

Annual Report

Funding Programme:	Helmholtz Young Investigators Groups
Project ID No.:	VH-NG-804
Project Title:	Towards Laboratory-Based Ultrafast Bright EUV and X-ray Sources: High-Power Fiber Laser Frequency combs and Cavity Enhanced Ultrafast Optics
Group Leader:	Guoqing Chang
Helmholtz Centre:	DESY
Participating University:	University of Hamburg
Report Period (=Calendar Year):	01/2013-12/2013

1) Group Structure

Please report briefly on the structure and personnel development of your group.

Current group includes the group leader and 2 PhD students. Four international students have visited the group and carried out short-term projects:

Jiawei Mei—Master student from Tsinghua University (China), 2 months, working on saturable absorber mode-locked fiber oscillators.

Hsiang-Yu Chung—Master student from National Taiwan University, 2 months, working on all normal dispersion fiber lasers.

Rudrakant Sollapur—Master student from Imperial college (UK), 4 months, working on Bi-doped fiber amplifiers. This work became part of his Master thesis.

Tao Chen—PhD student from Zhejiang University (China), 4 months, working on high-power fiber lasers.

2) Network

Please describe how you / your research group are integrated within the Helmholtz Centre and the partner university (e.g. as member of committees).

My group closely collaborates with Professor Franz Kaertner's group at DESY and HI-Jena on enhancement-cavity based terahertz and X-ray sources.

In a collaboration with Professor Henry Chapman at DESY and Professor Christian Betzel from University of Hamburg, I was able to launch a new project within the Hamburg Center for Ultrafast Imaging to develop a new type of nanocrystal analyzer, which is funded by about 100kEuro in equipment and one PhD student.

My group started to collaborate with Professor Dwayne Miller at DESY working on a new-type electron pulse source for bio-imaging.

Together with Professor Franz Kaertner, Professor Christian Betzel, and our collaborators from Chinese Academy of Science, we have established a Helmholtz-CAS joint research group.

3) Satisfaction

How satisfied are you with the general working conditions provided by the Helmholtz Centre /

partner university? Is there anything that meets your criticism?

The working conditions are excellent. As shown by my recent collaborations, I was able to establish quickly several new research projects with substantial funding and collaborations at DESY, UHH, HI-Jena and with CAS through the Helmholtz-CAS joint research program. With the strong support from DESY, I have co-organized and co-chaired the 1st Germany-China young scientist symposium on ultrafast light sources and spectroscopy applications.

4) Scientific Progress / Milestones

How has your work plan progressed? Which important milestones could be achieved during the report period? Is the progress of your work in accordance with original planning or has the work plan been changed?

In the summer of 2013, we finally finished setting up the lab starting from an empty room in the brandnew building of the Center for Free-Electron Laser Science (CFEL). As for the research projects, we have achieved following milestones:

1. We designed and constructed in cooperations with Jens Limpert (HI-Jena) a 200-W (expected average power) Yb-fiber laser system which will be the driving force for later compact X-ray or terahertz sources. The laser system consists of a home-built low-noise Yb-fiber oscillator, a two-stage pre-amplifier, a monolithic fiber stretcher, a high-power Yb-fiber amplifier, and a high-efficiency diffraction-grating based compressor. This laser system has been running at 20-W power level. We are waiting for high power mirrors before fully operating the system at the full power—200 W.
2. We systematically studied Raman soliton generation from photonic crystal fibers, and found that at a certain condition, the resulting Raman soliton exhibits extremely low noise—even one order of magnitude less than the initial excitation pulses. This finding is of particular importance for our project of implementing a high-power Mid-IR ultrafast laser source using difference frequency generation in the Helmholtz-CAS program.
3. We have come up with a new method for micro-/nano-crystal imaging, which relies on femtosecond lasers with low relative intensity noise. To experimentally demonstrate the idea, we have purchased a microscope. Construction of the low-noise laser system is in progress.

In addition to the work at DESY, I have visited Massachusetts Institute of Technology (MIT), USA on a regular basis as a visiting scientist and supervised the development of high repetition rate Yb-fiber laser frequency combs. The technology is crucial for the ongoing projects we are pursuing at DESY. The work at MIT has led to 6 journal papers and 14 conference papers which I coauthor since I established my Helmholtz Young Investigator group at DESY starting from August, 2012.

Besides construction of the high power fiber laser system for the table-top X-ray source, which I originally proposed as the Helmholtz Young Investigator project, I do see more exciting opportunities emerging in the nanocrystal project, which will have a big impact on life sciences. I have a number of original ideas and would like to spend more effort in this field. It will help me acquire a more distinct profile separating my work from the work of Prof. Franz Kaertner—my DESY host, and therefore will serve better my career perspectives.

5) Financial Plan / Time Schedule

Can you comply with the financial plan and time schedule or do you see a need for adjustment?

At this stage, everything works out in terms of the financial plan and time schedule.

6) Status

Do you hold a joint Junior Professorship or a W2/W3 Professorship? Do you aim for such a position? What is the status of your negotiations in this respect?

No, I do not hold a joint Junior Professorship or a W2/W3 Professorship.
Yes, I aim for such a position. The negotiations have not yet started.

7) Teaching Activities of the Group Leader

Co-teaching *Special Topics in Nonlinear Optics and Ultrafast Laser Physics* at the Center for Free Electron Laser science, DESY

8) Publications of the Group

My group at DESY have submitted one conference paper to Conference on Laser Electro-Optics—the major conference in our field. The paper has been accepted for oral presentation:

W. Liu, G. J. Zhou, J. K. Lim, H. -W. Chen, F. X. Kaertner, and **G. Q. Chang**, “Relative intensity noise of Raman solitons: which one is more noisy,” paper SM4N.7, CLEO/QELS, San Jose (2014)

Additionally, I have co-authored 6 journal papers and 14 conference papers from previously established research projects and collaboration.

6 Journal papers published since the starting of my DESY group in August, 2012

J. K. Lim, H. -W. Chen, S. H. Xu, Z. M. Yang, **G. Q. Chang**, and F. X. Kaertner, “3 GHz, Watt-level femtosecond Raman soliton source,” *Opt. Lett.* 39, 2060 (2014)

S. -H Chia, L. -J Chen, Q. Zhang, O. D. Muecke, **G. Q. Chang**, and F. X. Kaertner, “Broadband continuum generation in mode-locked lasers with phase-matched output couplers,” *Opt. Lett.* 39, 1445 (2014)

H. -W. Chen, H. Zia, J. K. Lim, S. H. Xu, Z. M. Yang, F. X. Kaertner, and **G. Q. Chang**, “3 GHz, Yb-fiber laser based, few-cycle ultrafast source at the Ti:sapphire laser wavelength,” *Opt. Lett.* 38, 4927 (2013)

J. K. Lim, H. -W. Chen, **G. Q. Chang**, and F. X. Kaertner, “Frequency comb based on a narrowband Yb-fiber oscillator: pre-chirp management for self-referenced f_{CEO} stabilization,” *Opt. Express* 21, 4531 (2013)

H. -W. Chen, J. K. Lim, S. -W. Huang, D. N. Schimpf, F. X. Kaertner, and **G. Q. Chang**, “Optimization of femtosecond Yb-doped fiber amplifiers for high-quality pulse compression,” *Opt. Express* 20, 28672 (2012)

G. Q. Chang, C. -H. Li, D. F. Phillips, A. Szentgyorgyi, R. L. Walsworth, and F. X. Kaertner, “Optimization of filtering schemes for broadband astro-combs,” *Opt. Express* 20, 24987 (2012)

14 conference papers published since the starting of my DESY group in August, 2012

G. Q. Chang, H. -W. Chen, J. K. Lim, S. H. Xu, Z. M. Yang, and F. X. Kaertner, "3 GHz, ultrafast Yb-fiber laser sources: filling the spectral gap," SPIE Optics&Photonics 2014 (2014) (invited paper)

G. Q. Chang, C.-H Li, A. G. Glenday, G. Furesz, N. Langellier, L. -J. Chen, J. K. Lim, H. -W. Chen, D. F. Phillips, D. Sasselov, A. Szentgyorgy, R. Walsworth, and F. X. Kaertner, "femtosecond laser frequency combs for astrophysical spectrograph calibration," paper ATh1A.4, ASSL, Paris (2013)

F. X. Kaertner and **G. Q. Chang**, "Low noise, GHz repetition-rate femtosecond lasers and frequency combs," paper FTu2A.1, Frontiers in Optics, Orlando (2013) (invited paper)

H. -W. Chen, J. K. Lim, Shanhui Xu, Zhongmin Yang, **G. Q. Chang**, and F. X. Kaertner, "3 GHz few-cycle ultrafast source at 850 nm," postdeadline paper FW6B.2, Frontiers in Optics, Orlando (2013)

H. -W. Chen, H. Zia, J. K. Lim, **G. Q. Chang**, and F. X. Kaertner, "Yb-fiber oscillator based, few-cycle ultrafast source at 850 nm," paper WA1-1, CLEO PR, Kyoto (2013) (best paper award)

C.-H Li, A. G. Glenday, N. Langellier, A. Zibrov, **G. Q. Chang**, L. -J. Chen, G. Furesz, F. X. Kaertner, D. F. Phillips, D. Sasselov, A. Szentgyorgy, R. Walsworth, "A broadband green astro-comb for sub-10 cm/s calibration on astrophysical spectrographs," paper CTu11.2, CLEO/QELS, San Jose (2013)

J. K. Lim, H. -W. Chen, **G. Q. Chang**, and F. X. Kaertner, "Stable frequency comb derived from a narrowband Yb-fiber laser: pre-chirp management for self-referenced fceo stabilization," paper CM2I.7, CLEO/QELS, San Jose (2013)

G. Q. Chang, H. -W. Chen, J. K. Lim, S. H. Xu, Z. M. Yang, and F. X. Kaertner, "3 GHz, femtosecond Raman soliton source," paper CM2I.4, CLEO/QELS, San Jose (2013)

N. Langellier, A. G. Glenday, C.-H Li, G. Furesz, **G. Q. Chang**, H. -W. Chen, J. K. Lim, F. X. Kaertner, D. F. Phillips, A. Szentgyorgy, R. Walsworth, "Green astro-comb for exoplanet searches," paper D1.00017, Joint Meeting of the APS Division of Atomic, Molecular & Optical Physics (DAMOP), Quebec City, Canada (2013)

D. F. Phillips, C.-H Li, A. G. Glenday, N. Langellier, G. Furesz, **G. Q. Chang**, H. -W. Chen, J. K. Lim, F. X. Kaertner, A. Szentgyorgy, R. Walsworth, "Green astro-comb for exoplanet searches at HARPS-N," paper B6.00007, Joint Meeting of the APS Division of Atomic, Molecular & Optical Physics (DAMOP), Quebec City, Canada (2013)

G. Q. Chang, H. -W.Chen, S. H. Xu, Z. M. Yang, and F. X. Kaertner, "2.46-GHz, fundamentally mode-locked, femtosecond Yb-fiber oscillator," paper WeC.3, 5th EPS-QEOD Europhoton conference, Stockholm, Sweden (2012)

J. K. Lim, H. -W.Chen, A. -L. Calendron, **G. Q. Chang**, and F. X. Kaertner, "Optimization of ultrafast Yb-doped fiber amplifiers to achieve high-quality compressed-pulses," paper TUE.PII. 2, Ultrafast Phenomena, Lausanne, Switzerland (2012)

E. Granados, K. -H. Hong, X. Fu, L. E. Zapata, H. -W.Chen, **G. Q. Chang**, and F. X. Kaertner, "Dual wavelength, cryogenically-cooled Yb:YLF chirped-pulse regenerative amplifier," paper THU.PIII. 4, Ultrafast Phenomena, Lausanne, Switzerland (2012)

H. -W.Chen, **G. Q. Chang**, C. Zhu, X. Q. Ma, A. Galvanauskas, and F. X. Kaertner, "Air-clad chirally-coupled-core Yb-fiber femtosecond oscillator with >10 W average power," paper THU.PIII. 1, Ultrafast Phenomena, Lausanne, Switzerland (2012)

9) External Funding

We submitted a joint proposal with our collaborators from Chinese Academy of Science and were awarded 360,000 Euros for three years to develop advanced ultrafast lasers for quantum materials spectroscopy (HCJRG-201). The project starts from January 1 of 2014.

Within the Hamburg Center for Ultrafast Imaging, I have launched a new project to develop a new type of nanocrystal analyzer, which is funded by about 100k Euro in equipment and one PhD student.

Supported by the China-Germany research center, I have co-organized and co-chaired the 1st Germany-China young scientist symposium on ultrafast light sources and spectroscopy applications. 36 scientists from Germany, China, and USA attended the symposium at CFEL, DESY. The China-Germany research center provided ~25k Euros for the full funding coverage.

10) Patent Applications

No. of pending/granted patents

None.

11) Awards received by Group Members / Professorship Appointments offered to Group Leader

The following conference paper—which I co-authored—was awarded the best paper award from the Conference on Laser Electro-Optics at Pacific Rim:

H. -W. Chen, H. Zia, J. K. Lim, **G. Q. Chang**, and F. X. Kaertner, "Yb-fiber oscillator based, few-cycle ultrafast source at 850 nm," paper WA1-1, CLEO PR, Kyoto (2013)