Status of Accelerator R&D @ PITZ: progress and plans

Frank Stephan for the PITZ team

Content:

• Refereed papers
• Last MAC talk from PITZ (reduced version):
  • The PITZ collaboration
  • Beam driven plasma acceleration activities:
    - Self modulation experiments (reminder)
    - Transformer ratio experiments (reminder)
    - Laboratory Astrophysics preparations (reminder & progress)
  • R&D program agreed with and co-funded by XFEL (reminder + details)
  • Operating experience with Gun 4.6 (update & new)
  • Gun quad corrector studies (update & new)
  • Bunch shaping with dielectric lined waveguides (new)
  • Technical design of Gun 5 (update & new)
→ MAC report (key points)
• Progress on generating 3D ellipsoidal beams
• Opening the gun cathode region in May 2017
• Short report from THz workshop at XFEL
• Summary & Outlook
G. Loisch co-author of a paper from Frankfurt University ...

> … about a new method to determine the hydrogen density in a lowly ionized hydrogen plasma

Determination of hydrogen density by swift heavy ions

Ge Xu,1,2,3,4 M. Barriga-Carrasco,4 A. Blazevic,5 B. Borovkov,6 D. Casas,4 K. Cistakov,1 R. Gavrilin,6 M. Iberler,1 J. Jacoby,1 G. Loisch,1 R. Morales,4 R. Mäder,1 S. Qin,7 T. Rienecker,1 O. Rosmej,5 S. Savin,6 A. Schömle,1 K. Weyrich,5 J. Wiechula,1 J. Wieser,8 G. Xiao,2 and Y. Zhao9

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6Institute for Theoretical and Experimental Physics, 117218 Moscow, Russia
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9School of Science, Xi’an Jiaotong University, Xi’an 710049, People’s Republic of China

(Dated: May 16, 2017)

A novel method to determine the total hydrogen density and accordingly a precise plasma temperature in a lowly ionized hydrogen plasma is described. The key of the method is to analyze the energy loss of swift heavy ions interacting with the respective bound and free electrons of the plasma. A slowly developing and lowly ionized hydrogen theta-pinch plasma is prepared. A Boltzmann plot of the hydrogen Balmer series and the Stark broadening of the H3-line preliminarily defines the plasma with a free electron density of 1.9E16 cm\(^{-3}\) and a free electron temperature of 0.8 – 1.3 eV. The temperature uncertainty results in a wide hydrogen density, ranging from 2.5E16 to 7.2E18 cm\(^{-3}\). A pulsed beam of \(^{48}\)Ca\(^{10+}\) with a velocity of 3.652 MeV/u is used as a probe to measure the total energy loss of the beam ions. Subtracting the calculated energy loss due to free electrons, the energy loss due to bound electrons is obtained, which linearly depends on the bound electron density. The total hydrogen density is thus determined as 1.9E17 cm\(^{-3}\) with a 35\% error margin, and the free electron temperature can be precisely derived as 1.01 ± 0.03 eV. This method should prove useful in many studies, e.g., inertial confinement fusion or warm dense matter.
PITZ paper about emission studies

1. Charge production studies from Cs$_2$Te photocathodes in a normal conducting RF gun


Deutsches Elektronen Synchrotron DESY, Platanenallee 6, 15738 Zeuthen, Germany

8. Abstract
This work discusses the behavior of electron bunch charge produced in an L-band normal conducting radio frequency gun from Cs$_2$Te photocathodes illuminated with ps-long UV laser pulses and presumed homogeneous flattop laser transverse distribution. The measured charge shows the expected linear dependence in the quantum efficiency limited emission regime at low laser pulse energies. At higher laser pulse energy, the measured charge in the space charge limited emission regime should saturate, assuming an ideal homogeneous flattop laser transverse distribution. However, this behavior is not observed experimentally. Instead of saturating, the measured charge continues to increase with laser pulse energy, albeit with much weaker dependence than in the quantum efficiency limited emission regime. Simulations with the space charge particle tracking code ASTRA show that the charge saturates as expected using a homogeneous flattop laser transverse distribution. The discrepancy between simulations and measured excess charge may be attributed to the presence of unintentional Gaussian-like decaying radial halo beyond the core of the otherwise presumed homogeneous flattop core. The rate of increase of the measured charge at high laser pulse energies seems to be proportional to the amount of halo despite charge saturation in the core of the transverse laser radial profile. By utilizing core + halo particle distributions based on measured radial laser profiles, ASTRA simulations and semi-analytical emission models reproduce the behavior of the measured charge for a wide range of RF gun and laser operational parameters within the measurement uncertainties.

29. Keywords: RF electron guns, space charge, laser radial halo.
Design of an L-band normally conducting RF gun cavity for high peak and average RF power

V. Paramonov\textsuperscript{a,\textordmasculine}, S. Philipp\textsuperscript{b}, I. Rybakov\textsuperscript{a}, A. Skassyrska\textsuperscript{a}, F. Stephan\textsuperscript{b}

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\textbf{A R T I C L E I N F O}

\textbf{A B S T R A C T}

To provide high quality electron bunches for linear accelerators used in free electron lasers and particle colliders, RF gun cavities operate with extreme electric fields, resulting in a high pulsed RF power. The main L-band superconducting linacs of such facilities also require a long RF pulse length, resulting in a high average dissipated RF power in the gun cavity. The newly developed cavity based on the proven advantages of the existing DESY RF gun cavities, underwent significant changes. The shape of the cells is optimized to reduce the maximal surface electric field and RF loss power. Furthermore, the cavity is equipped with an RF probe to measure the field amplitude and phase. The elaborated cooling circuit design results in a lower temperature rise on the cavity RF surface and permits higher dissipated RF power. The paper presents the main solutions and results of the cavity design.
M. Gross co-author of a DESY paper …

> … about small energy spread in plasma accelerators with modulated plasma density published in PRL

Chirp Mitigation of Plasma-Accelerated Beams by a Modulated Plasma Density

R. Brinkmann,1 N. Delbos,2 I. Dornmair,2 M. Kirchen,2 R. Assmann,1 C. Behrens,1 K. Floettmann,1 J. Grebenyuk,1 M. Gross,3 S. Jalas,2 T. Mehrling,1 A. Martínez de la Ossa,4 J. Osterhoff,1 B. Schmidt,1 V. Wacker,1 and A. R. Maier2,*

1Deutsches Elektronen-Synchrotron DESY, Notkestrasse 85, 22607 Hamburg, Germany
2Center for Free-Electron Laser Science and Department of Physics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany
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4Institut für Experimentalphysik, Universität Hamburg, 22761 Hamburg, Germany

(Received 8 December 2015; published 23 May 2017)

Plasma-based accelerators offer the possibility to drive future compact light sources and high-energy physics applications. Achieving good beam quality, especially a small beam energy spread, is still one of the major challenges. Here, we propose to use a periodically modulated plasma density to shape the longitudinal fields acting on an electron bunch in the linear wakefield regime. With simulations, we demonstrate an on-average flat accelerating field that maintains a small beam energy spread.

DOI: 10.1103/PhysRevLett.118.214801
Paper on SMI under review at Nature Communications

Time-resolved measurements of the self-modulation of an electron bunch in a plasma


Richter, T. Mehrling, M. Khojoyan, C. B. Schroeder, F. Grüner

Plasma acceleration has the potential to dramatically miniaturize accelerators for modern applications such as X-ray free electron lasers or high-energy physics. Using a proton bunch as driver would be attractive for the high-energy physics domain as it requires only a single acceleration stage for reaching 

\textit{novel-scale} electron energies. Available proton bunches are orders of magnitude too long, which can be corrected by utilizing the self-modulation instability. Here we demonstrate time-resolved measurements of self-modulation for the first time with electrons as a test bed for future proton drivers, modulating a 22.3 MeV electron bunch into three bunchlets with a $\sim 200$ keV/c amplitude momentum modulation. We use a combination of a radiofrequency deflector and a dipole spectrometer for simultaneous observation of the time- and energy structure of self-modulated electron bunches. Demonstrating this effect for the first time is a breakthrough for proton-driven plasma accelerator schemes aiming to utilize the same physical effect.

\begin{itemize}
\item In last 6 months: 2 papers published, 3 drafts under review (1 with high impact factor)
\item OK
\item let's continue common efforts on refereed publications!
\end{itemize}
Accelerator R&D progress and plans at PITZ

Matthias Gross and Frank Stephan for the PITZ team

Content:

- The PITZ collaboration
- Beam driven plasma acceleration activities:
  - Self modulation experiments (see last PITZ meeting)
  - Transformer ratio experiments (see last PITZ meeting)
  - Laboratory Astrophysics preparations (reminder & progress)
- R&D program agreed with and co-funded by XFEL (reminder + details)
- Operating experience with Gun 4.6 (update & new) → Y. Renier
- Gun quad corrector studies (update & new) → Y. Chen
- Bunch shaping with dielectric lined waveguides (new) → F. Lemery
- Technical design of Gun 5 (update & new) → ongoing
- Summary & Outlook

talk by Matthias Gross

talk by Frank Stephan
Founding partners of PITZ:
- DESY, HH & Z (leading institute)
- HZB (BESSY) (A. Jankowiak): magnets, vacuum
- MBI (S. Eisebitt): cathode laser
- TU Darmstadt (TEMF, T. Weiland, H. DeGersem): simulations

Other national partners:
- Hamburg university:
  - most PhD students;
  - HGF-Vernetzungsfond;
  - generation of short pulses
  - plasma experiments
- HZDR:
  - BMBF-PC-laser-project between MBI, DESY and HZDR, unitl ~2009;
  - collaboration between HZB, HZDR, MBI and DESY in SC-gun-cluster

International partners:
- IAP Nizhny Novgorod + JINR Dubna:
  3D elliptical laser pulses, THz radiation
- INFN Frascati + Uni Roma II (L. Palumbo, M. Ferrario): TDS and E-meter pre-studies
- INFN Milano (C. Pagani): photocathodes
- INR Troitsk (L. Kravchuk): CDS, TDS, Gun5
- INRNE Sofia (D. Tonev, G. Asova): EMSY + personnel
- LAL Orsay (A. Stocchi): HEDA1 + HEDA2
- STFC Daresbury (S. Smith, B. Militsyn): phase space tomography
- Thailand Center of Excellence in Physics (T. Vilaithong, Ch. Thongbai): personnel
- YERPHI Yerevan (V. Nikoghosyan): personnel
Beam driven plasma acceleration activities:

- Self modulation experiments

(see last PITZ meeting)
Beam driven plasma acceleration activities:

- High transformer ratio (HTR) experiments

(see last PITZ meeting)
Beam driven plasma acceleration activities:

- Laboratory Astrophysics preparations

(reminder & progress)
Laboratory Astrophysics

> Idea: find parameter scaling so that astrophysical phenomena can be investigated in the laboratory

> Currently: DESY Strategy Fund project to demonstrate Bell’s instability
  - Collaboration between 3 different divisions: THAT (Martin Pohl), PITZ (Frank Stephan) and FLA (Jens Osterhoff)
  - Simulation study / exploring experimental possibilities; best case: first experiments in 2018

> Bell’s instability: Amplification of magnetic fields in a plasma, induced by cosmic rays

> This could be part of the mechanism of cosmic particle accelerators
Current Work

> 1) PIC simulations for laboratory conditions

   - Preliminary results: Need
     - Low plasma density ($10^{13}$ or less)
     - Low beam energy (<10 MeV)
     - Long electron bunches (best DC) with at least mA current

   ➔ extensive simulations have started and will be continued

> 2) Study if these conditions can be provided by PITZ

   - Bunch length increased by 1.5 -> "base beam current" increased
   - $\bar{I} \approx 2$ mA
   - $R \approx 2$ mm
   - $E_{\text{kin}} \approx 1.6$ MeV

   ➔ Further studies needed

> So far: challenging, but no show stoppers found yet
Summary of beam driven plasma acceleration activities

> Self modulation experiments
  - Results of 1\textsuperscript{st} experimental run with novel, cross-shaped lithium plasma cell: first direct demonstration of self-modulation (paper under review at Nature Communic.)
  - Time resolved measurements $\rightarrow$ transverse oscillations
  - Longitudinal phase space $\rightarrow$ energy modulations

> High transformer ratio (HTR) experiments
  - TRs of 3 to 4 were observed the first time for shaped bunches in plasma using double triangular drive bunch

> Laboratory Astrophysics preparations
  - Preparations to investigate Bell’s instability have started (funding by DSF)
  - So far: challenging, but no show stoppers found yet
R&D program agreed with and co-funded by XFEL

(reminder + more details)
R&D program agreed with and co-funded by XFEL

> **Background** (reminder): To allow funding of future Astroparticle physics activities at DESY in Zeuthen, **PITZ works related to European XFEL should be funded by XFEL**

> **Current status:** The future contribution of XFEL to PITZ was agreed with XFEL machine coordination, XFEL council decision coming soon:

- Funding is expected already from ~mid 2017 on and current planning horizon is until 2021, yearly update (no major changes)

- A) From XFEL operations budget:
  - **Support of XFEL operation:** 4 weeks of PITZ operation for dedicated measurements + 1 physicist for working on improving pulsed guns (this part is pretty settled!)
    - e.g. gun quad corrector studies (see below), different operation modes (charges, bunch length), time resolved and emittance measurements, emission studies, test of unified procedures, diagnostics, stabilization, llrf and laser components, …
  - **Option** (on request from XFEL, ~1 year in advance): gun construction and conditioning (16 weeks)
R&D program agreed with and co-funded by XFEL

- **B) From XFEL R&D budget:**

  - **Advanced photo cathode laser shapes:** 2 weeks of PITZ operation for **generic R&D on ellipsoidal electron bunches** (see outlook)
    - Potential for improved beam quality (e.g. at reduced cathode gradient) and operation beyond current specs, ... → e.g. measurements (emitt., LPS, μ-bunching) for different laser shapes

  - **Developments towards CW guns:** 4 weeks of PITZ operation for basic CW gun research (e.g. beam dynamics at CW gun gradients, green cathodes) PLUS 1 physicist investigating a 216 MHz NC CW gun and supporting SRF gun activity
    - Experimental beam dynamics studies at CW gun gradients → e.g. emission properties, thermal emittance, optimum beam quality using different laser shapes, ...
    - Studies towards green cathodes → dark current, emission properties, thermal emittance, optimum beam quality using different laser shapes and gun gradients, ...
    - Physical design of a 216 MHz NC CW RF gun and buncher system → RF and beam dynamics simulations, beamline optimization, ...
R&D program agreed with and co-funded by XFEL

Carry home messages:

- PITZ will continue to run with **at least the same level of activity as now beyond 2021** (if gun conditioning is requested then even more).

- **Significant contribution will come from XFEL**
  - **Higher reliability** of the operation and construction periods has to be obtained
  - **Common effort** of the **scientific and technical groups** involved in PITZ!

- **Long term future of accelerator physics activity in Zeuthen is settled.**
  - preparation for POF IV goes towards 2026,
  - proposal for THz generation for pump-probe experiments at XFEL based on PITZ photo injector is under discussion at XFEL
Operating experience with Gun 4.6

(update & new)

→ Y. Renier
Summary of Gun 4.6 operation

> No problems with „watchband reloaded“ cathode spring design  
≥ seems to work !

> No problem anymore with DESY-type RF windows when operating with 2 vacuum windows at optimized position at 6.5 MW, 650µs, 10 Hz (>16 weeks of full operation mainly at these parameters)  
≥ two RF vacuum window solution seems to work !

> After 13 months successfull operation of Gun4.6 at PITZ problems to correctly insert cathode have shown up on 24.4.2017  
≥ problem (actuator / cathode region) unser study now  → to be solved

> Next setup: Gun 4.5 (contact stripe cathode spring design) will be equipped with 2 Thales windows at optimized position for conditioning and operation at PITZ
Gun quad corrector studies

(update & new)

→ Y. Chen
**Gun quads influence on emittance (measurements 2017)**

**Machine parameters:**
- BSA = 1.2 mm
- Booster power = 3 MW
- Charge = 500 pC
- Gaussian Laser temporal profile: ~11.5 ps
- Gun power = 6.5 MW
- Bunch length (TDS) = 15.8 ps
- The gun quad currents were selected to deliver the most round beam spot at High1Scr1 and High1Scr4 simultaneously

**No Gun Quads applied:** Gun Q1 = 0A / Gun.Q2 = 0A

**With Gun Quads:** Gun Q1 = -0.6A / Gun.Q2 = -0.5A

<table>
<thead>
<tr>
<th></th>
<th>No Gun Quads</th>
<th>With Gun Quads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emittance, mm·mrad</td>
<td>x: 1.11 y: 0.78</td>
<td>x: 0.82 y: 0.84</td>
</tr>
<tr>
<td></td>
<td>xy: 0.93</td>
<td>xy: 0.83</td>
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<tr>
<td>Beam RMS size, mm</td>
<td>0.46 0.32</td>
<td>0.28 0.32</td>
</tr>
<tr>
<td></td>
<td>X: -0.99 Y: 0.39</td>
<td>X: 0.06 Y: -0.01</td>
</tr>
<tr>
<td></td>
<td>X: 4.85 Y: 4.37</td>
<td>X: 3.18 Y: 3.24</td>
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<tr>
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<td>X: 0.41 Y: 0.26</td>
<td>X: 0.32 Y: 0.31</td>
</tr>
</tbody>
</table>

**“rounder” and smaller emittance!**

**“rounder” beam**

X & Y numbers are close
Bunch shaping with dielectric lined waveguides

(new) F. Lemery
Technical design of Gun 5
(update & new)
> Gun 5 new features (see V. Paramonov et al., NIM A 854 (2017) 113-126.):

- includes RF probe
  → fine control of RF stability, allows symmetric power coupler (2 input arms)
- improved water cooling and reduced deformation over RF pulse
  → more reliable operation at high duty cycle
- improved cell geometry
  → reduced RF heating & surface field strength

→ Technical design ongoing and experiments on test pieces started
The final MAC report ➔ extremely positive ➔ Citations:

> (on plasma activities):

- The MAC was impressed by the quality of the results obtained and congratulates the team on the first direct time-resolved observation of self-modulation in an electron beam. Very promising results were also presented on the experiments on the high transformer ratio, which seem to indicate for the first time that a factor 3 to 4 in energy multiplication can be achieved.

> (on other items):

- The MAC considers that the R&D programme agreed with XFEL is of high strategic value for PITZ and provides essential support to the XFEL.
- The progress with the development of the gun 4.6 is very convincing. The added technical solutions allowed achieving 6.5 MW, 650 μs long pulses in a reliable way as needed for XFEL operation.
- Bunch manipulation with additional gun quads and dielectric waveguide are very promising and continued studies in this area are endorsed by the MAC.
- The MAC encourages the team to continue to pursue multiple CW gun technology options. When the time comes in the future to make a technology down-selection to consolidate R+D efforts or move ahead with an upgrade project, it should be based on (emittance) performance that has been demonstrated at that time. We also encourage to intensify the connection with Cathode development efforts at other laboratories.

> Overall the MAC congratulates the PITZ team for this very complete and impressive programme achieved and the clear objectives set for the future.
Status of R&D towards generating 3D ellipsoidal electron bunches

(update & new)

→ See also J. Good
Motivation for 3D ellipsoidal laser pulses: Beam dynamics simulations for European XFEL and PITZ Photo Injector

> Beam dynamics simulations for the European XFEL photo injector (1nC case):

Besides further improvement of projected and slice emittance:
- 3D ellipsoidal beams → less transverse halo
- More regular (sinusoidal) longitudinal phase space → shorter bunches!

• 3D ellipsoidal pulses → ultimate improvement of the beam emittance
• Also very important for cw injector (lower cathode gradient)
3D ellipsoidal laser system (ELLA) from the Institute of Applied Physics (IAP, Nizhny Novgorod)

Under operation at PITZ:
- Hamamatsu SLM
- Laser integrated into PITZ laser beam line
- Synchronization with RF realized with uTCA
- Beam shaping studies begun (SLM masks)
- Electron beam measurements with regular shaped ELLA pulses (starting Dec.2016 → now)

Issues limiting current performance:
- Laser beam transport (transverse size)
- Oscillator + disc amplifier performance:
  - Synchronization (<10kHz)
  - Stability (pointing and intensity jitter, long term drift)
  - Spectrum → pulse too short
- Pockels cell (contrast, flatness)
- ...

Upcoming upgrade at PITZ:
- Pharos-20W-1MHz frontend laser delivered → should solve most of laser related problems
3D ellipsoidal laser system from IAP, new idea for the pulse shaper: 3D Volume chirp Bragg grating

Material:
Photo-Thermo-Reflective Glass

Method of production:
Interference of diverging and converging beams produces non equidistant changes of the refractive index

Can be applied for wavelengths:
800 nm - 2500 nm


→ Postdoc (DSF funds) selected → implementation at DESY together with IAP
> Summary of work on opening the gun cathode region in May 2017

(new)
Opening the gun cathode region in May 2017

> **Background:** Problems with re-inserting the cathode when re-starting the machine after a regular 2-week shutdown including extraction of photo cathode (for firing TSPs):

  - gun resonance temperature was off by up to +7 degrees
  - dark current was a factor 2-3 higher than before (>300µA)

> Several trials of re-inserting cathode or use of other cathodes did not help:

  - all cathodes were inspected and showed strange marks and scratches
  - decision to open cathode system and gun (from backplane side)
Summary of work at the cathode system and Gun4.6

> exchange of the Huntington z-manipulator
> gun opening from the backplane side for endoscopic observations
> exchange of the cathode spring, its holder (incl. screws) and bellow with guidance

Overview scheme:
- gun backplane
- cathode plug
- cathode spring
- cathode spring holder
- z-actuator head
- bellow with guidance
Observations from opening the gun cathode region

- Endoscopic investigations: conspicuous features (scratches, spots) were found at cathode spring holder, cathode spring and gun backplane.

Marks at the gun backplane

Traces and spots at the cathode spring holder (top: endoscope view, bottom: after dismounting)

Microscope view of the spot at the cathode spring holder
Observations from opening the gun cathode region

Traces from the dismounted cathode spring at the contact area in the gun backplane

Traces at the dismounted cathode spring

The new cathode spring installed in the gun
Conclusions from the gun opening in May 2017

> Some **peculiarities** have been **observed** when opening Gun4.6

> But still a clear reason for the observed problem with inserting the cathode was not found.

  - Most probable explanation is a **malfunctioning/damage** and a misalignment of the **z-manipulator**.

> Reason for damages on the inserted cathodes is not fully clear

  - Possible explanation with misaligned z-manipulator and marks on cathode spring holder

> Operation of **Gun4.6 restarted** on 29.5.2017 **without** major problems; conditioning up to the standard run parameters was very fast (**~1 week**)

  - Observed dark current still larger than before problems showed up
    → vacuum will still improve and fresh cathodes still to be installed
Short report from THz workshop at XFEL (new)
## Program of the THz workshop at XFEL

### Main Agenda:
- **1. day: scientific case**
  - with laser systems
  - with accelerators
  - different options in both cases
- **2. day: technical realization**

### 1st of June 2017

<table>
<thead>
<tr>
<th>Time</th>
<th>Session A: Correlated Materials</th>
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<tbody>
<tr>
<td>11:00</td>
<td>Welcome Address</td>
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<tr>
<td>11:10</td>
<td>Andrea Perruchi (Fermi)</td>
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<td>11:30</td>
<td>Stefano Benetti (U. Stockholm)</td>
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<td>12:00</td>
<td>Adrian Cavaijen (GIF)</td>
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<td>12:30</td>
<td>Lunch Break</td>
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<tr>
<td>14:00</td>
<td>Karsten Hollandack (HZB)</td>
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<td>14:30</td>
<td>Dmitry Turchinovich (U. Duisburg-Essen)</td>
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<tr>
<td>15:00</td>
<td>Coffee Break</td>
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<tr>
<td>15:30</td>
<td>Aaron Lindenberg (Stanford, SLAC)</td>
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<td>16:00</td>
<td>Keith Nelson (MIT)</td>
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<td>Louis DiMauro (Ohio State U.)</td>
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### 2nd of June 2017

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<th>Time</th>
<th>Session D: Laser-based Sources</th>
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<tr>
<td>09:00</td>
<td>Max Lederer (European XFEL)</td>
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<td>09:30</td>
<td>Matthias Hoffer (LCLS)</td>
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<td>10:00</td>
<td>Christoph Haun (PSI)</td>
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<td>Andrea Cavallini (MPSD)</td>
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<td>11:00</td>
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<tr>
<td>11:30</td>
<td>Mikhail Krasnikov (PITZ@DESY)</td>
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<td>12:00</td>
<td>Michael Gersch (HZDR, TELBE)</td>
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<td>12:30</td>
<td>Nicola Stojanovic (FLASH)</td>
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<td>13:00</td>
<td>Lunch Break</td>
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<td>14:00</td>
<td>Franz Kärtner (DESY)</td>
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<td>14:30</td>
<td>Andrej Savillov (IAP, RAS, N. Novgorod)</td>
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<tr>
<td>15:00</td>
<td>Zhidong Huang (Stanford, SLAC)</td>
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### Session on Various Sources

15:30-16:00 Open discussions, Tours
Adrian Cavalieri (MPSD): „Observation of coherent field-driven dynamics at XFELs“ → a method of data sorting

- Clock amplitude and phase and temporal overlap with correlated streaking
- Use characterized “streaking” pulse to drive field-dependent dynamics
- Effectively obtain CEP stabilization between unsynchronized sources
Outlook: Possible “PITHz” Layout

- “all options” included
- reduction in size and costs possible

Supplementary Systems and Infrastructure

General: Radiation protection and personal IL
Control system and DAQ

Electronics: e-beam diagnostics
Electronics: THz diagnostics

Water Cooling System

Supplementary Systems and Infrastructure

Laser(s)
UED
CTR

RF gun
DLW
Modulator
CDS-1
10MW MBK

10MW MBK
Magnets power supplies
S-band Klystron

Vacuum components supplies

Hardware costs: VERY rough estimations

Σ~15M€
### Possible scenario

#### Three stages of Terahertz generation

<table>
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<tr>
<th></th>
<th>Short-term</th>
<th>Mid-term</th>
<th>Long-term</th>
</tr>
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<tbody>
<tr>
<td><strong>Optical rectification, e.g. in LiNbO₃</strong></td>
<td>DFG, e.g. in organic crystals</td>
<td>Accel./Undulator</td>
<td></td>
</tr>
<tr>
<td><strong>Tunability</strong></td>
<td>No (0.2-0.3 THz)</td>
<td>Yes (2-15 THz)</td>
<td>Yes (0.5-15 THz)</td>
</tr>
<tr>
<td><strong>Peak pulse energy</strong></td>
<td>&gt; 100 μJ</td>
<td>&lt; 1 μJ (DFG), &lt; 100 μJ (OR, but not tunable)</td>
<td>&gt; 100 μJ</td>
</tr>
<tr>
<td><strong>Max. rep.-rate</strong></td>
<td>~ 100 kHz</td>
<td>? &lt; 100 kHz</td>
<td>4.5 MHz</td>
</tr>
<tr>
<td><strong>CEP-stable</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes, except SASE</td>
</tr>
<tr>
<td><strong>Complexity</strong></td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
</tbody>
</table>
Summary & Outlook

> Last 6 months: 2 papers published, 3 drafts under review (1 with high impact factor)
>
> MAC report:
  - Beam driven plasma acceleration activities:
    - First direct measurement of **self-modulation** in a long particle beam
    - **High transformer ratios** have been seen from shaped particle bunches in plasma
    - Laboratory Astrophysics experiments are under preparation
  - Part of the **R&D program** at PITZ will be **co-funded by XFEL** → long term perspective
  - **Gun 4.6** with „watchband reloaded“ cathode spring design and 2 DESY-type RF vacuum windows worked reliable at XFEL specs (6.5 MW, 650 µs, 10Hz).
  - Gun quad system allows **symmetric phase space** at injector exit
  - **Microbunch shaping** with dielectric lined waveguides was demonstrated
  - Technical design of **Gun 5** is progressing

  ➔ **MAC report extremely positive and supportive!**
>
> Developments towards generating ultimate low emittance (**3D ellipsoidal bunch shapes**) show first progress
>
> Problem with inserting cathodes in gun 4.6 solved, **re-conditioning was quick**
>
> Promising workshop on THz at XFEL, long-term interest in accl. based source
>
> **Outlook:**
  - Gun 4.6 operation will continue → to be delivered to XFEL in Oct.`17
  - Gun 4.5 will be mounted with 2 Thales windows @optimum position

M. Gross was invited to give at talk at EAAC 2017