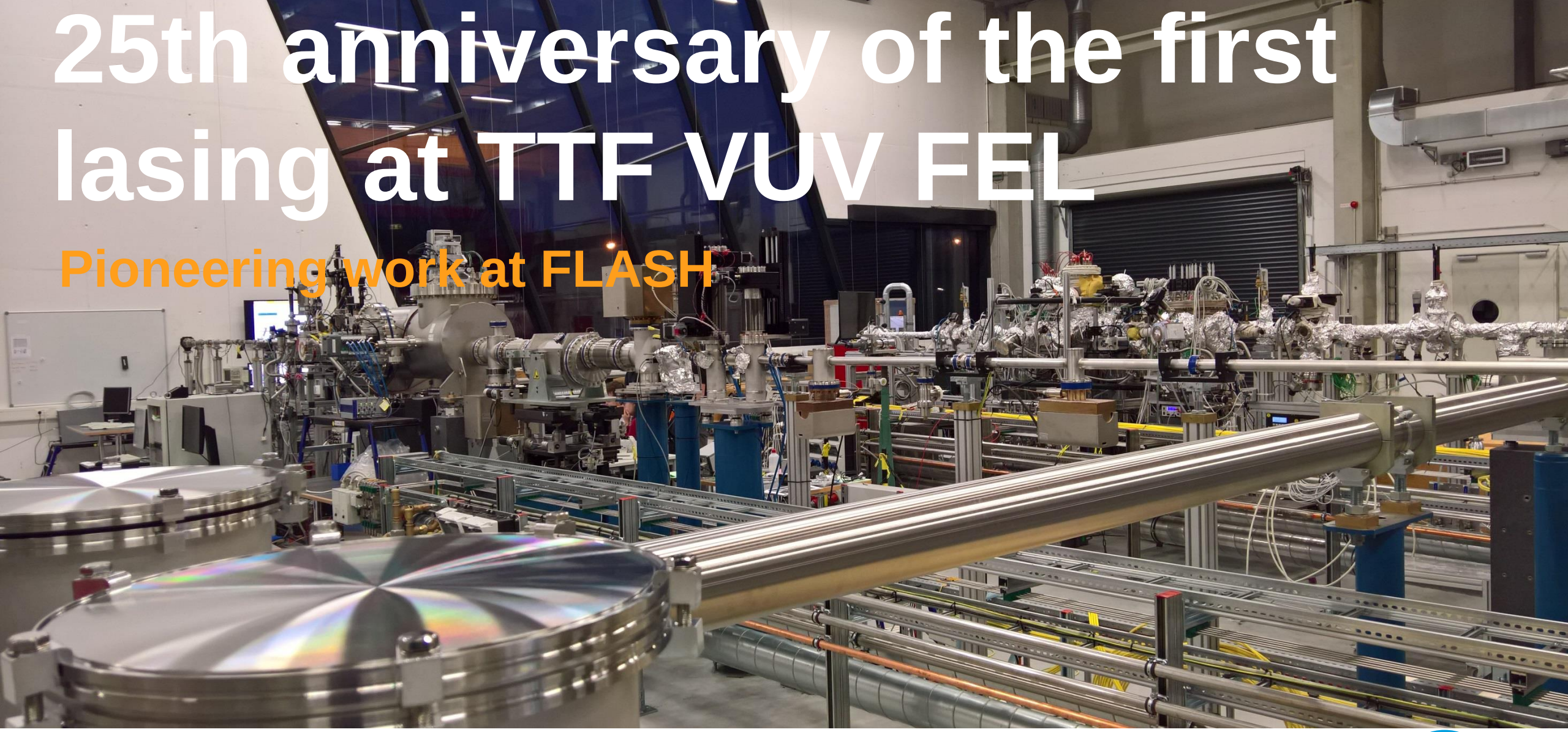
25th anniversary of the first lasing at TTF VUV FEL

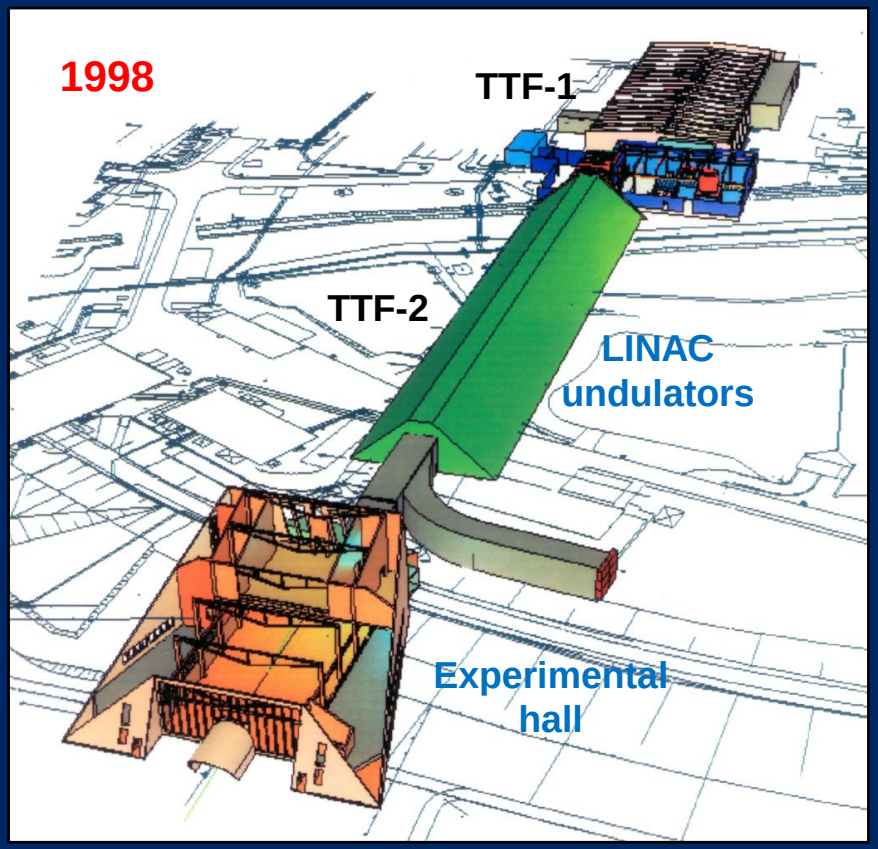
Pioneering work at FLASH



HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

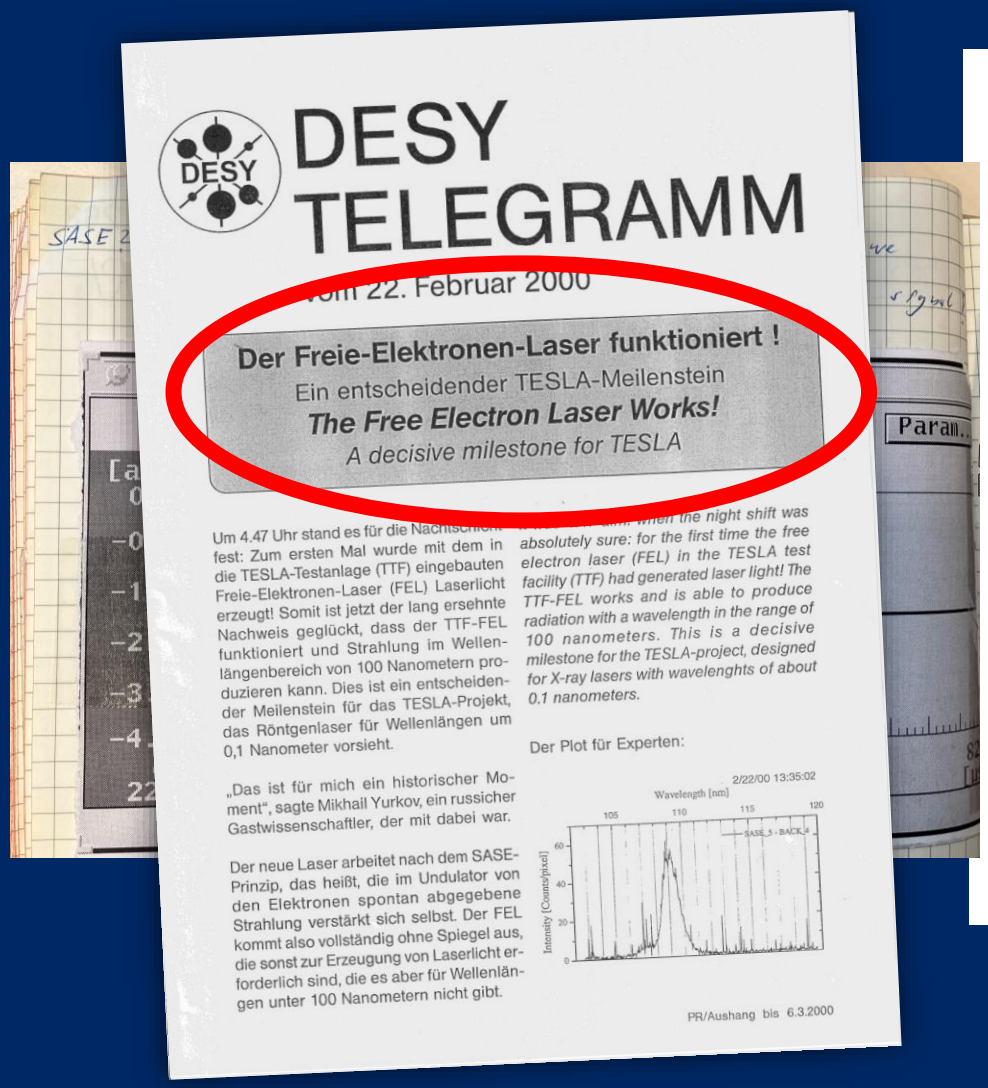
Light of the New Millenium



EXPO 2000 in Hannover – Regional Project Hamburg – ***1. June – 31. October 2000: More than 100000 visitors***

25 years of SASE at DESY

First Lasing at TTF-FEL on 22-February-2000 at 04:47 h



DESY

DESY TELEGRAMM

vom 22. Februar 2000

Der Freie-Elektronen-Laser funktioniert !

Ein entscheidender TESLA-Meilenstein

The Free Electron Laser Works!

A decisive milestone for TESLA

Um 4.47 Uhr stand es für die Nachtschicht fest: Zum ersten Mal wurde mit dem in die TESLA-Testanlage (TTF) eingebauten Freie-Elektronen-Laser (FEL) Laserlicht erzeugt! Somit ist jetzt der lang ersehnte Nachweis geglückt, dass der TTF-FEL funktioniert und Strahlung im Wellenlängenbereich von 100 Nanometern produzieren kann. Dies ist ein entscheidender Meilenstein für das TESLA-Projekt, das Röntgenlaser für Wellenlängen um 0,1 Nanometer vorsieht.

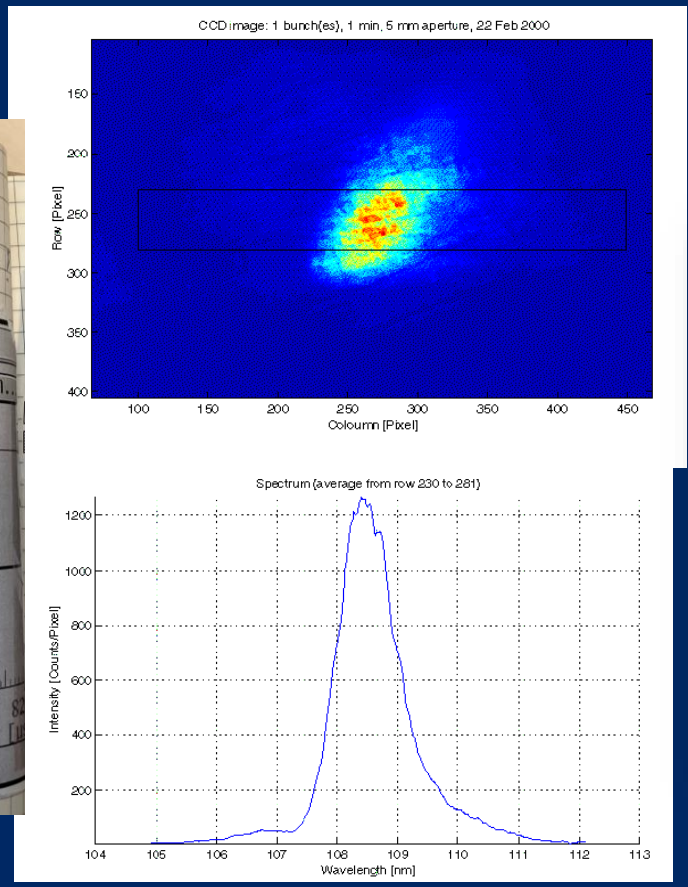
... When the night shift was absolutely sure: for the first time the free electron laser (FEL) in the TESLA test facility (TTF) had generated laser light! The TTF-FEL works and is able to produce radiation with a wavelength in the range of 100 nanometers. This is a decisive milestone for the TESLA-project, designed for X-ray lasers with wavelenghts of about 0.1 nanometers.

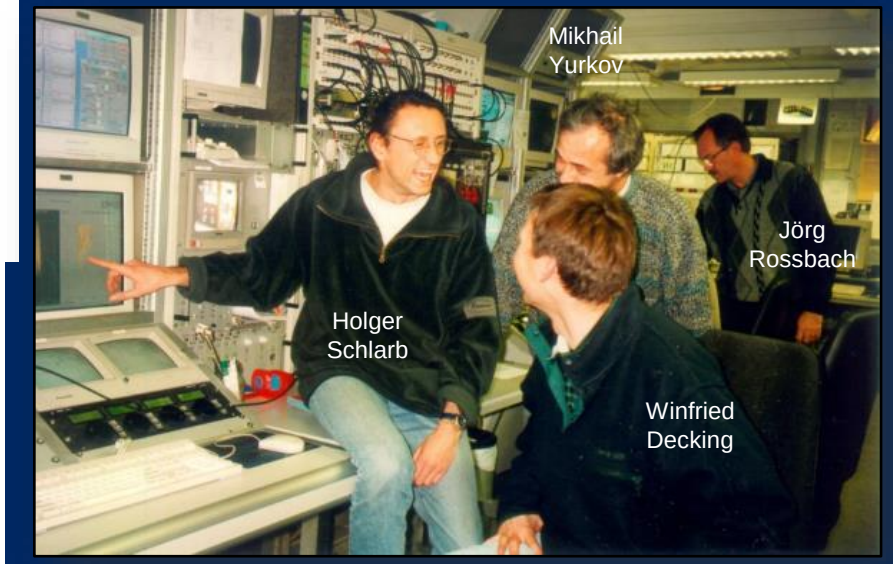
„Das ist für mich ein historischer Moment", sagte Mikhail Yurkov, ein russischer Gastwissenschaftler, der mit dabei war.

Der neue Laser arbeitet nach dem SASE-Prinzip, das heißt, die im Undulator von den Elektronen spontan abgegebene Strahlung verstärkt sich selbst. Der FEL kommt also vollständig ohne Spiegel aus, die sonst zur Erzeugung von Laserlicht erforderlich sind, die es aber für Wellenlängen unter 100 Nanometern nicht gibt.

Der Plot für Experten:

PR/Aushang bis 6.3.2000





2001 Proof of principle experiments at TTF VUV-FEL - Spectroscopy

Can we handle beams of fsec photon pulses of extreme power densities and do single particle experiments work?

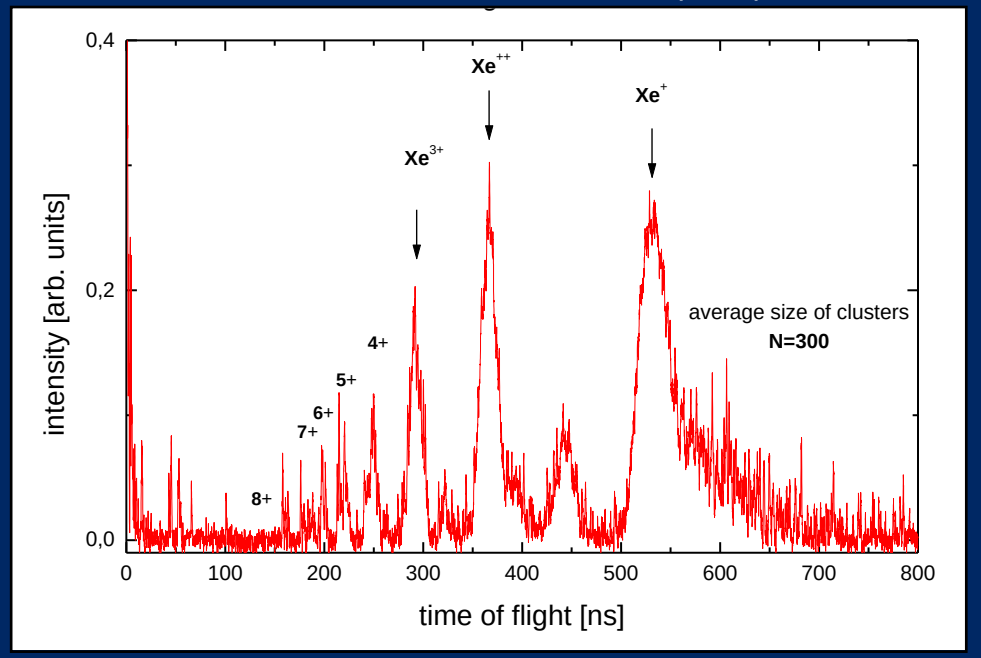
Thomas Möller
TU Berlin

FEL beam:
- puls duration 100 fsec
- wavelength 98 nm
- photon energy 12.7 eV
- power average intensity 2×10^{13} cm^{-2}

Xenon target:
- cluster with ~300 atoms
- ionization potential of Xe 12,1 eV

Coulomb explosion of Xenon clusters

H. Wabnitz et al., Nature **420**, 482 (2002)



Single shot time-of-flight spectrum

Explosion of interest for science with FELs in the community

FEL conferences in the early 2000's

DESY in the lead

Different focusing solutions for the TTF-FEL undulator #17
B. Faatz (DESY), J. Pfluger (DESY) (Oct, 2000)
Published in: *Nucl.Instrum.Meth.A* 475 (2001) 603-607 • Contribution to: 22nd International Free Electron Laser Conference and 7th FEL Users Workshop
links DOI cite reference search 3 citations

Development of a pump-probe facility combining a far-infrared source with laser-like characteristics and a VUV free electron laser #18
B. Faatz (DESY and Dubna, JINR and Warsaw, CFT), A.A. Fateev (DESY and Dubna, JINR and Warsaw, CFT), J. Feldhaus (DESY and Dubna, JINR and Warsaw, CFT), J. Krzywinski (DESY and Dubna, JINR and Warsaw, CFT), J. Pfluger (DESY and Dubna, JINR and Warsaw, CFT) et al. (Oct, 2000)
Published in: *Nucl.Instrum.Meth.A* 475 (2001) 363-367 • Contribution to: 22nd International Free Electron Laser Conference and 7th FEL Users Workshop
links DOI cite reference search 12 citations

Development of a pump-probe facility with sub-picosecond time resolution combining a high-power ultraviolet regenerative FEL amplifier and a soft X-ray SASE FEL #19
B. Faatz (DESY and Dubna, JINR and Warsaw, CFT), A.A. Fateev (DESY and Dubna, JINR and Warsaw, CFT), J. Feldhaus (DESY and Dubna, JINR and Warsaw, CFT), J. Krzywinski (DESY and Dubna, JINR and Warsaw, CFT), J. Pfluger (DESY and Dubna, JINR and Warsaw, CFT) et al. (Oct, 2000)
Published in: *Nucl.Instrum.Meth.A* 475 (2001) 368-372 • Contribution to: 22nd International Free Electron Laser Conference and 7th FEL Users Workshop
links DOI cite reference search 0 citations

Photon diagnostics for the study of electron beam properties of a VUV SASE FEL #20
C. Gerth (DESY), B. Faatz (DESY), T. Lokajczyk (DESY), R. Treusch (DESY), J. Feldhaus (DESY) (Oct, 2000)
Published in: *Nucl.Instrum.Meth.A* 475 (2001) 481-486 • Contribution to: 22nd International Free Electron Laser Conference and 7th FEL Users Workshop
links DOI cite reference search 6 citations

Observation of longitudinal phase space fragmentation at the TESLA Test Facility free electron laser #21
M. Huning (DESY), P. Piot (DESY), H. Schlarb (DESY) (Oct, 2000)
Published in: *Nucl.Instrum.Meth.A* 475 (2001) 348-352 • Contribution to: 22nd International Free Electron Laser Conference and 7th FEL Users Workshop
links DOI cite reference search 20 citations

An analysis of longitudinal phase space fragmentation at the TESLA Test Facility #22
T. Limberg (DESY), P. Piot (DESY), E.A. Schneidmiller (DESY) (Oct, 2000)
Published in: *Nucl.Instrum.Meth.A* 475 (2001) 353-356 • Contribution to: 22nd International Free Electron Laser Conference and 7th FEL Users Workshop
links DOI cite reference search 16 citations

Observation of selfamplified spontaneous emission in the wavelength range from 80-nm to 180-nm at the TESLA Test Facility FEL at DESY #23
J. Rossbach (DESY) (Oct, 2000)
Published in: *Nucl.Instrum.Meth.A* 475 (2001) 13-19 • Contribution to: 22nd International Free Electron Laser Conference and 7th FEL Users Workshop
links DOI cite reference search 10 citations

A test of the laser alignment system ALMY at the TTF-FEL #24
S. Roth (DESY and Munich, Max Planck Inst.), S. Schael (DESY and Munich, Max Planck Inst.), G. Schmidt (DESY and Munich, Max Planck Inst.) (Oct, 2000)
Published in: *Nucl.Instrum.Meth.A* 475 (2001) 537-544 • Contribution to: 22nd International Free Electron Laser Conference and 7th FEL Users Workshop
links DOI cite reference search 0 citations

X-ray FEL with a meV bandwidth #25
E.L. Saldin (DESY), E.A. Schneidmiller (DESY), Yu.V. Shvydko (Hamburg U.), M.V. Yurkov (Dubna, JINR) (Oct, 2000)
Published in: *Nucl.Instrum.Meth.A* 475 (2001) 357-362, *AIP Conf.Proc.* 581 (2001) 1, 153-161 • Contribution to: 22nd International Free Electron Laser Conference and 7th FEL Users Workshop, 18th Advanced ICFA Beam Dynamics Workshop on the Physics of and the Science with X-Ray Free Electron Lasers, 153-161
links DOI cite reference search 49 citations

Photoinjector test facility in the commissioning phase at DESY Zeuthen #17
I. Bohnet (DESY, Zeuthen), J. Bahr (DESY, Zeuthen), D. Lipka (DESY, Zeuthen), F. Stephan (DESY, Zeuthen), M. Winde (DESY, Zeuthen) et al. (Oct, 2001)
Contribution to: 23rd International Free Electron Laser Conference and the 8th FEL Users Workshop
links cite reference search 0 citations

Study of frequency multiplication process in multistage HGHG FEL #18
W. Brefeld (DESY), B. Faatz (DESY), J. Feldhaus (DESY), M. Korfer (DESY), T. Moller (DESY) et al. (Oct, 2001)
Published in: *Nucl.Instrum.Meth.A* 483 (2002) 80-88 • Contribution to: 23rd International Free Electron Laser Conference and the 8th FEL Users Workshop
links DOI cite reference search 6 citations

Development of a femtosecond soft X-ray SASE FEL at DESY #19
W. Brefeld (DESY), B. Faatz (DESY), J. Feldhaus (DESY), M. Korfer (DESY), T. Moller (DESY) et al. (Oct, 2001)
Published in: *Nucl.Instrum.Meth.A* 483 (2002) 75-79 • Contribution to: 23rd International Free Electron Laser Conference and the 8th FEL Users Workshop
links DOI cite reference search 2 citations

Linac-based synchrotron radiation facility with femtosecond soft X-ray pulses #20
W. Brefeld (DESY), B. Faatz (DESY), J. Feldhaus (DESY), K. Flottmann (DESY), M. Korfer (DESY) et al. (Oct, 2001)
Contribution to: 23rd International Free Electron Laser Conference and the 8th FEL Users Workshop
links cite reference search 0 citations

Generation of high power femtosecond pulses by sideband-seeded X-ray FEL #21
W. Brefeld (DESY), B. Faatz (DESY), J. Feldhaus (DESY), M. Korfer (DESY), T. Moller (DESY) et al. (Oct, 2001)
Published in: *Nucl.Instrum.Meth.A* 483 (2002) 62-69 • Contribution to: 23rd International Free Electron Laser Conference and the 8th FEL Users Workshop
links DOI cite reference search 1 citation

Electro-optic experiments at the TESLA test facility #22
M. Brunken (Darmstadt, Tech. Hochsch.), H. Genz (Darmstadt, Tech. Hochsch.), C. Hessler (Darmstadt, Tech. Hochsch.), H. Loos (Darmstadt, Tech. Hochsch.), A. Richter (Darmstadt, Tech. Hochsch.) et al. (Oct, 2001)
Contribution to: 23rd International Free Electron Laser Conference and the 8th FEL Users Workshop
links cite reference search 0 citations

Use of micro-channel plate for nondestructive measurement of VUV radiation from the SASE FEL at the TESLA test facility #23
B. Faatz, A.A. Fateev, J. Feldhaus, C. Gerth, U. Hahn et al. (Oct, 2001)
Contribution to: 23rd International Free Electron Laser Conference and the 8th FEL Users Workshop
links cite reference search 0 citations

Alignment of the optical feedback system of VUV regenerative FEL amplifier at the TESLA test facility at DESY #24
B. Faatz (DESY), A.A. Fateev (Dubna, JINR), J. Feldhaus (DESY), Ch. Gerth (DESY), U. Hahn (DESY) et al. (Oct, 2001)
Published in: *Nucl.Instrum.Meth.A* 483 (2002) 412-417 • Contribution to: 23rd International Free Electron Laser Conference and the 8th FEL Users Workshop
links DOI cite reference search 6 citations

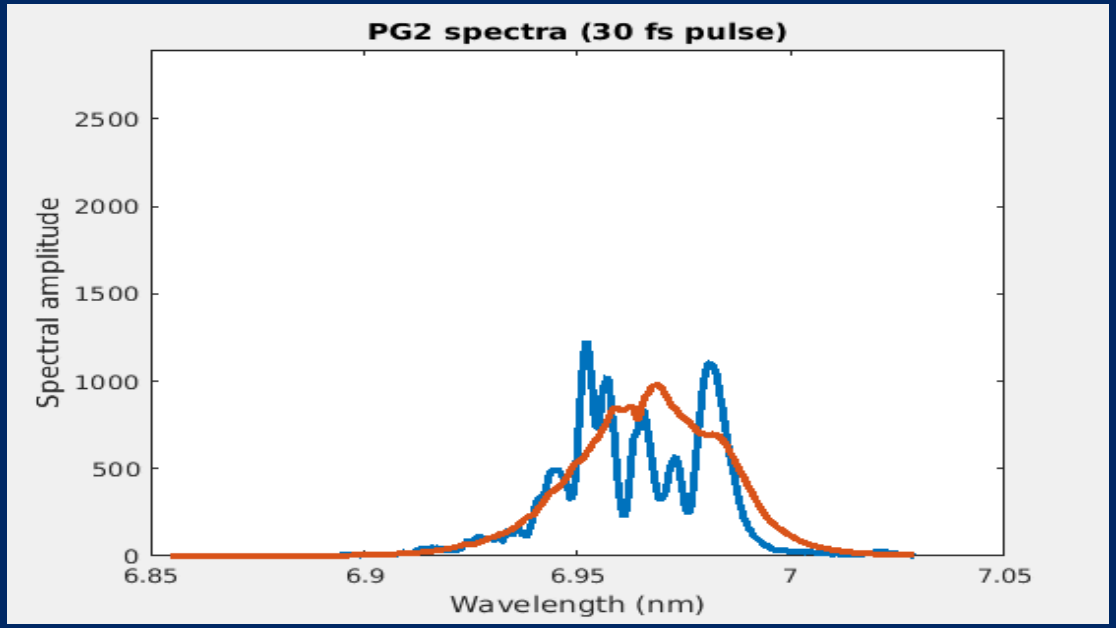
A concept of a 150-nm FEL oscillator driven by rf linear accelerator with a thermionic gun #25
B. Faatz (DESY and Dubna, JINR and UCLA), A.A. Fateev (DESY and Dubna, JINR and UCLA), V.I. Kobets (DESY and Dubna, JINR and UCLA), I.N. Meshkov (DESY and Dubna, JINR and UCLA), S. Reiche (DESY and Dubna, JINR and UCLA) et al. (Oct, 2001)
Contribution to: 23rd International Free Electron Laser Conference and the 8th FEL Users Workshop
links cite reference search 0 citations

Diagnostic tools

Pioneering work at FLASH

What kind of diagnostic tools do user need to make efficient use of FELs?

- intensity
- beam position
- focus size
- spectral distribution
- temporal radiation pulse profile
- polarisation

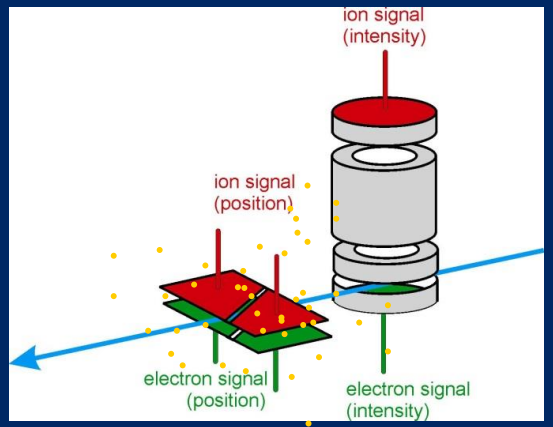


Due to the SASE specific shot-to-shot fluctuation the users need most this information for every single pulse => online, non-destructive

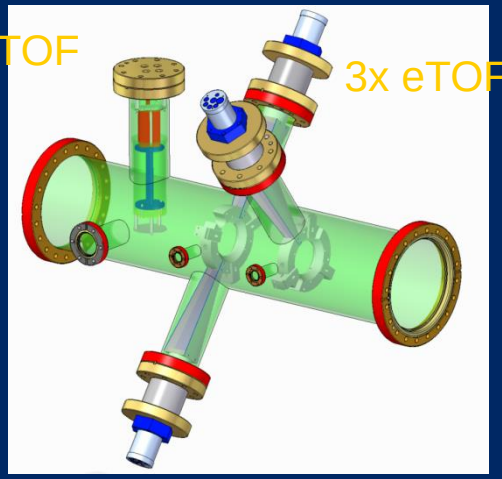
Non-destructive detectors at FLASH – Atomic PI of rare gases

Developed during the last 20 years

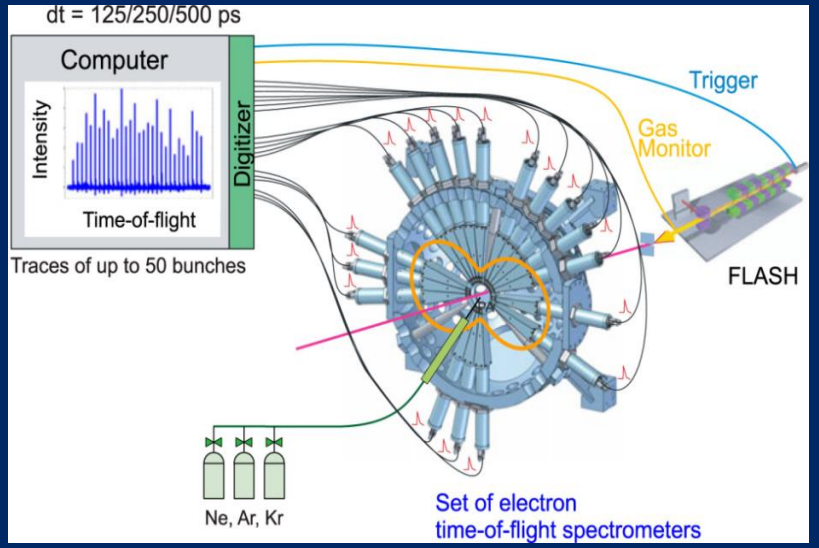
Intensity: Measurement of number of charged particles



Spectral distribution: Measurement of the kinetic energy of the electrons

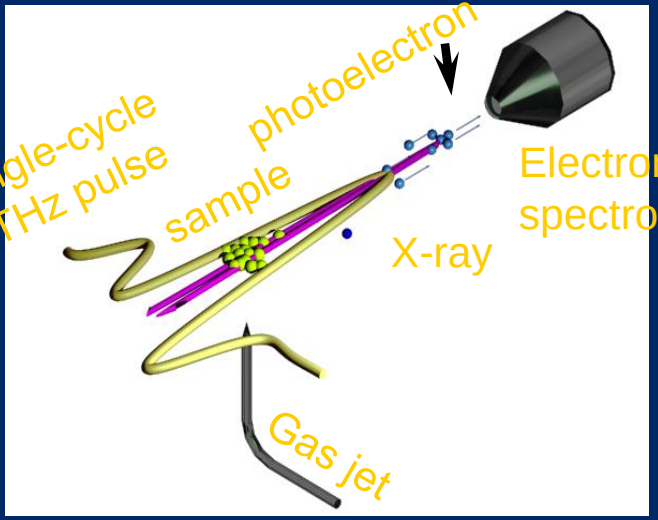


Polarisation:
Measurement of angular distribution of the emitted photoelectrons



Courtesy J. Viefhaus

Temporal radiation pulse profile:



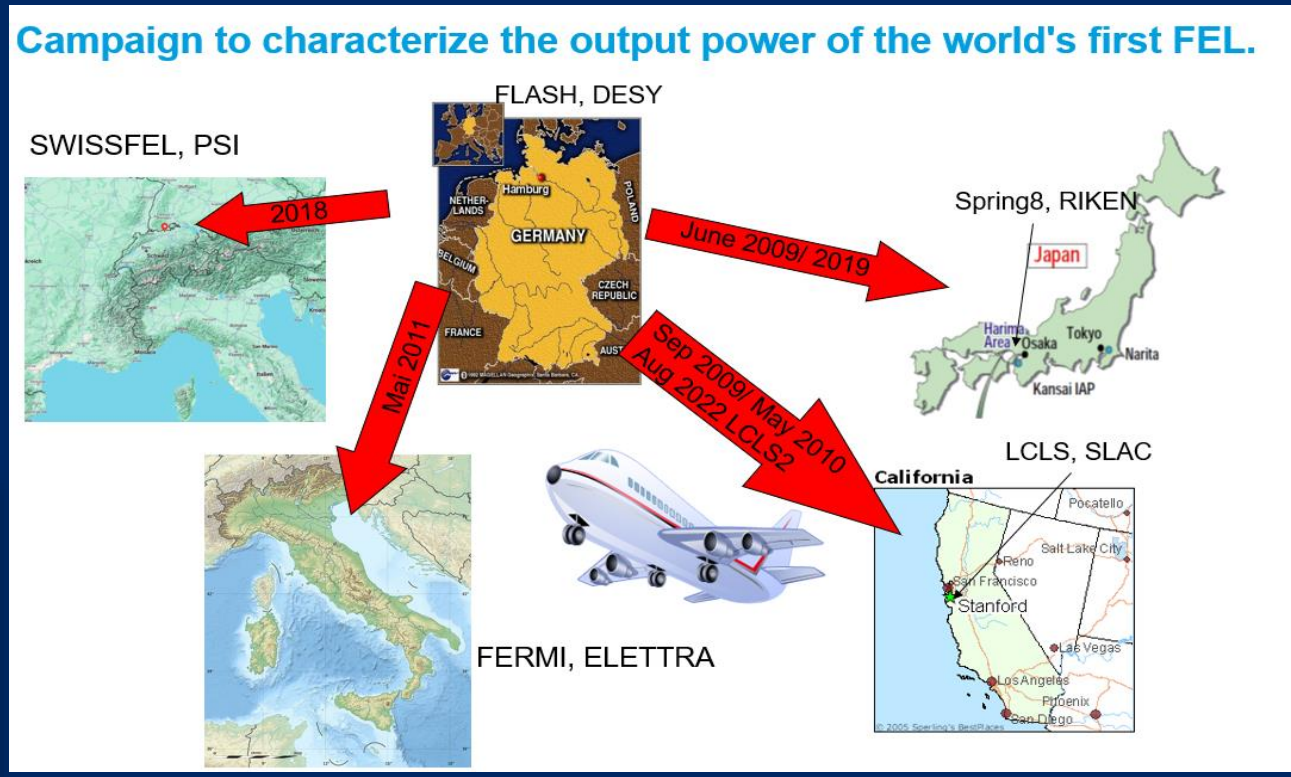
Non-destructive detectors at FLASH – Atomic PI of rare gases

Developed during the last 20 years

Intensity: Measurement of number of charged particles.

1st gen. GMD (FLASH1)

XGMD HAMP HAMP XGMD



3rd generation GMD (6 for XFEL, 2 for SwissFEL, 2 for LCLS & LCLS2, 4 for FLASH)

Personal note – a little bit of FELIX in FLASH:-)

Developed during the last 20 years

Electro-optic time profile monitors for femtosecond electron bunches at the soft x-ray free-electron laser FLASH #1
B. Steffen (DESY and PSI, Villigen), V. Arsov (DESY), G. Berden (FOM, Rijnhuizen), W.A. Gillespie (Dundee U.), S.P. Jamison (Daresbury) et al. (Mar 2, 2009)
Published in: *Phys.Rev.ST Accel.Beams* 12 (2009) 032802
pdf DOI cite claim reference search 54 citations

Limitations of Electro-optic Longitudinal Electron Bunch Length Measurements #2
S.P. Jamison (Daresbury), G. Berden (Unlisted), W.A. Gillespie (Dundee U.), P.J. Phillips (Dundee U.), A. MacLeod (Unlisted) (Jun 24, 2008)
Published in: *Conf.Proc.C* 0806233 (2008) TUPC042 • Contribution to: EPAC 2008
links cite claim reference search 0 citations

Benchmarking of electro-optic monitors for femtosecond electron bunches #3
G. Berden (FOM, Rijnhuizen), W.A. Gillespie (Dundee U.), S.P. Jamison (Daresbury), E.A. Knabbe (DESY), A.M. MacLeod (Dundee U.) et al. (2007)
Published in: *Phys.Rev.Lett.* 99 (2007) 164801
DOI cite claim reference search 72 citations

Single shot longitudinal bunch profile measurements at FLASH using electro-optic techniques #4
B. Steffen (DESY), E.A. Knabbe (DESY), B. Schmidt (DESY), G. Berden (FOM, Rijnhuizen), A.F.G. van der Meer (FOM, Rijnhuizen) et al. (Jun, 2006)
Published in: *Conf.Proc.C* 060626 (2006) 1055-1057 • Contribution to: 10th European Particle Accelerator Conference (EPAC 06), 1055-1057
links cite claim reference search 0 citations

Time resolved single-shot measurements of transition radiation at the THz beamline of FLASH using electro-optic spectral decoding #5
B. Steffen (DESY), E.A. Knabbe (DESY), B. Schmidt (DESY), G. Berden (FOM, Rijnhuizen), A.F.G. van der Meer (FOM, Rijnhuizen) et al. (Jun, 2006)
Published in: *Conf.Proc.C* 060626 (2006) 1058-1060 • Contribution to: 10th European Particle Accelerator Conference (EPAC 06), 1058-1060
links cite claim reference search 0 citations

Femtosecond bunch length measurements #6
S.P. Jamison (Daresbury), G. Berden (FOM, Rijnhuizen), W.A. Gillespie (Dundee U.), P.J. Phillips (Dundee U.), A. MacLeod (Dundee U.) et al. (Jun, 2006)
Published in: *Conf.Proc.C* 060626 (2006) 915-919 • Contribution to: 10th European Particle Accelerator Conference (EPAC 06), 915-919
links cite claim reference search 1 citation

Electro-optic techniques for temporal profile characterisation of relativistic Coulomb fields and coherent synchrotron radiation #7
S.P. Jamison (Strathclyde U. and FOM, Rijnhuizen and Dundee U.), G. Berden (Strathclyde U. and FOM, Rijnhuizen and Dundee U.), A.M. MacLeod (Strathclyde U. and FOM, Rijnhuizen and Dundee U.), D.A. Jaroszynski (Strathclyde U. and FOM, Rijnhuizen and Dundee U.), B. Redlich (Strathclyde U. and FOM, Rijnhuizen and Dundee U.) et al. (2006)
Published in: *Nucl.Instrum.Meth.A* 557 (2006) 305-308 • Contribution to: ERL 2005
DOI cite claim reference search 9 citations

Real-time, single-shot temporal measurements of short electron bunches, terahertz CSR and FEL radiation #8
G. Berden (FOM, Rijnhuizen), B. Redlich (FOM, Rijnhuizen), A.F.G. van der Meer (FOM, Rijnhuizen), W.A. Gillespie (Dundee U. and Strathclyde U.), S.P. Jamison (Dundee U. and Strathclyde U.) et al. (Jun, 2005)
Contribution to: 7th European Workshop on Beam Diagnostics and Instrumentation for Particle Accelerators (DIPAC 2005), 69-71
links cite claim reference search 0 citations

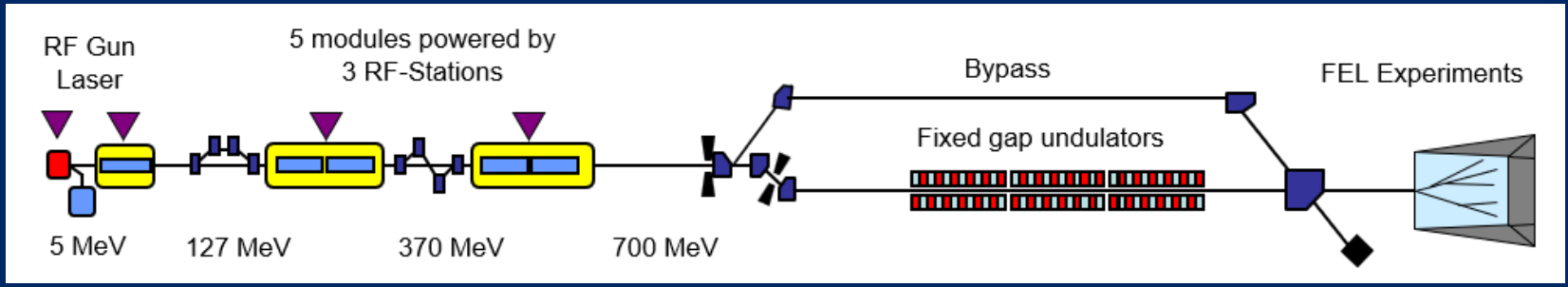
Electro-Optic Technique with Improved Time Resolution for Real-Time, Nondestructive, Single-Shot Measurements of Femtosecond Electron Bunch Profiles #9
G. Berden (FELIX, Nieuwegein), S.P. Jamison (Sydney U. and Dundee U.), A.M. MacLeod (Sydney U. and Dundee U.), W.A. Gillespie (Sydney U. and Dundee U.), B. Redlich (FELIX, Nieuwegein) et al. (Sep 10, 2004)
Published in: *Phys.Rev.Lett.* 93 (2004) 114802
DOI cite claim reference search 69 citations

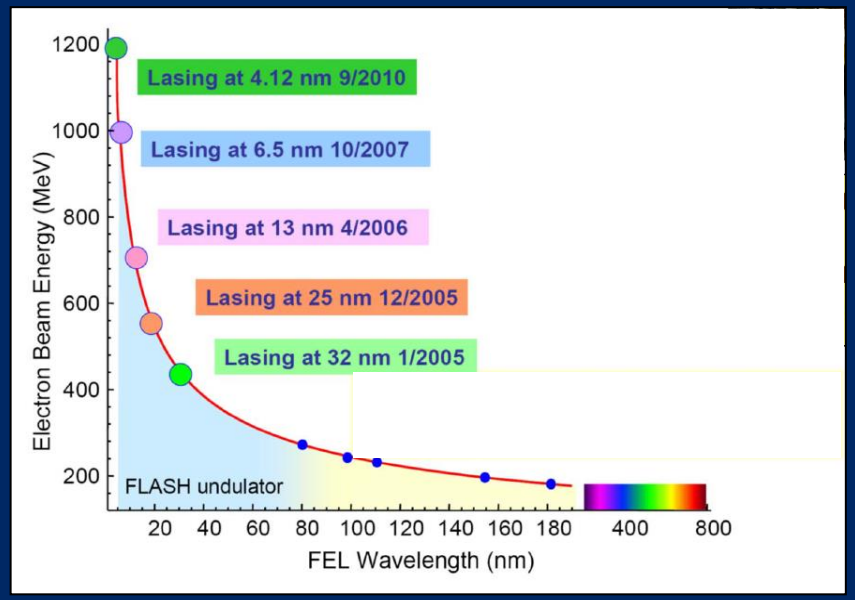
25 years of SASE at DESY

The team is the key

On the way to a VUV-FEL user facility at DESY

Continuous improvements of the facility and start of the user operation

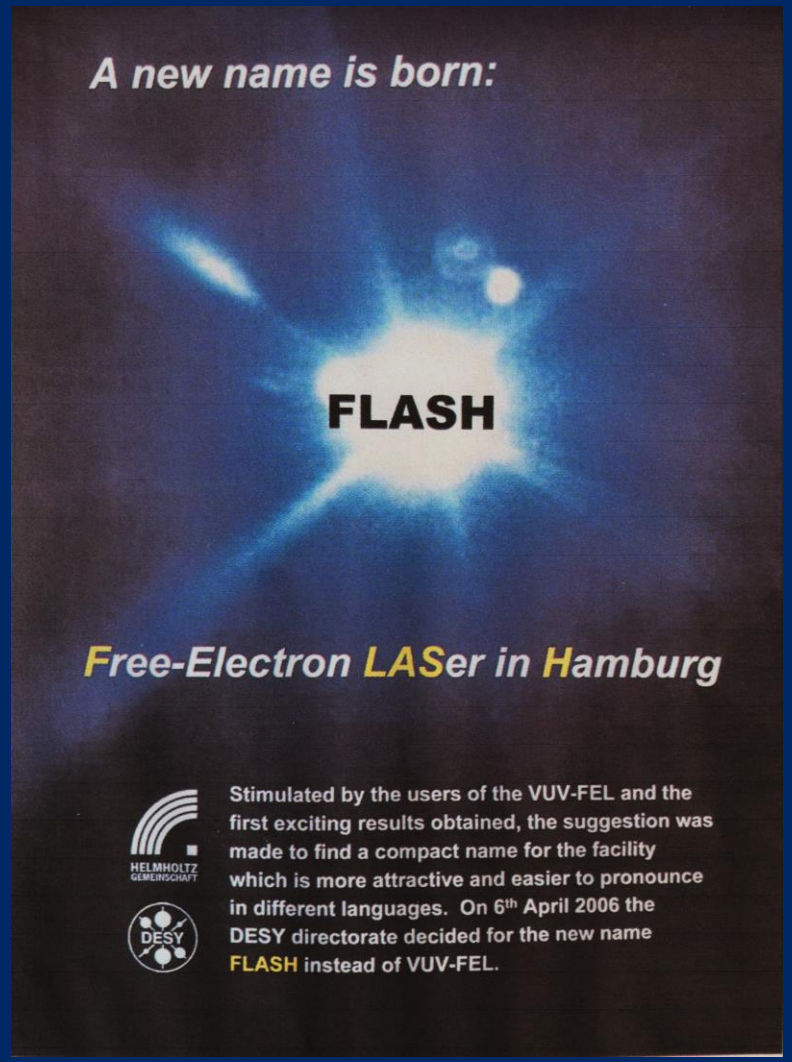




Getting shorter wavelength by increasing the number of cryo-modules and by improving their performance

25 years of SASE at DESY

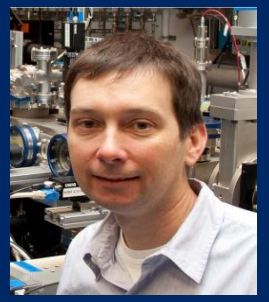
Continuous improvements of the facility and start of the user operation



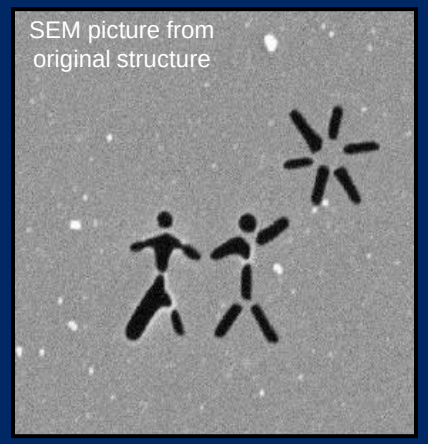
Jörg Rossbach and Evgeni Saldin (DESY) received the FEL Prize in 2006

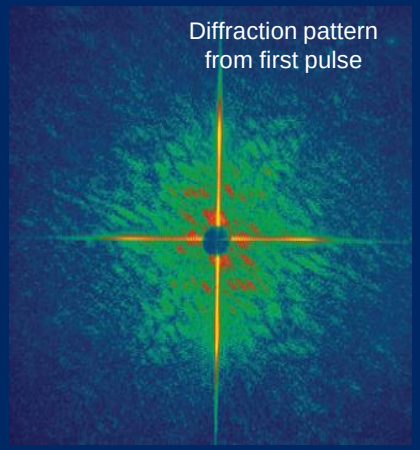
2005 Single shot imaging: Does it work at all ?

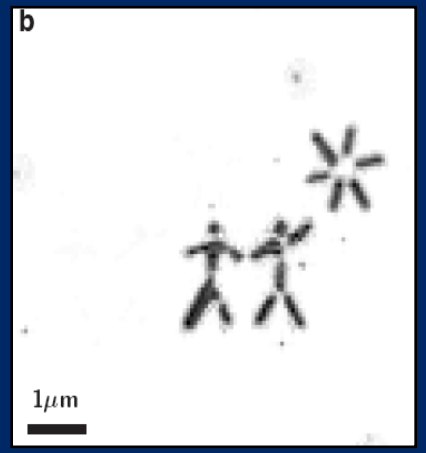
H. Chapman et al., Nature Physics 2, 839 (2006)

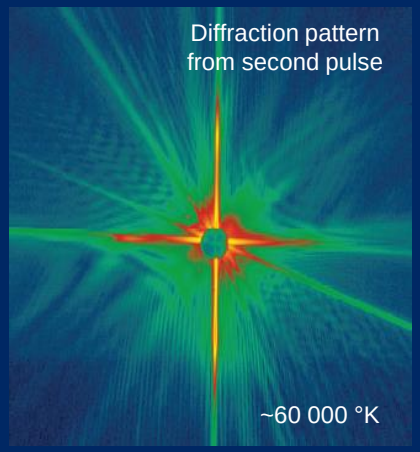


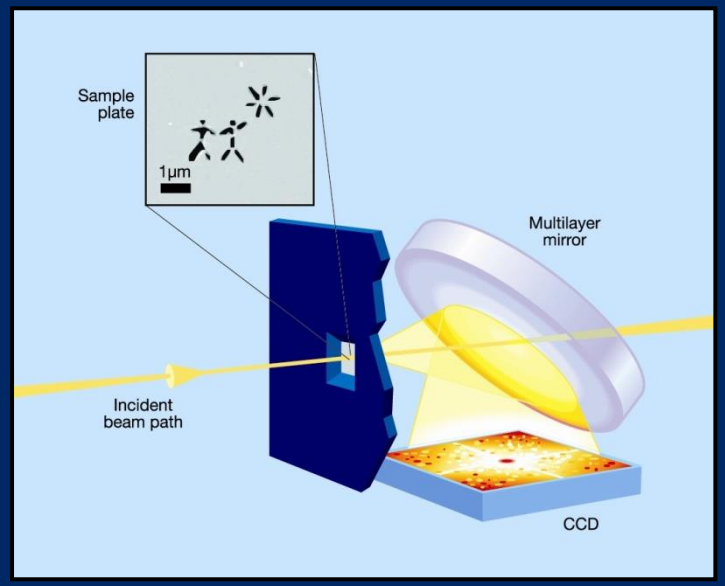
Henry Chapman
DESY-CFEL







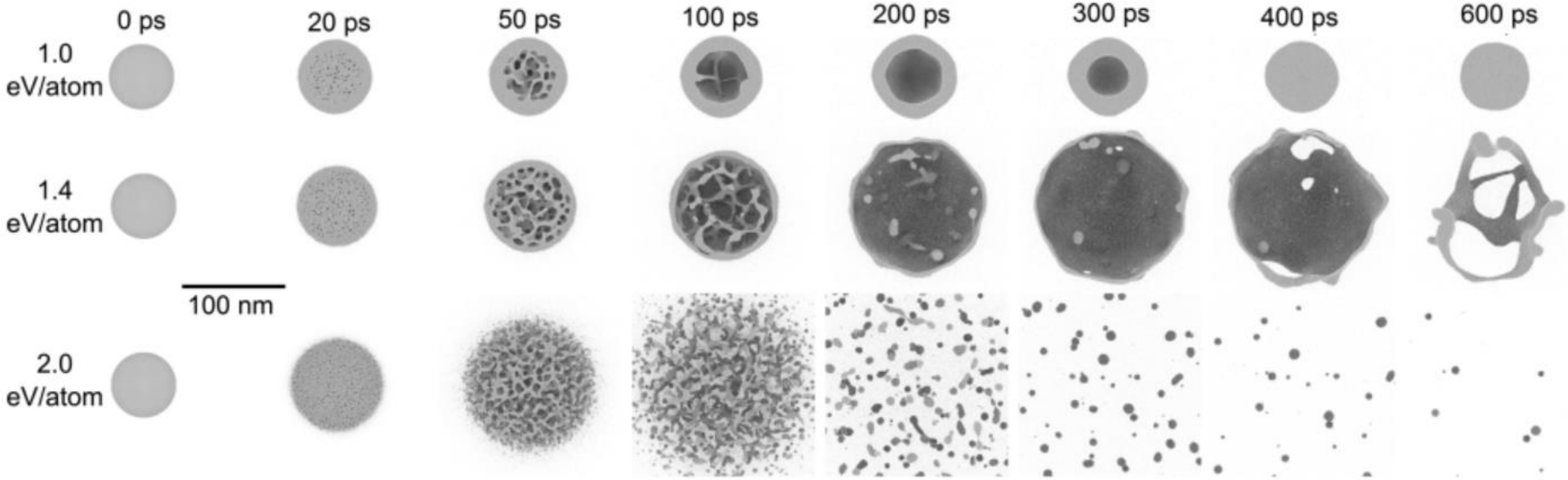


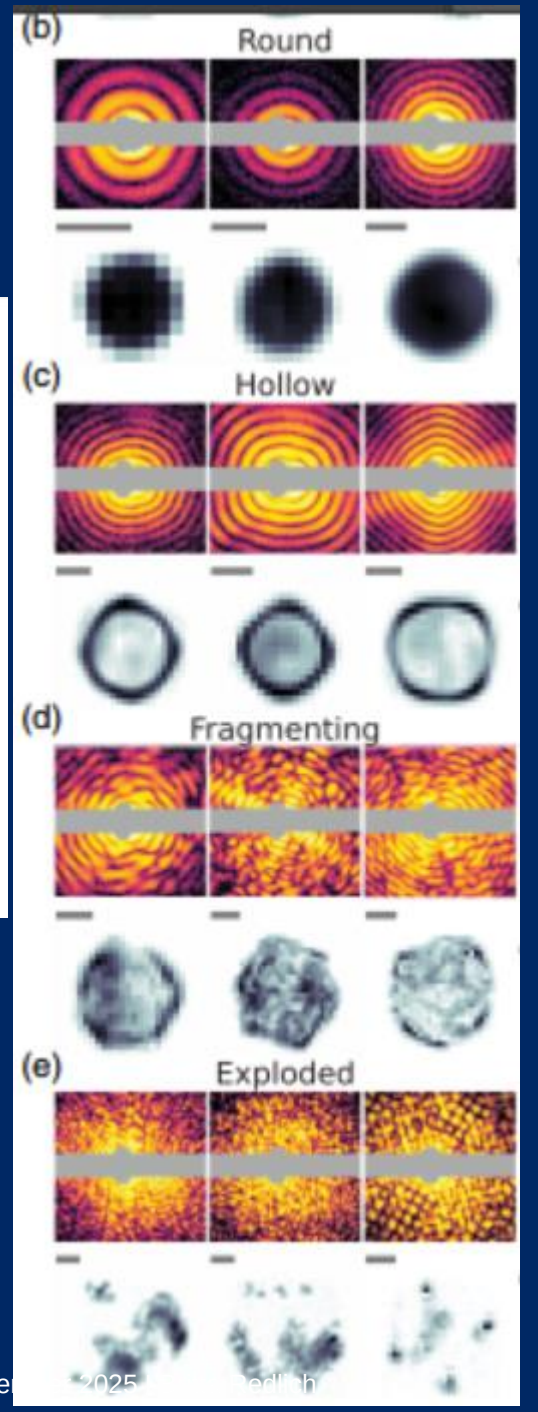


FEL pulse at FLASH:
~20 fs, 32 nm, 3 x 10^{13} W/cm^2, 10^{12} photons/pulse

Science at FLASH today

Melting, Bubblelike Expansion, and Explosion of Superheated Plasmonic Nanoparticles





- Silver nanoparticles are excited on their plasmon resonance with 1 ps laser pulses
- Coherent Diffractive Imaging at CAMP instrument
- Formation of voids visible – which is very sensitive on electron-phonon coupling

Dold, Reichenbach, Colombo *et al.*
Phys. Rev. Lett. **134**, 136101 (2025)

25th anniversary of the first lasing at TTF VUV FEL I 17 November 2025 I Britta Redlich

FLASH2020+

Lifecycle management via continuous upgrades

Linac upgrade: *Finished*

3rd BC FLASH2	Injector laser
New BCs (linac)	Energy upgrade
Laser heater	Afterburner FLASH2
Fast orbit correctors	New beamline FL23 (FLASH2)
TDS (FLASH2)	Interim P-P laser (FLASH1)

Seeding upgrade: *Now!*

High rep. rate seeding (FLASH1)
Photon diagnostics (FLASH1)
THz generation

Short term upgrades

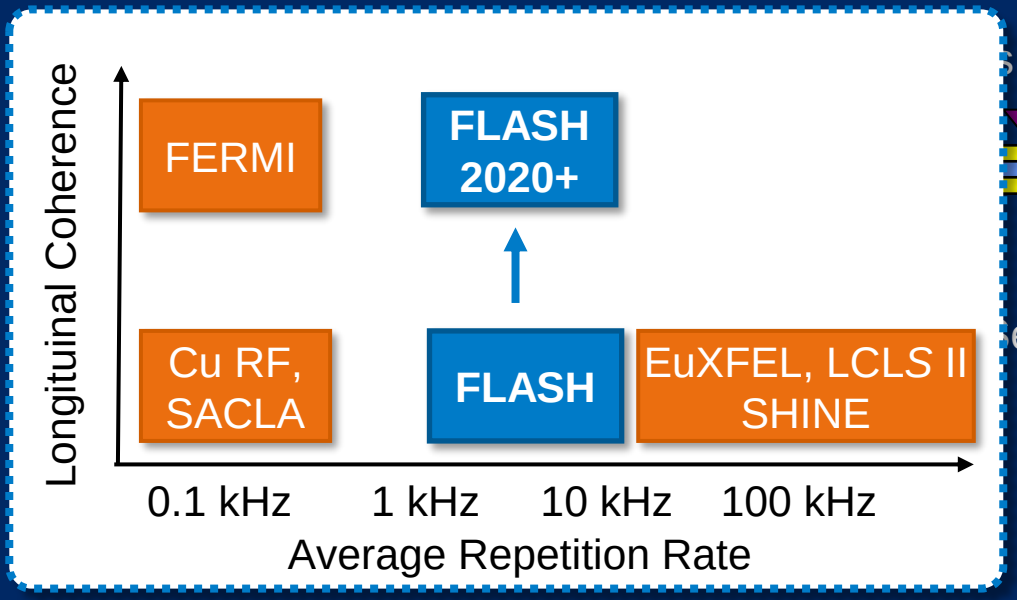
Flexible pump-probe lasers
New beamlines
Intense THz Source

Mid term upgrades

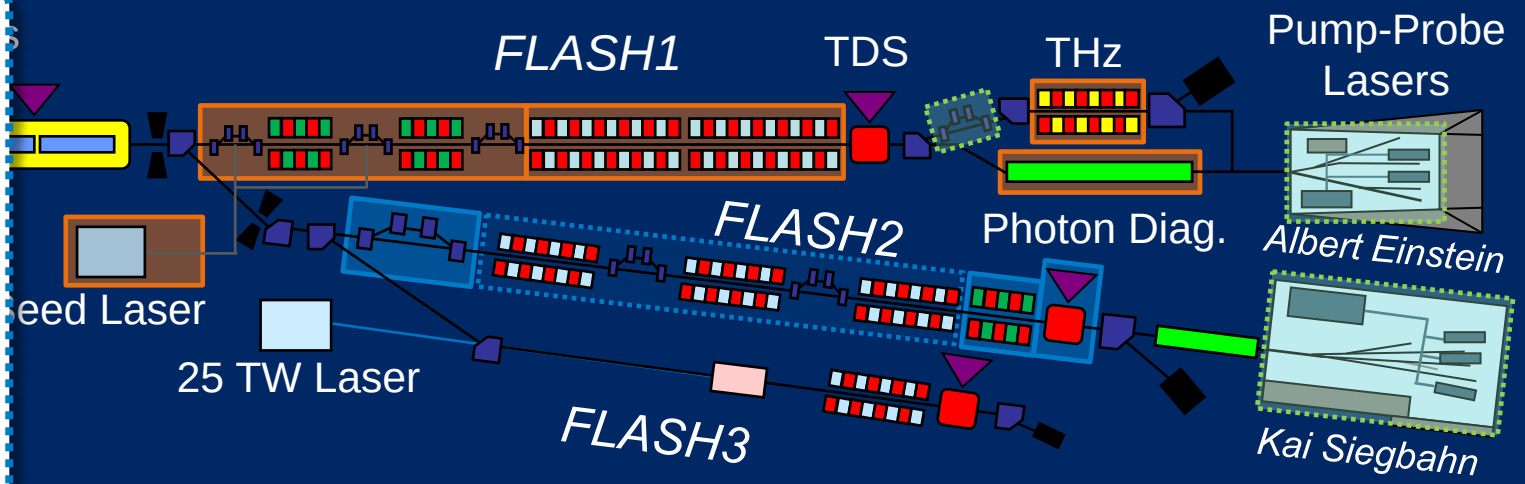
New undulator schemes (FLASH2)
New lasing concepts (FLASH2)

- Added new operation modes
- Increased parameter range
- Improved electron beam & diagnostics

→ **Enables new user experiments**



New Sub-Synch
Sub 50 fs FHWM demonstrated

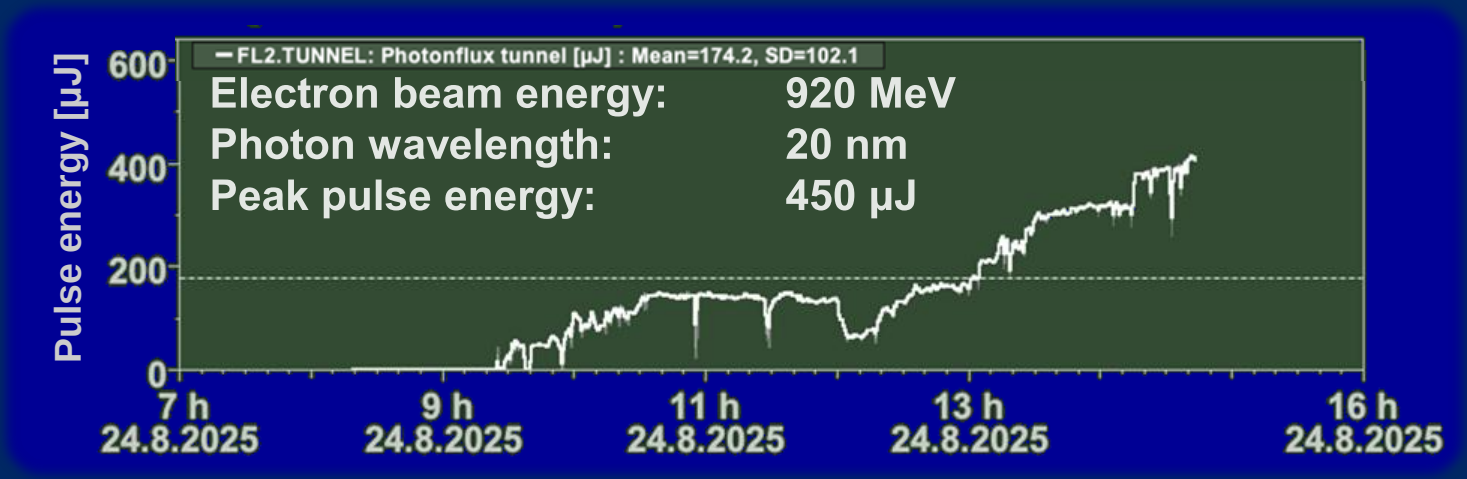


FLASH now

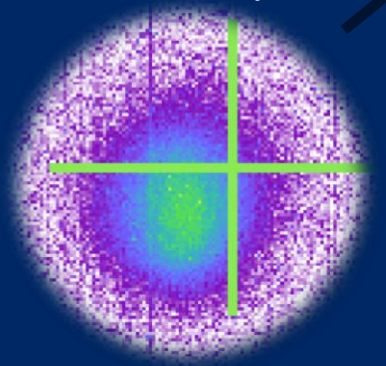
FLASH is back!

Transmission in FLASH1 & Lasing in FLASH2

Electron beam profiles upstream and downstream of modulator 1 and 2

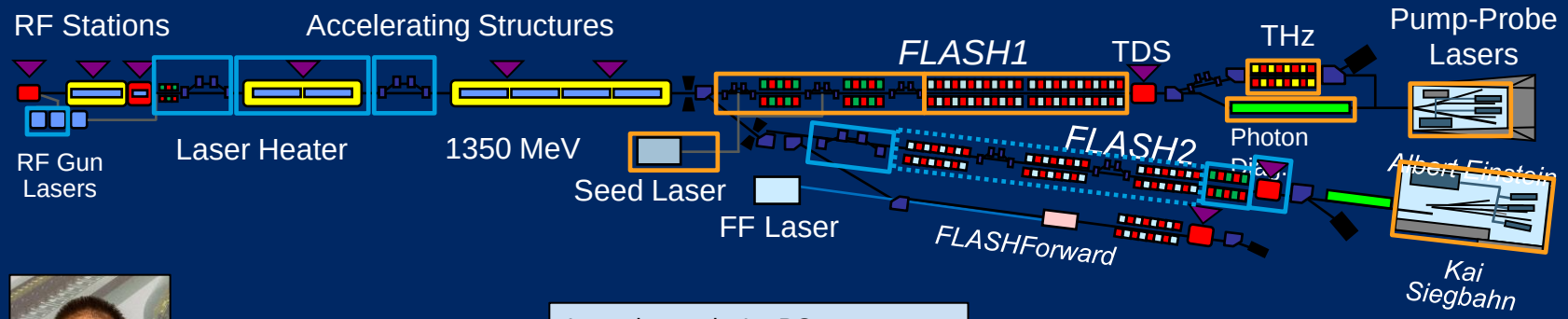


Photon beam profile



Light of the New Millenium

A new regime for an XUV- and soft X-ray facility



Lucas Schaper
FLASH2020+
project lead

Laser heater in 1st BC
New 2nd bunch compressor (BC)

Variable gap undulators (FLASH1)
Pump-probe laser (FLASH1)

New variable gap undulators + chicanes for new lasing concepts (FLASH2)

High rep.rate seeding (FLASH1)
Photon diagnostics (FLASH1)

Markus Gühr
FLASH lead FS

Experiments at FLASH

Early 2000s → **2024** → **2030**

Strong x-ray matter interaction
Often done by people at the facilities

Laser pump – FEL probe
Experiments on model systems

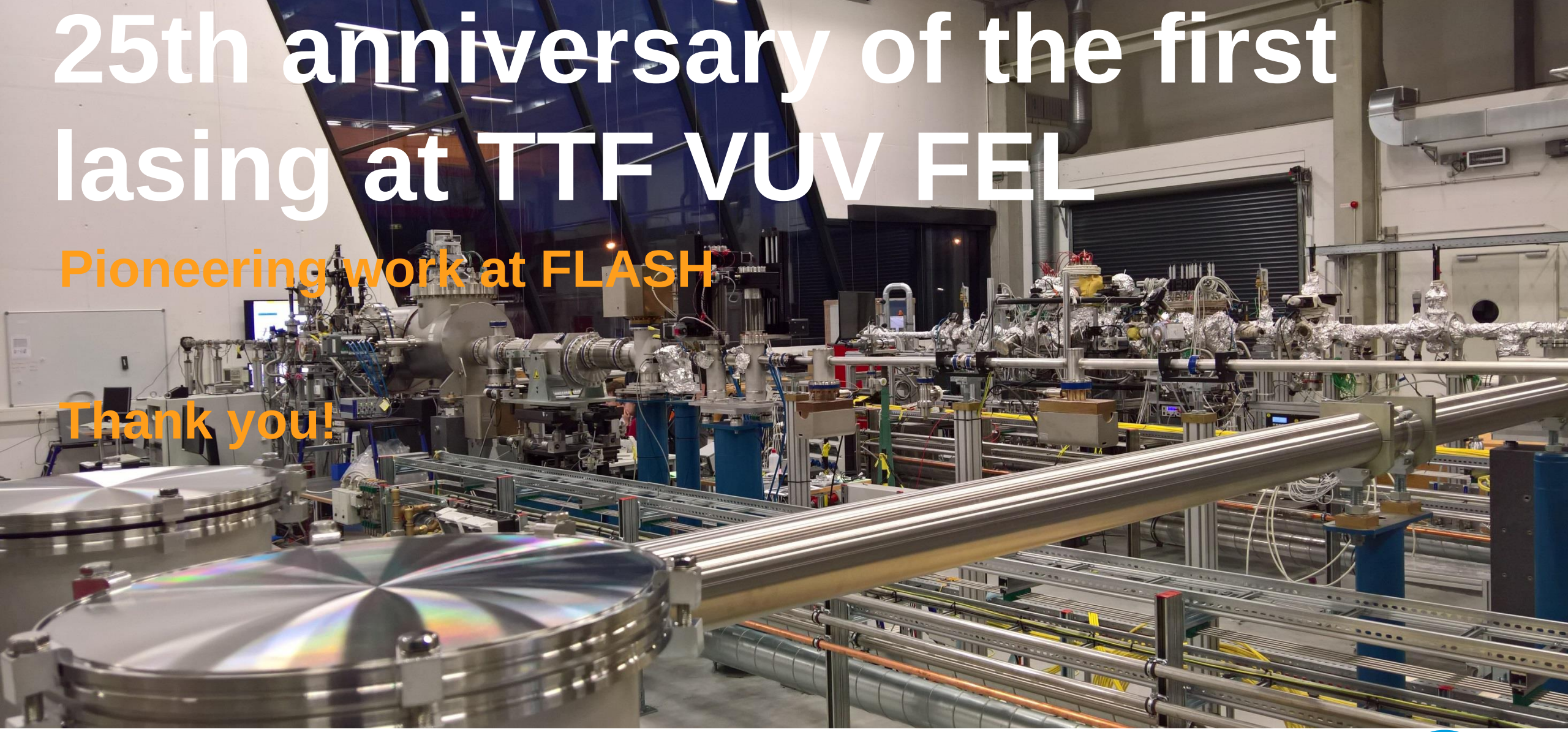
Expert community whith strong bounds to the facilities

Experiments on relevant samples

Attract topical expert community

Increase possibilities for existing community

25th anniversary of the first lasing at TTF VUV FEL



Pioneering work at FLASH

Thank you!

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.