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Sub-100ps Magnetic Imaging at the PolLux Endstation of the Swiss Light Source

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Pump-probe x-ray microscopy is a powerful investigation technique in condensed matter research. Time-resolved x-ray microscopy allows for the investigation of dynamical processes with a combination of high spatial and temporal resolutions. One of the main applications of such technique is time-resolved imaging of magnetodynamical processes, such as e.g. gyration dynamics of topological objects [1], domain wall and skyrmion motion [2], and spin wave generation and propagation [3,4].

Various synchrotron-based techniques can be employed for time-resolved x-ray imaging. These techniques exploit the x-ray pulses generated by synchrotron light sources (pulse widths on the order of 50-100 ps for third generation synchrotron light sources) as the probing signal, while the pumping signals are typically either electrical or optical excitations, obtained e.g. through the injection of a fast current pulse across the sample, or by illuminating the sample with a fast laser pulse. One of such techniques, particularly suited for pump-probe imaging, is scanning transmission x-ray microscopy (STXM). STXM is a transmission microscopy technique that measures the transmission of a focused x-ray beam (achieved through the use of a Fresnel zone plate) across an x-ray transparent sample with a suitable detector. By scanning the sample with a piezoelectric stage and recording the transmitted x-ray intensity at each point of the scan, an image can then be obtained. Monochromatic x-rays enable element-specific imaging and the magnetic configuration of magnetic materials can be investigated by employing circularly polarized x-rays, exploiting the x-ray magnetic circular dichroism (XMCD) effect.

Typical detectors employed in STXM imaging include photomultiplier tubes and avalanche photodiodes (APD). APDs are particularly interesting for time-resolved imaging, as these diodes are capable of single-photon x-ray detection with response times faster than the bunch rate of the synchrotron light source, which is on the order of 100-500 MHz. The fast response of APD detectors, combined with their ability for single photon detection, can then be employed to resolve the time structure of the multibunch filling pattern of the synchrotron light source, providing two important advantages over "standard" synchrotron based pump-probe techniques: the entire filling pattern can be employed for the time-resolved measurements, resulting in much shorter measurement times, and the repetition rate of the pump-probe measurement is no longer locked to the repetition rate of the camshaft bunch employed for the standard pump-probe measurements (i.e. to the ring repetition period, on the order of 1 μs).

To be able to take advantage of the fast response time of APD detectors, dedicated read-out and data processing electronics, which read-out the signal from the APD and distribute it into distinct channels based on the x-ray photon arrival time, need to be employed. Furthermore, such electronics are also required for the generation of the reference and triggering signals synchronized to the x-ray flashes generated by the synchrotron light source. These signals are necessary for the correct synchronization of the electronics employed for the excitation of the sample. Such setups are typically based on field-programmable gate arrays (FPGA) combined with fast analog to digital (ADC) converters. One of such setups, based on a Xilinx Virtex-II Pro FPGA [5], has been developed and installed at the PolLux (X07DA) STXM endstation of the Swiss Light Source [6], where time-resolved magnetic imaging with

500 ps temporal resolution has been demonstrated [5].

Here, we present an upgraded setup developed for the sub-100 ps time-resolved STXM imaging of dynamical processes based on the setup described in Ref. [5]. In particular, in comparison to the setup described in Ref. [5], the FPGA has been substituted with a Xilinx Virtex-6T FPGA, and the ADC has been replaced with a 2 GSa/s IoXos ADC 3112 based on a Texas Instruments ADS 5409. With upgrades in both the hardware and software of this setup, allowing both for the reduction of the jitter between the timing signals and the master clock of the synchrotron light source, and for an increase in the number of available time channels, time-resolved STXM imaging of magnetization dynamics excited by a 6 GHz oscillating magnetic field has recently been shown, with a demonstrated temporal resolution on the order of 50 ps.

The IoXos 3112 ADC operates at a sampling frequency of 2 GSa/s, four times higher than the 500 MHz bunch rate available at the Swiss Light Source. This high sampling rate ADC is aimed at a future upgrade of the data acquisition process, which will probe the APD signal at 1 GSa/s, allowing for the measurement of the baseline in-between two consecutive x-ray flashes. By subtracting the baseline from the measured signal, an improvement of the signal-to-noise ratio of the measurements is expected. Furthermore, a two-threshold protocol, aimed at the improvement of the acquired signal, is currently being implemented, which will allow for the recognition (and exclusion) of two-photon events, and when higher order photons are detected.

In conclusion, we presented an upgrade of the FPGA-based time-resolved APD read-out and data acquisition setup installed at the PolLux endstation of the Swiss Light Source. With this setup, the available temporal resolution for time-resolved pump-probe imaging has been increased, to allow the imaging of dynamical processes up to frequencies of 6 GHz. [7]

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