# The experimental challenges at TTF 1

In collaboration with: Polish Academy of Sciences; University of Białystok
Institute of Nuclear Physics, Cracow; University of Mining and Metallurgy, Cracow;
Warsaw University of Technology; Laboratorio Nacional de Luz Sincrotron, Campinas, Brazil

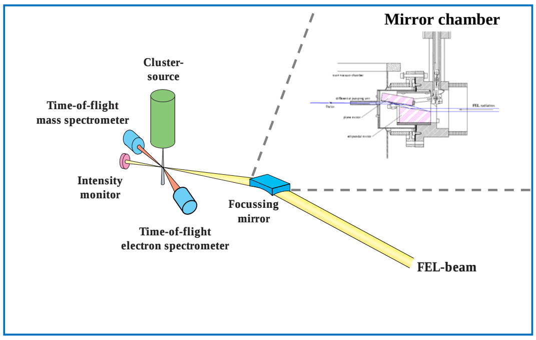
## Motivation

**The TTF1-FEL provides femtosecond light pulses in the VUV spectral range of unprecedented power. The investigation and understanding of the interaction of such intense pulses with matter is of fundamental interest and important for future experiments with FELs and other intense VUV-light sources presently under development.**

**Two different experiments were performed covering a broad field from atomic to condensed matter physics. In a first study the FEL beam was focused on surfaces in order to gain insight into the interaction of intense VUV pulses with matter to derive damage thresholds for optical components. In a second study the absorption and ionisation of atoms, molecules and clusters irradiated by intense FEL pulses are investigated.**

## FEL Cluster experiment

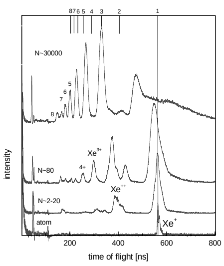
### Experimental set-up



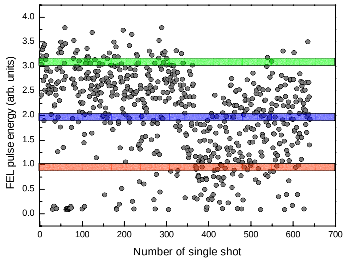

**FEL-Parameters:**
Wavelength: 80-120 nm
Spectral width: 1%
Pulse energy: 30-100 µJ
Pulse duration: 30-100 fs
Repetition rate: 1 Hz
No. of Bunches/train: 1 to 10

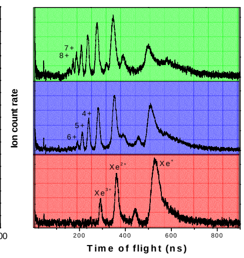
**Optics:**
Source distance: 13 m
Divergence: 260 µrad
Beam incidence: 10 degree
Rad. Diameter at:
Source 250 µm
Focussing mirror 3400 µm
Focal spot 20 µm
Max. $P_{FEL}$: ~ $3x10^{13}$ W/cm²

### Ionisation of Xenon atoms and clusters by VUV-FEL pulses

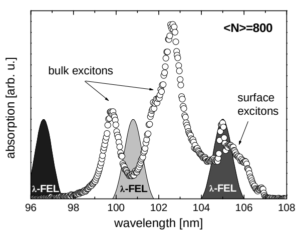


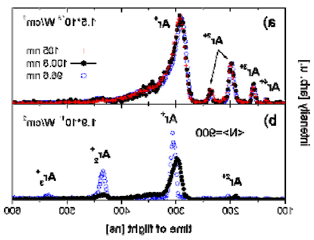

### Pulse energy fluctuations and non-linear power density dependence of ionisation



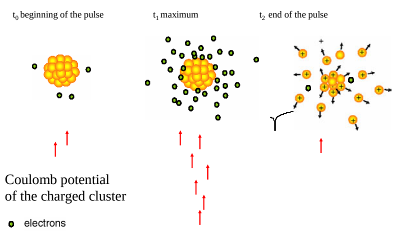




### Spectral tunability of FEL and site selective excitation in Clusters



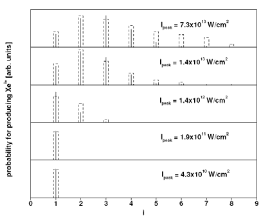



### Coulomb explosion of clusters




### Recent theoretical work on cluster ionization

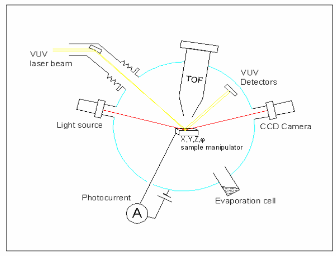
Robin Santra, Chris H. Green, (Boulder), PRL in press



## FEL ablation experiment

Investigation of the damage threshold for optical components

### Experimental set-up




### Estimated damage thresholds after irradiation with focussed beam

| Sample/thickness | | damage threshold [J/ cm²] |
|---|---|---|
| Cu | bulk | 0.5 |
| Au | 10 nm | 0.04 |
| Si | bulk | 0.03 |
| Graphite | 40 nm | 0.06 |
| YAG | bulk | 0.07 |

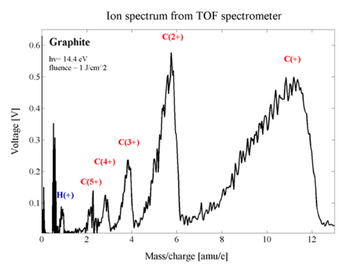
**Mirrors will survive!**

**Damage thresholds 50-100 times higher than needed (13 eV)**

## Summary

**Femtosecond pulses from the TTF1-FEL allow a first study of the interaction of VUV radiation at a Gigawatt level with matter.**
**Rare gas clusters irradiated by focussed FEL radiation become multiply ionized and disintegrate by Coulomb explosion into highly charged atomic ions. The underlying ionization and absorption mechanisms differ substantially from that observed with optical lasers. Further, the spectral tunability of the FEL allowed for site selective excitation of the clusters. The absorption is almost independent of the specific electronic structure above a power density of ~$10^{12}$W/cm².**
**In an ablation experiment, different optically important samples were investigated. The damage thresholds were found to be almost 100 times higher than that needed for beam transportation in TTF2.**

**References: H. Wabnitz et al., Nature 420, 482 (2002)**
**B. Steeg, S. Jacobi, R. Sobiraski, C. Michaelsen, J. Feldhaus Free Electron Lasers 2002, II-31, K.J. Kim and S. Milton (eds) Elsevier 2003**
**T. Laarmann et al. submitted to PRL (2003)**




responsible author:
Thomas Möller, DESY
thomas.moeller@desy.de, Oct 2003