Universität Hamburg
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HELMHOLTZ GEMEINSCHAFT
DESY

sFLASH

First Seeding at FLASH

15.05.2012

On behalf of the sFLASH team
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Hamburg University

•Supported by BMBF under contract 05 ES7GU1
•DFG GrK 1355
•Joachim Herz Stiftung

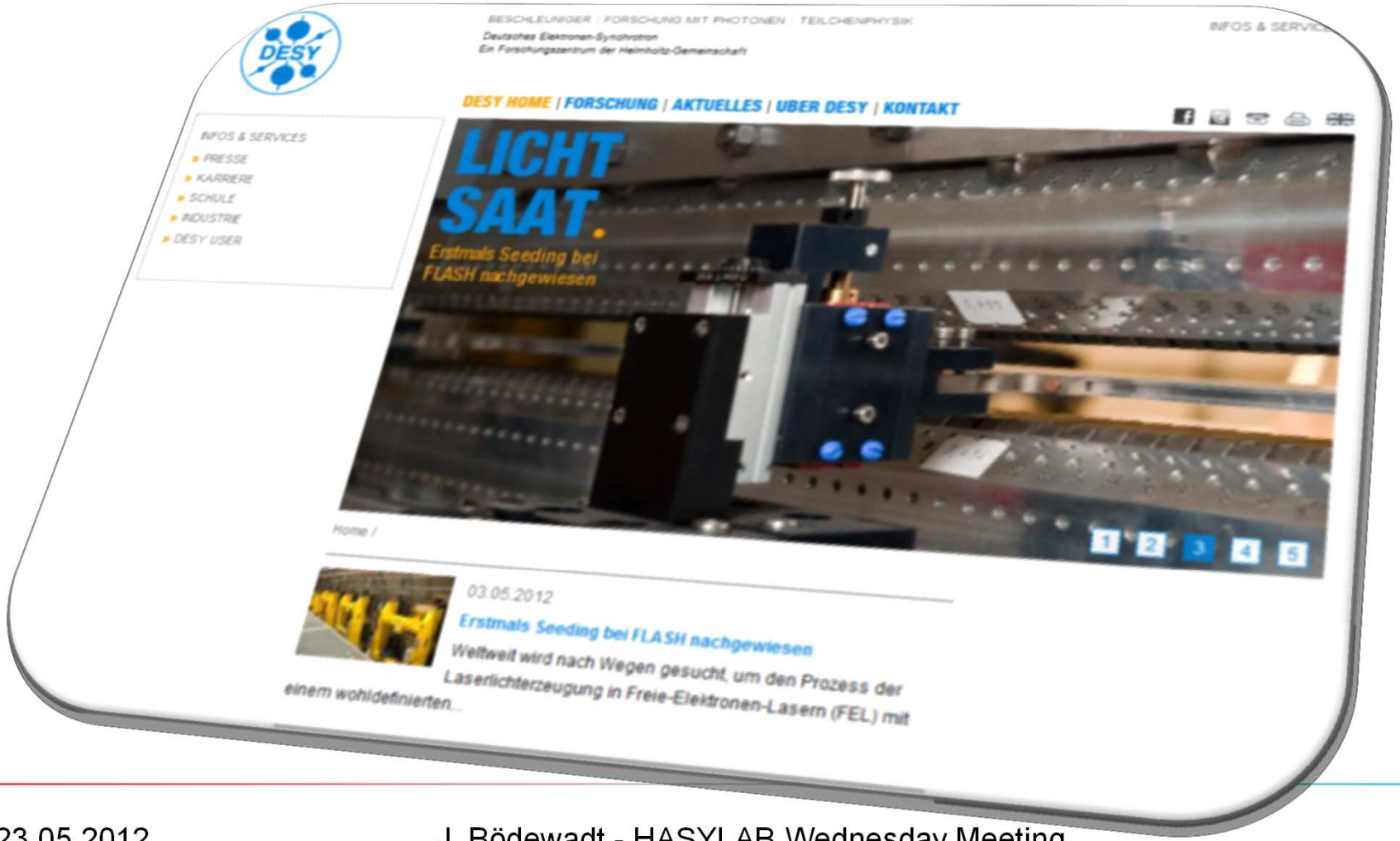
Bundesministerium für Bildung und Forschung

DFG Deutsche Forschungsgemeinschaft

JOACHIM HERZ STIFTUNG

NEW WORLD RECORD at FLASH

- **For the first time direct FEL seeding at 38.5 nm was achieved on April 29th 2012 with sFLASH**



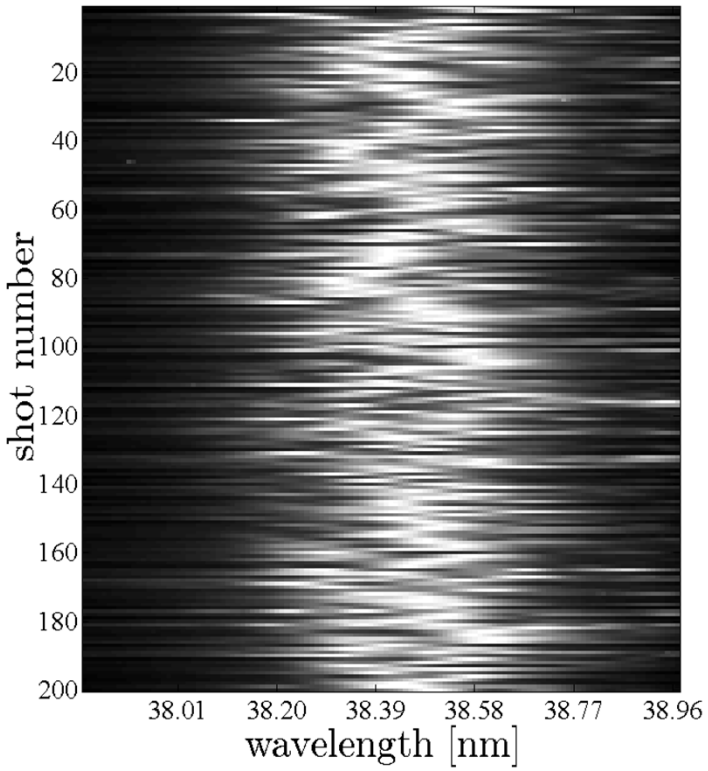
Outline

- Motivation / seeding schemes
- sFLASH setup
- Results till spring 2011
- Upgrade program 2011
- Results of beam time in 2012

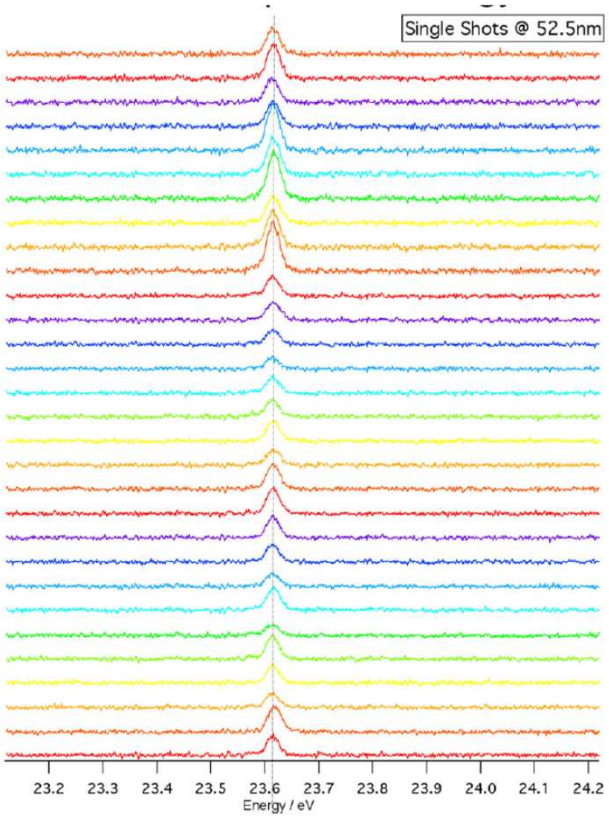
Motivation (Spectrum)

- Use external laser seeding to stabilize the spectral distribution of the FEL

SASE spectra measured at sFLASH@38.4 nm



HGHG seeded spectra measured at FERMI@52.5 nm



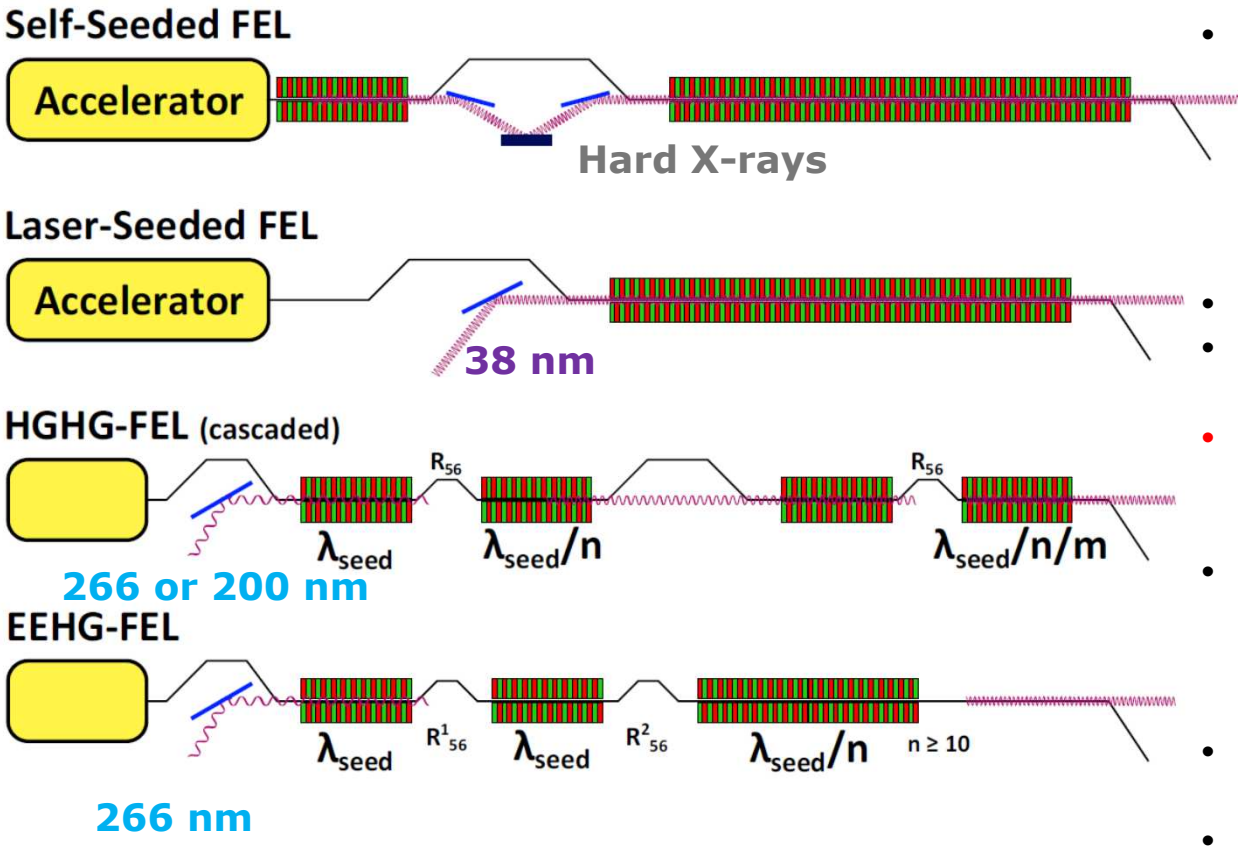
Courtesy E. Allaria, High Gain Harmonic Generation operation of a Free Electron Laser, Seeding Workshop 2011 Berkeley

Motivation (Timing)

- With existing FELs the temporal resolution for IR-XUV pump-probe experiments is limited due to the relative arrival time jitter of both pulses
  - Ideally the jitter should be smaller than the individual pulse lengths
  - Not all experiments are capable to use other arrival time measurements to sort the data
- With external laser seeding the drive laser for the seed and the FEL output pulse are intrinsically synchronized
- Still needs sophisticated synchronization of the seed laser and the machine

Seeding schemes

- Other FEL seeding schemes (XUV and soft X-ray)



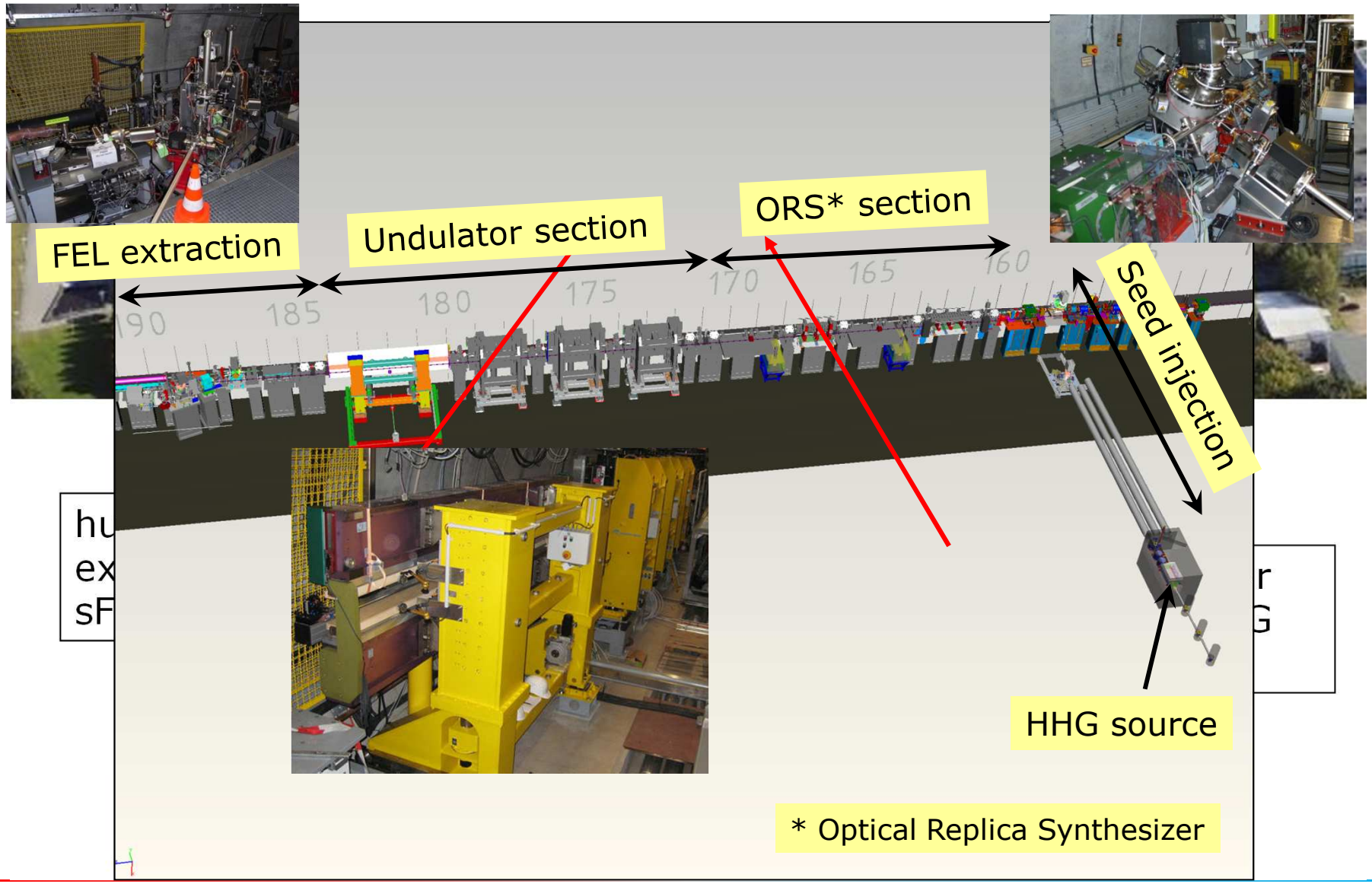
- Demonstrated at LCLS in January this year (hard X-rays)

- HHG seeded FEL
- Proof of principle SCSS@160nm
- **sFLASH first seeding at 38nm**

- Fermi@Elettra in operation (20 - 40 nm)

- Proof of principle @ SLAC >300 nm
- Other facilities
  - SDUVFEL (SINAP)
  - FLASH

sFLASH Installation



* Optical Replica Synthesizer

Results in 2011

- sFLASH setup fully commissioned
  - overlap diagnostics (transversal, longitudinal, spectral)
  - SASE gain of 10^5 – 10^6 achieved
  - tools for on-line data analysis tested

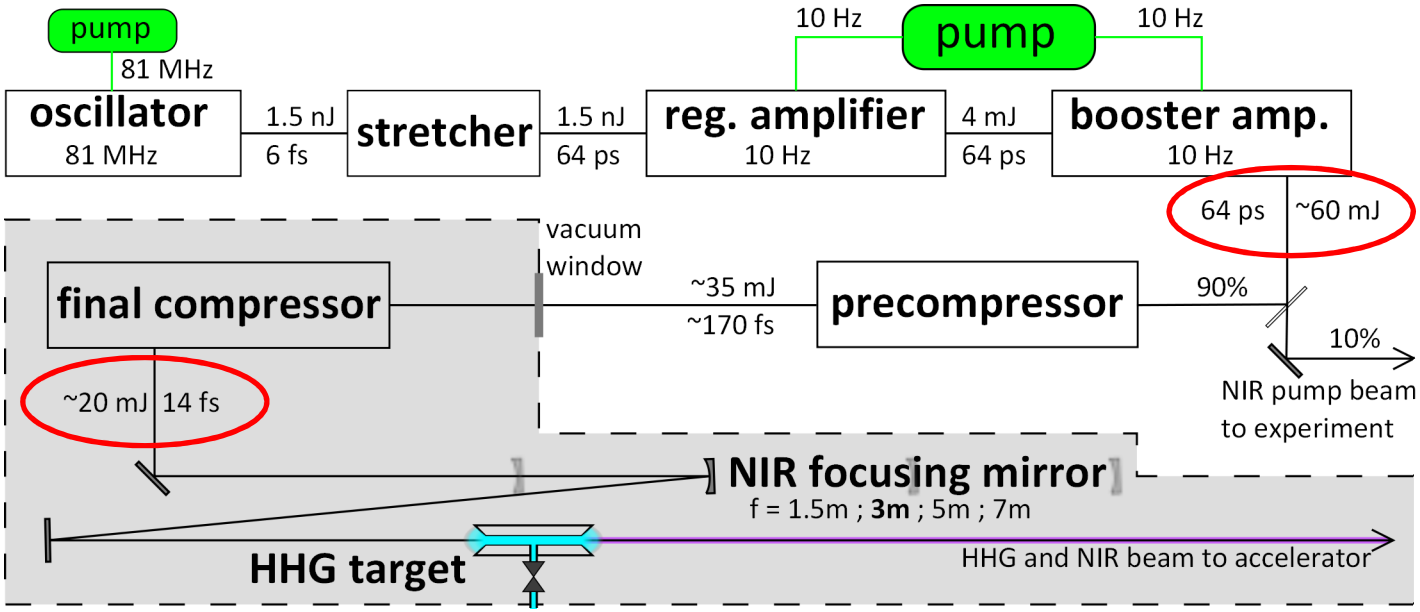
- but NO signal for seeding detected
  - la

    - HHG energy @ 38nm at the source ≈ **2 nJ**
    - Full HHG energy at the undulator ≈ **0.1 nJ** (measured transmisson of 5%)
    - HHG energy coupled to electron beam ≈ **0.004 nJ** (due to $\sigma_{HHG} >> \sigma_{e^- beam}$)
    - Effective seed power ≈ **200 W**. Shot noise power ~ 1**00 W**
    - **Energy contrast ~0.3 ⇒ very difficult to demonstrate the effect of the seeding**

- -> upgrade of sFLASH components was needed
  - Seed laser system
  - Tunnel diagnostics
    - XUV photo diode, Streak Camera, spectrometers

HHG laser system before upgrade

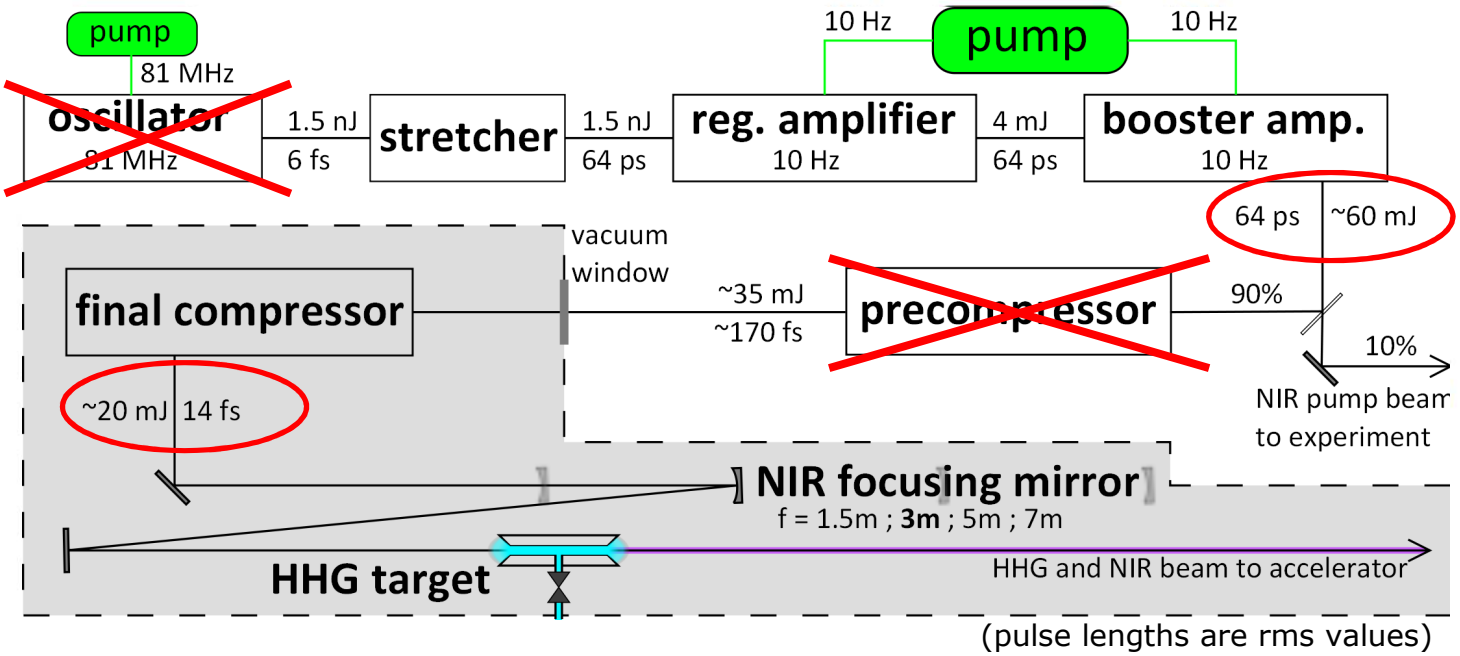
- 81 MHz Ti:sapphire oscillator
- CPA – reg. amplifier with 4x multi pass booster section



(pulse lengths are rms values)

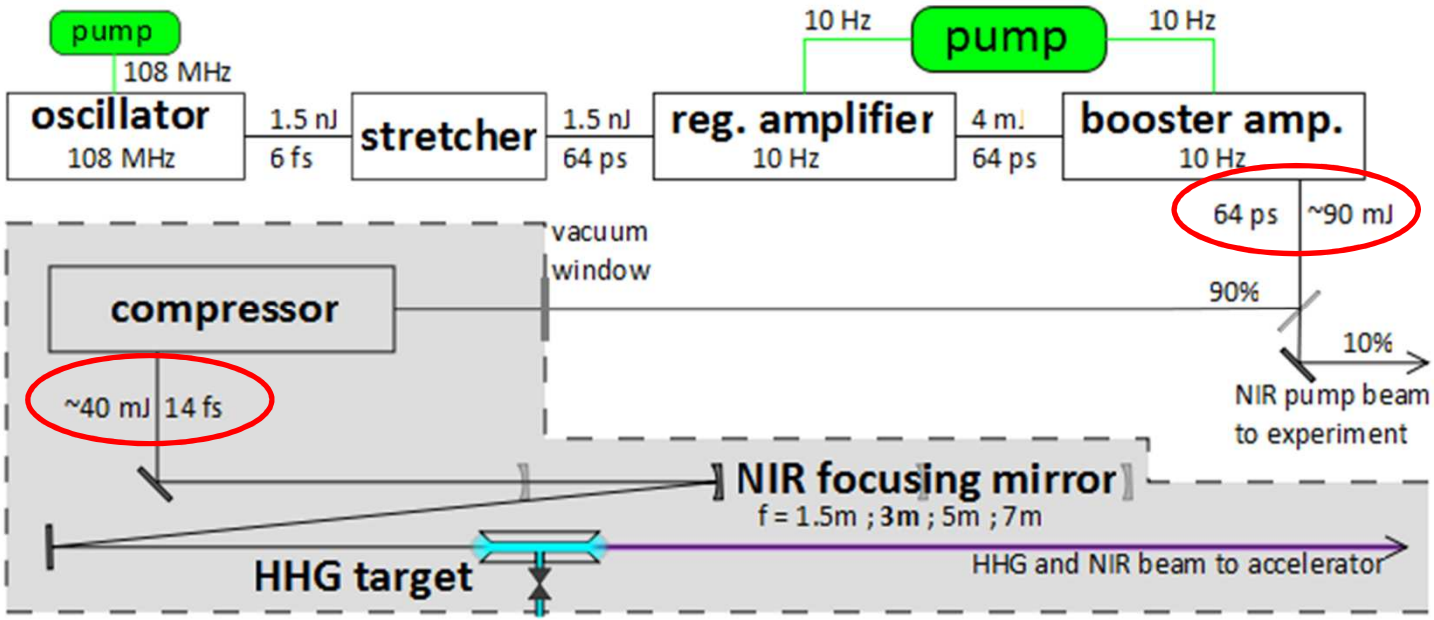
HHG laser system

- new 108 MHz Ti:sapphire oscillator (better suited for synchronization)
- Amplifier system maintained and new crystals installed
- changed compression scheme to a single compressor setup



HHG laser system 2012

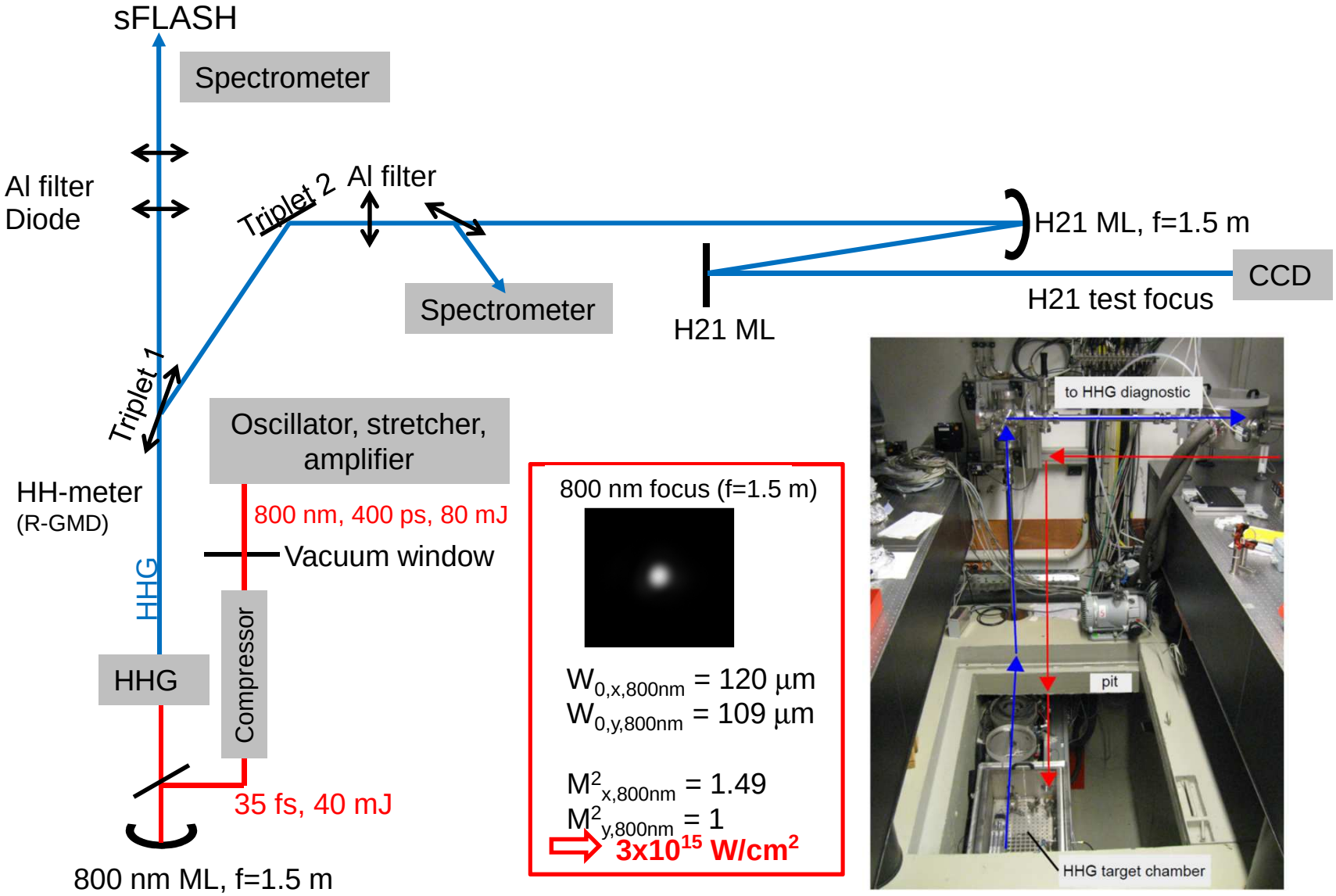
- new 108 MHz Ti:sapphire oscillator (better suited for synchronization)
- Amplifier system maintained and new crystals installed
- changed compression scheme to a single compressor setup



(pulse lengths are rms values)

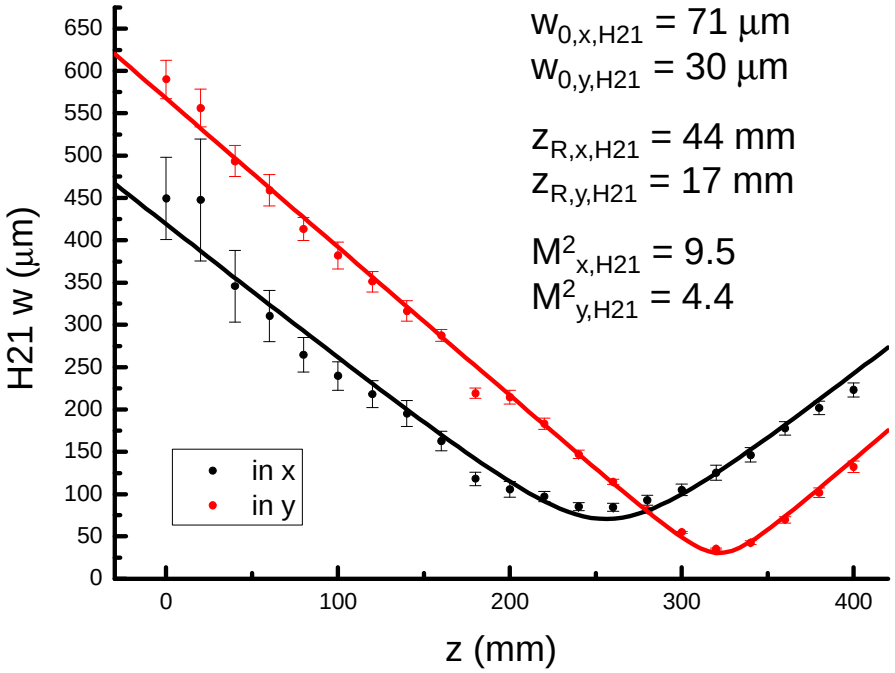
- Increase of NIR pulse energy by a factor of 2
- Better control of NIR pulse and beam shape

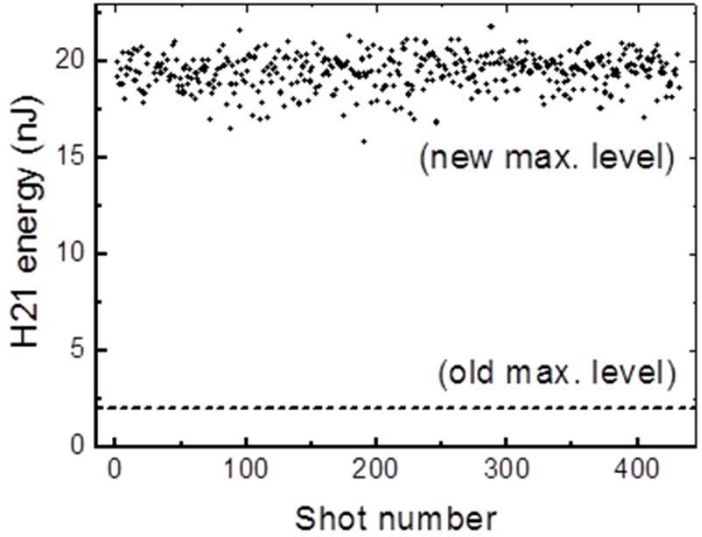
HHG source and diagnostic



Seed laser performance 28g

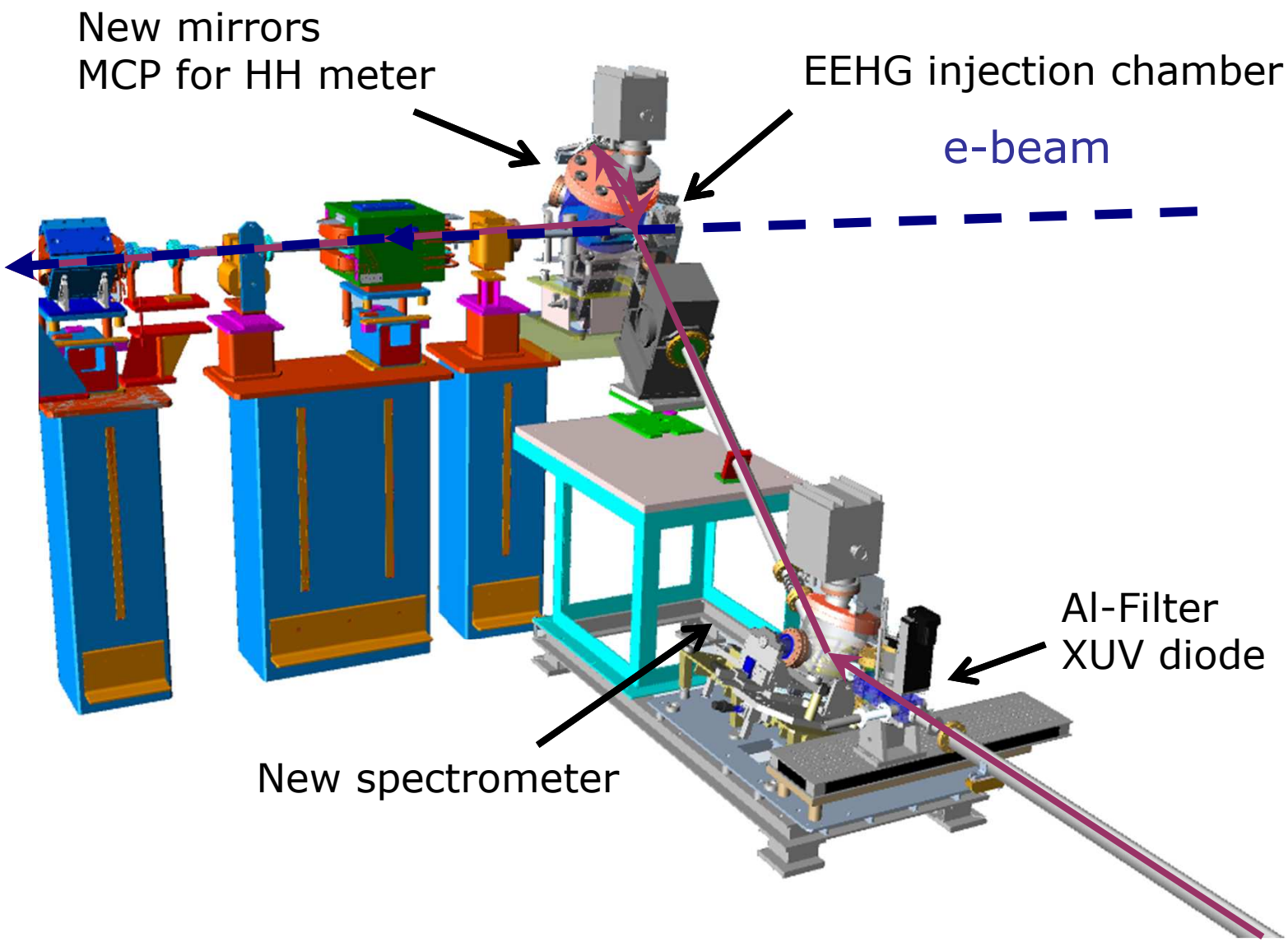
Test focus scan in diagnostic branch



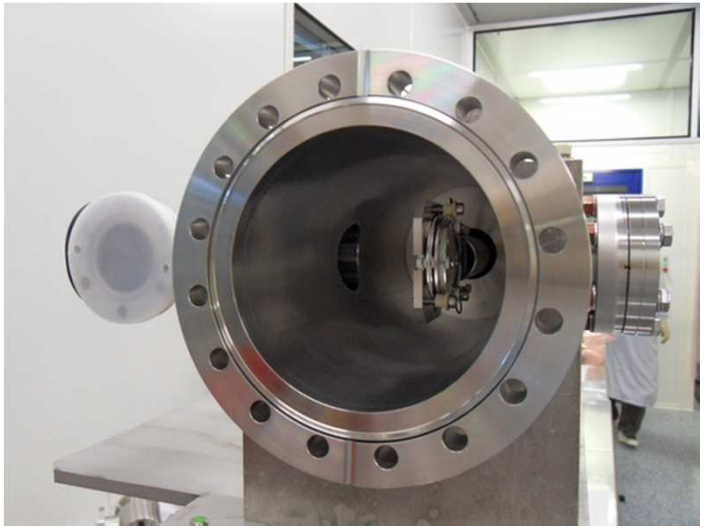


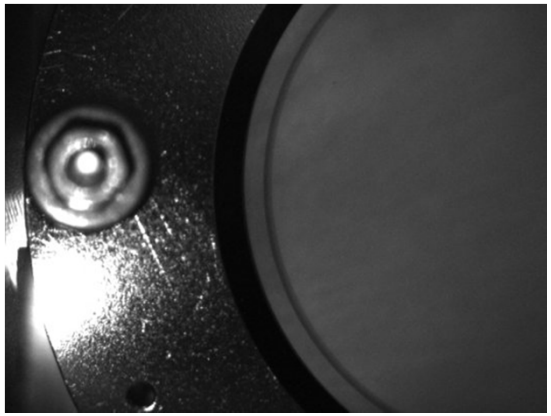
H21 (38 nm)
pulse energy at source:
≈ 10 - 20 nJ with 5 - 15% rms

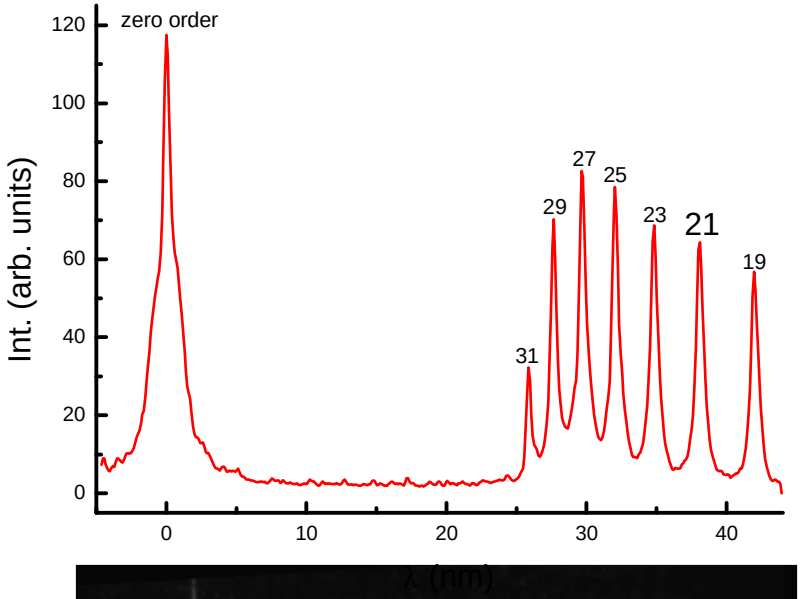
Injection beamline 2012

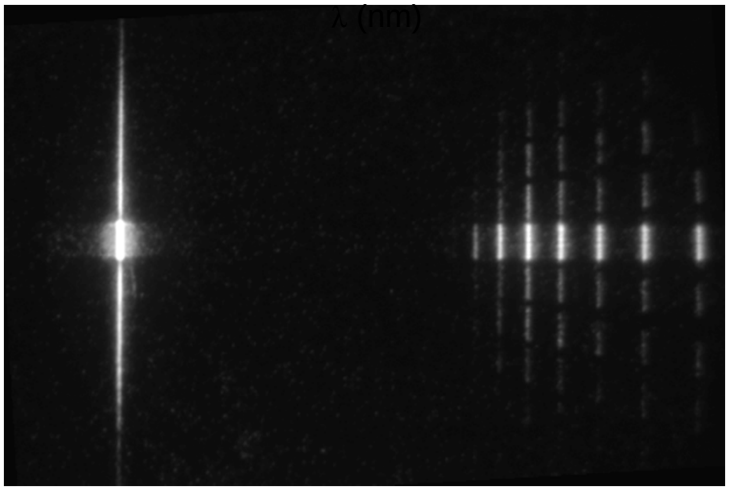


HHGBL spectrometer

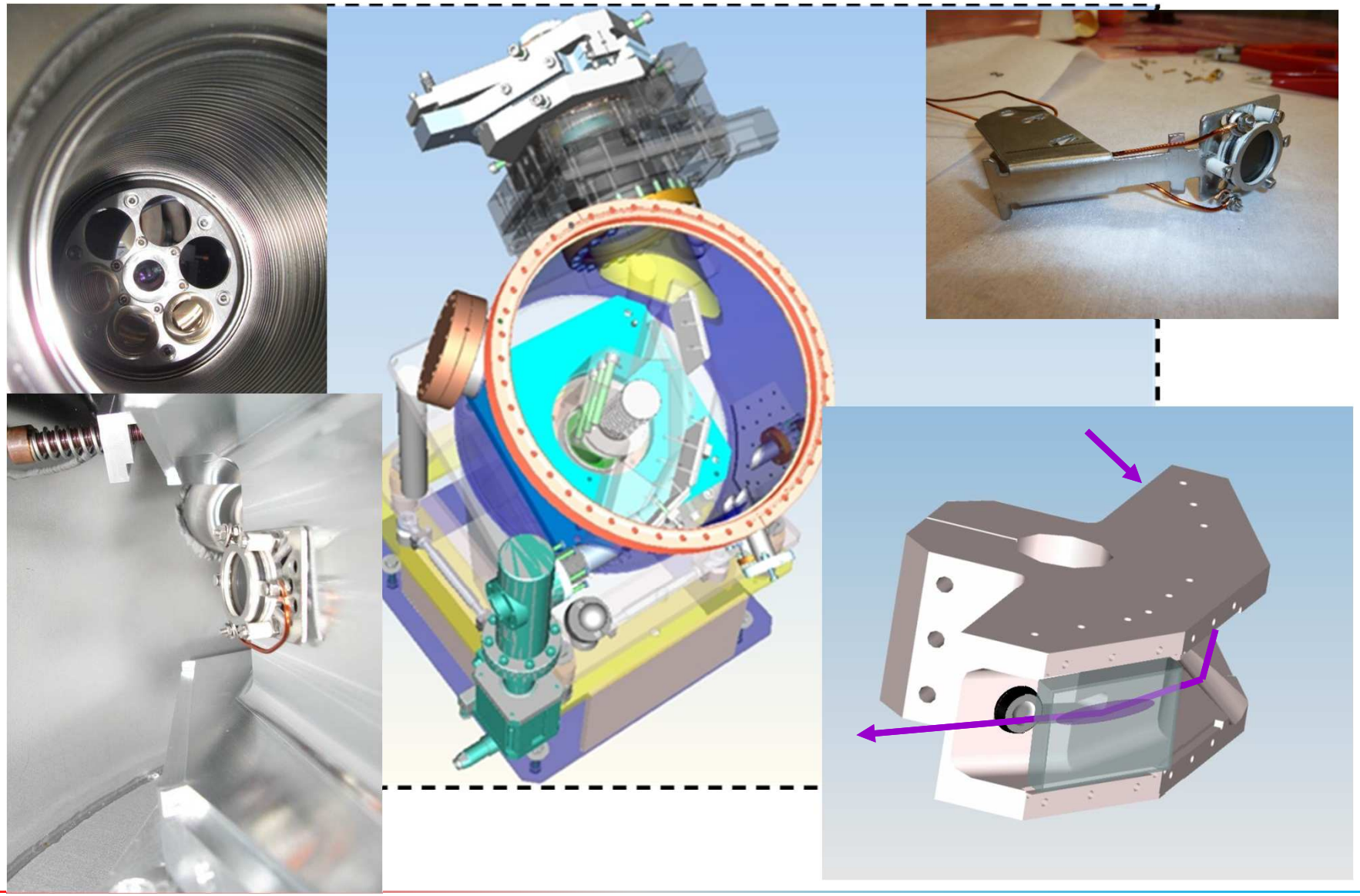




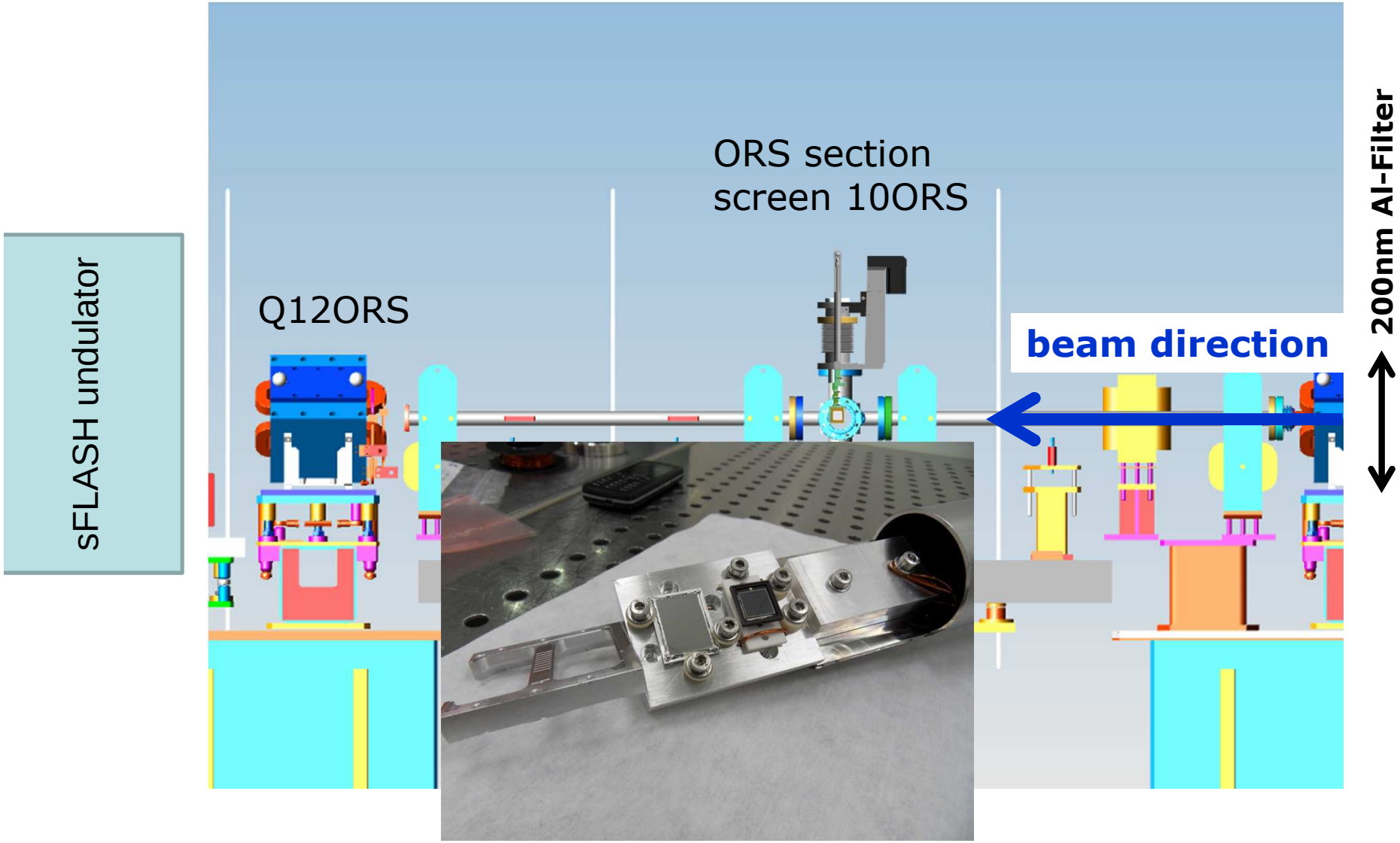




Mirror chamber 2, HH-meter



XUV photo diode at 10ORS



HHG pulse energy at undulator 1

- April 29th 2012:
  - Measured charge Q_{meas} = 49 pC
  - Assuming only 21st harmonic -> E_{21st} = Q* Ep / QE
    - QE = 6.76 (for 38nm); Ep = 32.55 eV
    - -> **E_{21st} = 235 pJ** (value from February: 250 pJ)

  - Assuming 4 harmonic orders (seen on spectrometer): 19th, 21th, 23th, 25th -> Q_{21st} = ½ * Q_{meas}
  - E_{21st} = Q_{21st} * Ep / QE
    - -> E_{21st} = ½*235 pJ = **117 pJ**
- For the measurements a 200nm Al-filter has to be inserted into the beamline to block the NIR laser. At 38 nm the transmission is about 0.35. For seeding this filter is always removed. So the seed pulse energy is a factor 3 larger:

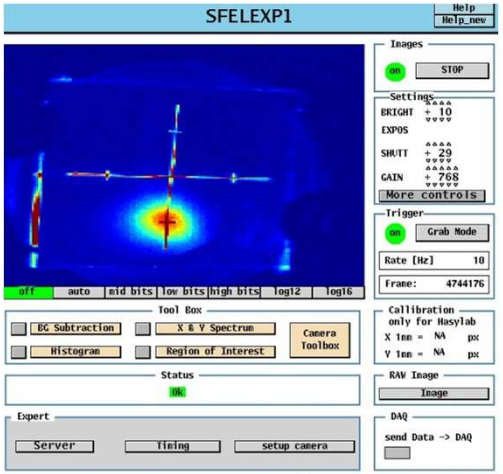
E_{21st} = 330 – 670 pJ

New Streak Camera

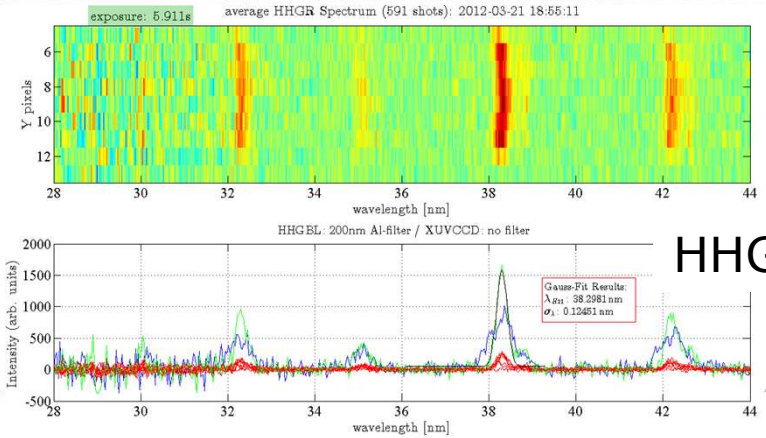
- The Hamamatsu FESCA 200 was removed and returned to photo injector laser (Siggi)
- A new Streak Camera type Hamamatsu C5680 (Synchroscan) was installed
  - Has a slightly lower resolution than the FESCA but can be synchronized to the RF-signal

Spectrometer in 28h

- Due to technical problems with the sFLASH tunnel spectrometer (broken image intensifier) we had to install a backup solution in 28h
- Using an existing XUV spectrometer from Lasse Schroedter
  - Nominal wavelength range 10 – 75nm



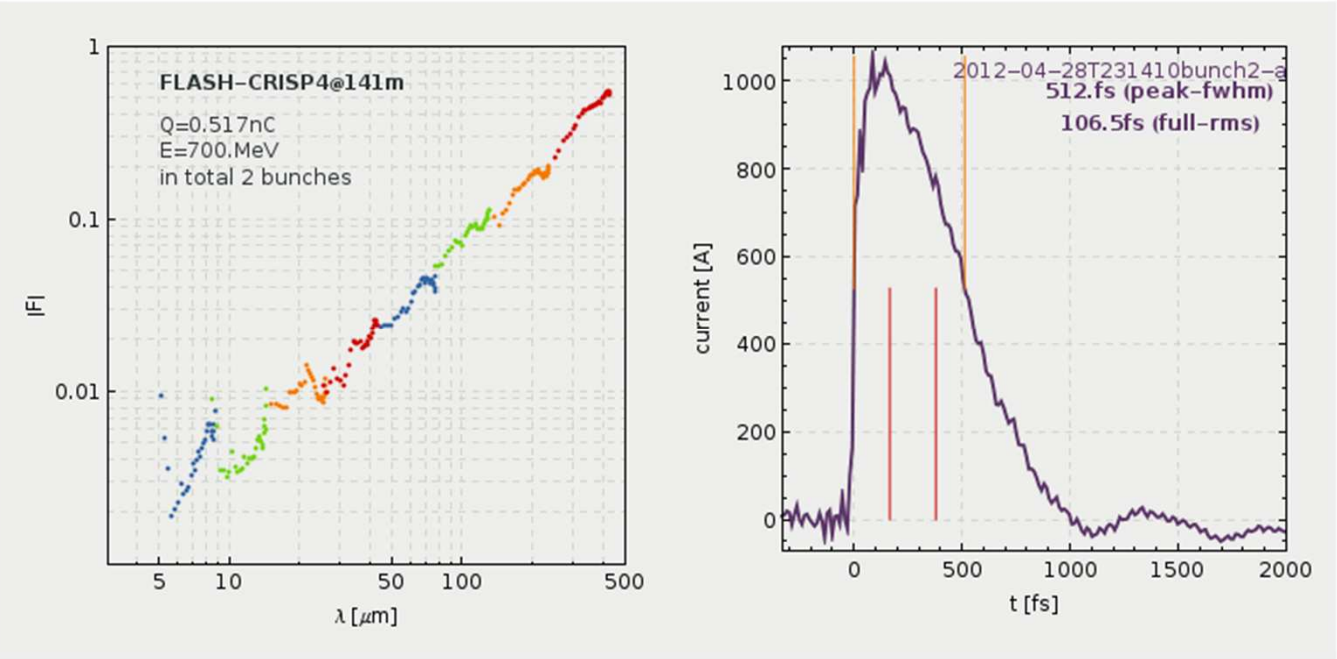
FEL beam in 28h



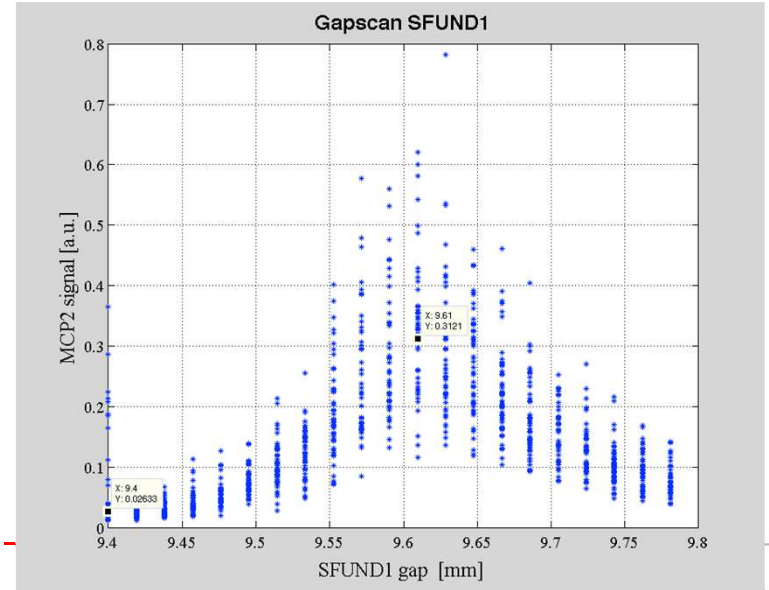
HHG spectrum

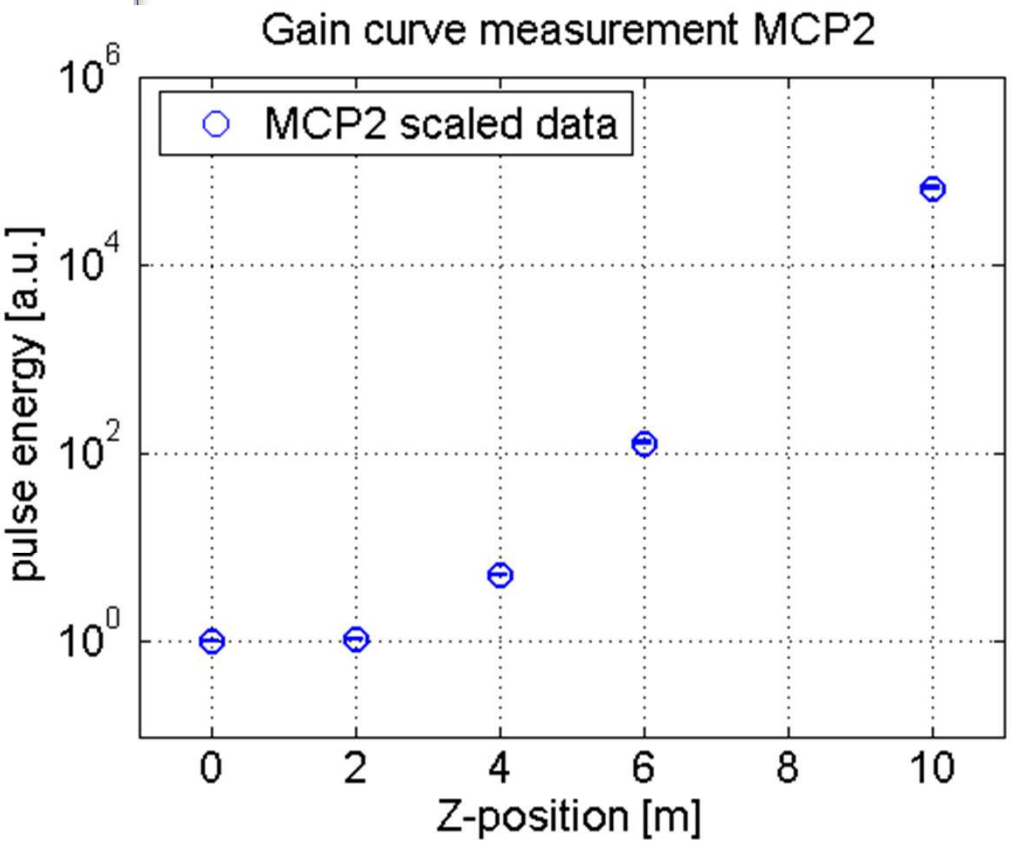
Machine preparation

- Beam energy: 695 MeV
- Charge: 0.5 nC
- Compression: 500 fs (FWHM) Gaussian current distribution (CRISP4)
- Orbit: using wire scanners for reference positions in first undulator module
- No beam losses, SDUMP mode, Pyro and energy feedbacks on



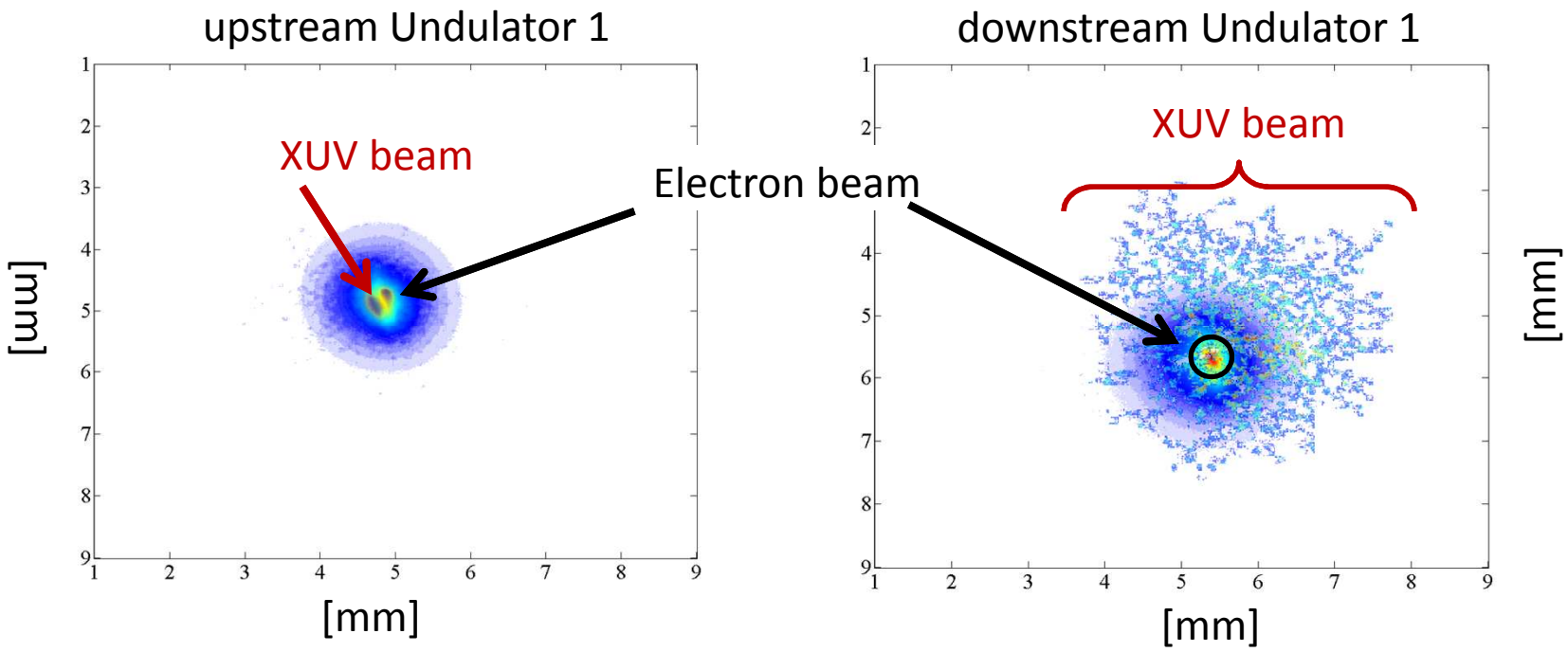
sFLASH SASE Gain curve



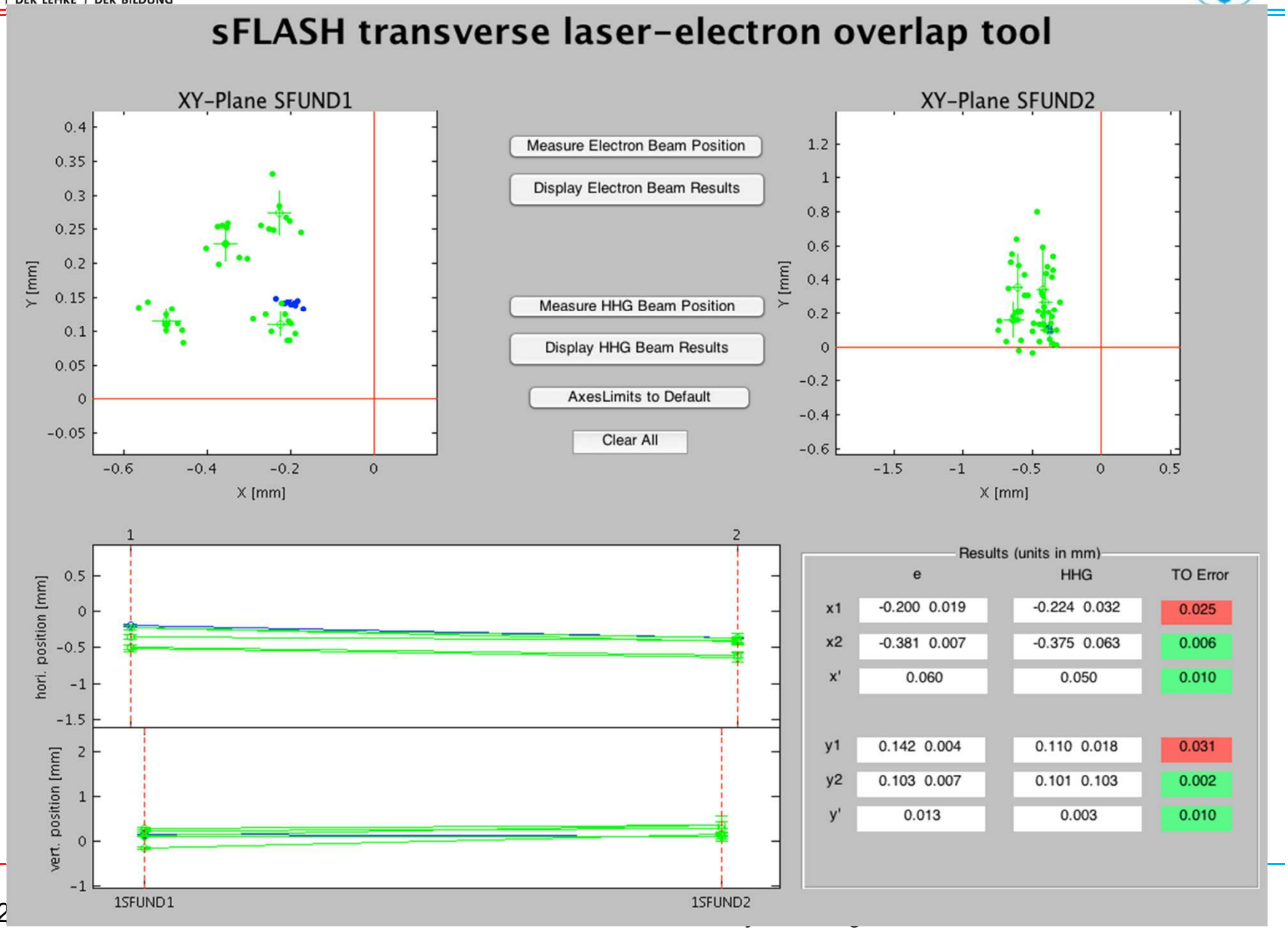


Transverse overlap

Superimposed beam profiles measured on Ce:YAG screen

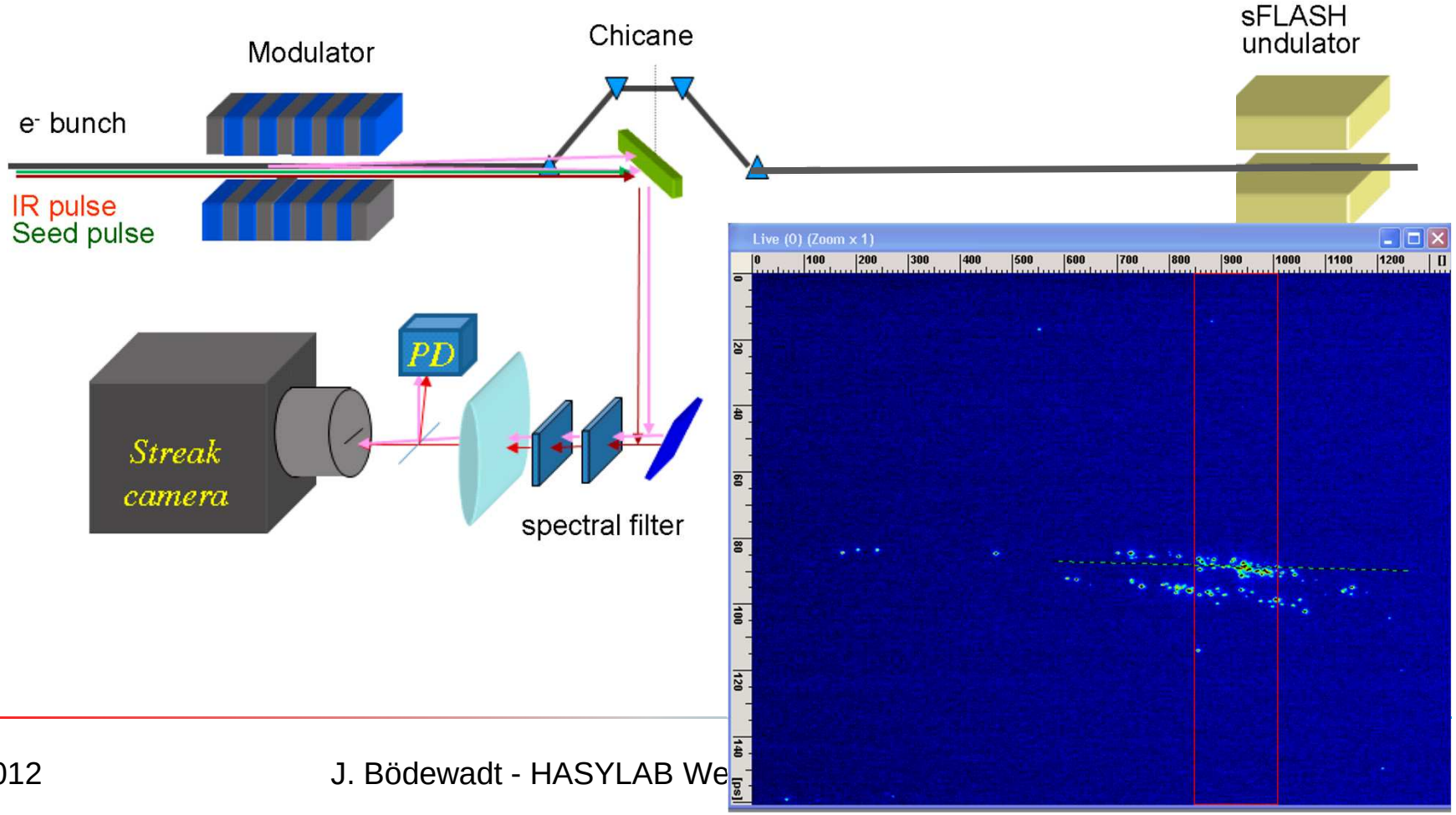


Transverse overlap

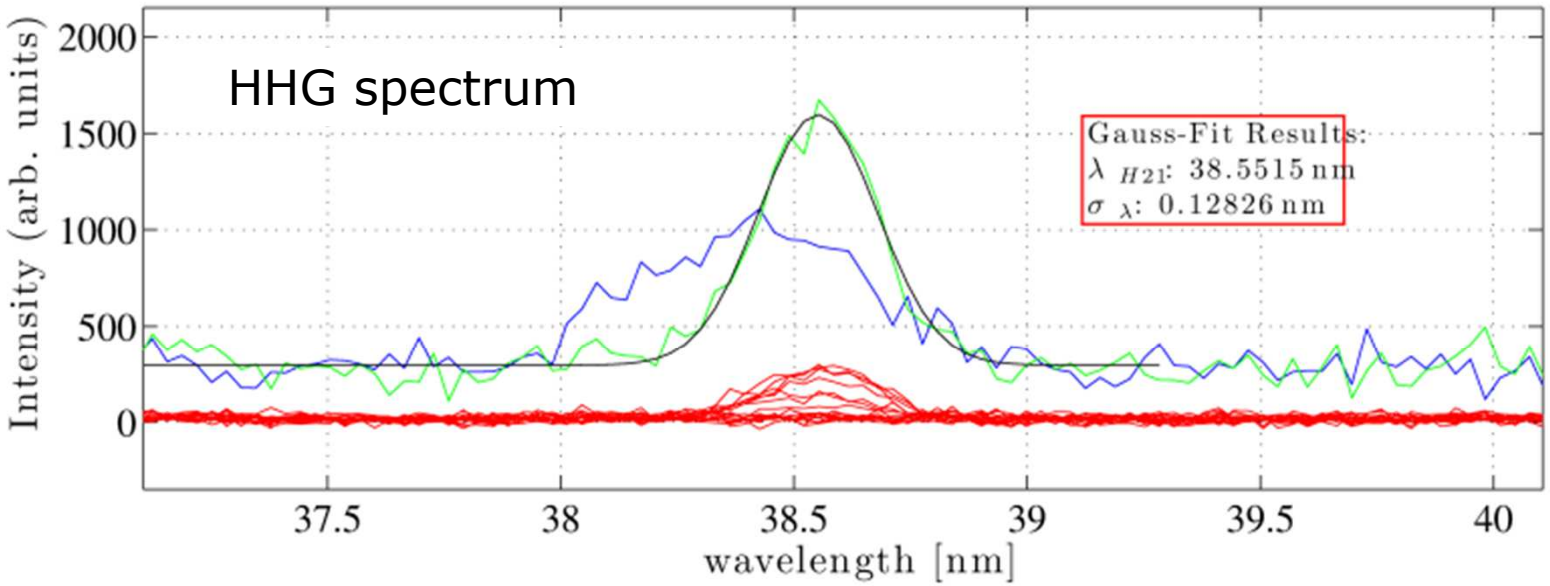


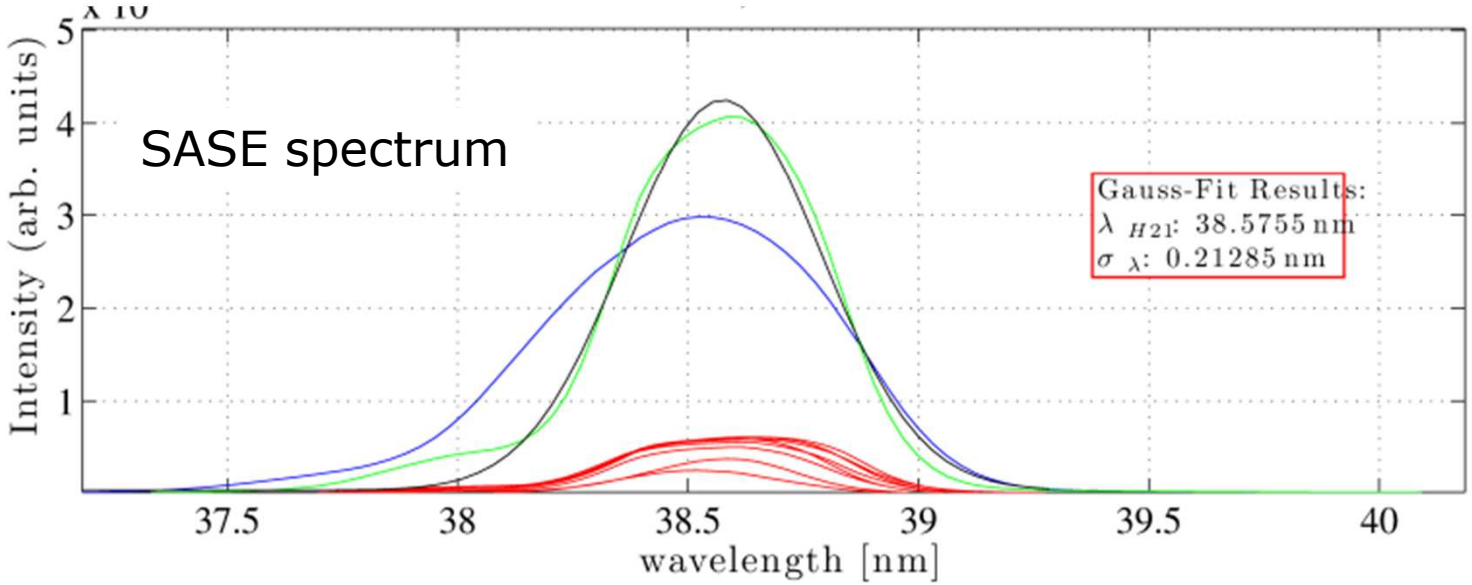
Longitudinal overlap („coarse“)

- using synchrotron radiation from a short (N=5) electro-magnetic undulator together with 800nm laser pulses on a streak camera to find the temporal overlap



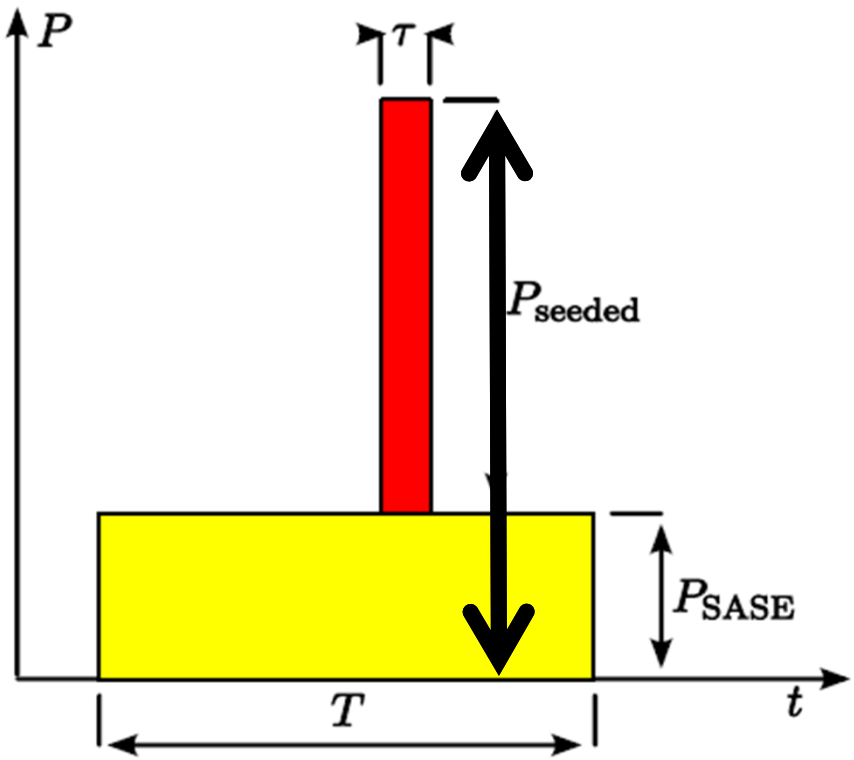
Spectral overlap





How to detect seeding

- If you don´t expect a dramatic enhancement of your signal…



Typical numbers:

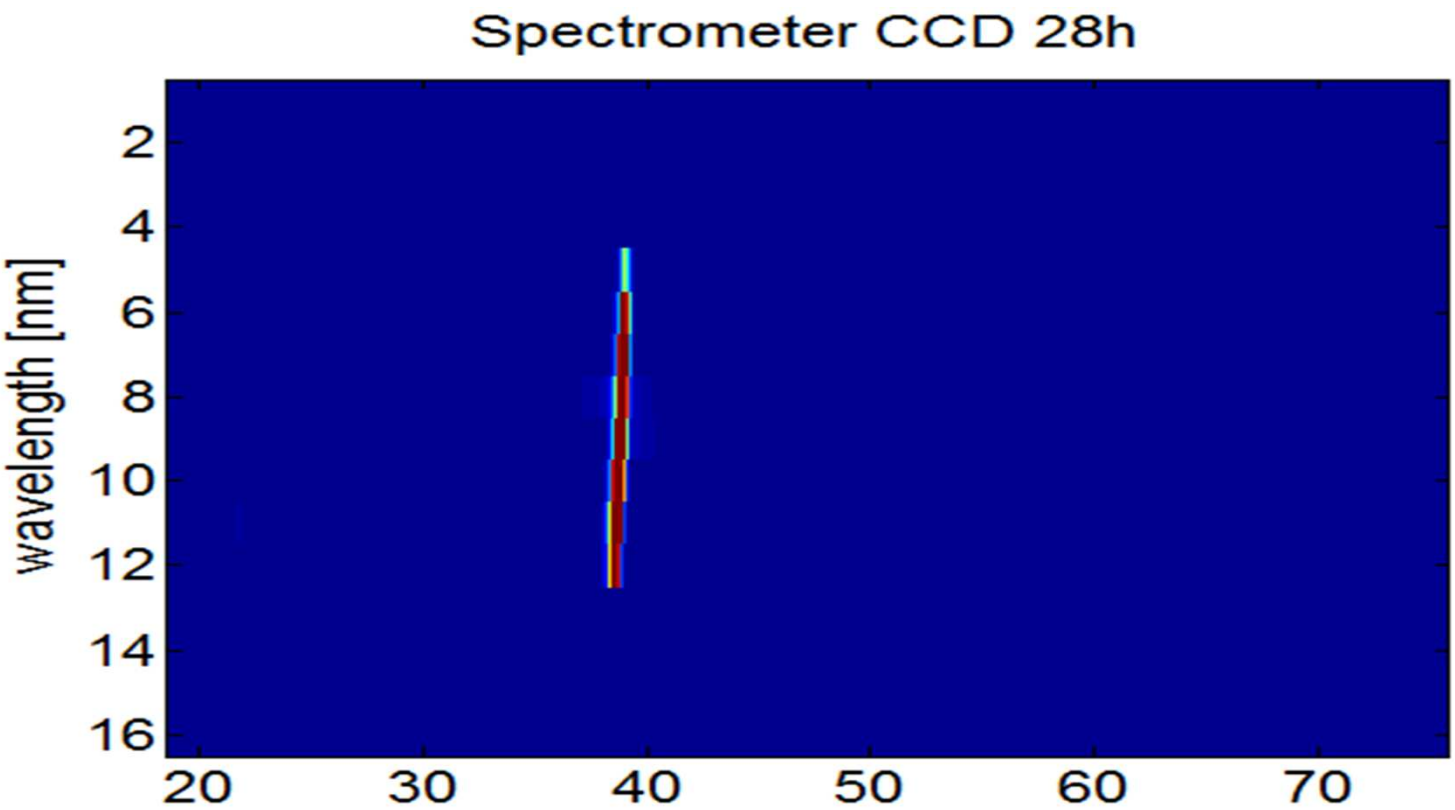
$$T = 200\ fs$$
$$\tau = 20\ fs$$

$$P_{seed} = 20 \cdot P_{SASE}$$

$$\frac{E_{tot}}{E_{SASE}} = \frac{T \cdot P_{SASE} + \tau \cdot (P_{seed} - P_{SASE})}{T \cdot P_{SASE}} = 2.9$$

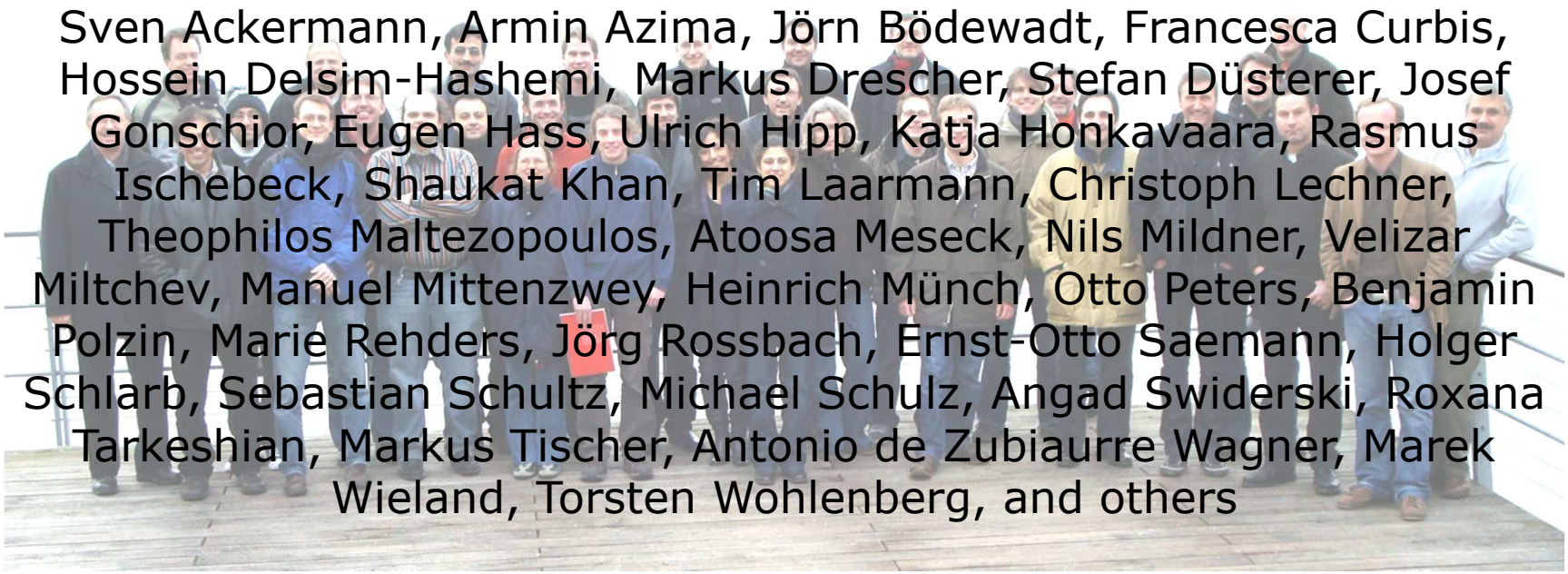
Spectral data

- With all undulators closed the CCD of the spectrometer was saturated @ 38.5nm



On behalf of the sFLASH team

Thank you for your attention



Sven Ackermann, Armin Azima, Jörn Bödewadt, Francesca Curbis, Hossein Delsim-Hashemi, Markus Drescher, Stefan Düsterer, Josef Gonschior, Eugen Hass, Ulrich Hipp, Katja Honkavaara, Rasmus Ischebeck, Shaukat Khan, Tim Laarmann, Christoph Lechner, Theophilos Maltezopoulos, Atoosa Meseck, Nils Mildner, Velizar Miltchev, Manuel Mittenzwey, Heinrich Münch, Otto Peters, Benjamin Polzin, Marie Rehders, Jörg Rossbach, Ernst-Otto Saemann, Holger Schlarb, Sebastian Schultz, Michael Schulz, Angad Swiderski, Roxana Tarkeshian, Markus Tischer, Antonio de Zubiaurre Wagner, Marek Wieland, Torsten Wohlenberg, and others