AQS & day-1 instrumentation

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Instrument Scientist

Satellite meeting soft X-ray instruments SQS and SCS
Hamburg, January 24th 2017
SQS = AQS + NQS

SQS: Small Quantum Systems
AQS: Atomic Quantum Systems
NQS: Nano Quantum Systems

SASE3: 250 – 3000 eV

\[ N \times h\nu \]

2 – 100 fs
0.2 – 11 mJ

10^{14} \text{ photons/pulse}
10^{18} \text{ photons/s}


Erk et al. 345 288 Science (2014)
The AQS instrument

- Non-linear X-ray physics on gas samples: atoms, molecules, and clusters
- Time-resolved fs molecular dynamics: isomerization, fragmentation, ...

Techniques:
- Angle resolved electron spectroscopy
- Ion spectroscopy
- Multi-particle coincidence: electrons-electrons, ions-ions, electrons-ions
- XUV fluorescence
- Pump-probe: XUV + IR

SQS specifications
- 0.25-3000 keV
- 11 mJ pulse energy
- 2-100 fs pulse duration
- 1 μm focus size
- $10^{19}$ W/cm$^2$

High repetition machine: 600μs 4.5MHz trains @ 10Hz
**SQS experimental hutch**

- Accessible by XFEL staff summer 2017
- Radiation shielded
- Climatized ±0.5 or ±0.1°C
- Chicanes, cable trays, ...

The diagram shows various components within the SQS experimental hutch, including laser rooms, KB mirrors, Diff. vacuum, Diagnostic, Align. laser, Laser incoupling, and Pump room. The control room, Refocusing optics, Time diagnostic, and Beam stop are also indicated on the diagram.
Geometry of the SQS-AQS instrument

KB focusing mirrors

Diff. pumping

F1 focus

F1’ focus

2.715 m

1.715 m

39 cm
## Spectrometers of the SQS-AQS instrument

<table>
<thead>
<tr>
<th>Position</th>
<th>Electron Energy Resolution</th>
<th>Angle Acceptance</th>
<th>Electrons</th>
<th>Ions</th>
<th>Photons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kinetic Energy</td>
<td>Rep. rate</td>
<td></td>
</tr>
<tr>
<td>eTOF</td>
<td>F1</td>
<td>10,000</td>
<td>~0.14% of $4\pi$</td>
<td>Yes</td>
<td>≤5000 eV</td>
</tr>
<tr>
<td>VMI</td>
<td>F1</td>
<td>100</td>
<td>~100% of $4\pi$</td>
<td>Yes</td>
<td>≤1200 eV</td>
</tr>
<tr>
<td>Magnetic bottle</td>
<td>F1’</td>
<td>50</td>
<td>~100% of $4\pi$</td>
<td>Yes</td>
<td>≤300 eV</td>
</tr>
<tr>
<td>XUV spectrometer</td>
<td>F1’</td>
<td>-</td>
<td>-</td>
<td>No</td>
<td>-</td>
</tr>
</tbody>
</table>

**Images:**
- [Image of F1 and F1’](#)
- [Image of FEL](#)
- [Image of European XFEL](#)
**Electron time-of-flight spectrometer(s)**

- #1: commissioned at PETRA PO4, Aug 2016
- #2-3 in production, ready summer 2017
- #4-6, ready Dec 2017
- Retardation ≤ 5 keV
- Mu-metal or Helmholtz coils

### eTOF specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>400mm</td>
</tr>
<tr>
<td>Detector</td>
<td>Hamamatsu, MCP, diam. 27mm, single anode</td>
</tr>
<tr>
<td>Readout</td>
<td>Digitizer 3GHz 10GS/s 14bit</td>
</tr>
<tr>
<td>Acceptance</td>
<td>0.14% of $4\pi$</td>
</tr>
</tbody>
</table>

6mm aperture

38mm
Electron time-of-flight spectrometer(s)

Vibrational resolution in 1s emission from molecules

Good transmission at low energy
Velocity Map Imaging spectrometer

- Designed by S.Deinert, T.Mazza, I.Schevchuk, ready Sept 2017
- Molecular jet (Y.O.) ready to be commissioned
- Energy $\leq 500$ eV (mode1), $\leq 1200$ eV (mode2)
- Resolution $\Delta E/E$ now 3%, aiming for 1%
- Detector: Phosphor-CMOS 10 Hz or Delay-line 4.5 MHz
- Spectroscopy or coincidence possible
- Can run in parallel with the vertical
Velocity Map Imaging spectrometer

- Prototype commissioned at PETRA PO4, May 2016

Ar 2p photoelectrons, $E \leq 30$ eV

Ar 2p Auger, $E \leq 200$ eV
Magnetic bottle spectrometer

- In-kind contribution from R. Feifel, Gothenburg
- Commissioning aimed for late 2017
- $4\pi$ sr acceptance, ≥95% collection up to 300 eV, Resolution $\Delta E/E \sim 2\%$
- Electrons-ions or electrons-electrons coincidence possible
- Rep. rate $\leq 120 \text{ kHz}$ (electrons only), $\leq 20 \text{ kHz}$ (electrons + ions)
- “Tried-and-tested” at many facilities (FERMI, LCLC, FLASH, SACLA, SOLEIL, …)

Eland and Feifel *Chemical Physics* 327 85 (2006)
1D-imaging XUV spectrometer

In-kind contribution from J.E. Rubensson, Uppsala

Please see next talk
Fast DAQ

- Our unique time pattern, 600 µs @4.5MHz @10Hz is a blessing, but it’s also a challenge!
- 4.5MHz SASE beam rules out “counting” electronics
- Solution: most DAQ based on fast digitizers + FPGA embedded algorithm
  - SPDevices ADC7, 14 bit, 3GHz, 10GS/s
AQS support: bottom

- Designed by Y. Ovcharenko with Newport, here now, users ready summer 2017.
- Stable steel welded structure
- Tripod uncoupled system for leveling Z vertical axis motion, a longitudinal X and lateral Y motion, 2 rotation axis Theta (X, Z) and 1 rotation axis Theta Y.

<table>
<thead>
<tr>
<th></th>
<th>Range</th>
<th>Resolution</th>
<th>Repeatability</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel X, Y</td>
<td>≤100 mm</td>
<td>≤ 1μm</td>
<td>≤ 5 μm</td>
<td>≤ 2 mm/s</td>
</tr>
<tr>
<td>Travel Z</td>
<td>≤150 mm</td>
<td>≤ 1μm</td>
<td>≤ 5 μm</td>
<td>≤ 0.2 mm/s</td>
</tr>
<tr>
<td>Rx Ry</td>
<td>≤ 2°</td>
<td>≤ 1m°</td>
<td>≤ 5 m°</td>
<td>≤ 0.01 m°/s</td>
</tr>
<tr>
<td>Rz</td>
<td>≤ 2°</td>
<td>≤ 1m°</td>
<td>≤ 5 m°</td>
<td>≤ 0.01 m°/s</td>
</tr>
</tbody>
</table>

- Payload ≤1500 kg
- Foot print: ≤ 2100 x 1500 x 350 mm
AQS support: intermediate

- Designed by Y. Ovcharenko with Newport, due here Jan 2017, users ready summer 2017.
- Solid aluminium, welded
- ANSYS FEA analysis combined with real hall measurement: extent of vibrations can be tolerated
AQS schedule

- Jan 2017: AQS vacuum tank will arrive has arrived
- Feb 2017: AQS mech. support arrives in Schenefeld
- March 2017: AQS non magnetic turbomolecular pumps arrive
- July 2017: Experimental hutch handed to us
- Aug 2017: eTOF #1-3 (dipole plane) ready
- Sept 2017: Hutch infrastructure ready
- Aug 2017: Diagnostic users’ ready
- Sept 2017: VMI users’ ready
- Dec 2017: eTOF #4-6 (non-dipole plane) ready
- Late 2017: MBES users’ ready
- Late 2017: sublimation oven
- Early 2018: Wavefront sensor
- Early 2018 commissioning with beam
- Spring 2018 users’ beamtime, TBC
Thank you for attention

The SQS team


- XFEL Advance Electronics
  - P. Gessler, N. Coppola, H. Sotoudi Namin

- XFEL Control & Analysis
  - D. Goeries, A. Parenti

- DESY, spectrometers commissioning
  - J. Viefhaus, J. Buck, G. Hartmann

- Uppsala, XUV spectrometer in-kind contribution
  - J. E. Rubensson, J. Nordgren

- Gothenburg, MBES spectrometer in-kind contribution
  - R. Feifel, R. Squibb

European XFEL