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XPP: X-ray Pump Probe station at BESSY II

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Abstract: The X-ray Pump-Probe (XPP) experimental station predominantly aims at investigating hard and soft matter under a broad range of ambient conditions using time-resolved X-ray diffraction.

1 Introduction

The X-ray Pump-Probe (XPP) experimental station is dedicated to time-resolved material research of solid-state and soft condensed matter systems. The station utilizes a fiber-based femtosecond laser systems that yields optical pulses of 250 fs duration and 10 μJ pulse energy at variable repetition rates of up to 1.25 MHz. The sample environment comprises an in-vacuum 4-circle diffractometer with cryostat for cooling down to 20 K. Diffracted X-ray photons are detected with a hybrid pixel area detector allowing for ultrafast reciprocal space mapping.
Optical pump light and the X-ray probe pulses enter the vacuum chamber on quasi collinear beam paths. The goniometer axes allow for scanning of a large reciprocal space volume while preserving the illuminated pump area on the sample surface. Hence, several in-plane and out-of-plane diffraction peaks can be measured under comparable optical pump conditions.

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The setup is specifically optimized for experiments at high laser repetition rates where fast heat removal from the excited samples is required. Two cooling options are provided:

1. The sample holder is connected to a 4 K cryostat via flexible copper wires. While allowing full mechanical flexibility the sample can be cooled down to temperatures of less than 20 K without laser excitation. Exciting the sample with the high repetition laser system leads to a typical static temperature increase of up to 100 K depending on laser power and sample heat conduction.
2. At ambient pressure the excited sample surface can be directly cooled with a cold nitrogen jet. The temperature range of the coolant extends from room temperature to 90 K. This configuration can either be used for efficient heat removal from the excited sample surface or for real cooling to cryogenic temperatures.

Samples are excited by ultrafast optical pulses emitted from an ytterbium-doped fiber laser. Laser parameters are listed in Table 1. Alternative excitation concepts are currently developed, e.g., sample excitation with ultrashort current or voltage pulses. The XPP-station is fully operational since April 2015.

2 Instrument application

- Thermal transport in nanoscale systems
- Coherent lattice dynamics
- Electronic and magnetic coupling to the crystal structure in multiferroic systems
- Phase transitions and phase change materials
- New methods for time-resolved XRD

3 Technical data

The laser source is a multi-stage ytterbium-doped oscillator - amplifier system (Impulse, Clark-MXR). It is synchronized to the RF-signal of the storage ring with accuracy better than 5 ps. The main laser parameters are:

Repetition Rate	Adjustable by user from 200 kHz to 25 MHz
Pulse Energy	Adjustable by user: 0.8 µJ @ f_{rep} > 2 MHz < 25 MHz 10 µJ @ f_{rep} < 2 MHz
Average Output Power	Adjustable by user: max. 10 W f_{rep} = 2 MHz typical operation: 2 W f_{rep} = 208 kHz
Pulse Duration	250 fs
Center Wavelength	1030 nm
Pump probe delay	up to 5 µs f_{rep} = 208 kHz with 4 ps resolution

Table 1: Specification of the excitation laser.

Specifications of the Beamline and of the sample environment are listed in Table 2. The diffractometer in the vacuum vessel is shown in Figure 1.

Monochromator	U41-FSGM
Experiment in vacuum	Yes
Temperature range	<20 K to room temperature
Detector	• Dectris, Pilatus 100k hybrid pixel area detector • Home-build fast scintillator (trise < 1 ns) + time-correlated SPC • CyberStar Scintillator Detector • Energy dispersive detector: (XFlash, Roentec; ΔE/E ≈ 170 eV @8 keV)
Manipulators	Diffractometer layout: 3 sample circles: Circle — With Cryostat — Without Cryostat ω — -3° - 33° — 0° - 90° φ — -10° - 100° — 0° - 360° χ — 0° - 180° — 0° - 180° 1 detector circle (Θ): 0° - 110° x-y-z- translation for sample positioning adjustment of optical pump - X-ray probe overlap via transversal positioning of focusing lens

Table 2: Specification of the sample environment.

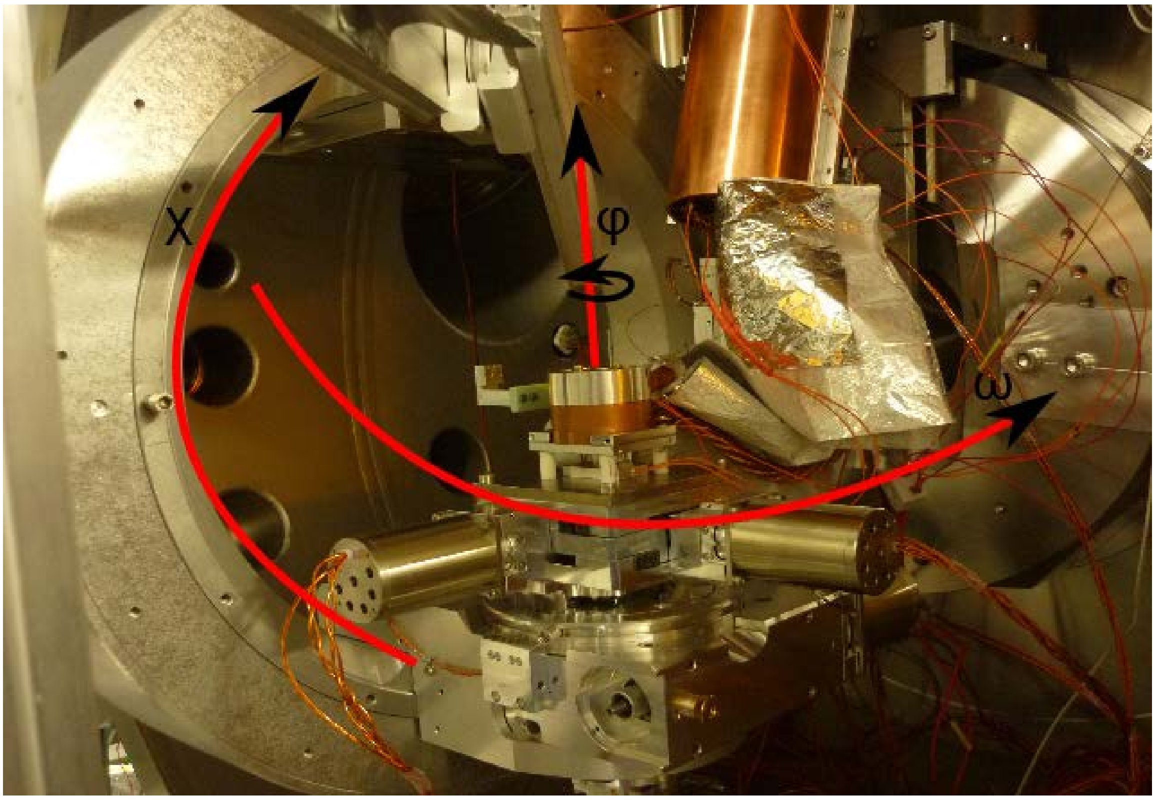

Figure 1: Diffractometer in the vacuum vessel.

References

Gaal, P., Schick, D., Herzog, M., Bojahr, A., Shayduk, R., Goldshteyn, J., … Bargheer, M. (2012). Time-domain sampling of x-ray pulses using an ultrafast sample response. *Applied Physics Letters*, *101*(24), 243106. http://dx.doi.org/10.1063/1.4769828

Gaal, P., Schick, D., Herzog, M., Bojahr, A., Shayduk, R., Goldshteyn, J., … Bargheer, M. (2014). Ultrafast switching of hard X-rays. *Journal of Synchrotron Radiation*, *21*(2), 380–385. http://dx.doi.org/10.1107/S1600577513031949

Herzog, M., Bojahr, A., Goldshteyn, J., Leitenberger, W., Vrejoiu, I., Khakhulin, D., … Bargheer, M. (2012). Detecting optically synthesized quasi-monochromatic sub-terahertz phonon wavepackets by ultrafast X-ray diffraction. *Applied Physics Letters*, *100*(9), 094101. http://dx.doi.org/10.1063/1.3688492

Navirian, H. A., Schick, D., Gaal, P., Leitenberger, W., Shayduk, R., & Bargheer, M. (2014). Thermoelastic study of nanolayered structures using time-resolved X-ray diffraction at high repetition rate. *Applied Physics Letters*, *104*(2), 021906. http://dx.doi.org/10.1063/1.4861873

Shayduk, R., Herzog, M., Bojahr, A., Schick, D., Gaal, P., Leitenberger, W., … Bargheer, M. (2013). Direct time-domain sampling of subterahertz coherent acoustic phonon spectra in $SrTiO_3$ using ultrafast X-ray diffraction. *Physical Review B*, *87*, 184301. http://dx.doi.org/10.1103/PhysRevB.87.184301

Shayduk, R., Navirian, H., Leitenberger, W., Goldshteyn, J., Vrejoiu, I., Weinelt, M., … Bargheer, M. (2011). Nanoscale heat transport studied by high-resolution time-resolved X-ray diffraction. *New Journal of Physics*, *13*(9), 093032.