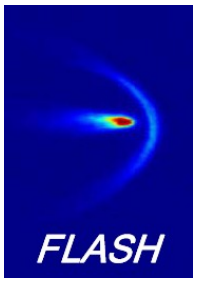
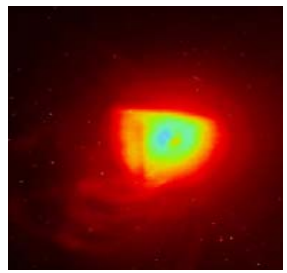
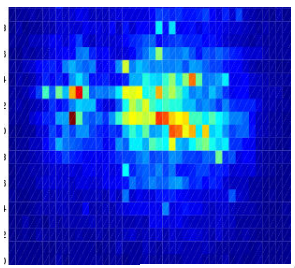
VUV-FEL
Vacuum-Ultraviolet
Free-Electron Laser

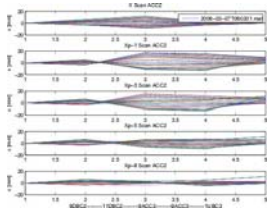


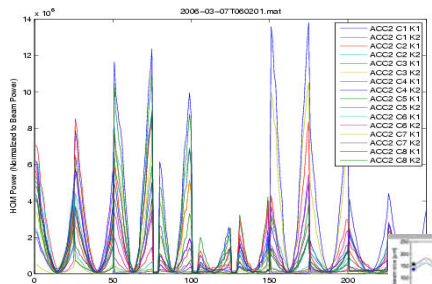
Summary of accelerator studies at VUV-FEL (FLASH) 27.2-9.4.2006

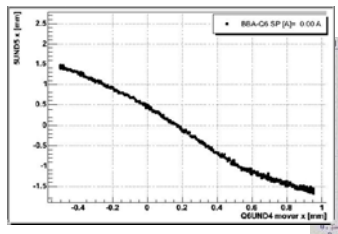


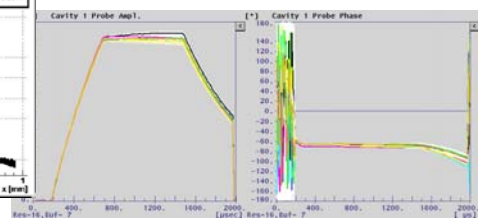
Katja Honkavaara
Uni HH / DESY

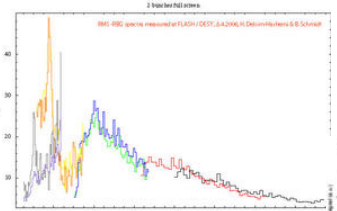


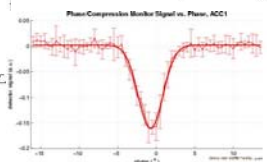


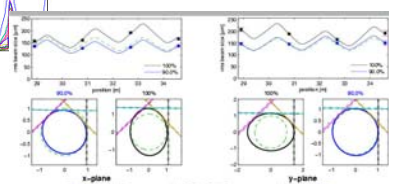


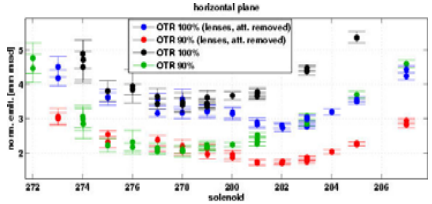


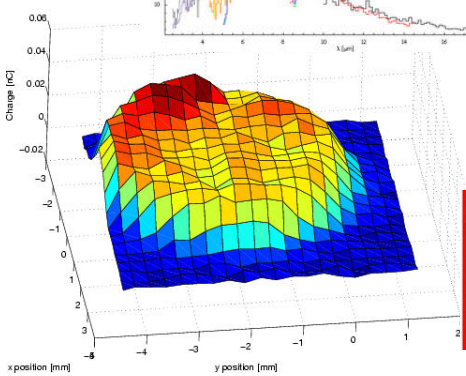


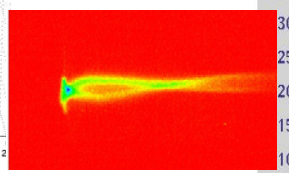


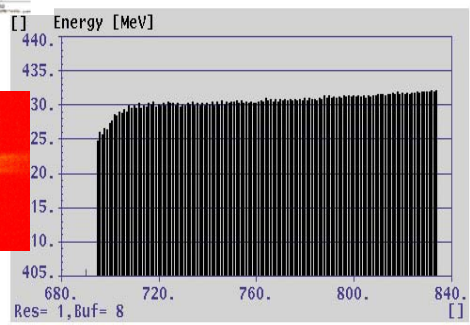


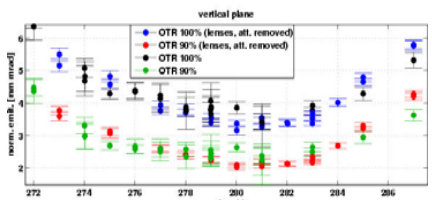












Accelerator studies in weeks 9-14

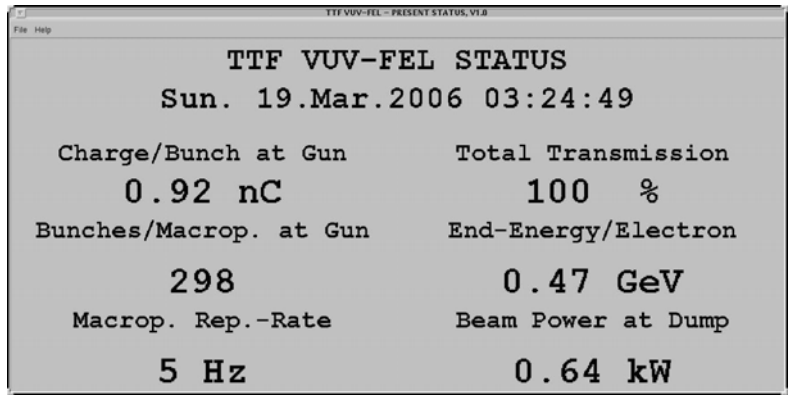
- Accelerator study weeks are open: they are mainly intended for general accelerator studies related to VUV-FEL and to the future projects (mostly XFEL and ILC)
  - in contrast to the FEL study weeks which concentrate on the requirements for the next FEL user period
- Requests are collected well in advance, beam-time has been allocated according to available beam time and possibilities, supervised by the Beam-time Allocation Committee (chair H. Weise)
- Requests for many different experiments: ~140 shifts (available 126 shifts, 1shift = 8 hours)
- Machine/beam time was required also
  - for maintenance (~ 1 shift / week)
  - to start-up after maintenance, to set-up of different machine conditions
  - down time (not included in schedule)
- Collaborators from different laboratories participated in studies
  - SLAC, FNAL, INFN-LNF/Roma2, INFN-Milano/LASA, CEA-Saclay, institutes from Poland, …

Study subjects

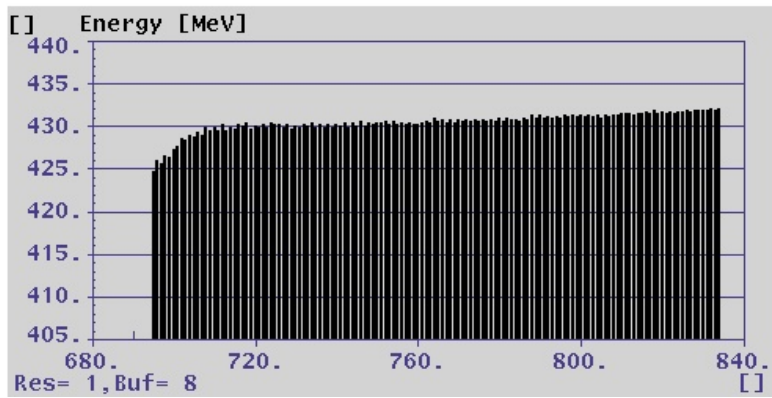
Study	VUV-FEL	XFEL	ILC
Long electron bunch trains	X	X	
High beam energy (~ 630 MeV)	X		
Transverse emittance	X		
LLRF developments	X	X	X
Electron beam diagnostics	X	X	X
High order mode (HOM)	X	X	X
Laser / RF-gun	X	X	
Miscellaneous	X		

Long electron bunch trains

- Transport of beam up to dump without losses
- Machine protection
  - Protection system based on toroid signals
  - Fast switch-off of the machine when loss detected by beam loss monitor system
- LLRF adjustments
  - Stable long pulse operation of RF-gun and acceleration modules
  - Beam load compensation and exception handling



Up to 300 bunches with 1 MHz bunch spacing transported via by-pass line to the dump



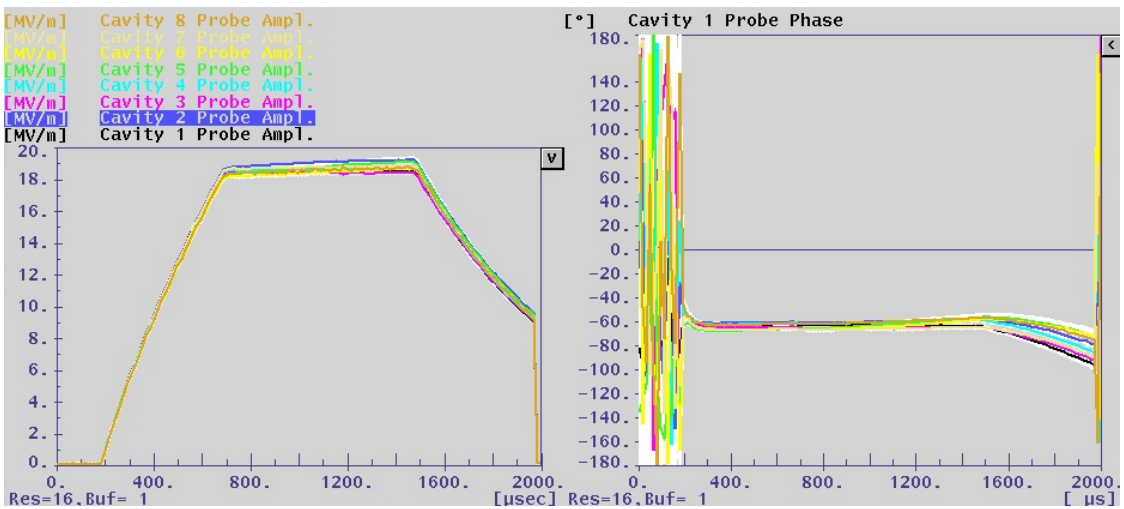
- Next steps
  - Transport of long bunch trains through undulator
  - Increase of number of bunches in the train (up to 800)
  - Lasing with > 30 bunches

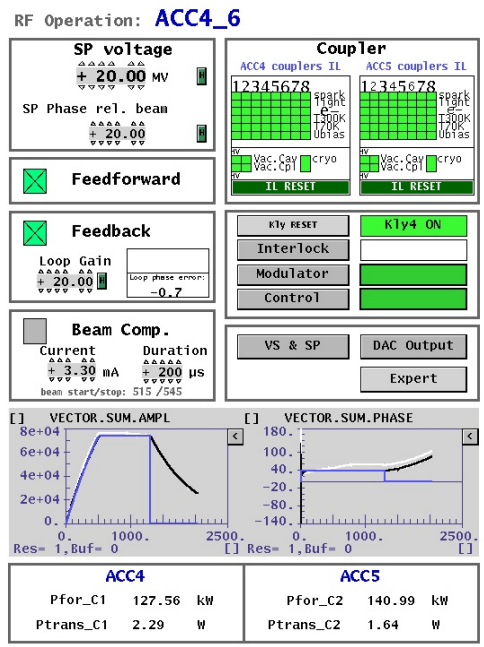
High beam energy

- Goal: maximum possible stable electron beam energy with present hardware
  - Output power of klystron running accelerator modules ACC4/5 was limited to ~ 2 MW
- Gradient of modules ACC4/5 increased to ~ 18 MV/m

Electron beam with energy of ~ 630 MeV transported both via by-pass line and through the undulator to the dump

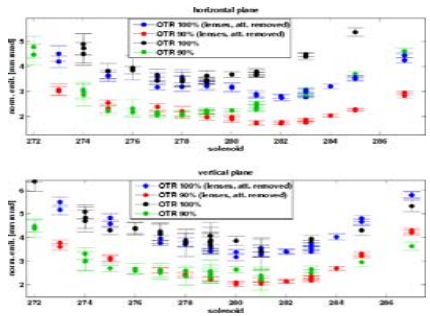
After maintenance in week 15, another klystron available for ACC4/5: beam energy increased up to ~ 700 MeV (lasing with 13.1 nm wavelength)



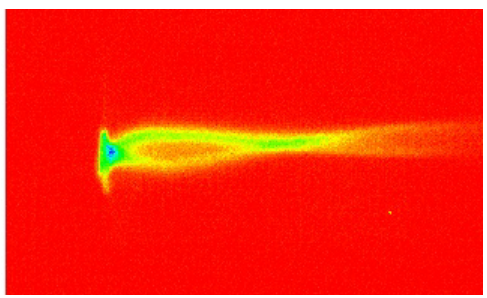


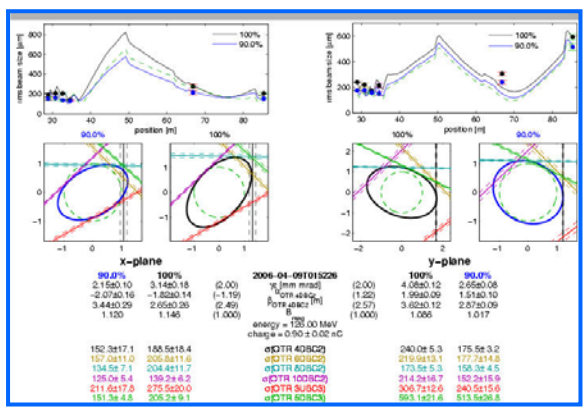
Emittance studies

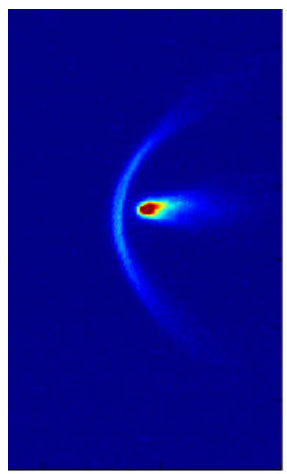
- Projected emittance at the injector (downstream of first bunch compressor)
  - Effects of solenoid current, steering, and laser (attenuator, lenses) studied
  - **90% rms emittance: ~ 2 mm mrad; 100% rms emittance: ~ 3 mm mrad**
- Studies of projected emittance to be continued:
  - Optimization of emittance
  - Emittance with a longitudinally flat laser pulse
  - Emittance transport through the linac



- Development of tools for beam optics matching along the linac
- Slice emittance and slice energy spread measurements using transverse deflecting cavity
  - Analysis not finished yet





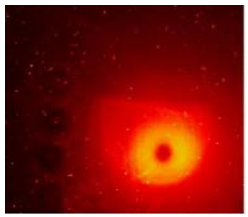
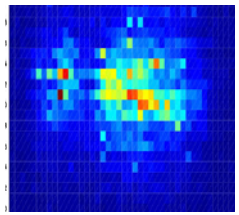
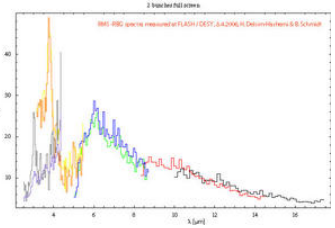
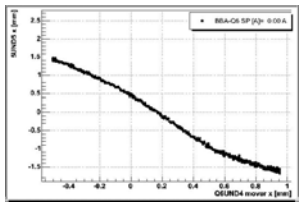


LLRF developments

Study	VUV-FEL	XFEL	ILC
LLRF control of RF-gun and accelerating modules using FPGA (SIMCON) board: improved stability	X	X	
LLRF control with adaptive feed forward	X		
Finite State Machines (RF and klystron): automation of operation	X		
Characterization of klystron non-linearities	X	X	
Transient measurements	X	X	
Piezo tuner		X	X
Alternating acceleration gradient (along the RF pulse and pulse to pulse)			X

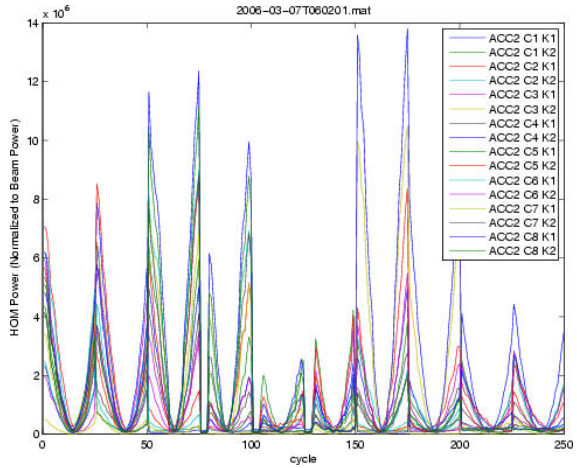
Electron beam diagnostics

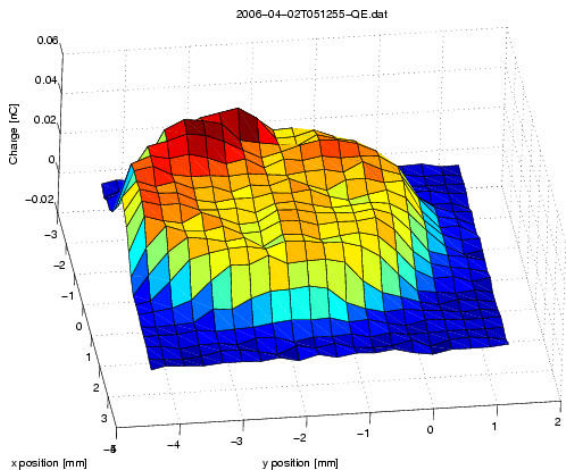
VUV-FEL
Vacuum-Ultraviolet
Free-Electron Laser

   	VUV-FEL	XFEL	ILC
Optical diffraction radiation experiment: development of non-destructive transverse beam size monitor		X	X
Detection of THz radiation and electro optical measurements: information of longitudinal bunch shape	X	X	
Beam position monitors	X	X	X
Energy server (electron beam energy measurements)	X		
Feedbacks (charge, orbit)	X		
Dark current kicker	X		
Miscellaneous diagnostics	X		

Miscellaneous studies

- High order mode (HOM) measurements
  - Study of dipole mode signals from accelerating cavities
  - Calibration of HOM dipole response to use eventually the HOM signal as a BPM
- Laser / RF-gun studies
  - Dark current measurements
  - Quantum efficiency measurements
  - Mapping of the charge emitted from the cathode
- Double-pulse generation
  - Preparation for pump/probe experiments with IR undulator
  - A second laser pulse delayed by some ns
  - Double electron bunches transported to the dump via by-pass line





Distribution of beam time

Beam time used to	Done	Planned
Electron beam diagnostics	20%	21%
LLRF developments	18%	18%
DOWN	17%	-
Long bunch trains	12%	14%
Transverse emittance	10%	14%
Maintenance	5%	4%
HOM measurements	4%	5%
Laser / RF-gun studies	3%	3%
Double pulse	2%	1%
Tuning of 630 MeV beam	2%	7%
SASE	2%	1%
Tuning	2%	7%
Miscellaneous	2%	-
Energy measurements	1%	1%
Quench protection	-	2%
Cryo measurements	-	2%

Beam time distribution for diagnostics

20% of the total beam time was used for electron beam diagnostics developments and experiments. This beam time was distributed among the different experiments as:

Beam time used for	Done	Planned
Optical diff. radiation (ODR)	31%	35%
THz + EOS	22%	24%
Dark current kicker	10%	4%
BPM development	9%	10%
BPM calibration (operator)	8%	-
Energy server + feedbacks	8%	14%
BPM offsets	4%	8%
SR monitor	3%	4%
Camera alignment	3%	1%
Phase monitor	2%	-

Down time statistics

KW 9-14 (17%): down due to	
Cryo	52%
Klystron / Modulator	32%
Magnets	5%
LLRF	5%
Other	6%

Week	Down	Main reason
9	54%	Cryo (99%)
10	16%	Klystron 2 (85%)
11	6%	-
12	1%	-
13	19%	Power cut (70%)
14	7%	-

Week 11 (6%): down due to	
LLRF	46%
Klystron / modulator	18%
Magnets	10%
Operator	10%
Water	5%
Other	11%

Week 14 (7%) : down due to	
Klystron / Modulator	28%
Diagnostics	20%
Water	12%
LLRF	9%
Photon beamline	9%
Laser	9%
Visit	9%
Operator	4%

Summary

- FLASH benefits from most of the studies done during the accelerator study weeks
- Important goals achieved:
  - Long bunch trains (300 bunches @ 1 MHz) transported through the by-pass line
  - Electron beam energy increased up to ~ 630 MeV
  - Preliminary results of experiments promising; off-line analysis needed to finally judge their success
- Results of experiments are presented in the FLASH seminars
- Next accelerator study block (3 weeks) in summer 2006 (KW 30-32)
  - Dead-line for beam time requests: May 4th
  - Requests for > 120 shifts (available 3 x 21 shifts = 63 shifts)
    - Some of FLASH (FEL) related studies may be shifted to FEL study blocks
    - Number of requested shifts may be reduced and some studies shifted to next accelerator study block (December 2006)
  - Summary of requests to BAC (meeting in June, 1st) → Decision of priorities
  - Draft schedule in begin of June; Final chedule before end of June