

Schlussbericht

Förderinstrument:	Postdoktorandenprogramm
Impulsfonds-Förderkennzeichen:	PD-004
Projekttitel:	Temporal Characterization of Femtosecond X-ray Pulses and Beam-driven Wakefield Acceleration Experiments
Postdoktorand/in:	Dr. Christopher Behrens
Helmholtz-Zentrum:	DESY
Berichtszeitraum (Förderzeitraum):	01/2013-12/2015

1. Zusammenfassung

Stellen Sie kurz die wesentlichen Ergebnisse und Fortschritte Ihres Forschungsprojektes im Vergleich zum Zeitpunkt der Antragstellung dar und geben Sie einen Ausblick auf mögliche künftige Arbeiten.

One of the two main projects - **Temporal Characterization of Femtosecond X-ray Pulses**- has been successfully completed. The proposed technique for **Simultaneous temporal diagnosis of electron and x-ray pulses by using a transverse deflecting r.f. structure** has been demonstrated with exceptional results at LCLS. The results have been communicated in several talks at international conferences, and a paper has been accepted for publication in Nature Communications. Further publications with theoretical and experimental results connected to this project have been published. This project has been carried out within the one-year stay at SLAC-Stanford in CA, USA.

Within the topic **THz streaking technique for simultaneous x-ray temporal and arrival time information**, a paper on the demonstration, using THz streaking, of an all-optical synchronization system demonstrating overall performance at the femtosecond level at FLASH has been published in Nature Communications. Another paper for the same journal on experimental results at LCLS is close to submission.

The second main **topic Beam-driven wakefield acceleration experiments** is still ongoing and to date, extensive simulations and design work have been done, which resulted to an official project at DESY on beam-driven wakefield acceleration called FLASHForward. The first considerable installations will occur in 2016. Results from the design and preparation studies were communicated via journal papers. Furthermore, a beam time proposal by a PhD student, who was hired within this Fellowship, for a beam-driven plasma wakefield experiment at FACET at SLAC-Stanford has been ranked very good. We are part of the Helmholtz Virtual Institute on plasma wakefield acceleration at FLASHForward and coordinated one of the four working groups (VI-photons).

In summary, all the proposed projects evolved well and within the planned budget and time schedule.

2. Berufliche Planung

Wie sieht Ihre berufliche Planung nach Ablauf der Förderung aus? Haben sich durch die Förderung Kontakte / Chancen für Ihre nächsten beruflichen Schritte entwickelt?

The postdoc program resulted in valuable experiences and contacts and exceptional career chances. Collaborations with colleagues at SLAC are still on going. Interesting chances have been offered and moreover, new ideas for career paths have been developed which are being followed.

3. Publikationen und Preise

Papers:

- [1] D. Ratner, C. Behrens, Y. Ding, Z. Huang, A. Marinelli, T. Maxwell, and F. Zhou, Time Resolved Imaging of the Microbunching Instability and Energy Spread at the Linac Coherent Light Source, *Phys. Rev. ST Accel. Beams* 18, 030704 (2015). □
- [2] A. Marinelli, D. Ratner, A.A. Lutman, J. Turner, J. Welch, F.-J. Decker, H. Loos, C. Behrens, S. Gilevich, A.A. Miahnahri, S. Vetter, T. Maxwell, Y. Ding, R. Coffee, S. Wakatsuki, and Z. Huang, High-intensity double-pulse X-ray free-electron laser, *Nature Communications* 6 6369 (2015). □
- [3] D. Ratner, R. Abela, J. Amann, C. Behrens, D. Bohler, G. Bouchard, C. Bostedt, M. Boyes, K. Chow, D. Cocco, F.J. Decker, Y. Ding, C. Eckman, P. Emma, D. Fairley, Y. Feng, C. Field, U. Flehsig, G. Gassner, J. Hastings, P. Heimann, Z. Huang, N. Kelez, J. Krzywinski, H. Loos, A. Lutman, A. Marinelli, G. Marcus, T. Maxwell, P. Montanez, S. Moeller, D. Morton, H.D. Nuhn, N. Rodes, W. Schlotter, S. Serkez, T. Stevens, J. Turner, D. Walz, J. Welch, and J. Wu, Experimental Demonstration of a Soft X-Ray Self-Seeded Free-Electron Laser, *Phys. Rev. Lett.* 114, 054801 (2015). □
- [4] S. Schulz, I. Grguraš, C. Behrens, H. Bromberger, J.T. Costello, M.K. Czwalinna, M. Felber, M.C. Hoffmann, M. Ilchen, H.Y. Liu, T. Mazza, M. Meyer, S. Pfeiffer, P. Predki, S. Schefer, C. Schmidt, U. Wegner, H. Schlarb, and A.L. Cavalieri, Femtosecond all-optical synchronization of an X-ray free-electron laser, *Nature Communications* 6 5938 (2015). □
- [5] S. Düsterer, M. Rehders, A. Al-Shemmary, C. Behrens, G. Brenner, O. Brovko, M. Dell'Angela, M. Drescher, B. Faatz, J. Feldhaus, U. Frühling, N. Gerasimova, N. Gerken, C. Gerth, T. Golz, A. Grebentsov, E. Hass, K. Honkavaara, V. Kocharian, M. Kurka, Th. Limberg, R. Mitzner, R. Moshhammer, E. Ploñjes, M. Richter, J. Rösch-Schulenburg, A. Rudenko, H. Schlarb, B. Schmidt, A. Senftleben, E.A. Schneidmiller, B. Siemer, F. Sorgenfrei, A. A. Sorokin, N. Stojanovic, K. Tiedtke, R. Treusch, M. Vogt, M. Wieland, W. Wurth, S. Wesch, M. Yan, M. V. Yurkov, H. Zacharias, and S. Schreiber, Development of experimental techniques for the characterization of ultrashort photon pulses of extreme ultraviolet free-electron lasers, *Phys. Rev. ST Accel. Beams* 17, 120702 (2014). □
- [6] C. Behrens, F.-J. Decker, Y. Ding, V. A. Dolgashev, J. Frisch, Z. Huang, P. Krejcik, H. Loos, A. Lutman, T. J. Maxwell, J. Turner, J. Wang, M.-H. Wang, J. Welch, and J. Wu, Few-femtosecond time-resolved measurements of X-ray free-electron lasers, *Nature Communications* 5 3762 (2014). □
- [7] A. Martinez de la Ossa, C. Behrens, J. Grebenyuk, T. Mehrling, L. Schaper, and J. Osterhoff, High-quality electron beams from field-induced ionization injection in

the strong blow-out regime of beam-driven plasma accelerators, Nucl. Instrum. Methods Phys. Res., Sect. A 740, 231 - 235 (2013). □

[8] T.J. Maxwell, C. Behrens, Y. Ding, A.S. Fisher, J. Frisch, Z. Huang, and H. Loos, Coherent-Radiation Spectroscopy of Few-Femtosecond Electron Bunches Using a Middle-Infrared Prism Spectrometer, Phys. Rev. Lett. 111, 184801 (2013). □

Books:

[9] P. Schmußer, M. Dohlus, J. Rossbach, and C. Behrens, Free-Electron Lasers in the Ultraviolet and X-Ray Regime: Physical Principles, Experimental Results, Technical Realization, 2nd edition, Springer-Verlag, Berlin (2014).

Conference Papers:

[1] T.J. Maxwell, C. Behrens, Y. Ding, Z. Huang, P. Krejcik, A. Marinelli, L. Piccoli and D. Ratner, Femtosecond-scale x-ray FEL diagnostics with the LCLS X-band transverse deflector, Proc. SPIE 9210, Advances in X-ray Free-Electron Lasers: Radiation Schemes, X-ray Optics, and Instrumentation, San Diego, USA (2014). □

[2] Y. Ding, F.-J. Decker, V. A. Dolgashev, J. Frisch, Z. Huang, P. Krejcik, H. Loos, A. Lutman, A. Marinelli, T. J. Maxwell, D. Ratner, J. Turner, J. Wang, M.-H. Wang, J. Welch, J. Wu, and C. Behrens, Results from the LCLS X-band Transverse Deflector With Femtosecond Temporal Resolution, Proceedings of the 27th Linear Accelerator Conference, Geneva, Switzerland, 2014, THIOB03. □

[3] R. Assmann, C. Behrens, R. Brinkmann, U. Dorda, K. Floßmann, B. Foster, J. Grebenyuk, M. Gross, I. Hartl, M. Hüning, F. Kärtner, B. Marchetti, Y. Nie, J. Osterhoff, A. Rühl, H. Schlarb, B. Schmidt, F. Stephan, A.S. Müller, M. Schuh, F. Grüner, B. Hidding, A. R. Maier, and B. Zeitler, SINBAD - a Proposal for a Dedicated Accelerator Research Facility at DESY, Proceedings of the 5th International Particle Accelerator Conference, Dresden, Germany, 2014, □

[4] C. Behrens, Review of Femtosecond x-ray pulse temporal characterization in free-electron lasers, Proc. SPIE 8849, Advances in X-ray Free-Electron Lasers: Radiation Schemes, X-ray Optics, and Instrumentation, San Diego, USA (2013). □

[5] P. Krejcik, F.-J. Decker, Y. Ding, J.C. Frisch, Z. Huang, J.R. Lewandowski, H. Loos, J.L. Turner, J.W. Wang, M.-H. Wang, J.J. Welch, and C. Behrens, Commissioning the New LCLS X-band Transverse Deflecting Cavity with Femtosecond Resolution, Proceedings of the 2nd International Beam Instrumentation Conference, Oxford, UK, 2013, TUAL2. □

[6] M. Yan, C. Behrens, C. Gerth, R. Kammering, F. Obier, V. Rybnikov, A. Langner, and J. Wychowaniak, First Realization and Performance Study of a Single-Shot Longitudinal Bunch Profile Monitor Utilizing a Transverse Deflecting Structure, Proceedings of the 2nd International Beam Instrumentation Conference, Oxford, UK, 2013, TUPC36. □

[7] E. Hass, C. Behrens, C. Gerth, B. Schmidt, M. Yan, and S. Wesch, Longitudinal Bunch Profile Reconstruction Using Broadband Coherent Radiation at FLASH, Proceedings of the 2nd International Beam Instrumentation Conference, Oxford, UK,

2013, MOPC37. □

[8] Y. Ding, J.Frisch, Z. Huang, P. Krejcik, J.R. Lewandowski, H.Loos, J. W. Wang, M-H Wang, J. Welch, and C. Behrens, □Commissioning of the X-band Transverse Deflector for Femtosecond Electron/X-Ray pulse Length Measure- ments at LCLS, Proceedings of the 4th International Particle Accelerator Conference, Shanghai, China, 2013, WEOBB201. □

[9] G. Kube, C. Behrens, S. Weisse, W. Lauth, A.S. Gogolev, Y. Popov, and A. Potylitsyn, Investigation of the Applicability of Parametric X-ray Radiation for Transverse Beam Profile Diagnostics, Proceedings of the 4th International Particle Accelerator Conference, Shanghai, China, 2013, MOPME011. □