User run 2006/7

Impossible to represent all experiments adequately !!!

Stefan Düsterer
for
The Flash team and all users …

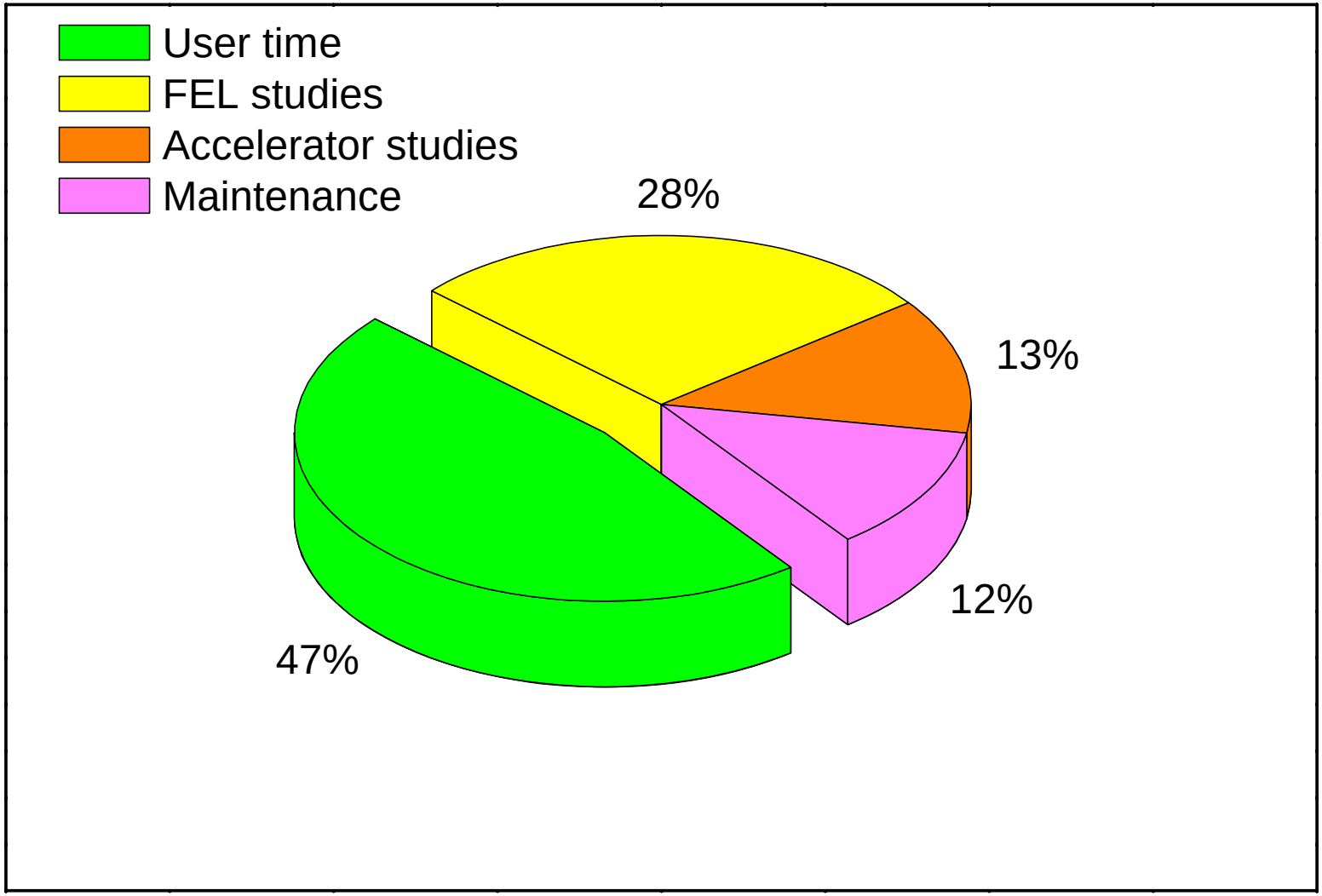
User Experiments

30 proposals submitted in 2002
29 proposals approved in Sept. 2002
200 scientists involved from
60 institutes and
11 countries

- *11 proposals were combined in a joint project ("peak brightness collaboration")*
- *2 proposals were combined into one project on biological samples (Hajdu, Chapman)*

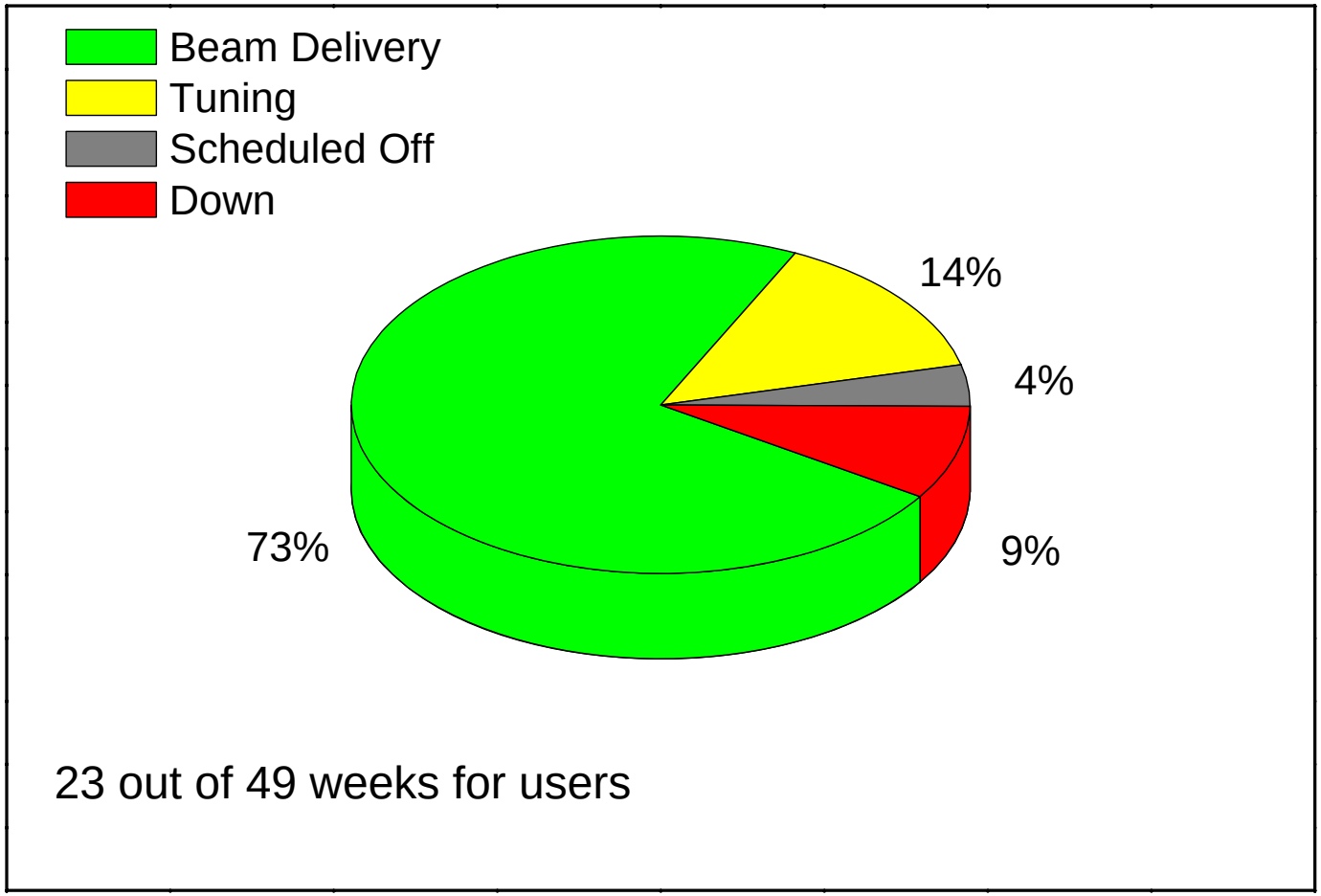
➔ *18 projects had beamtime in two campaigns:*
Aug. 2005 – Feb. 2006 & May 2006 – March 2007 (ongoing)

Total scheduled beam time 2nd period



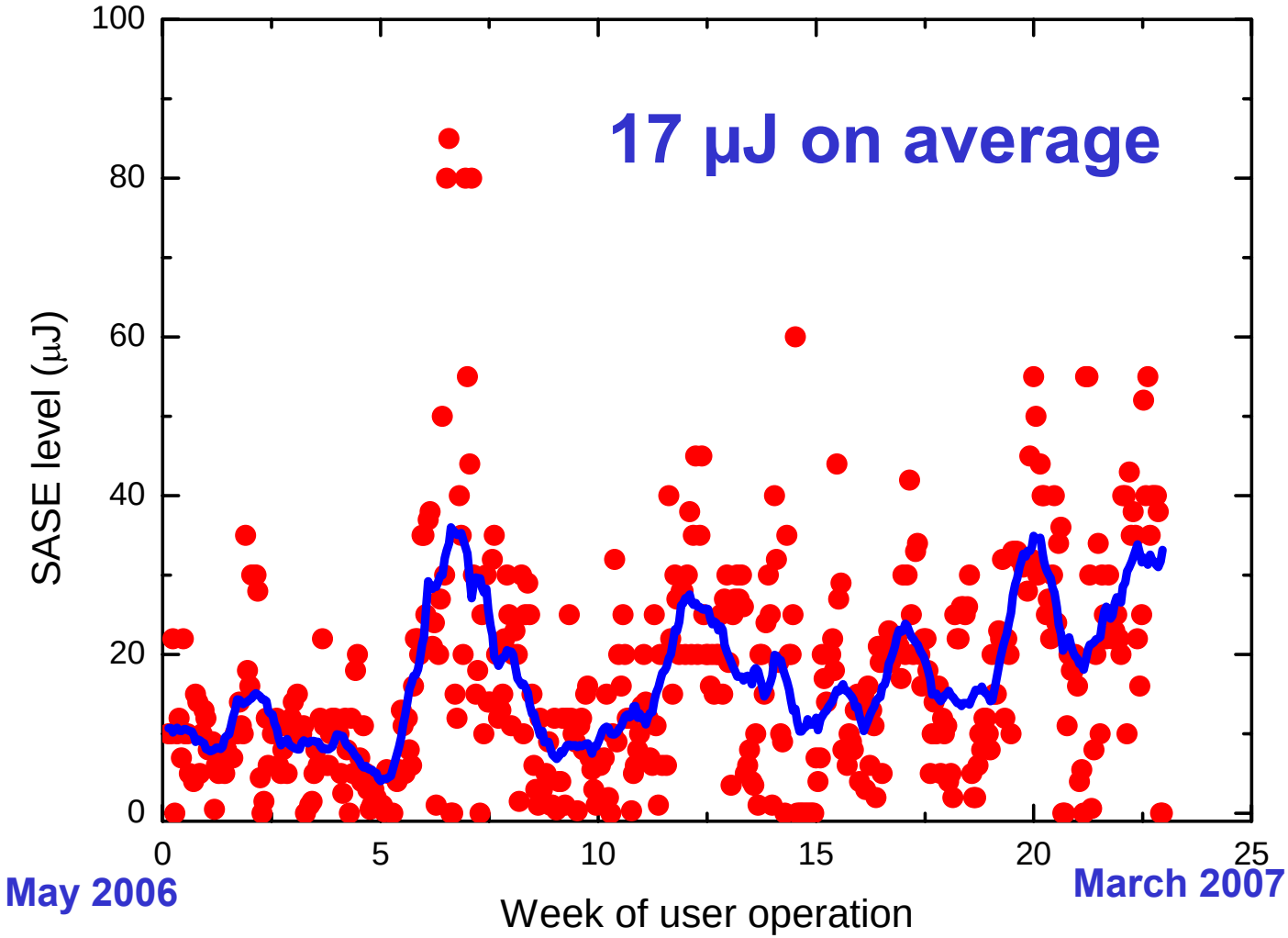
Courtesy of Bart Faatz

Use of beam time during the 2nd user period



Courtesy of Bart Faatz

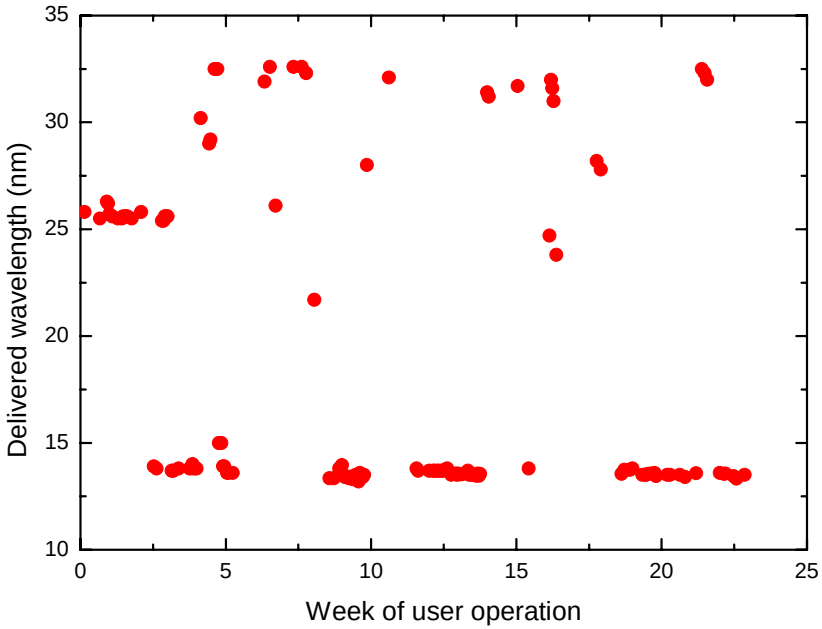
Average SASE level per shift during user operation (taken from logbook)

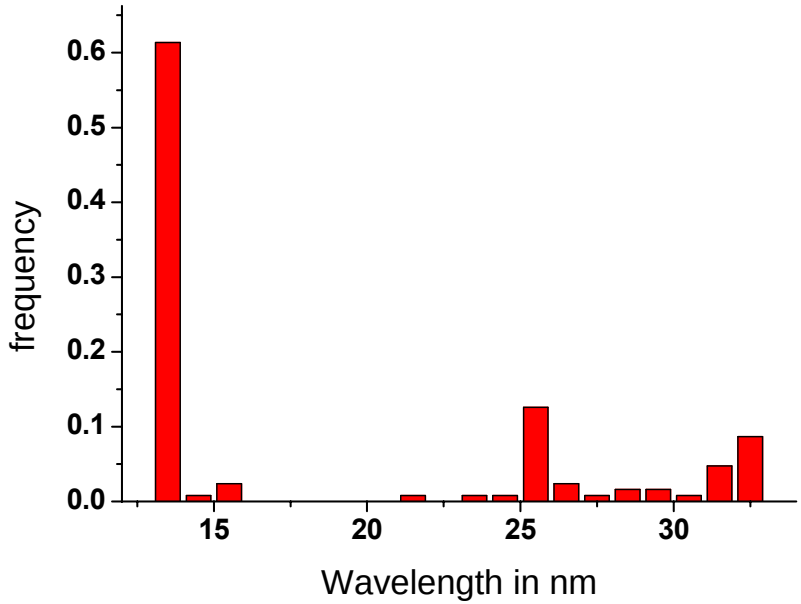


Around week 20, small apertures were inserted by users

Courtesy of Bart Faatz

Wavelength delivered

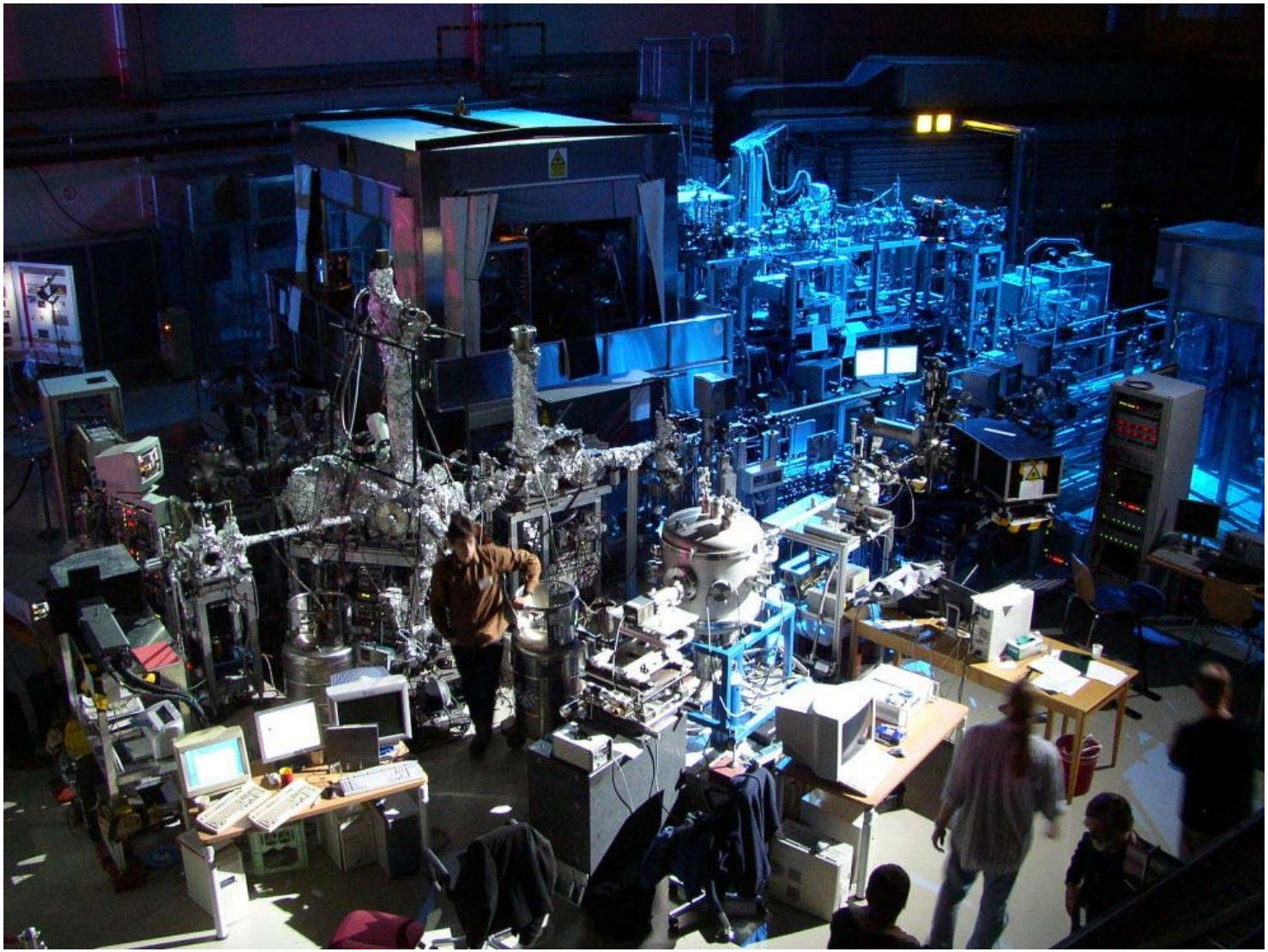




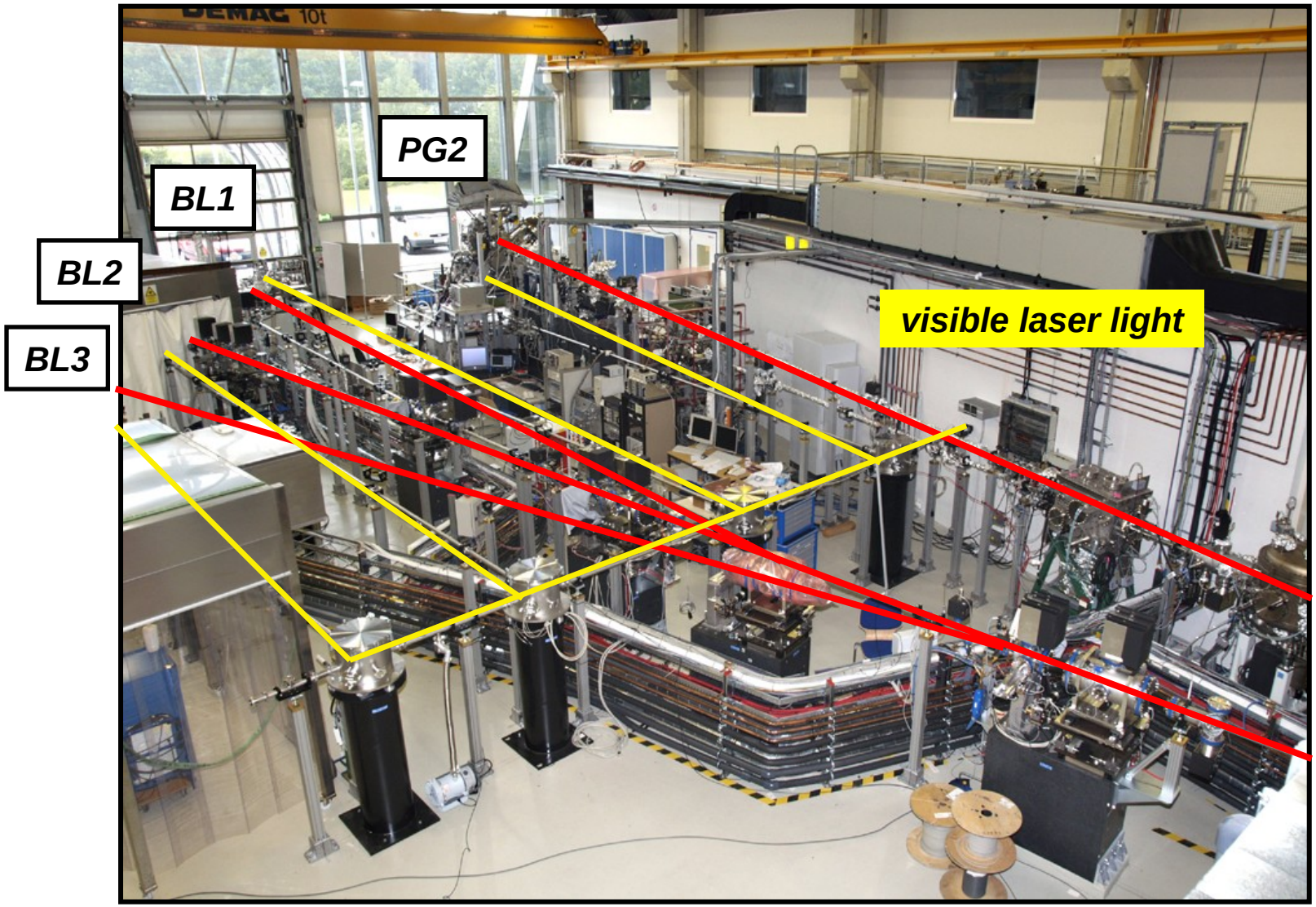
As can be seen, mainly 13.5, 25 and 32 nm requested

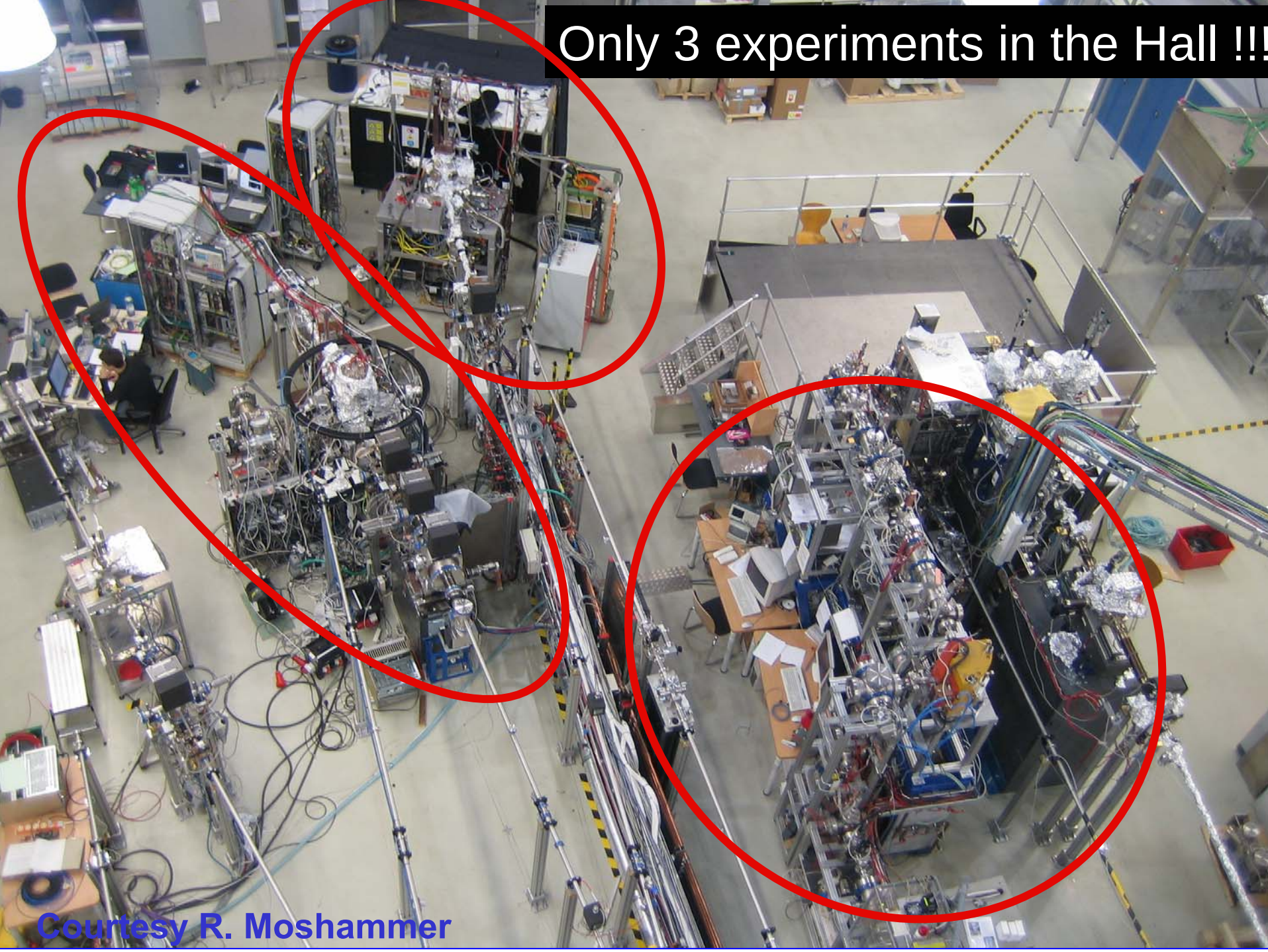
Courtesy of Bart Faatz

FLASH experimental hall



FLASH experimental hall




Only 3 experiments in the Hall !!!
Courtesy R. Moshammer

One experiment collaboration: M.Meyer et al.

Experimental

- **LIXAM / LURE (Orsay, France)**
  D. Cubaynes, P. O'Keeffe, M. Meyer
- **DESY (Hamburg, Germany)**
  S. Düsterer, P. Radcliffe, H. Redlin, E. Plönjes, J. Feldhaus
- **Dublin City University (Dublin, Ireland)**
  H. Luna, P. Yeates, E. Kennedy, J. Costello
- **Queens University Belfast (U Kingdom)**
  Ph. Orr, D. Riley, J. Pedrosa, C. Lewis
- **Max-Born-Institut (Berlin, Germany)**
  I. Will

Theory

- **LCP-MR (Paris, France)**
  R. Taïeb, A. Maquet
- **FORTH (Heraklion, Greece)**
  P. Lambropoulos
- **University of Moscow**
  A. Grum-Grzhimailo, E.Gryzlova, A. Magunov, S. Strakhova

Research Areas I

- **Interaction of ultra-intense XUV pulses with matter**
  - **multiphoton excitation of atoms, molecules, clusters…** (*Richter, Becker, Moshammer, Möller*)
  - **creation and characterization of dense plasmas** (*Lee et al.*)
  - **Optically induced breakdown of matter (="damage")** (*Lee et al.*)

- **Single-shot Diffraction imaging of (biological) samples** (*Hajdu/Chapman*)

- **Femtosecond time-resolved experiments**
  - **synchronization FEL - optical laser** (*Drescher, Meyer*)
  - **pump-probe expts. on atoms and molecules** (*Meyer, Drescher*)
  - **pump-probe expts. on solids** (*Föhlisch, Drescher*)
  - **sum-frequency generation** (*Gahl*)

Research Areas II

- **Investigation of extremely dilute samples**
  - **photodissociation of molecular ions** (*Wolf*)
  - **highly charged ions** (*Crespo*)
  - **mass selected clusters** (*Meiwes-Broer*)

- **Investigation of surfaces and solids**
  - **Surface chemistry - XUV laser desorption** *(Zacharias)*
  - **surface dynamics** (*Föhlisch*)
  - **luminescence under FEL radiation** (*Kirm*)
  - **meV-resolution photon and photoelectron spectroscopy** (*Kipp*)

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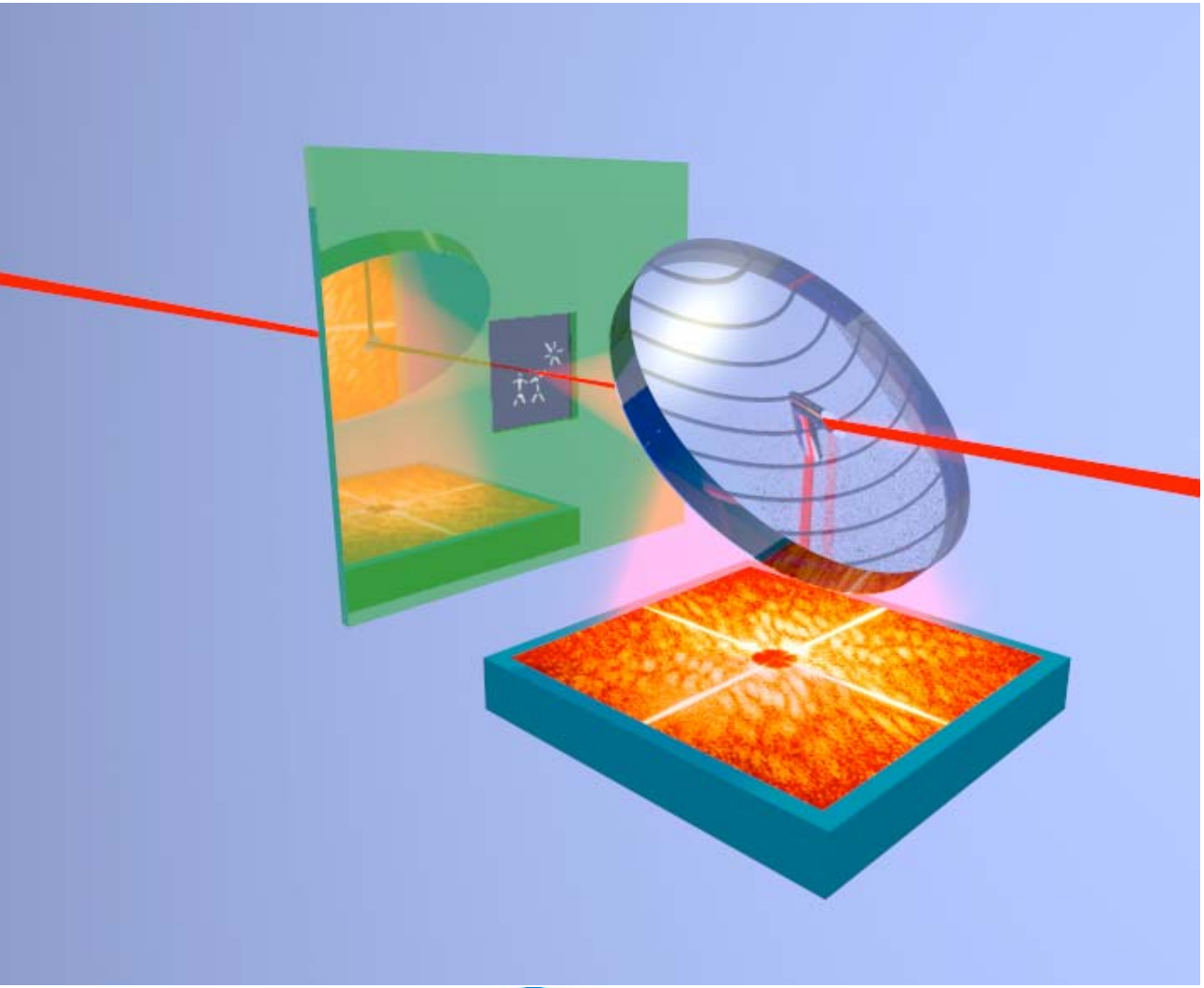
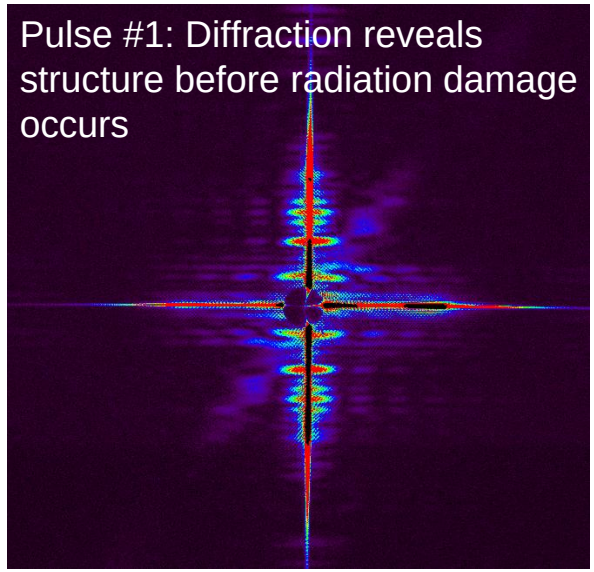
First demonstration of coherent diffraction imaging with a soft-X-ray FEL (J.Hajdu, H.Chapman)





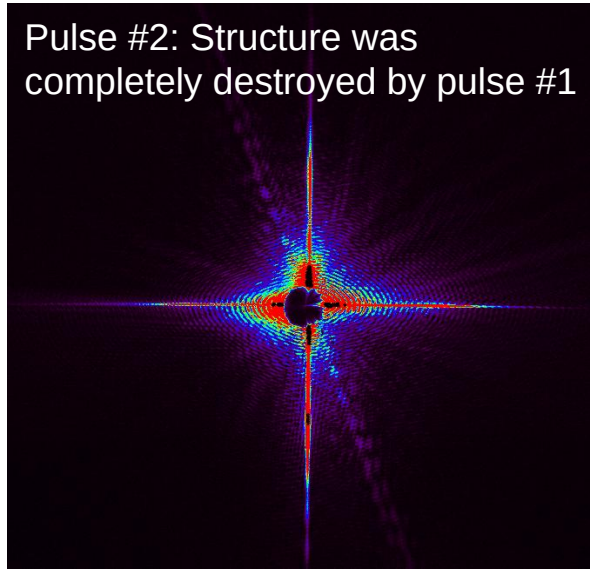
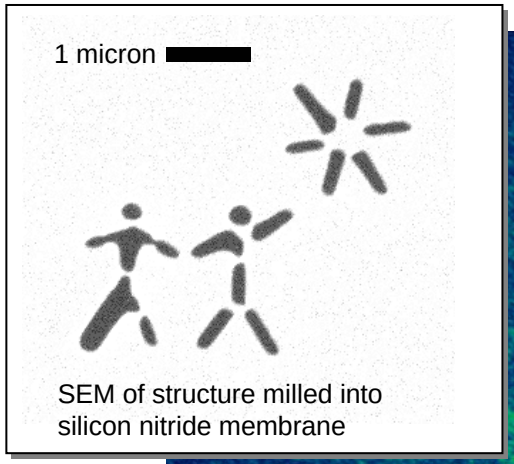
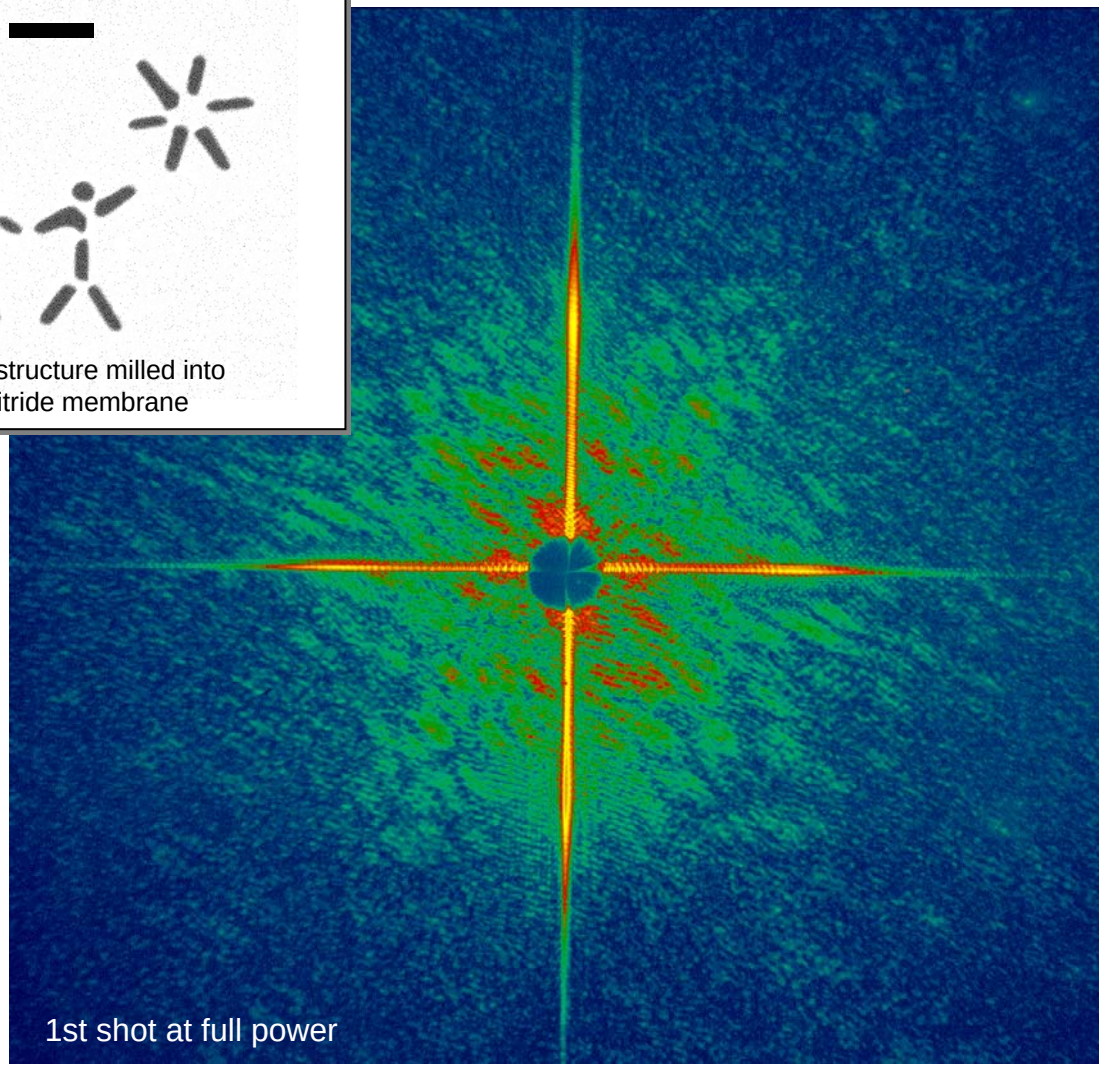
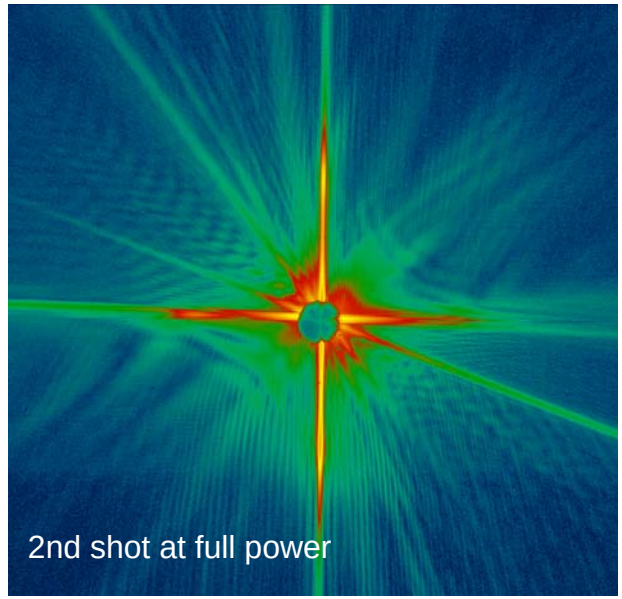


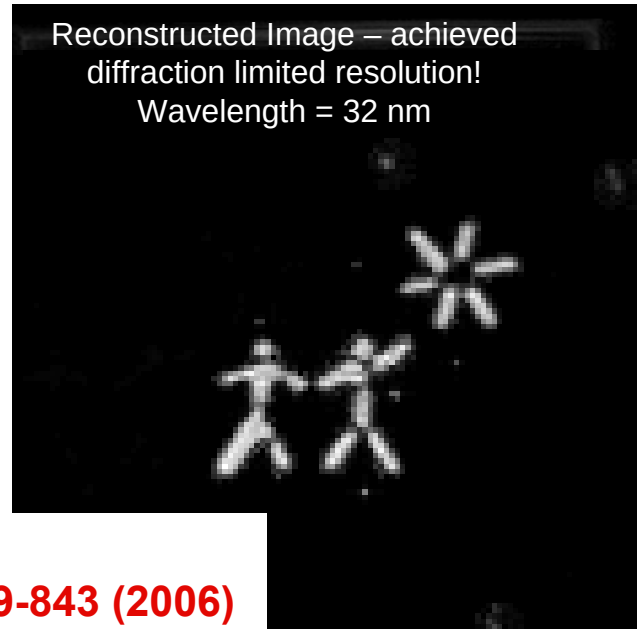
Image reconstructed from ultrafast diffraction pattern



SEM of structure milled into silicon nitride membrane





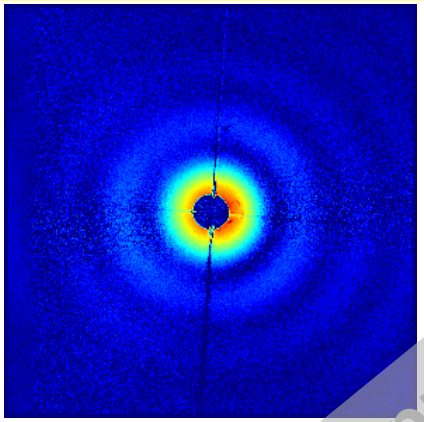


H.N.Chapman et al.,
Nature Physics 2, 839-843 (2006)

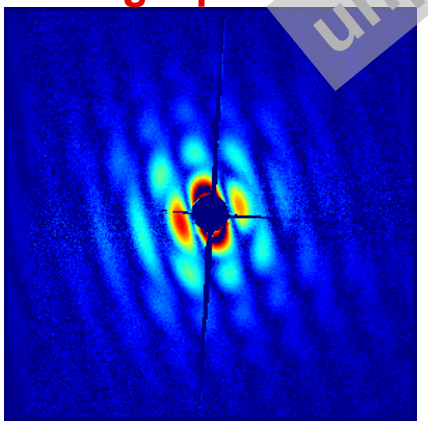
some more diffraction examples:

(not published yet, do not distribute!)

DNA-sugar complex (about 200 nm diameter), particle jet!

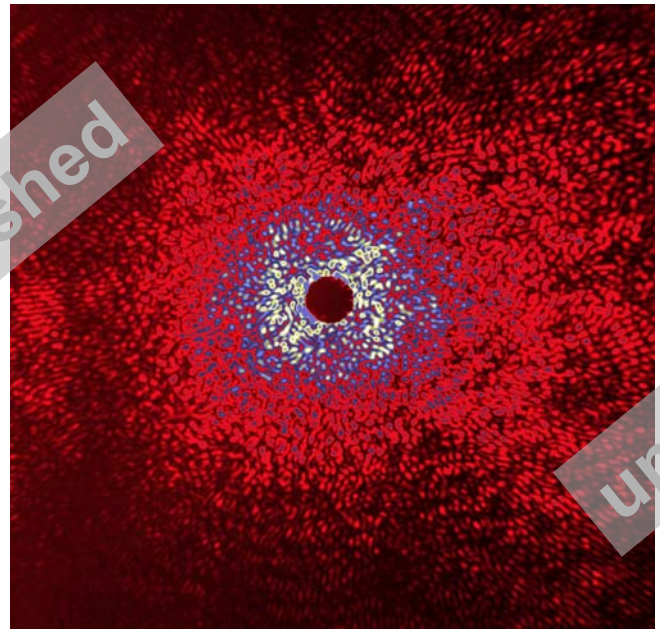


single particle



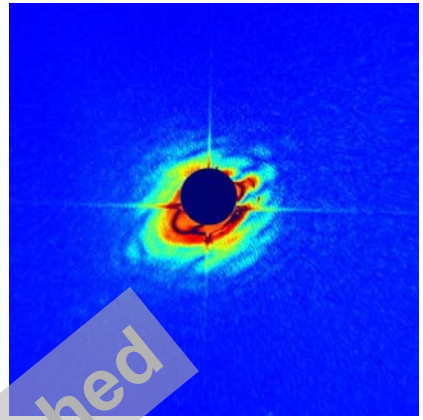
two particles in one shot

coccolith shell (plankton with a $CaCO_3$ skin)

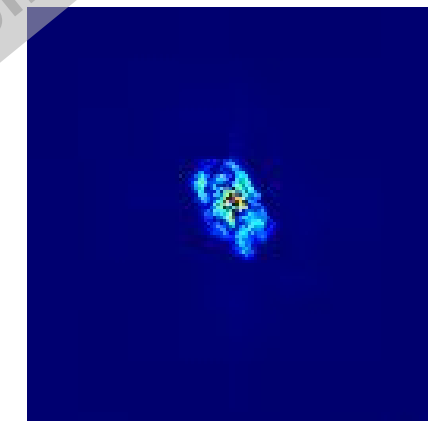


excellent resolution, probably around 20nm (as expected)

"maybe" alive picoplankton (on SiN_3 membrane)



diffraction image

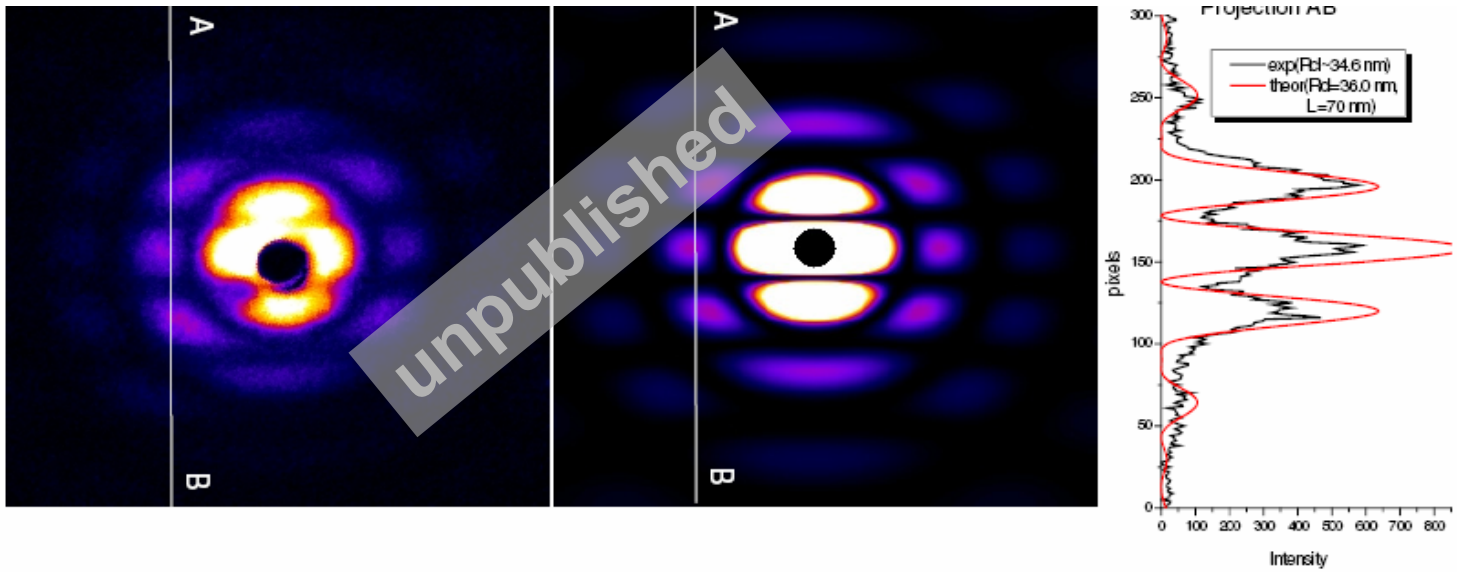


crude reconstruction

Single shot imaging by x-ray scattering of single and few nm-gasphase particles

single shot 2D- scattering patterns of a single twin-cluster
(35 nm radius Xenoncluster, 'double slit' experiment)

experiment **simulation**



Clusters stay intact during exposure (30 fs)
(Ions move ~ 3 Å in 30 fs)

C. Bostedt, E. Eremina, M. Hoener, H. Thomas, T. Möller
in Collaboration with:
H. Wabnitz[1], E. Ploenjes[1], M. Kuhlmann[1], Rubens de Castro[2], Tim Laarmann[3], K.H.Meiwes-Broer [4], J. Tiggesbäumker [4], T. Fennel [4]
[1] DESY, [2] LNLS, Campinas Brasil, [3] Max-Born Institut, [4] Uni Rostock

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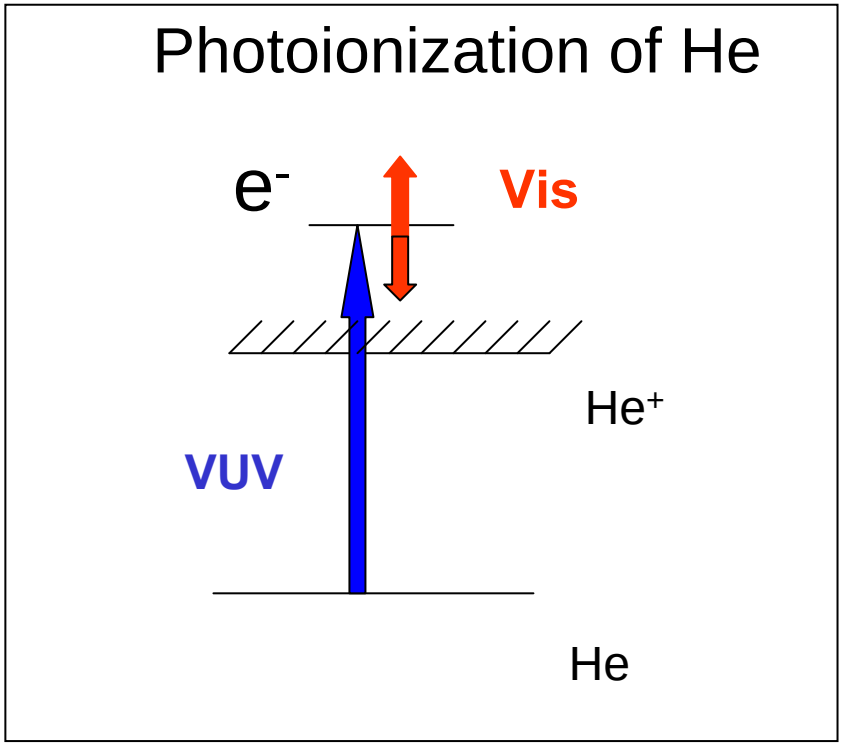
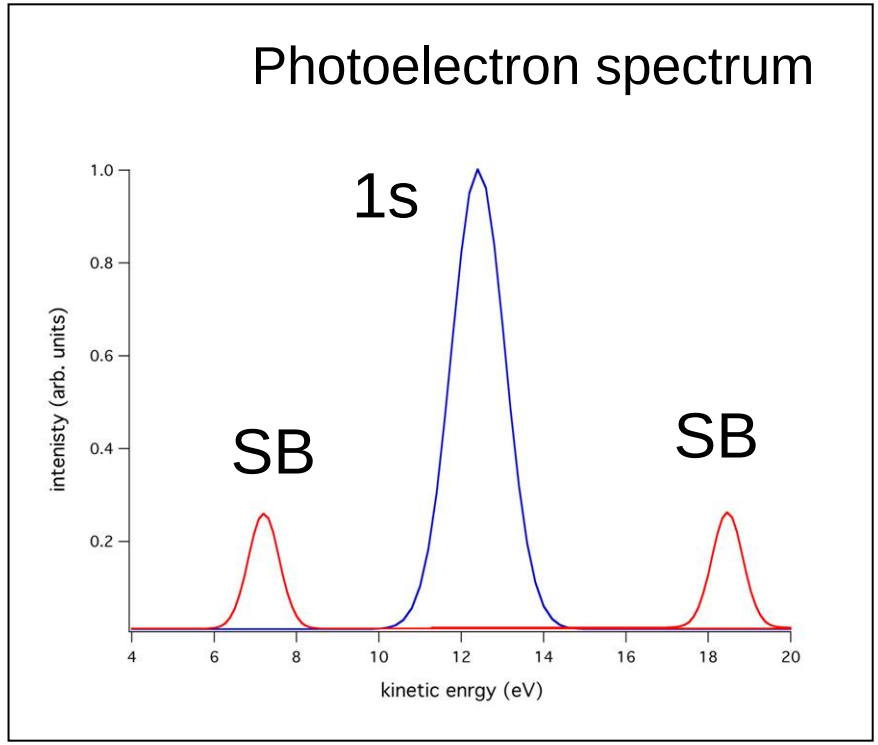
Two-color ionization in a strong optical field





TiSa-laser: 800nm , 120 fs, 15 µJ

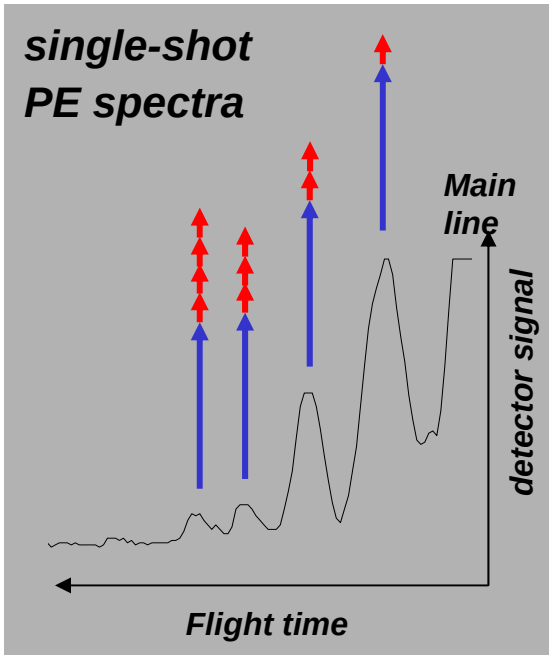
Sideband intensity very sensitive to temporal overlap

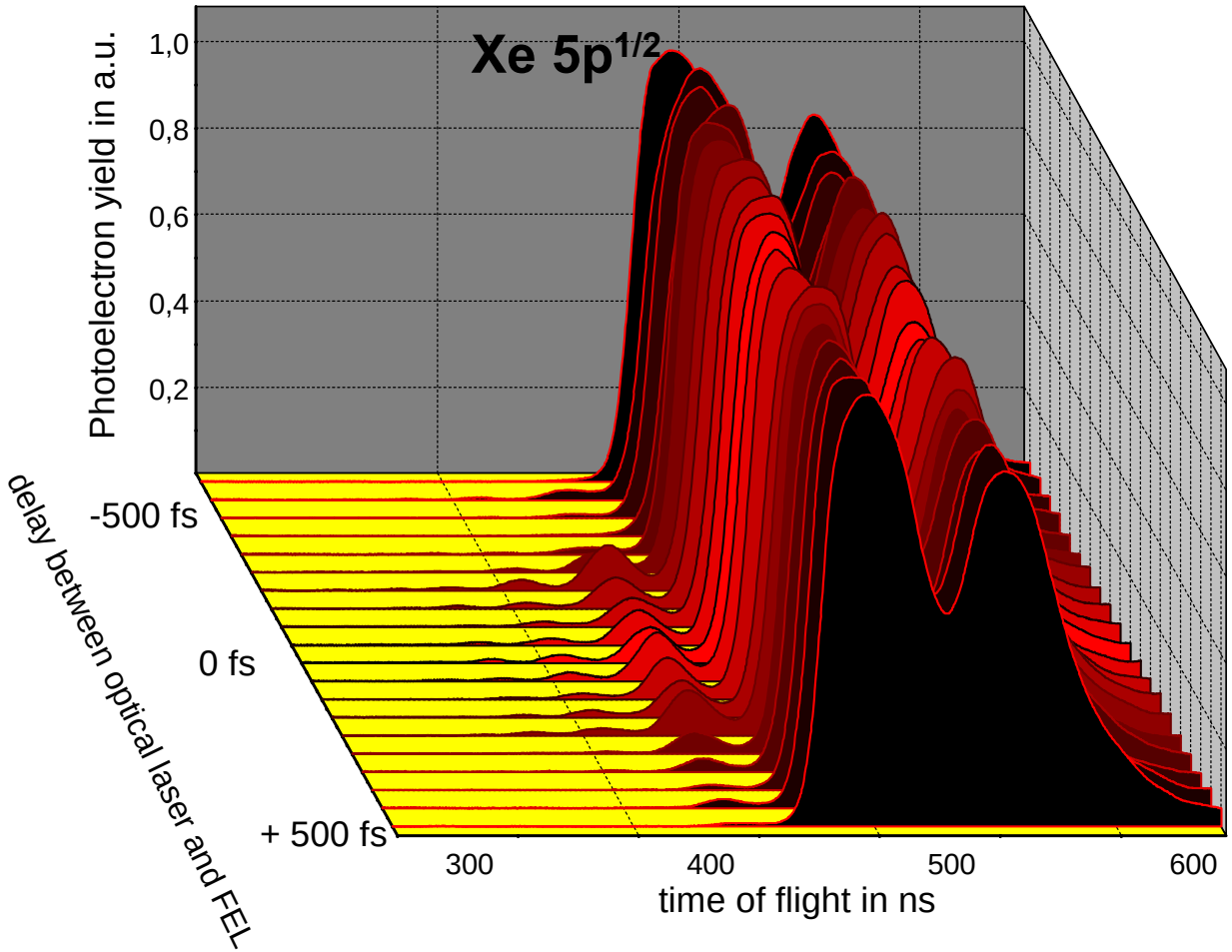
E.S. Toma et al.
Phys. Rev. A 62, 061801 (2000)

M. Meyer et al.
Phys. Rev. A 75, 011401 (2006)

FLASH: Two-colour photo ionisation

Above-threshold ionization (ATI) leading to side bands:





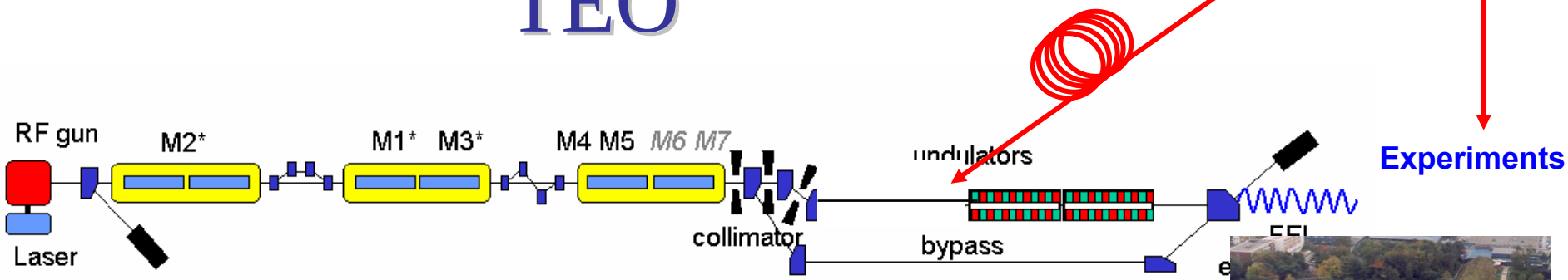
M. Meyer et al.,
LIXAM - DESY - DCU - QUB - MBI - LCP-MR - FORTH - U Moscow collaboration

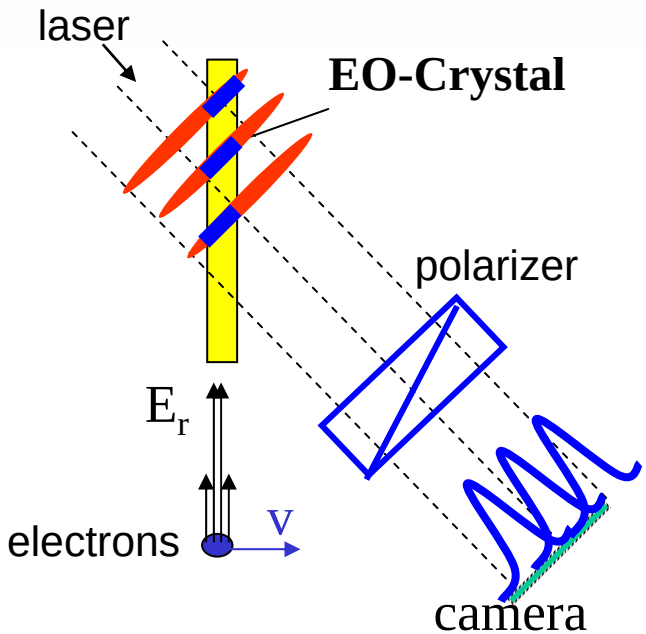
25 nm
30 fs
few 10^{13} W/cm^2

Timing Electro-Optical Sampling

pump-probe fs-laser for FEL-experiments

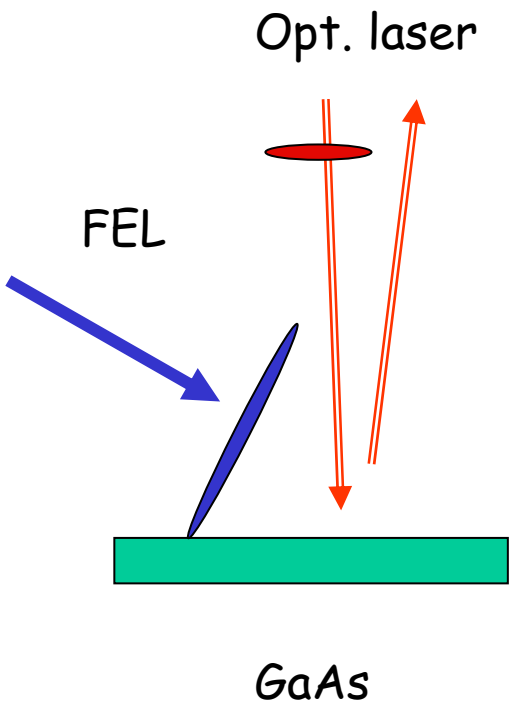
TEO



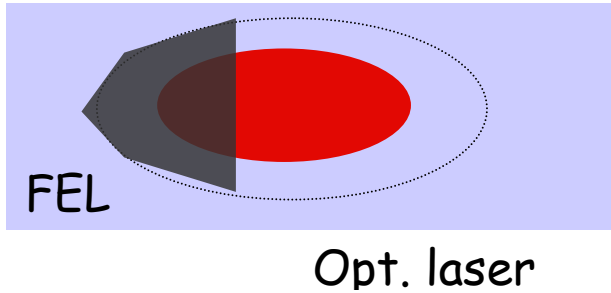


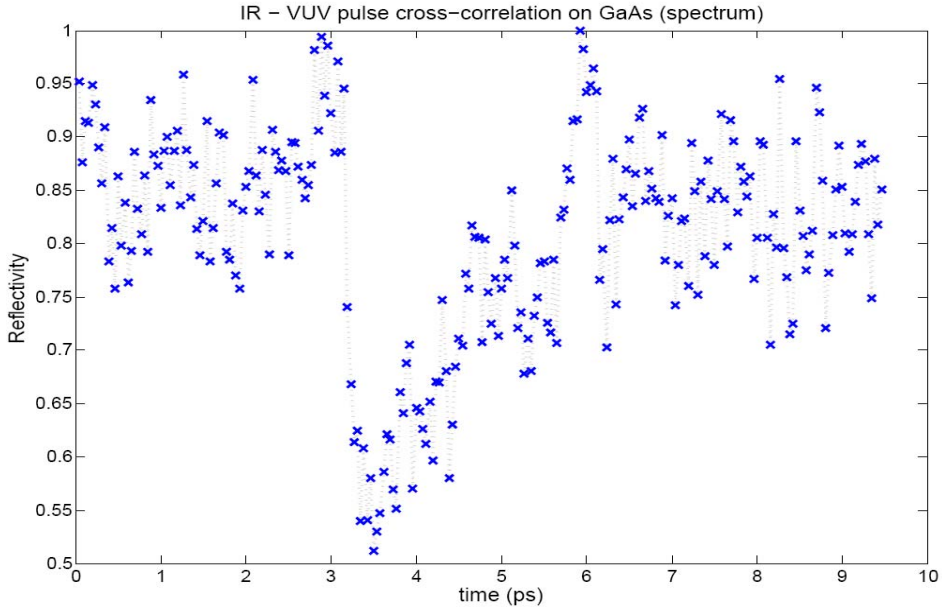
Goal:
50 fs timing resolution
-> input for PP experimets

Correlation TEO – Experiment (Drescher AG)



Reflectivity signal





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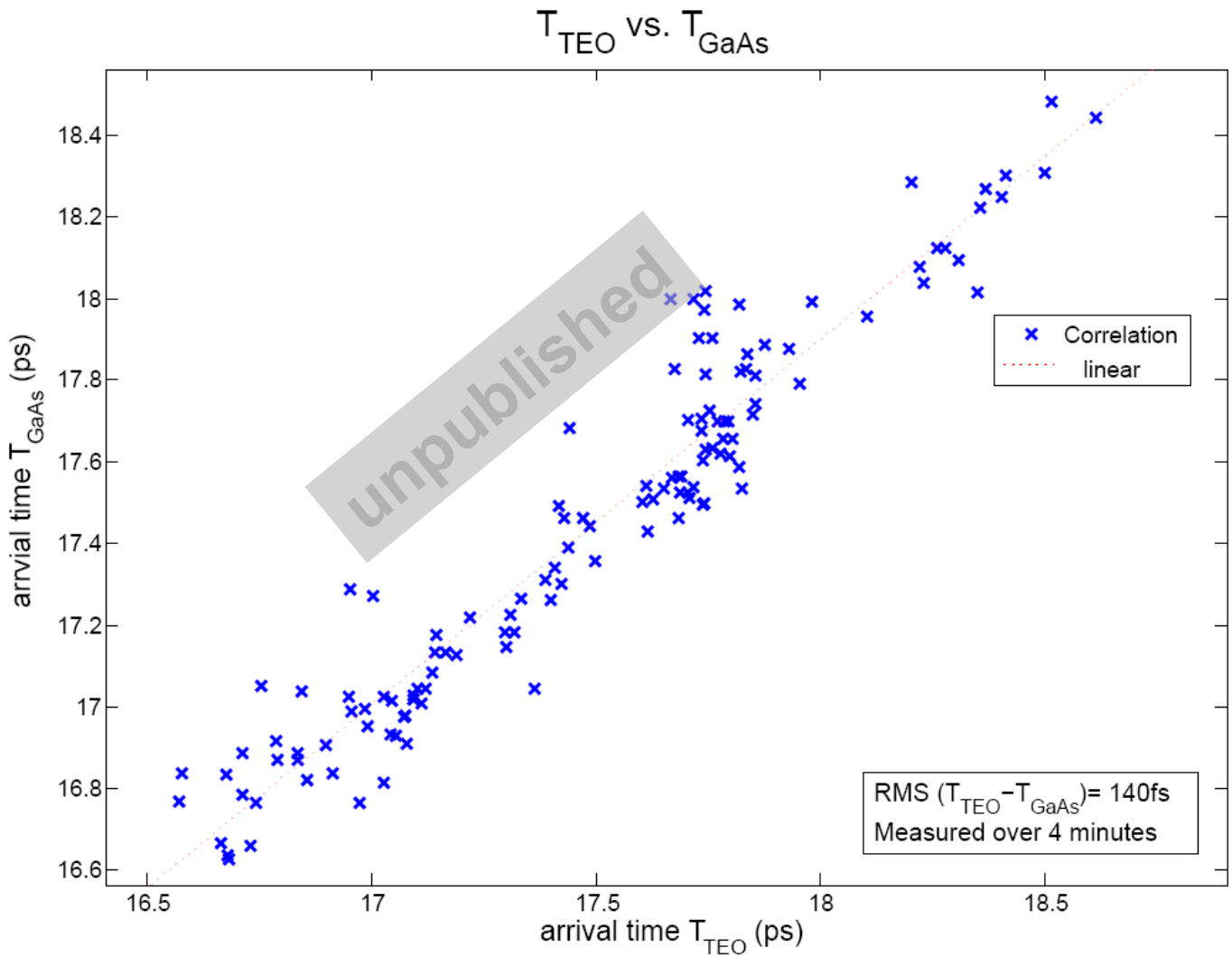

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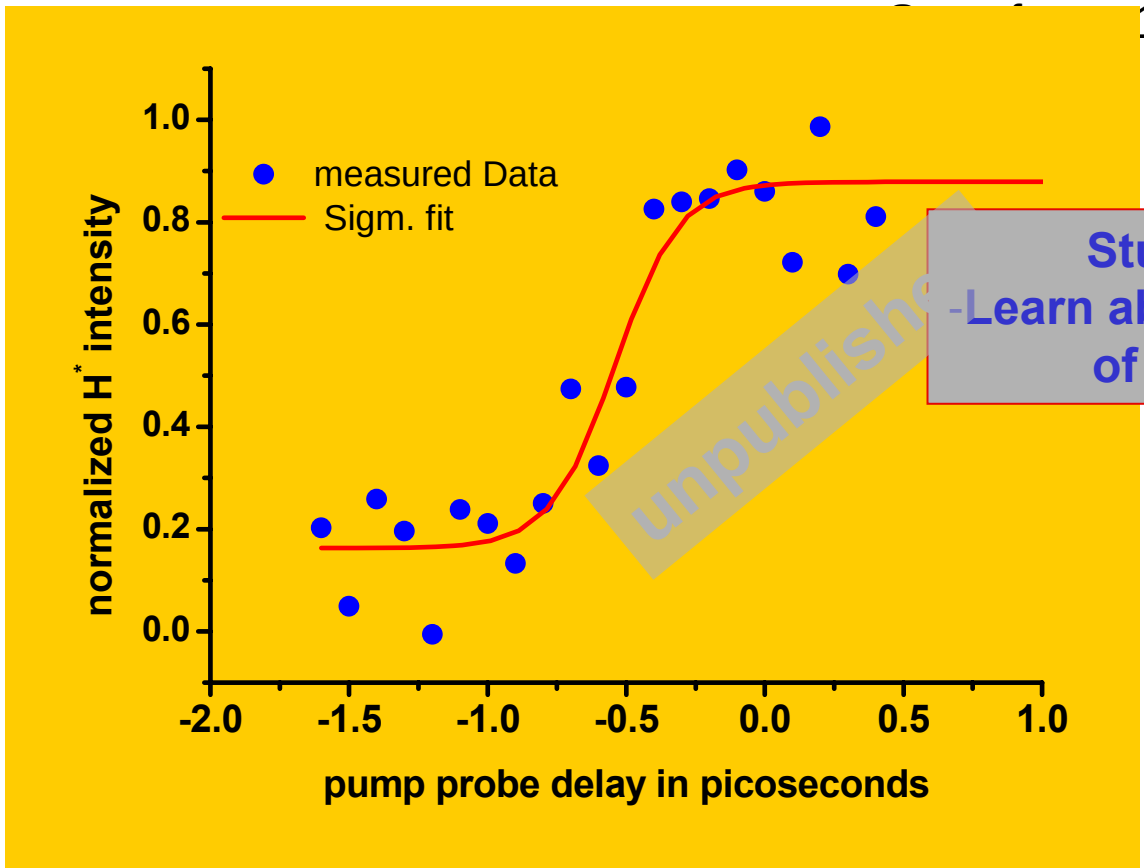
Photodissociation of H_2

First two-color fs- pump-probe experiment at FLASH

1. H_2 + FEL → $H^+ + H^* + e^-$ **Direct ionization of H_2 with FEL**
2. H^* + IR → $H^+ + e^-$ **Probe H* with optical laser**

1.5 ps to ~10 ns



Study decay times
-Learn about time-dependence of level population

M.Meyer et al.

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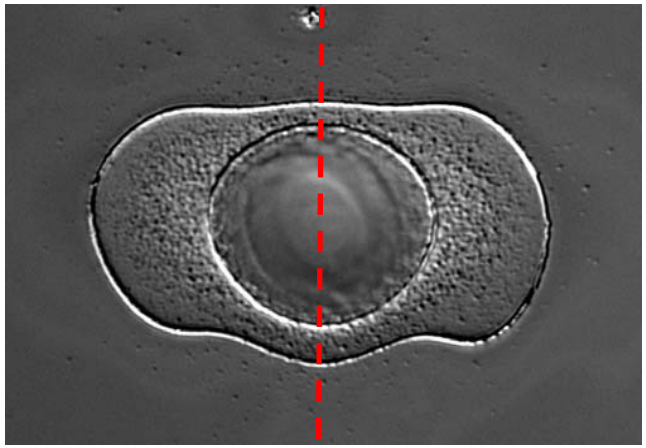
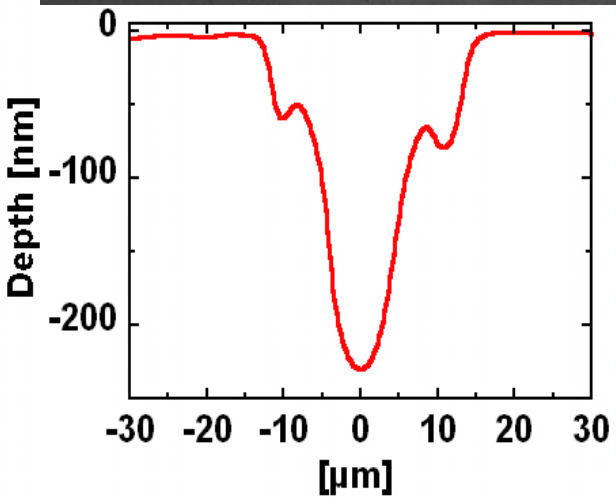
Results: surface morphology

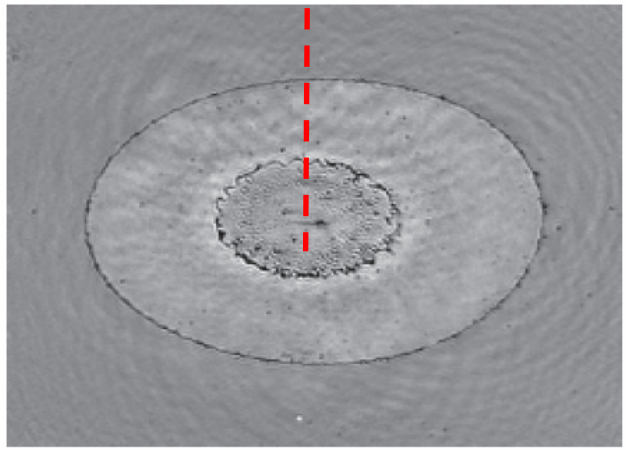
GaAs

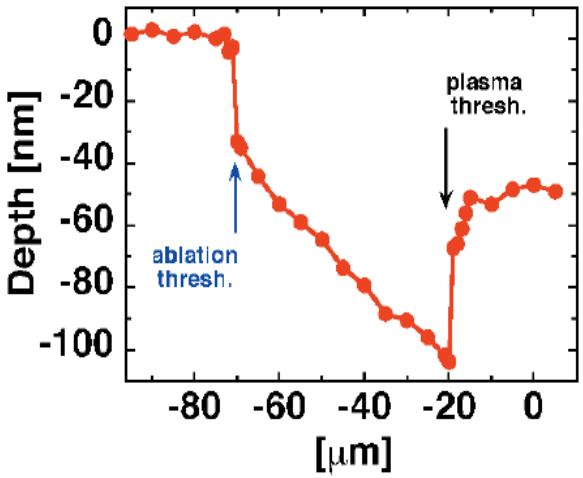
FLASH (32 nm)





fs opt. laser

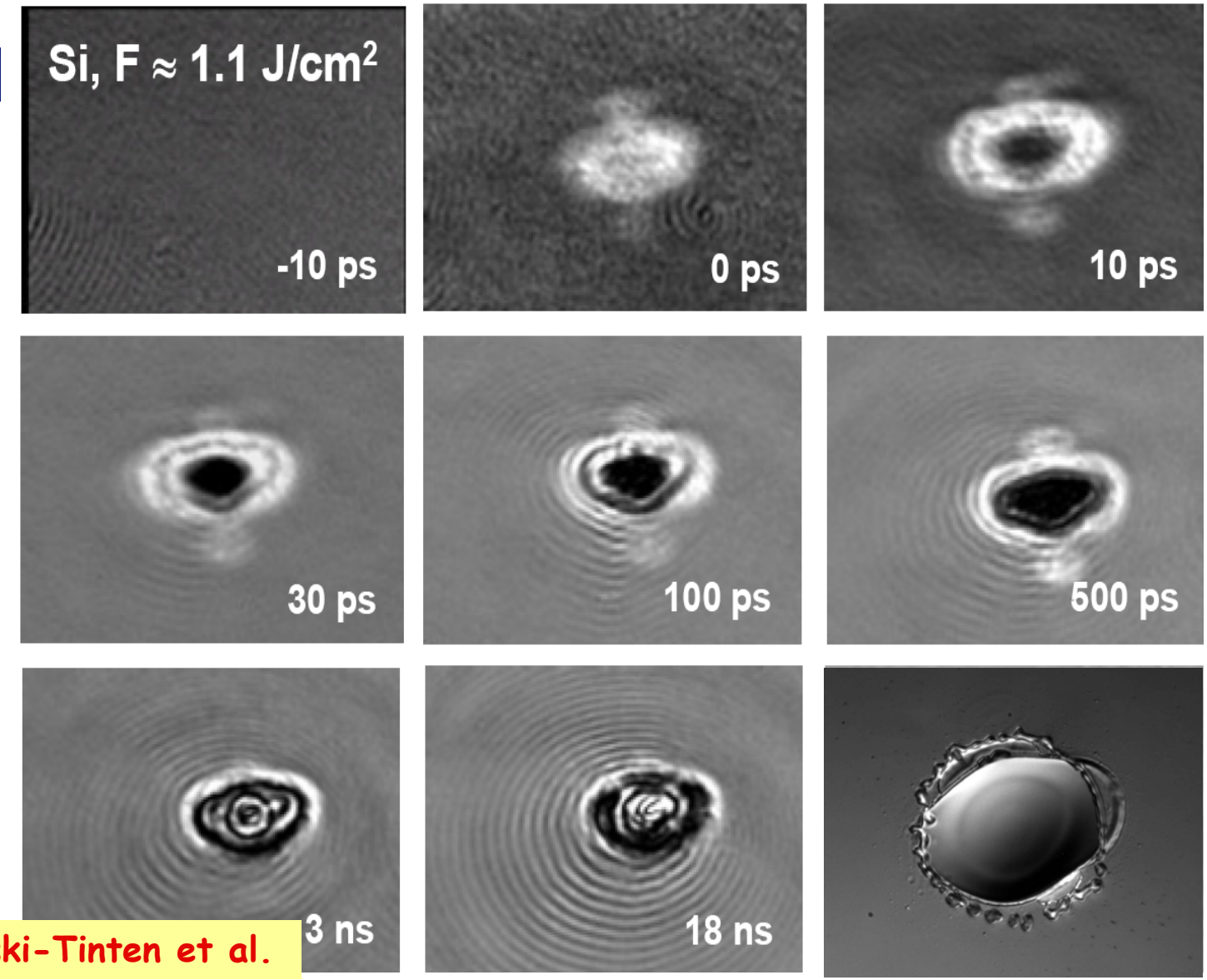




N.Stojanovic et al. Appl. Phys. Lett. 89, 241909 (2006)

K.Sokolowski-Tinten et al.

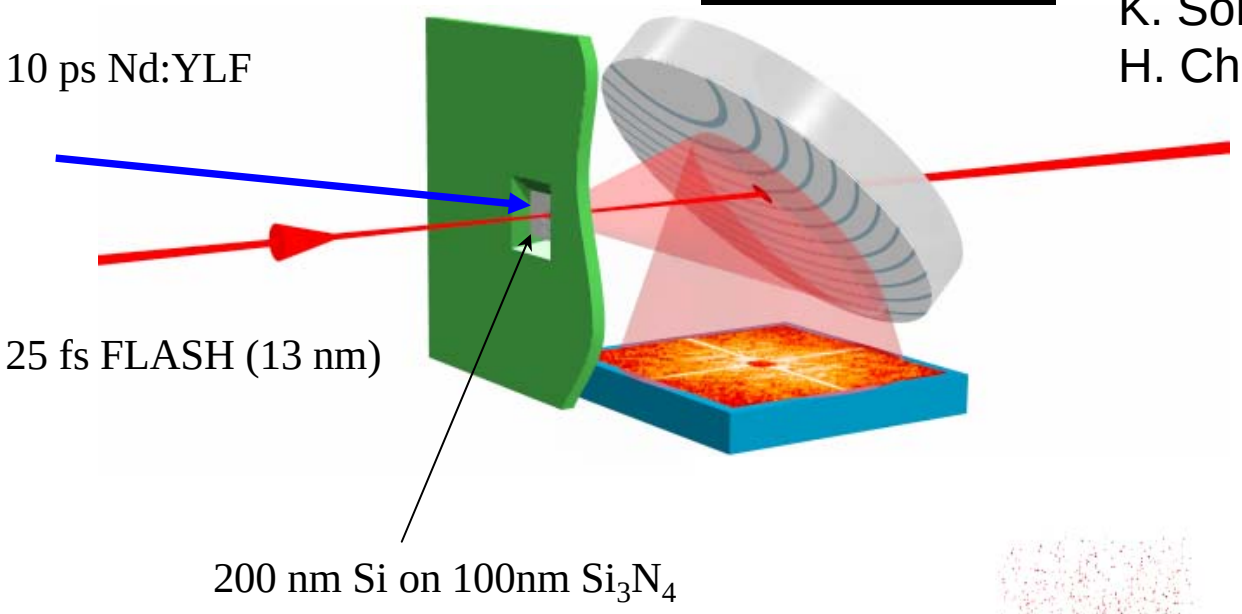
Results: Transient Reflectivity

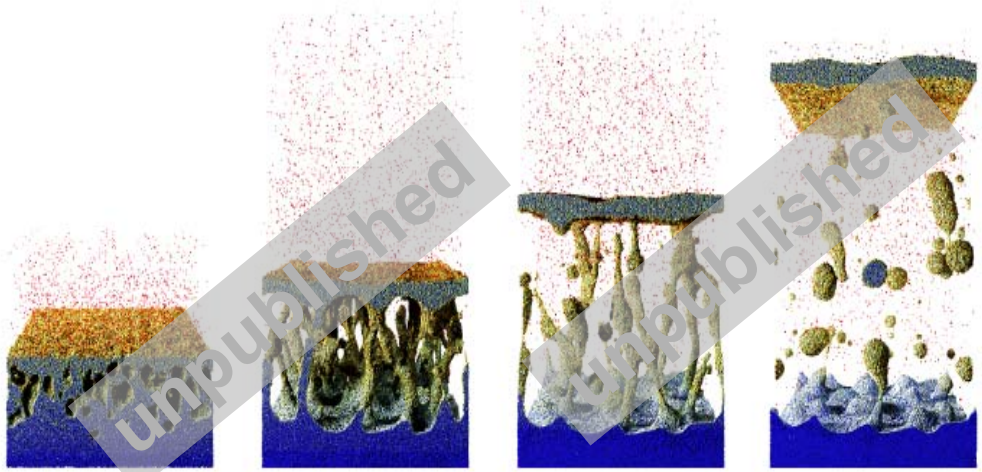


K.Sokolowski-Tinten et al.

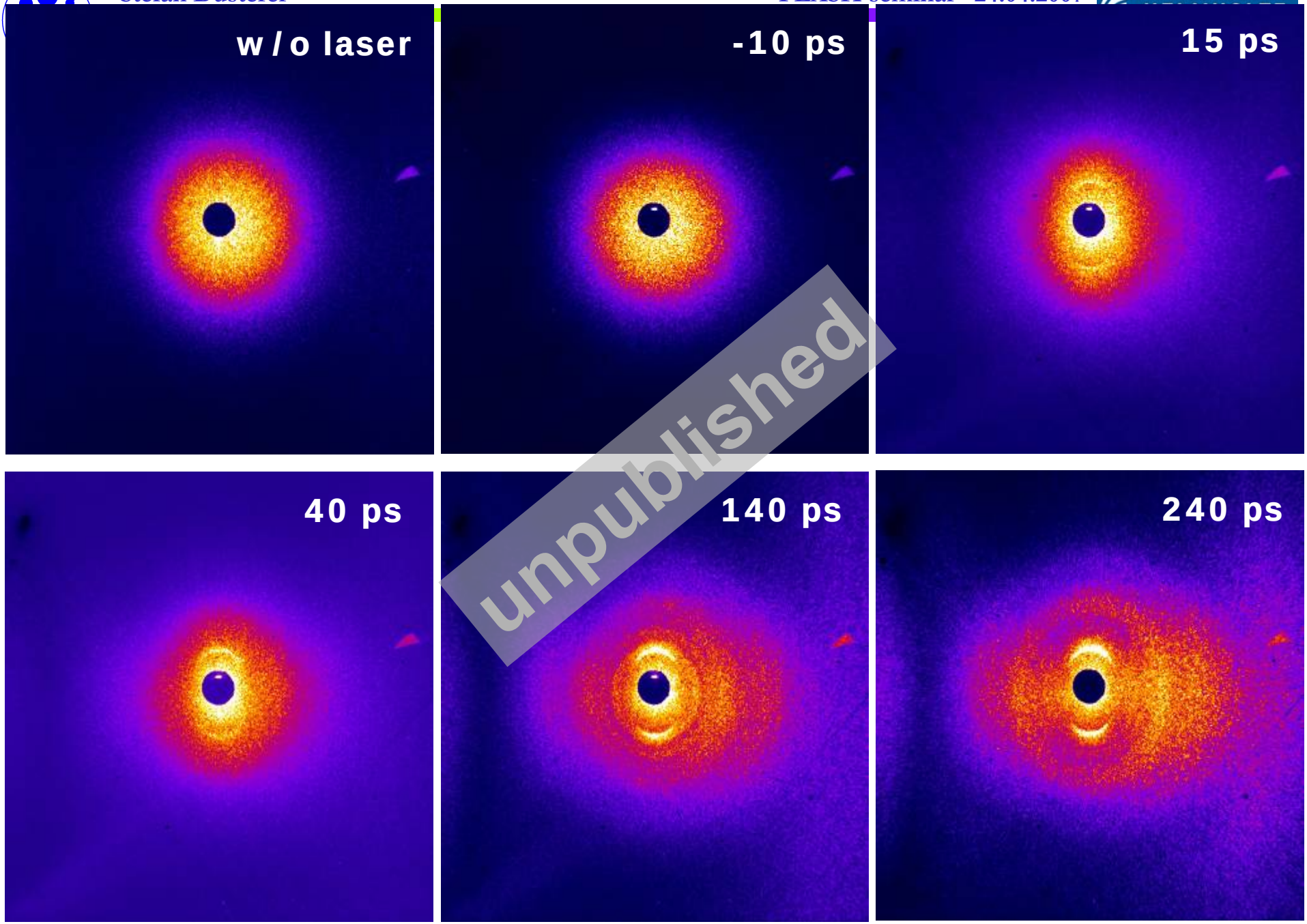
Structural changes on laser-irradiated surfaces

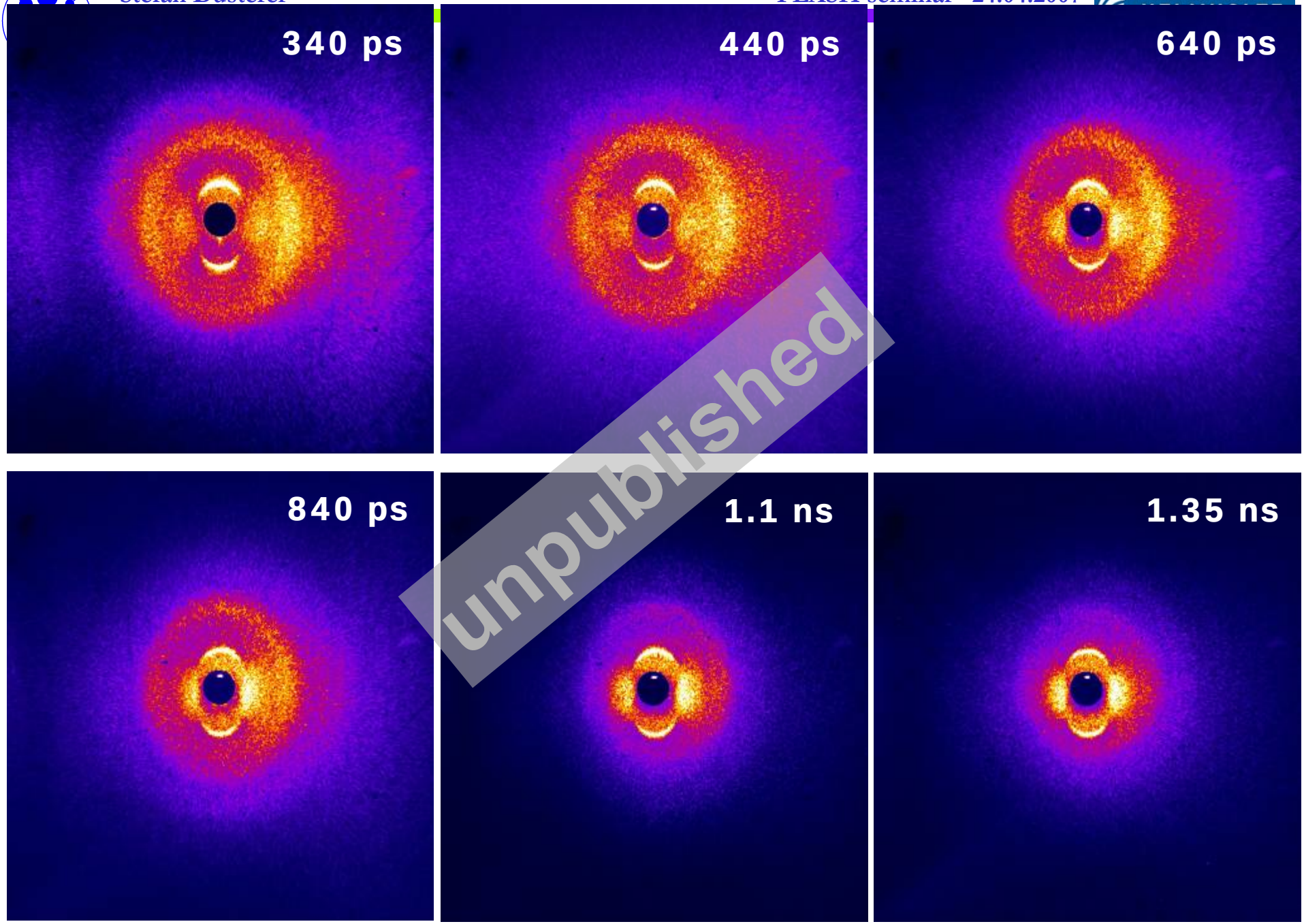
K. Sokolowski-Tinten (DUE)
H. Chapman (LLNL)

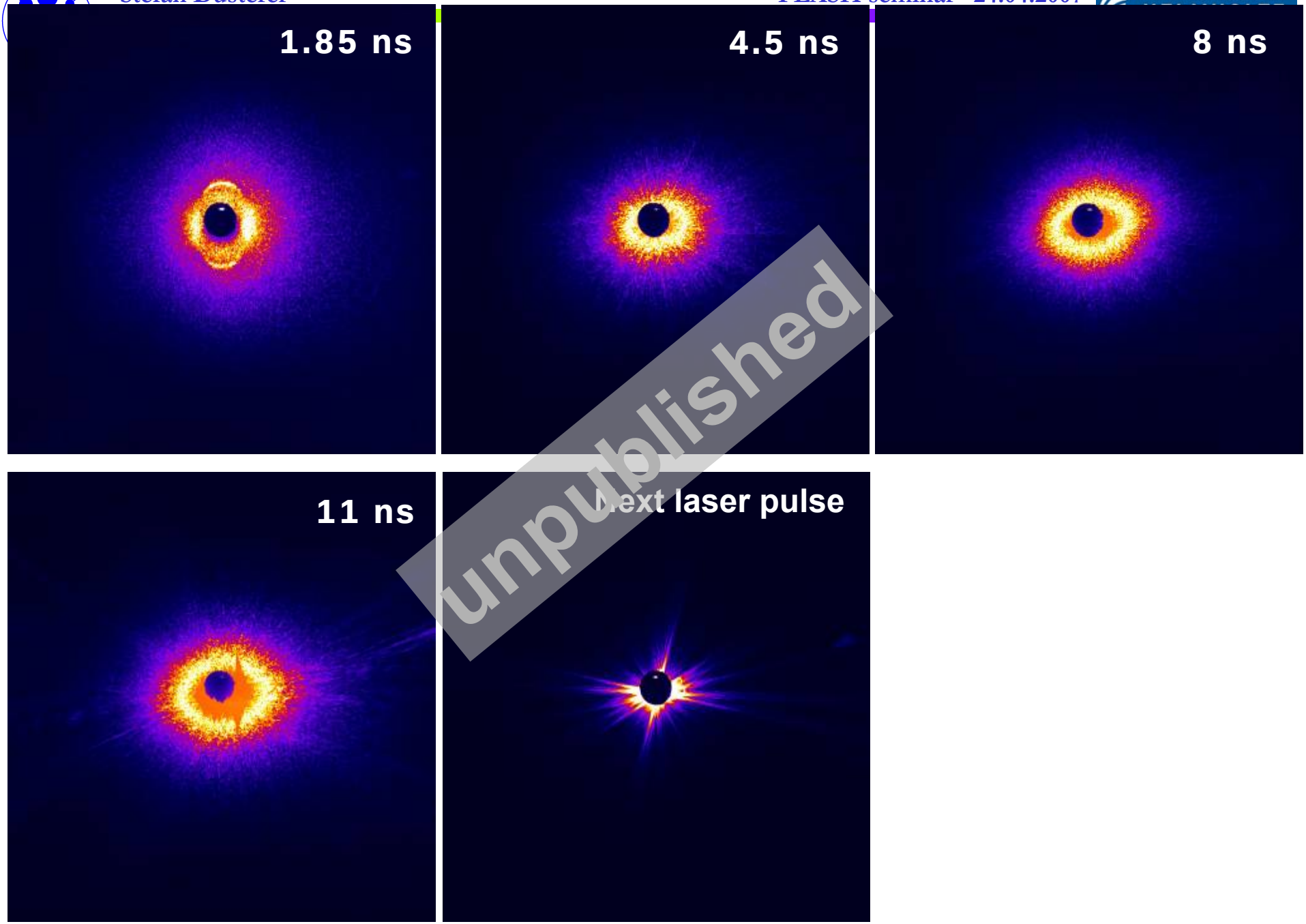




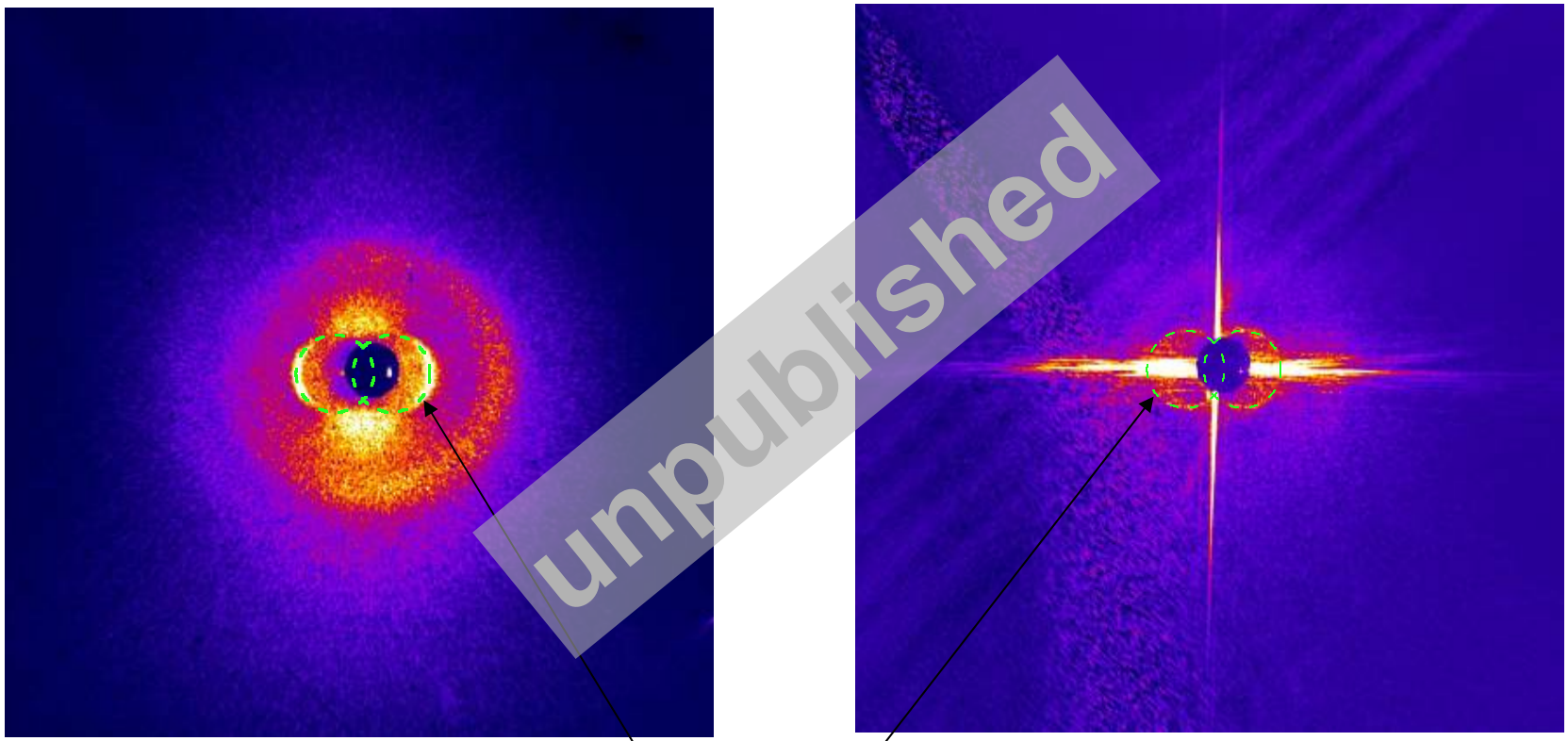
G. H. Gilmer et al., LLNL
Phase separation predicted, but not measured


w/o laser
-10 ps
15 ps
40 ps
140 ps
240 ps
unpublished


340 ps
440 ps
640 ps
840 ps
1.1 ns
1.35 ns
unpublished


1.85 ns
4.5 ns
8 ns
11 ns
next laser pulse
unpublished

Scattering from surface ripples



p-pol. pump

Δt = 840 ps

s-pol. pump

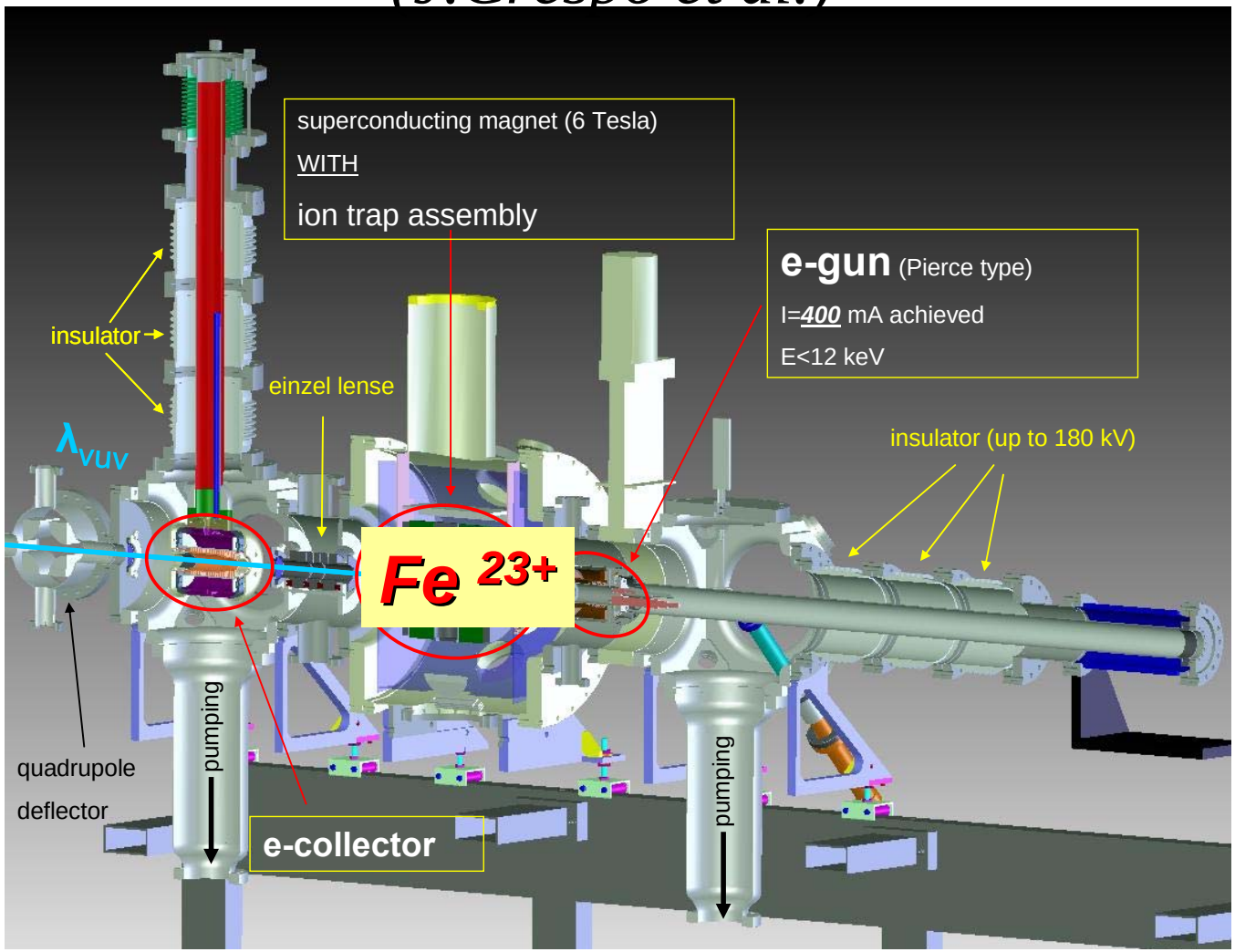
predicion by theory (no adjustable parameter!)
(J. F. Young et al., PRB **27**, 1155 (1983))

Research Areas II

- **Investigation of extremely dilute samples**
  - photodissociation of molecular ions (*Wolf*)
  - highly charged ions (*Crespo*)
  - mass selected clusters (*Meiwes-Broer*)

- **Investigation of surfaces and solids**
  - Surface chemistry - XUV laser desorption *(Zacharias)*
  - surface dynamics (*Föhlisch*)
  - luminescence under FEL radiation (*Kirm*)
  - meV-resolution photon and photoelectron spectroscopy (*Kipp*)

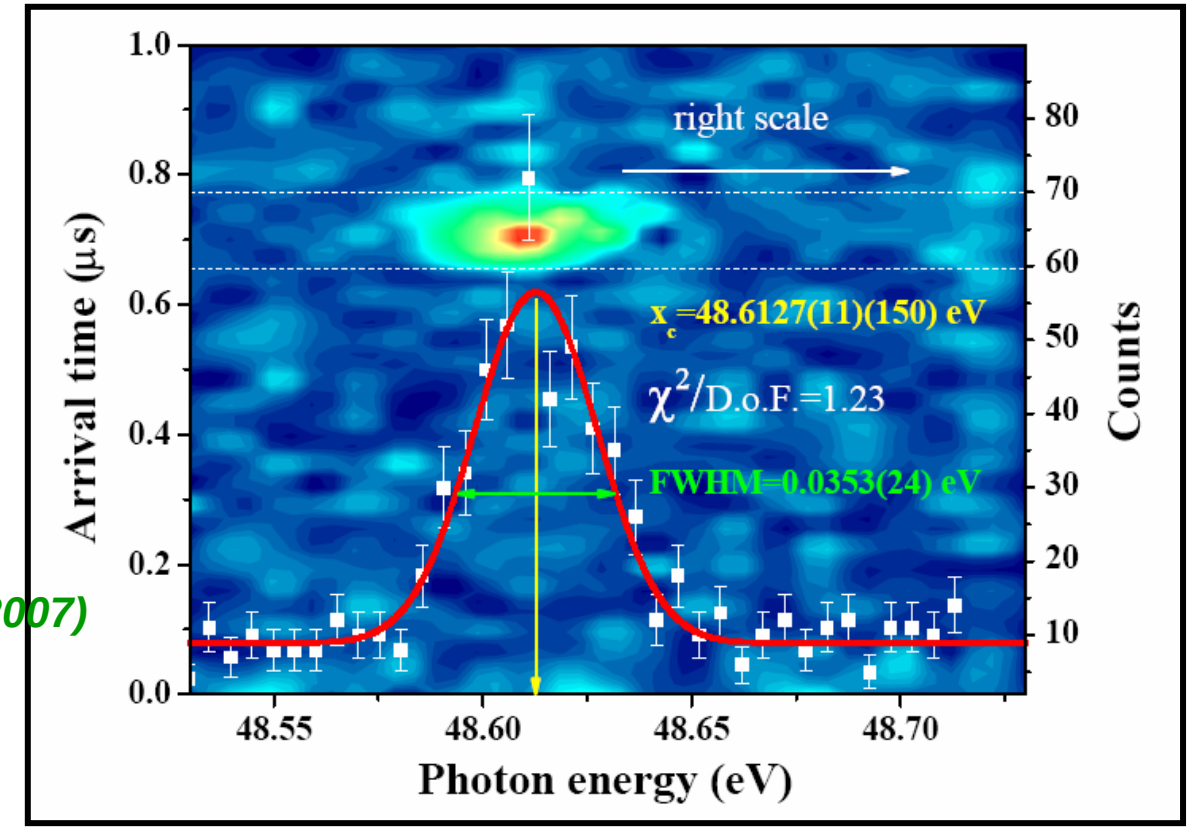
Resonant ionization of highly charged ions (J.Crespo et al.)



Laser spectroscopy on trapped highly charged ions

J. Crespo López-Urrutia, S. Epp J. Ullrich et al.
(MPI für Kernphysik, Heidelberg)

2 $^2S_{1/2}$ to 2 $^2P_{1/2}$ line of Li-like Fe^{23+} at 48 eV



Phys. Rev. Lett., 98, 183001 (May 1, 2007)

2D plot of the fluorescence signal as a function of the photon arrival time relative to the FEL pulse. Inst: Projection of the 2D representation onto the energy axis yielding the number of photons (white squares) per 5 meV photon energy interval as a function of photon energy

Research Areas II

- Investigation of extremely dilute samples
  - photodissociation of molecular ions (*Wolf*)
  - highly charged ions (*Crespo*)
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- **Investigation of surfaces and solids**
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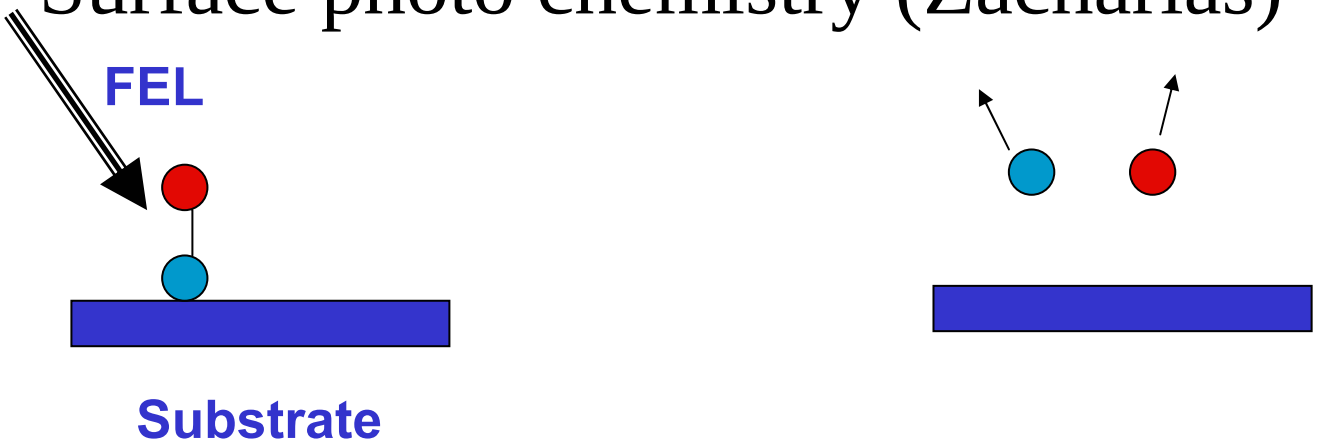
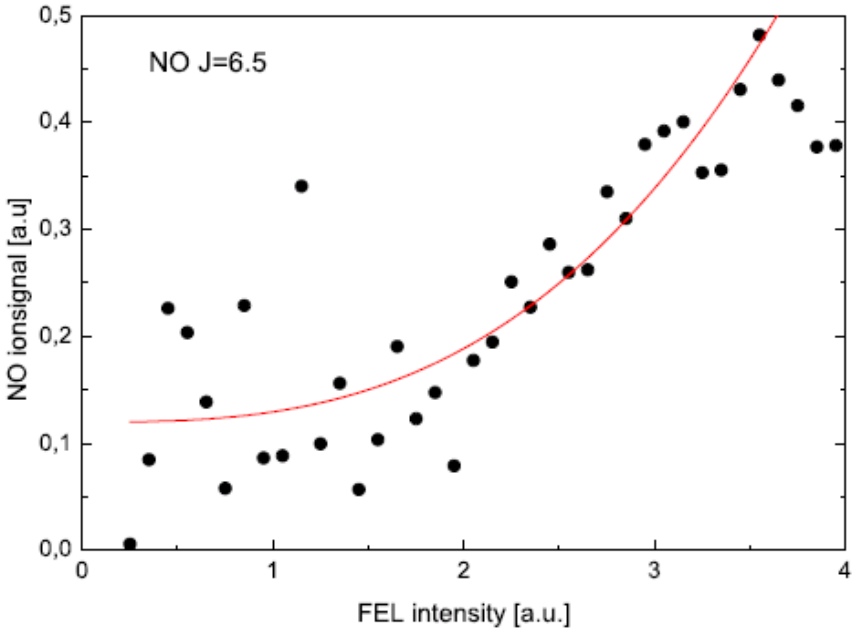
  - luminescence under FEL radiation (*Kirm*)
  - meV-resolution photon and photoelectron spectroscopy (*Kipp*)

Surface photo chemistry (Zacharias)





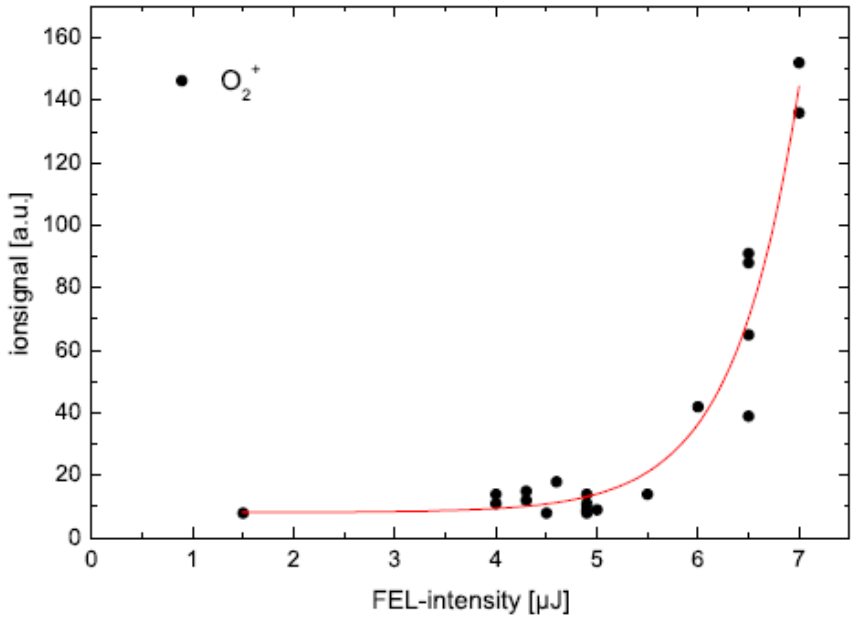


Figure 1: Non-linear desorption yield of neutral NO molecules (J" = 6.5) and O_2^+ desorbing from HOPG induced by laser desorption with the FEL at $h\nu = 38.7$ eV ($\lambda = 32$ nm.)

Articles 2006 / 2007

- **Grazing-incidence spectrometer for the monitoring of the VUV FEL beam at DESY**
  P. Nicolosi, L. Poletto, M.G. Pelizzo, L. Epulandi, P. Zambolin, J. Feldhaus, U. Jastrow, U. Hahn, E. Plönjes, K. Tiedtke
  Journal of Electron Spectroscopy and Related Phenomena 144–147 (2005) 1055–1058
  Nicolosi_JESP.pdf

- **Monochromator beamline for FLASH**
  M. Martins, M. Wellhöfer, J.T. Hoeft, W. Wurth, J. Feldhaus, R. Follart
  Review of Scientific Instruments **77** (11), Art. No.115108 (2006).
  M_Martins_Rev_Sci_Inst_2006.pdf

- **Multi-photon ionization of molecular nitrogen by femtosecond soft x-ray FEL pulses**
  A.A. Sorokin, S.V. Bobashev, K. Tiedtke, M. Richter
  J. Phys., B (London) **39** (2006) L299, L304
  Sorokin_J_Phys_B_2006.pdf

- **Method based on atomic photoionization for spot-size measurement on focused soft x-ray free-electron laser beams**
  A.A. Sorokin, A. Gottwald, A. Hoehl, U. Kroth, H. Schöppe, G. Ulm, M. Richter, S.V. Bobashev, I.V. Domracheva, D.N. Smirnov, K. Tiedtke, S. Düsterer, J. Feldhaus, U. Hahn, U. Jastrow, M. Kuhlmann, T. Nunez, E. Plönjes, R. Treusch
  Applied Physics Letters **89**, 221114 (2006)
  Sorokin_APL_2006.pdf

- **Spectroscopic characterization of vacuum ultraviolet free electron laser pulses**
  S. Düsterer, P. Radcliffe, G. Geloni, U. Jastrow, M. Kuhlmann, E. Plönjes, K. Tiedtke, R. Treusch, J. Feldhaus, P. Nicolosi, L. Poletto, P. Yeates, H. Luna, J.T. Costello, P. Orr, D. Cubaynes, M. Meyer
  Opt. Lett. **31** (2006) 11, 1750
  Duesterer_Opt_Lett_2006.pdf

- **Time-to-space mapping in a gas medium for the temporal characterization of vacuum-ultraviolet pulses**
  S. Cunovic, N. Müller, R. Kalms, M. Krikunova, M. Wieland, M. Drescher, Th. Maltezopoulos, U. Frühling, H. Redlin, E. Plönjes-Palm, J. Feldhaus
  Applied Physics Letters **90,** 121112 (2007)
  Cunovic_APL_2007.pdf

Articles 2006 / 2007

- **Single-shot characterization of independent femtosecond extreme ultraviolet free electron and infrared laser pulses**
  P. Radcliffe, S. Düsterer, A. Azima, H. Redlin, J. Feldhaus, J. Dardis, K. Kavanagh, H. Luna, J. Pedregosa Gutierrez, P. Yeates, E.T. Kennedy, J.T. Costello, A. Delserieys, C.L.S. Lewis, R. Taieb, A. Maquet, D. Cubaynes, M. Meyer
  Applied Physics Letters **90**, 131108 (2007)
  Radcliffe_APL_2007.pdf

- **Ablation of solids using a femtosecond extreme ultraviolet free electron laser**
  N. Stojanovic, D. von der Linde, K. Sokolowski-Tinten, U. Zastrau, F. Perner, E. Förster, R. Sobierajski, R. Nietubyc, M. Jurek, D. Klinger, J. Pelka, J. Krzywinski, L. Juha, J. Cihelka, A. Velyhan, S. Koptyaev, V. Hajkova, J. Chalupsky, J. Kuba, T. Tschentscher, S. Toleikis, S. Düsterer, H. Redlin
  Applied Physics Letters **89** (2006) 241909-1, 241909-3
  APL89_2006.pdf

- **Femtosecond diffractive imaging with a soft-X-ray free-electron laser**
  H.N. Chapman et al.
  Nature Physics 2 (12): 839-843 DEC 2006
  nphys461.pdf

- **Two-color photoionization in xuv free electron and visible laser fields**
  M. Meyer, D. Cubaynes, P. O' Keeffe, H. Luna, P. Yeates, E.T. Kennedy, J.T. Costello, P. Orr, R. Taieb, A. Maquet, S. Duesterer, P. Radcliffe, H. Redlin, A. Azima, E. Plönjes, J. Feldhaus
  Phys. Rev. A **74** (2006) 011401-1, 011401-4
  Meyer_Phys_Rev_2006.pdf

- **Photoelectron spectroscopy as non-invasive method to monitor SASE-FEL spectra**
  M. Wellhöfer, J.T. Hoeft, M. Martins, W. Wurth, M. Braune, J. Viefhaus, M. Richter and K. Tiedtke
  Submitted to NIM A

- **Damage threshold of inorganic solids under free-electron-laser irradiation at 32.5 nm wavelength**
  S.P. Hau-Riege, R.A. London, R.M. Bionta, M.A. McKernan, S.L. Baker, J. Krzywinski, R. Sobierajski, R. Nietubyc, J. B. Pelka, M. Jurek, L. Juha, J. Chalupský, J. Cihelka, V. Hájková, A. Velyhan, J. Krása, J. Kuba, K. Tiedtke, S. Toleikis, Th. Tschentscher, H. Wabnitz, M. Bergh, C. Caleman, K. Sokolowski-Tinten, N. Stojanovic, U. Zastrau
  Accepted for publication in APL

- **X-ray laser interaction with matter and the role of multiphoton ionization: Free-electron laser studies on neon and helium**
  A.A. Sorokin, M. Wellöfer, S.V. Bobashev, K. Tiedtke, M. Richter
  Accepted for publication in Physical Review A as Rapid Communication

Second Round of User Experiments at FLASH

45 proposals submitted in 2006
32 proposals approved in Dec 2006
Beamtime: Oct 2006 - ~Dec 2008

	Proposal no	Proposer, Project Leader	Title
	II-20060122	Jose Ramon Crespo Lopez-Urrutia	Resonant single- and multi-photon excitation and photoionization of highly charged ions by FEL radiation
Collaboration	II-20060250	Robert Moshammer	Few Photon Multiple Ionization of Atoms and Molecules using a Reaction Microcope
	II-20060251	Robert Moshammer	Coulomb-Explosion Imaging of Small Molecules and Pump-Probe Experiments
	II-20060259	Reinhard Dörner	Multiple Fragmentation Processes of Molecules and Clusters Probed by Momentum Imaging Spectroscopy
	II-20060262	Alexander Dorn	A Lithium Magneto Optical Trap in a Reaction Microscope at FLASH: I. Complete Photo-Fragmentation of Lithium Atoms II. Dynamics of a Strongly Coupled Ultra Cold Plasma
	I-20060263	Uwe Hergenhahn	Intermolecular Coulombic decay in doped water clusters
	II-20060278 EC	Marc Vrakking	Velocity map imaging of strong field processes
	I-20060280 EC	Michael Meyer, John Costello	Two-color photoionization of atoms and molecules
	I-20060293	Axel Reinköster, Uwe Becker	Study of multiphoton-ionization processes of free atoms and molecules
	I-20060297	Nora Berrah	High field studies of negative and positive ions at FLASH
	II-20060277	Karl-Heinz Meiwes-Broer	Electron Structure and Dynamics in Clusters
	II-20060286	Thomas Möller	Ultrafast processes and imaging of clusters
Collaboration	II-20060257	Ivan Vartaniants, Christian Gutt	Characterization and Coherent Scattering Applications of the Femtosecond Pulses at the FLASH Facility
	II-20060289	Axel Rosenhahn	Single pulse digital in-line holography with VUV radiation and soft X-rays at FLASH
	II-20060264	Stefan Eisebitt	Time Resolved Imaging and Scattering for the Study of Sub-Picosecond Correlations on Nanometer Lengthscales
	II-20060270	Henry Chapman	Flash Diffraction Imaging of Biological Samples
	II-20060296	Simone Techert	Probing the molecular dynamics of supramolecular assemblies by time-resolved x-ray diffraction in the low q regime
	II-20060253	Klaus Sokolowski-Tinten	Transient response of solids to high intensity femtosecond XUV-excitation
	II-20060267 EC	David Riley	Probing plasma dynamics using time-resolved spectroscopy
	II-20060271	Art Nelson	Creation and characterization of WDM using high intensity XUV radiation
	II-20060279 EC	Arne Höll, Gianluca Gregori	Thomson scattering measurements of plasma dynamics
	II-20060283 EC	Janos Hajdu, N. Timneanu	X-ray induced Coulomb explosions and nuclear fusion
	I-20060254 EC	Andrea Cavalleri	Resonant Soft X-ray Scattering in Complex Oxides with near-2-nm Free Electron Laser Pulses
	II-20060258	Kai Rossnagel	Femtosecond Dynamics of Photoinduced Insulator-to-Metal Transitions in Layered Transition-Metal Compounds Probed by Time- and Momentum-Resolved Photoemission
	I-20060269	Marco Rutkowski, Helmut Zacharias	Investigation of highly excited surface reactions
	II-20060276	Alexander Föhlisch	Non-equilibrium dynamics and low energy excitations in complex systems
	II-20060285	Hermann Dürr	Femtosecond electron and spin dynamics in functional materials
Collaboration	II-20060108	Michael Martins	Multi-photon processes in soft X-ray regime
	II-20060292	Mathias Richter	Quantitative gas-phase experiments for FEL photon diagnostics at high photon energies and smal spot size
	II-20060261	Lutz Kipp	VUV-FEL Nanospectroscopy
	I-20060266	Marco Rutkowski, Helmut Zacharias	Evaluation of FEL pulse duration by non-linear autocorrelation in atoms and molecules
	II-20060268	Michael Rübhausen	Light Scattering at the FEL
	II-20060272	Markus Drescher	Pump-probe experiments exploiting FLASH's intrinsic temporal resolution

Gas phase (atoms, molecules, ions)

Clusters

Imaging, diffraction

Warm dense matter

Solids, surfaces

Technical developments

Summary of user experiments

- 18 projects had beam
- Most experiments are very complex and include many components ➔ collaborations, large teams
- reports about (almost) all experiments can be found in the HASYLAB annual report
- Many publications:
  - ~ 15 publications are out (+ accepted)
  - > 20 in preparation;

... bright future

Thanks for your attention