Operational experience and recent results from FLASH

(VUV FEL at DESY)

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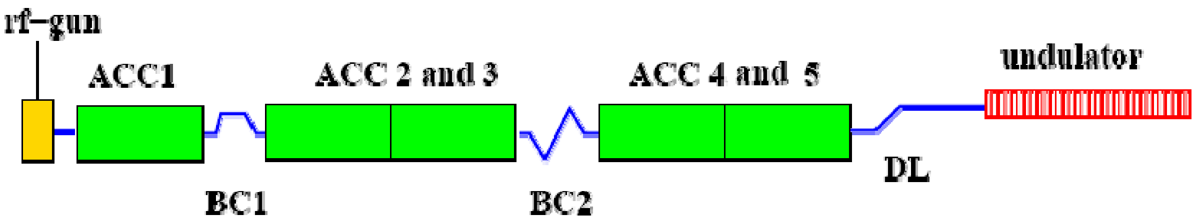
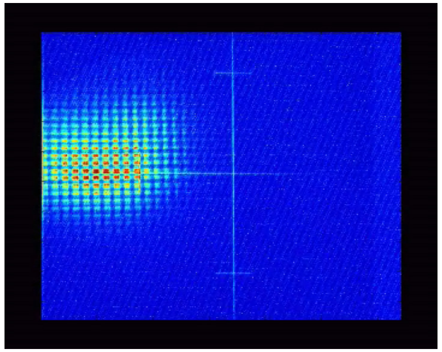
FLS2006, May 16, 2006

- Milestones
- Parameters of FEL radiation
- Beam dynamics: consequences for machine operation
- Tuning SASE: tools and general remarks
- Main problems
- Lasing at 13 nm



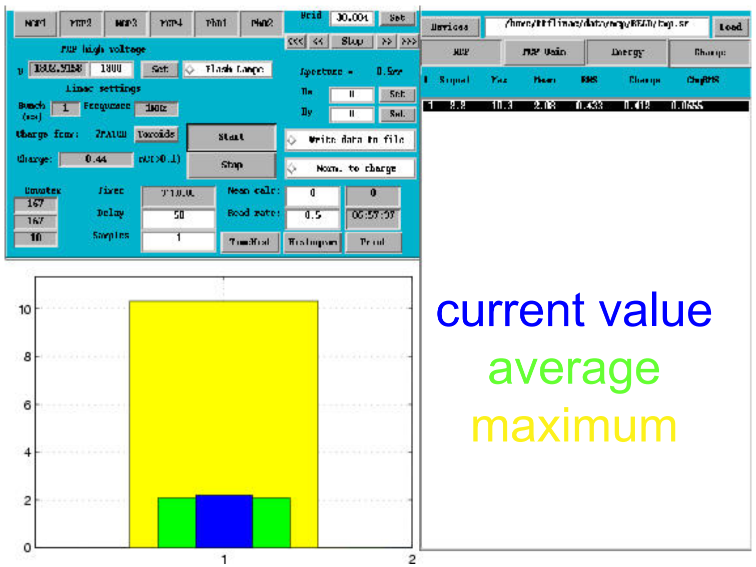


14-29.01.2005

Milestones

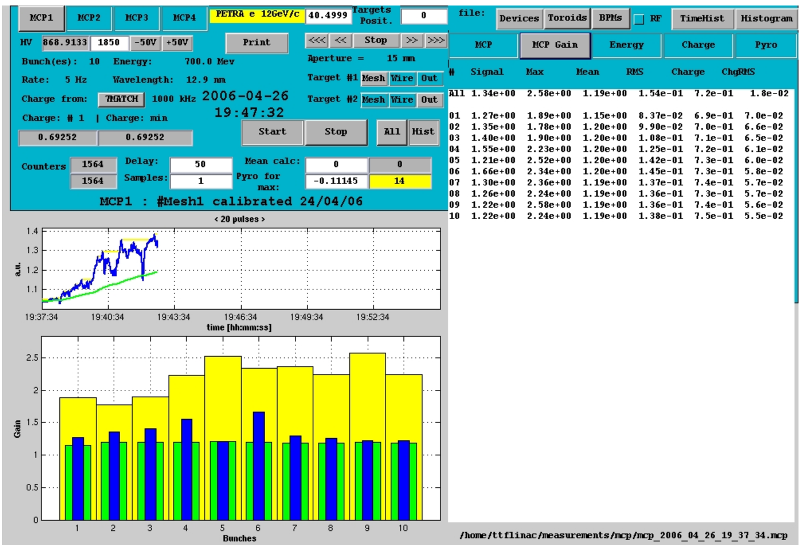
- December 2004: beam through the undulator
- January 2005: first lasing (32 nm)
- June 2005: nonlinear regime, harmonics, stable operation
- August 2005: begin of regular user runs
- November 2005: tunability 25-45 nm
- April 2006: lasing at 13 nm

14.01.2005



32 nm

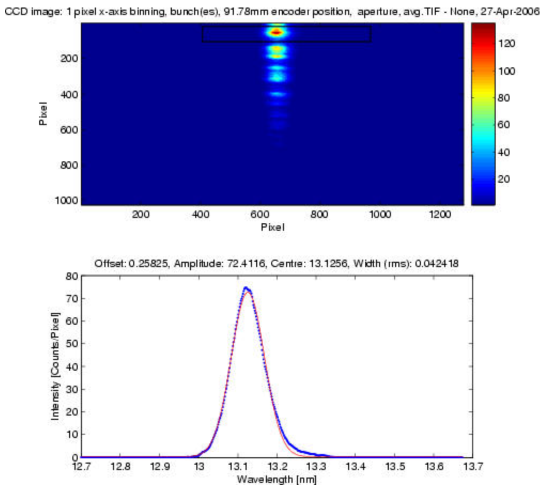
26.04.2006



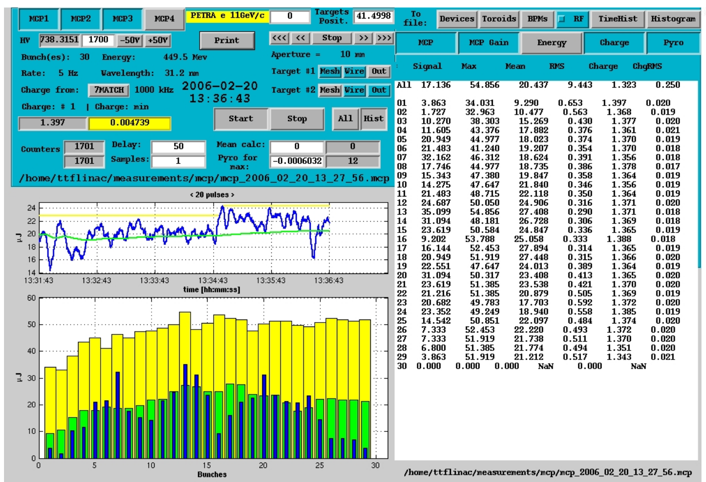
13 nm

Main parameters of FEL radiation

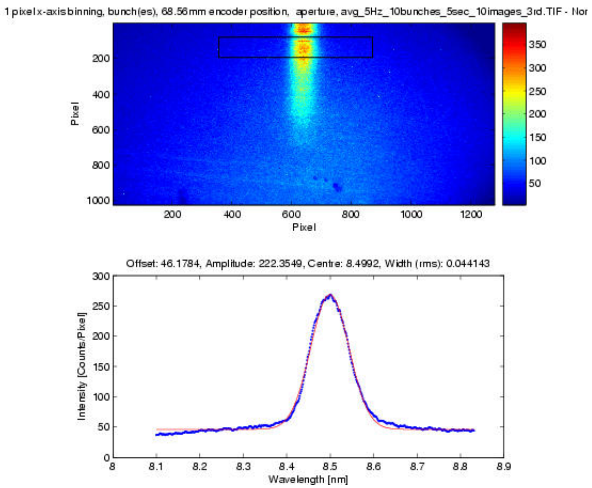
- Wavelength range (fundamental): 13-45 nm
- FEL third harmonic: 8.5 nm
- Pulse energy: up to 30-40 uJ (aver.), ~100 uJ (peak)
- Peak power: > 1 GW
- Average power: up to 3 mW
- Pulse duration (FWHM): 20-50 fs
- Spectral width (FWHM): 0.5-1 %
- Peak brilliance: ~ 10^{29}



13.1 nm (1st harm.)



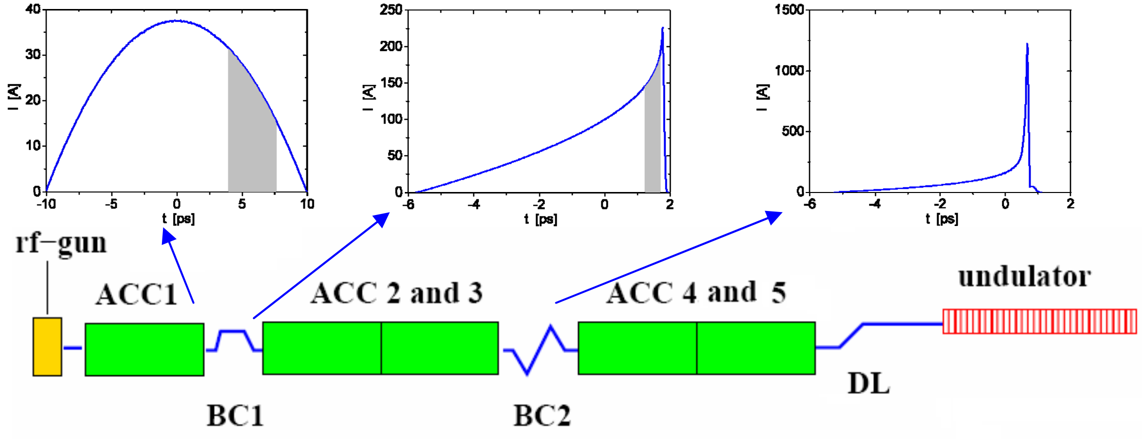
average power 3 mW



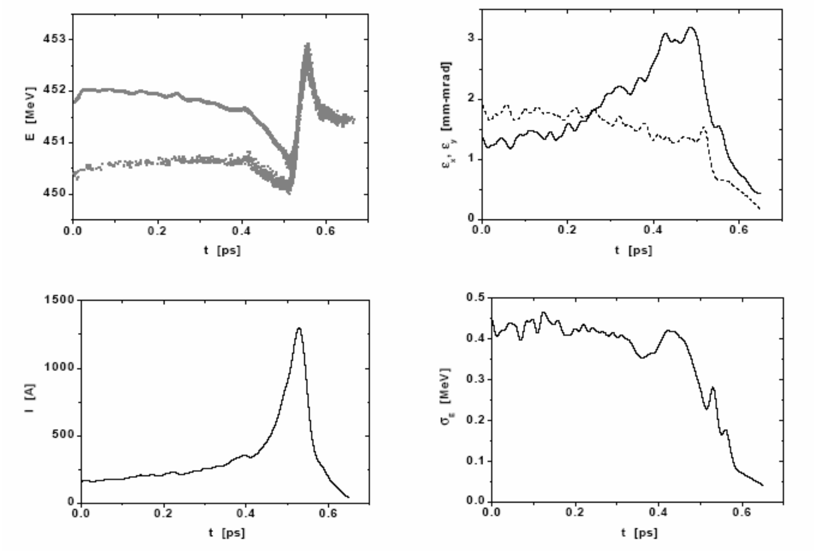
8.5 nm (3rd harm.)

Production of ultra-short radiation pulses

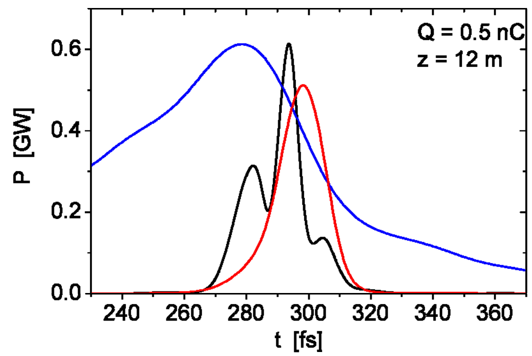
An ultra-short current spike (50-100 fs FWHM) with peak current 1-2 kA is formed in the nonlinear beam formation system of the VUV FEL



s2e simulations



radiation pulses ~20 fs



~10% of charge, properties very different from those of entire bunch

Consequence for machine operation

One can distinguish between two levels:

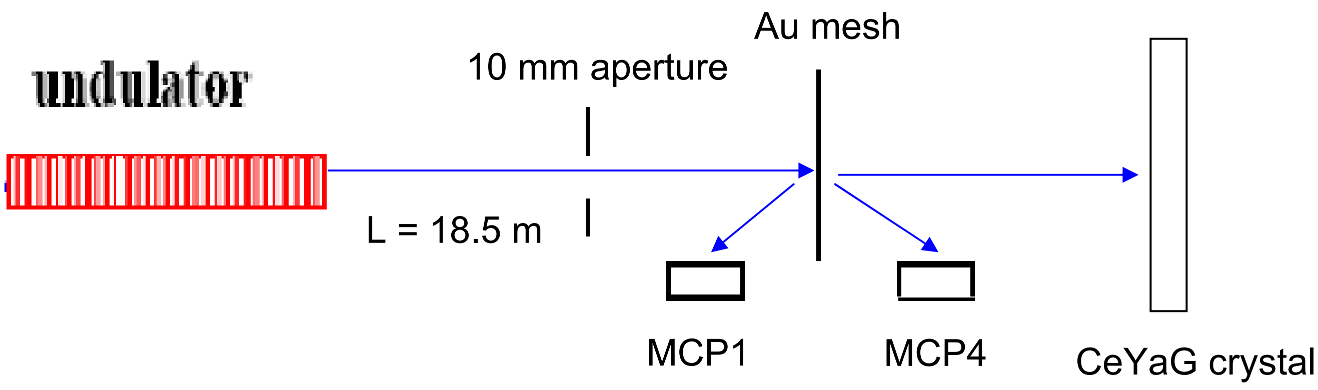
- Zero-order: no compression, single-particle dynamics (except for injector part), standard work on accelerator performance using standard diagnostics

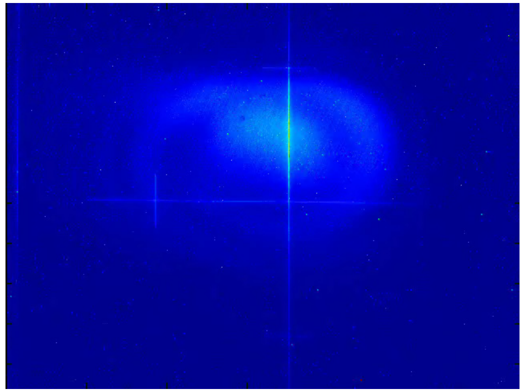
We still have a lot to do at this level

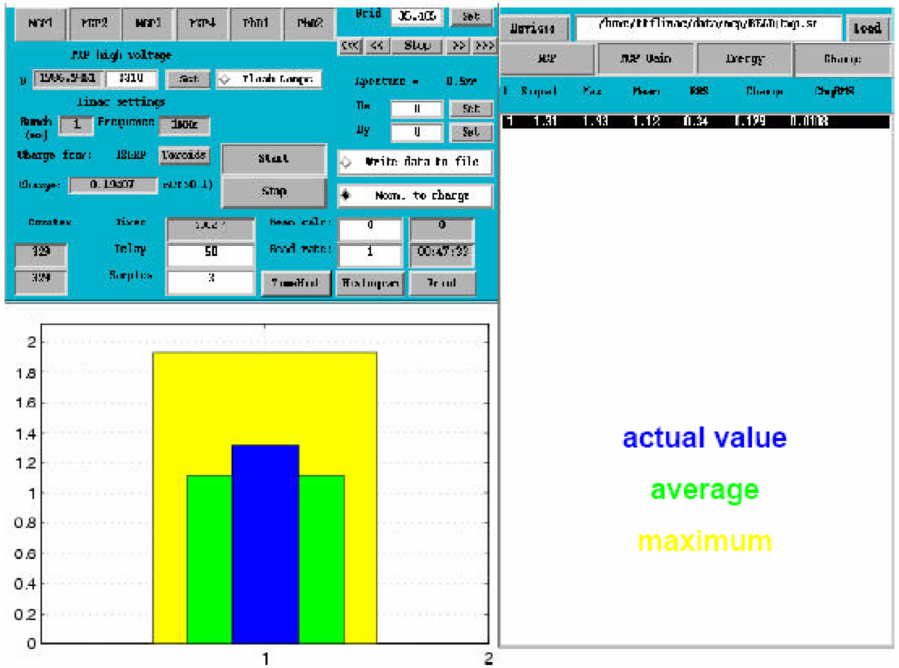
- Making beam for SASE: compression, strong collective effects, unprecedented beam parameters, poor diagnostics

Main method: multi-knob empirical tuning

Main tools for SASE search and optimization





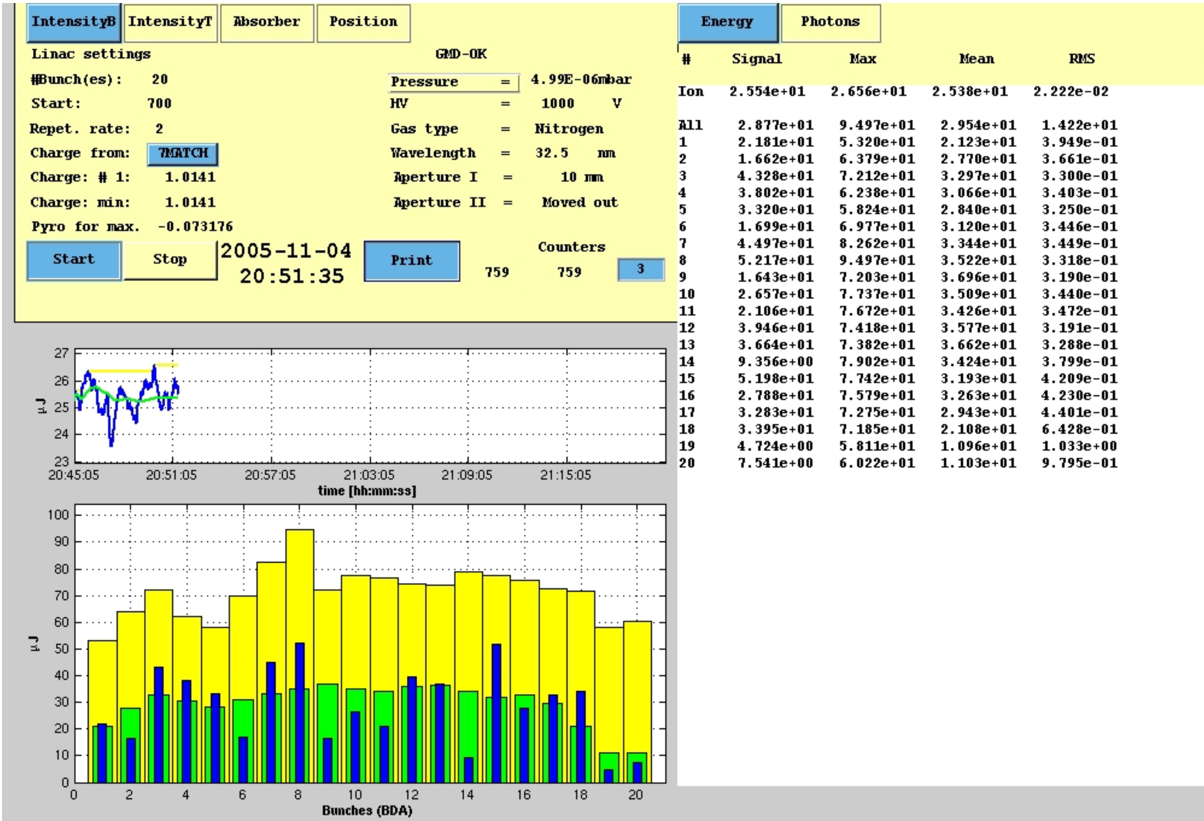


Micro-channel plate (MCP) detector

- Low electronic noise (about 1 mV)
- Low radiation background (about 1 mV)
- High level of signal (above 100 mV)
- Large dynamic range
- Normalization of MCP signal to bunch charge
- Reliable detection of amplification just above spontaneous emission level

Intensity monitoring during user operation

Gas monitor detector (GMD): non-destructive intensity measurement

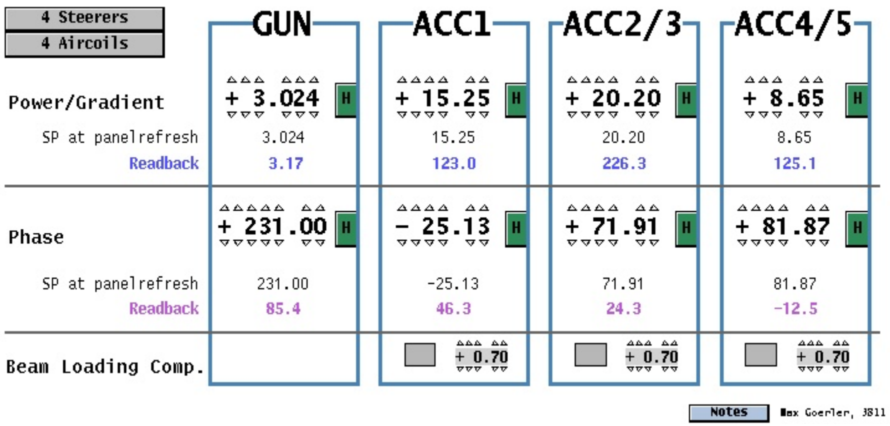


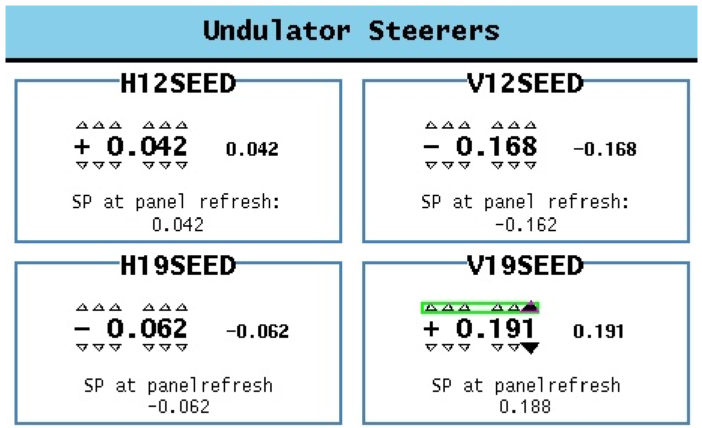
Measures ion and electron currents of an ionized gas

How do we tune SASE?

•Starting from scratch (after shutdown, new wavelength etc.): sometimes easy, but often a complicated task; extensive scan of parameter space, many subjective (sometimes intuitive) decisions to be taken

•Fine tuning (keep/improve) during user operation: not so many knobs involved (RF settings + 4 steerers), now relatively easy for every operator





Experience of the FLASH team has grown significantly:
smooth user runs as a result

Main problems

Undulator orbit

no working procedures but empirical tuning; suspicion of stray fields; suspicion of season drifts; work in progress

Losses in the undulator (mainly dark current)

radiation dose; sometimes a compromise between losses and FEL performance; difficult to play with orbit; fast kicker to be commissioned

Laser/RF phase stability: jitters and slow drifts

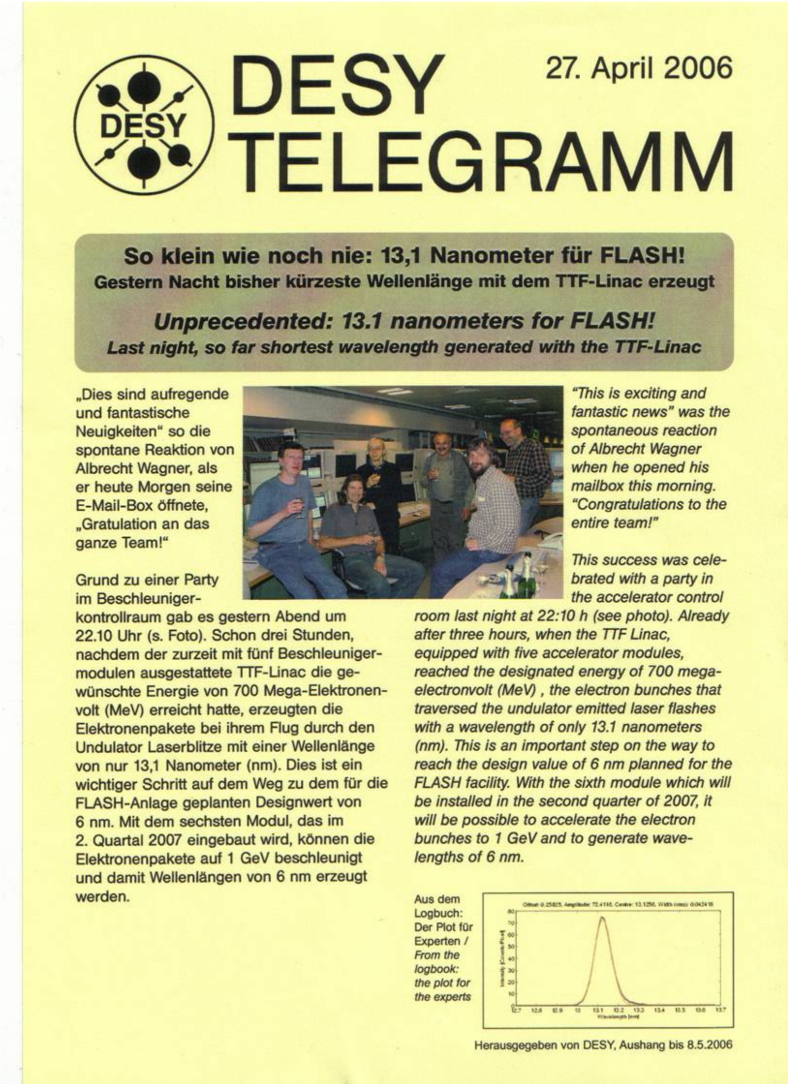
reduces average intensity and stability of SASE; complicates tuning; improved since first lasing, to be improved further

Dispersion

next talk by E.Prat

…

Lasing at 13 nm



DESY TELEGRAMM

27. April 2006

So klein wie noch nie: 13,1 Nanometer für FLASH!
Gestern Nacht bisher kürzeste Wellenlänge mit dem TTF-Linac erzeugt

Unprecedented: 13.1 nanometers for FLASH!
Last night, so far shortest wavelength generated with the TTF-Linac

„Dies sind aufregende und fantastische Neuigkeiten" so die spontane Reaktion von Albrecht Wagner, als er heute Morgen seine E-Mail-Box öffnete, „Gratulation an das ganze Team!"

Grund zu einer Party im Beschleuniger-kontrollraum gab es gestern Abend um 22.10 Uhr (s. Foto). Schon drei Stunden, nachdem der zurzeit mit fünf Beschleuniger-modulen ausgestattete TTF-Linac die gewünschte Energie von 700 Mega-Elektronenvolt (MeV) erreicht hatte, erzeugten die Elektronenpakete bei ihrem Flug durch den Undulator Laserblitze mit einer Wellenlänge von nur 13,1 Nanometer (nm). Dies ist ein wichtiger Schritt auf dem Weg zu dem für die FLASH-Anlage geplanten Designwert von 6 nm. Mit dem sechsten Modul, das im 2. Quartal 2007 eingebaut wird, können die Elektronenpakete auf 1 GeV beschleunigt und damit Wellenlängen von 6 nm erzeugt werden.

"This is exciting and fantastic news" was the spontaneous reaction of Albrecht Wagner when he opened his mailbox this morning. "Congratulations to the entire team!"

This success was celebrated with a party in the accelerator control room last night at 22:10 h (see photo). Already after three hours, when the TTF Linac, equipped with five accelerator modules, reached the designated energy of 700 mega-electronvolt (MeV), the electron bunches that traversed the undulator emitted laser flashes with a wavelength of only 13.1 nanometers (nm). This is an important step on the way to reach the design value of 6 nm planned for the FLASH facility. With the sixth module which will be installed in the second quarter of 2007, it will be possible to accelerate the electron bunches to 1 GeV and to generate wavelengths of 6 nm.

Aus dem Logbuch: Der Plot für Experten / *From the logbook: the plot for the experts*

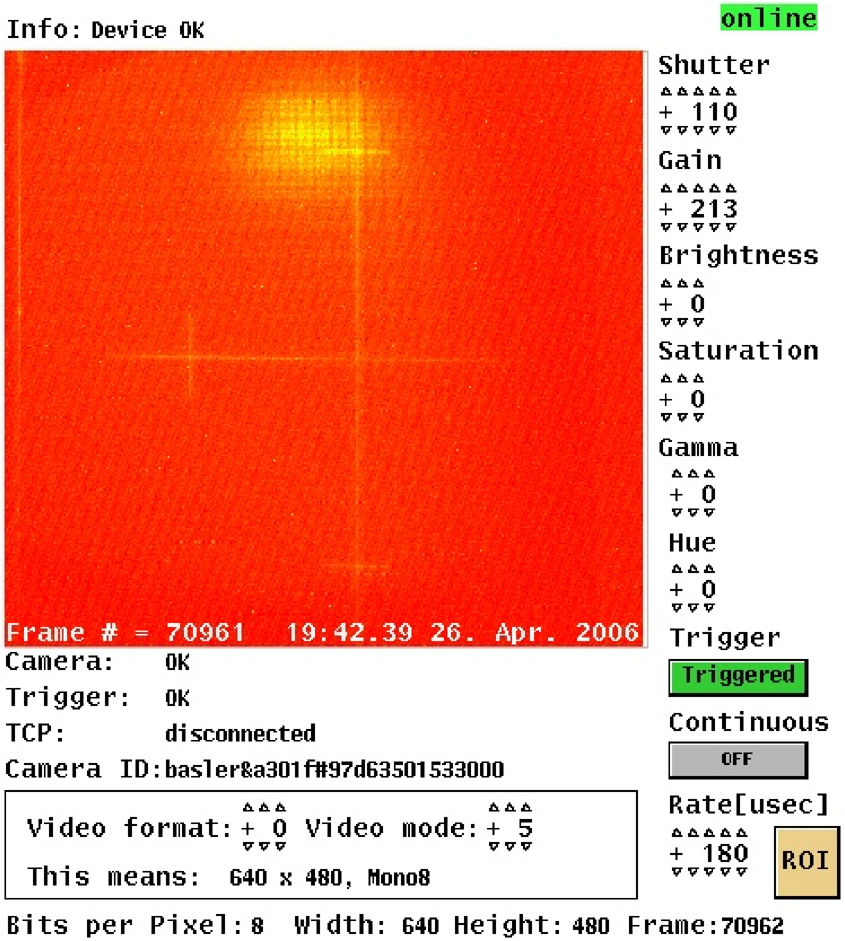
Herausgegeben von DESY, Aushang bis 8.5.2006

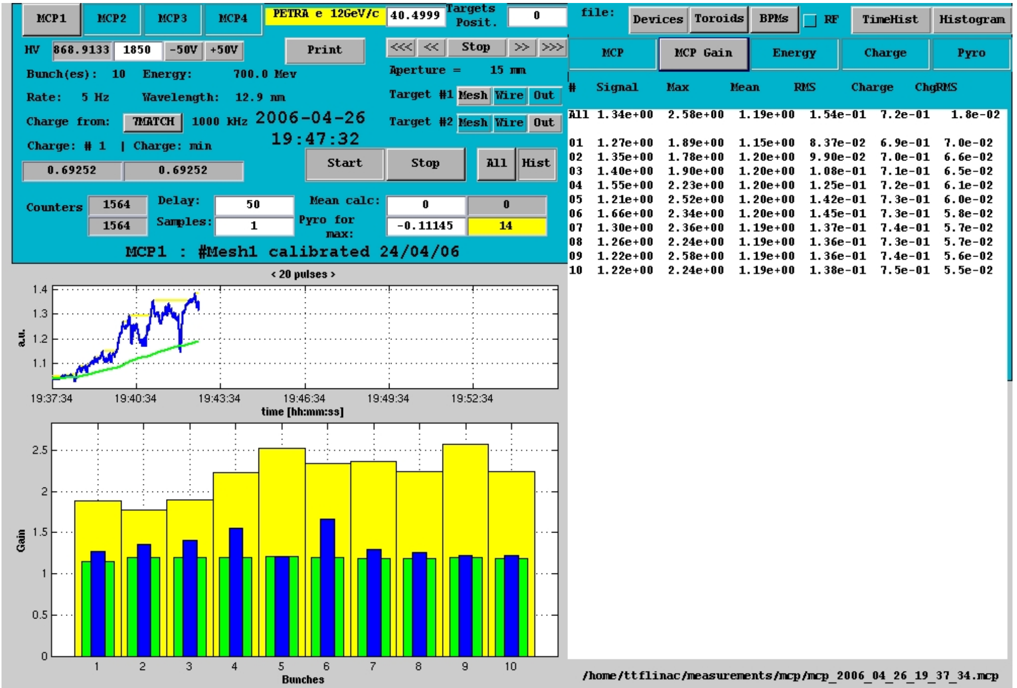
Quick and easy lasing:

- Machine was relatively well prepared (optics, undulator BPMs)
- It was stable
- As expected, operation at higher energy was easier (SC effects less important)
- Experience also helped

Lasing at 13 nm

First hints

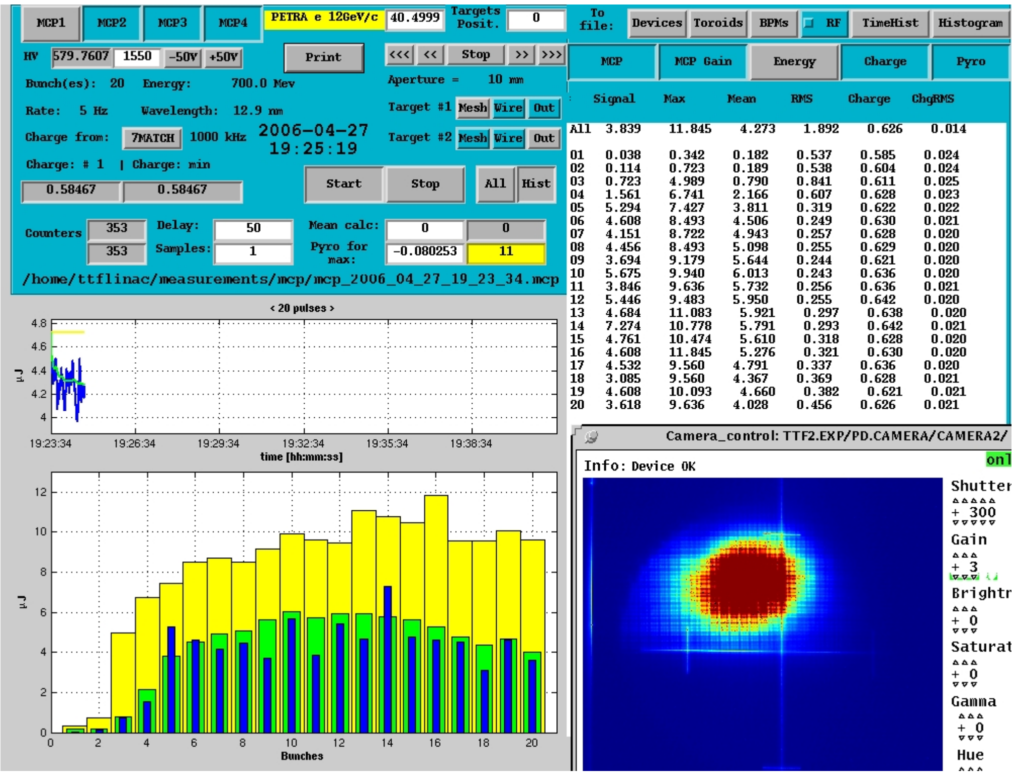


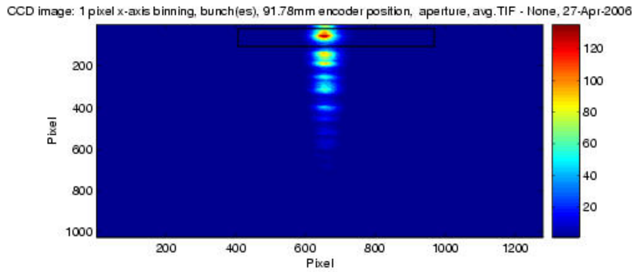


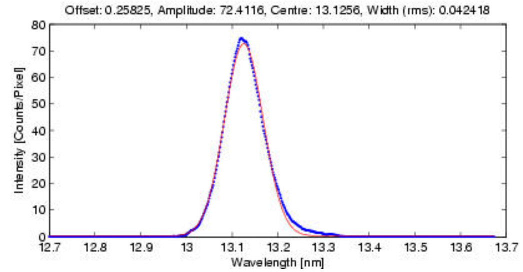
Lasing at 13 nm

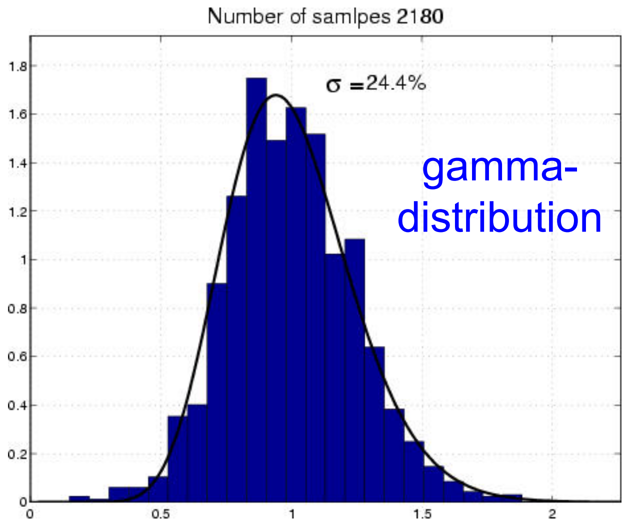
Next day: after some tuning

~5 uJ (average)









Final remarks

- *The first VUV FEL user facility works.* *At the moment we operate unique user facility providing photon beams with ultimate peak brilliance, 100 millions times above the best SR storage rings.* *Users are happy:*

10.02.2006: Summary from FEL users We loved those 15 microJ pulses! Today we measured time-delay holograms of exploding latex spheres (pump-probe, using a multilayer mirror to reflect the pulse back onto the particle). Will post picture in logbook. Thanks for all the photons. (H.Chapman et al., BL2)*

18.02.2006: Summary from FEL users WHAT AN EXCELLENT RUN!!! We really enjoyed the 15-22 microJ average and were able to complement our previous cluster data with higher pulse energies. This shift with higher energies was very valuable to us. Hopefully we can get similar intensities tomorrow...*

** Christoph Bostedt, TU Berlin*