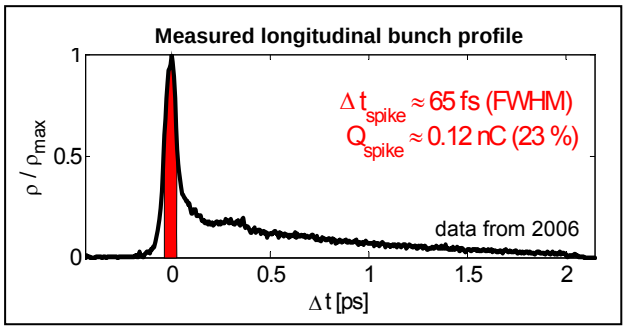
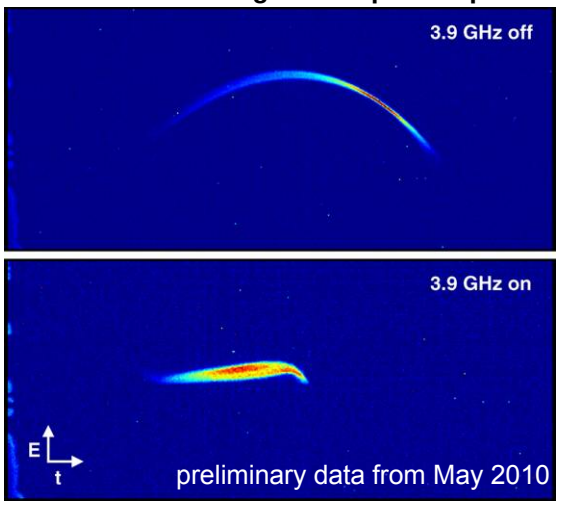
Free-Electron Laser in Hamburg

- lasing process requires simultaneously a small emittance and a high peak current
- compression scheme used so far leads to non-linear bunch compression
  longitudinal bunch shape with a sharp spike (~ 50 fs) with a high peak current and a long tail
  - only a fraction of the bunch contributes to lasing
- longitudinal phase space can be linearized by 3rd harmonic cavities
  - more regular shape of the compressed bunch
  - larger part of the electron bunch contributes to lasing
- 3.9 GHz module installed downstream of the first accelerating module
  - 4 nine-cell superconducting cavities
  - operated at 3.9 GHz (3rd harmonic of 1.3 GHz)
  - designed and constructed at FNAL in a collaboration with DESY



Linearization of longitudinal phase space



Poster THPD003

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Mounting of accelerating modules in injector

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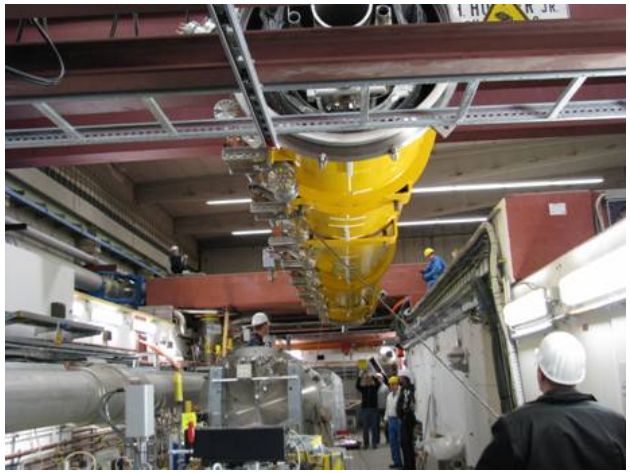

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Energy upgrade

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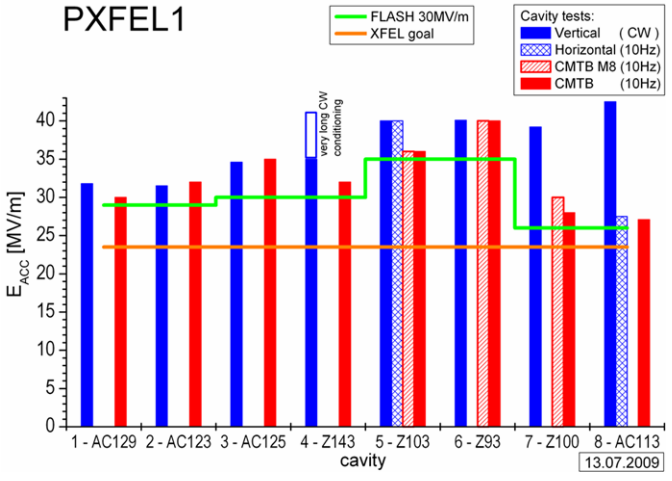
- 7th superconducting TESLA type accelerating module installed
  - prototype module for the European XFEL
- electron beam energy up to 1.2 GeV ↔ ~ 5 nm photon wavelength

1.2 GeV demonstrated with beam in May 2010

Results of cavity tests



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Transport of 7th accelerating module

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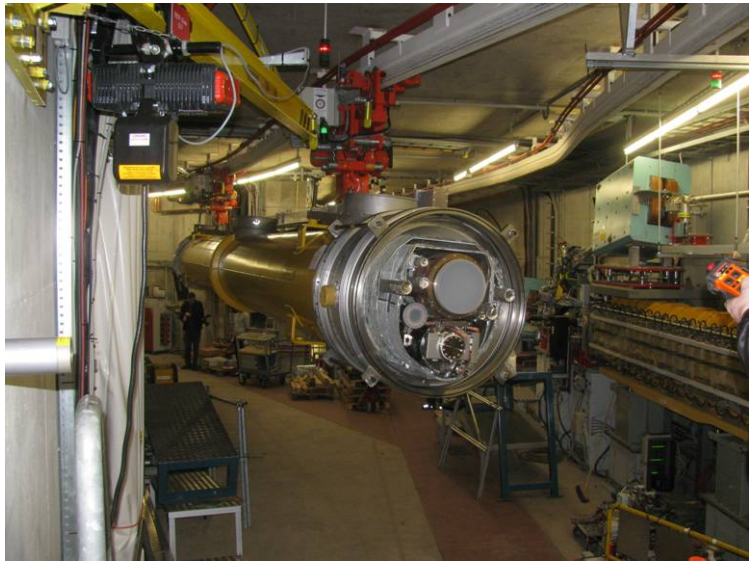

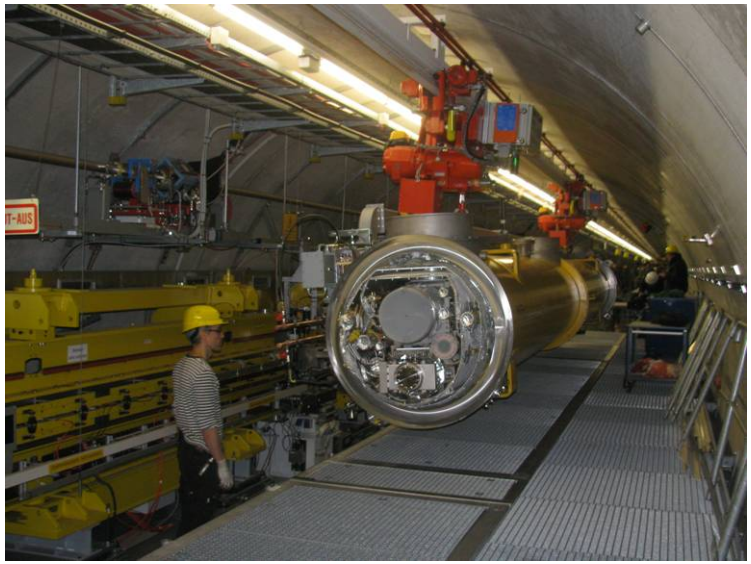

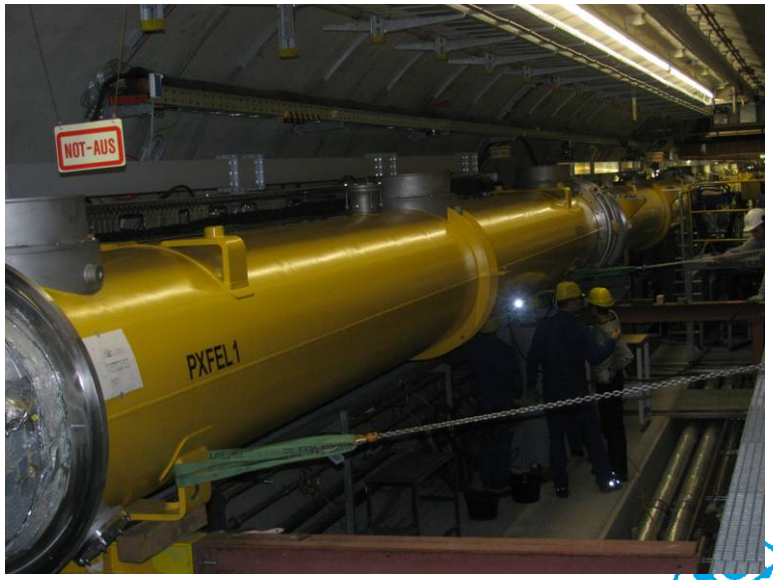

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Upgrade of RF stations and waveguide system

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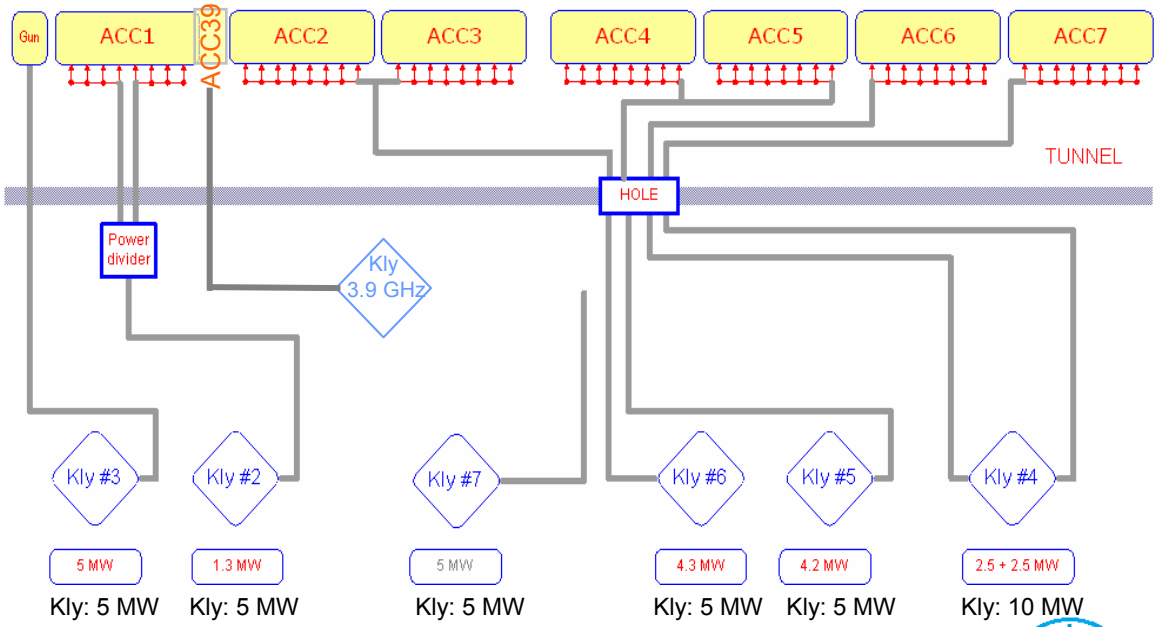
- 2 complete RF stations + 1 modulator replaced
  - all stations of same type now
- one additional RF station to optimize operation with seven accelerating modules
- accelerating modules 1, 6, and 7 have the optimized XFEL type waveguide distribution
  - power for each cavity pair can be adjusted individually to optimize energy reach



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sFLASH: experiment for seeded FEL radiation

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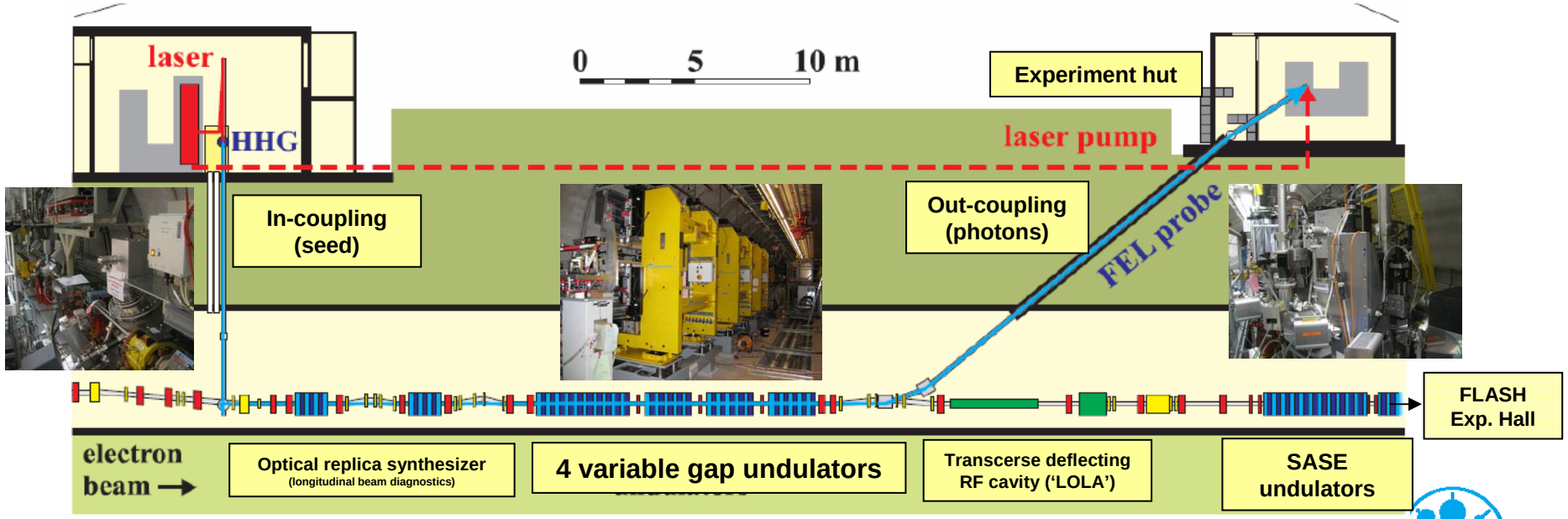
Free-Electron Laser in Hamburg

- goal: generation of seeded FEL radiation for piloting experiments
- installed between the collimator and SASE undulators in the FLASH linac → new electron beamline with a length of ~ 40 m
- HHG seeding at ~ 38 nm (~ 13 nm as an option)
  - **HHG = high harmonic generation**
- synchronisation goal for pump probe experiments 10 fs
- collaboration of DESY and University Hamburg



Poster TUPE009

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Operation with long bunch trains

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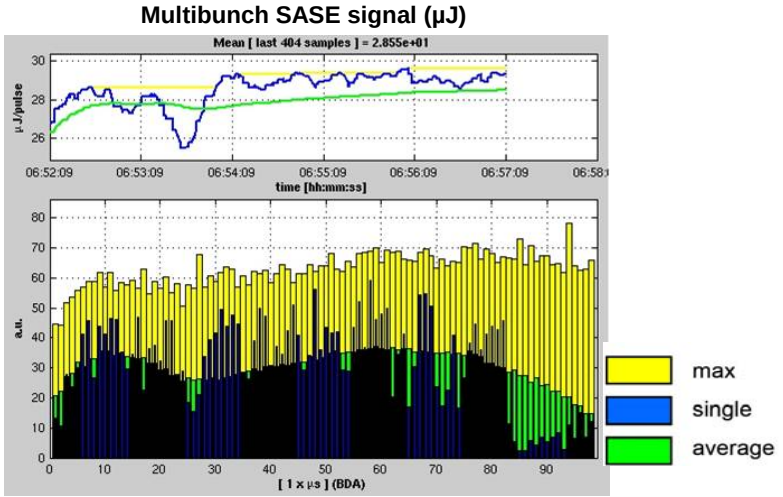
- lasing with 800 bunches / train demonstrated in spring 2007
  - 1 MHz bunch spacing, 5 Hz rep. rate
- some user experiments with ~100 bunches / train in spring 2008
- 3rd user period: trains with a few hundred photon pulses will be available
  - repetition rate increased from 5 Hz to 10 Hz
  - variable bunch spacing, e.g. 1 MHz, 500 kHz, 200 kHz, 100 kHz, 40 kHz
  - variable number of pulses per train (max train length 800 us)

- example from March 2008
  - 100 bunches / train
  - 500 kHz bunch spacing
  - photon wavelength 7.05 nm



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FLASH II

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Free-Electron Laser in Hamburg

- second undulator line and experimental hall
- common proposal by DESY and Helmholtz-Zentrum Berlin
- in planning phase

Poster TUPE005

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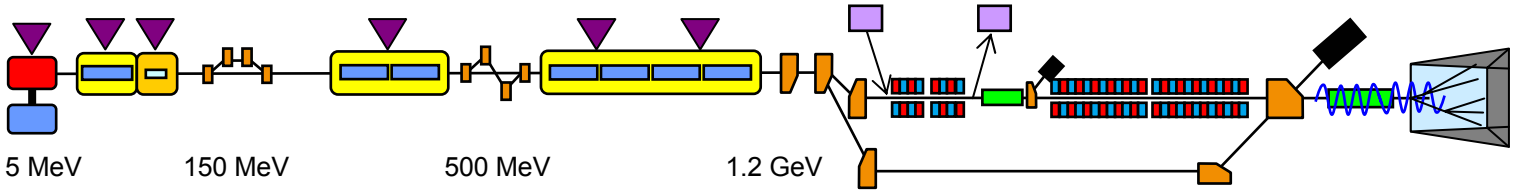
Summary and outlook

FLASH.
Free-Electron Laser in Hamburg

- FLASH finished in August 2009 the very successful 2nd user period
- upgrade shutdown from autumn 2009 to early 2010
- major modifications
  - energy upgrade to 1.2 GeV (7th accelerating module installed)
  - installation of the 3rd harmonic module
  - sFLASH seeding experiment
- commissioning of the upgraded facility on-going
- lasing expected in June 2010
- 3rd FEL user period scheduled to start late summer 2010



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