Application Note: Model IMPULSE™ PhaseShifter Installation at BESSY

Synchronizing sub-250 fs laser pulses in both frequency and phase

A new beamline was required at BESSY to enable ultrafast X-ray diffraction and absorption experiments using pump-probe techniques. To achieve the required picosecond timescale, it was necessary to acquire a commercial high-power femtosecond laser, with high MHz repetition rate that could synchronize with the X-ray synchrotron beam.

The ideal laser for this application is the IMPULSE™ "PhaseShifter" designed and manufactured by Clark-MXR, Inc. The IMPULSE™ is an all-diode-pumped, direct-diode-pumped, Yb-doped fiber oscillator/amplifier laser system. It is capable of producing variable pulse energies up to 10 μJ at user-adjustable repetition rates between 200 kHz and 25 MHz. With 20 watts average power output at 2 MHz, IMPULSE™ offers more than an order-of-magnitude higher power than has traditionally been available in a one-box ultrashort pulse laser design.

Figure 1. Clark-MXR Model IMPULSE™ PhaseShifter

The electronics of IMPULSE™ were used to synchronize its optical pulse train to the X-ray synchrotron pulse train at a repetition rate of 1.25 MHz with a temporal jitter that is detector-limited to less than one picosecond (figure 1). The time of arrival of the two pulse trains at a target can be shifted electronically with respect to each other.

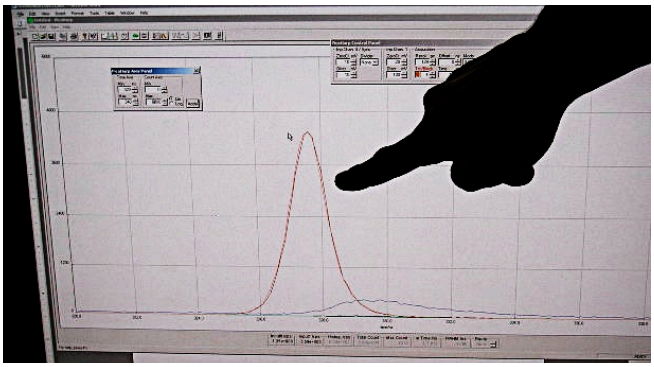

Figure 2. Electronic synchronization: optical pulse train in red and X-ray synchrotron pulse train in blue

The pulses at BESSY have different time structures, and are produced either in single bunch, hybrid or low alpha mode, as shown in Figure 3.

The pulses at BESSY have different time structures, and are produced either in the single bunch, hybrid or low alpha mode. Using the trigger signal of approximately 500 MHz from BESSY, the output of IMPULSE™ was synchronized to the single pulse of the single bunch mode, running at a repetition rate of 1.25 MHz.

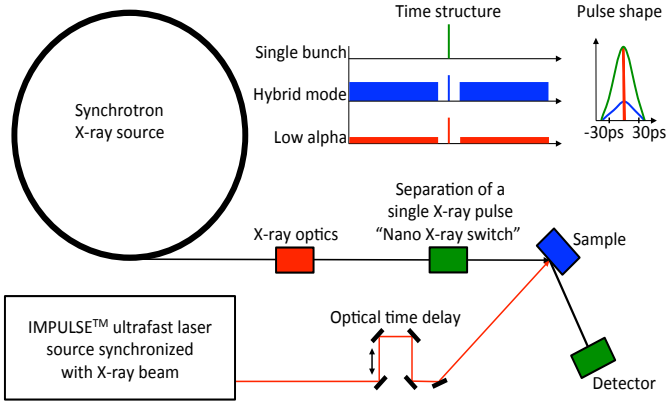

Figure 3. Different X-ray pulse modes at BESSY

X-ray pulses from BESSY and optical pulses from IMPULSE™ are detected using a plastic scintillator and a photomultiplier. The scintillator produces a small flash of light when an X-ray pulse passes through it. The photomultiplier detects this flash of light and turns it into an electrical signal. The photo-multiplier also detects the pulse from IMPULSE™, so the user simply sends a very small amount of a pulse from IMPULSE™ into the photomultiplier along with the X-ray pulse from the synchrotron. The pulses from the laser have a width of around 220 fs, while the X-ray pulses have a width of about 10 ps. Both appear similar in length due to the limited temporal resolution of the detector.

The integration of IMPULSE™ with the X-ray synchrotron has two key features. Firstly, the laser is locked to a harmonic of the BESSY reference X-ray: f(ref)=n*f(rep). In addition, an arbitrary offset frequency (or phase) between the laser beam and the reference X-ray beam enables asynchronous optical sampling. This is beneficial for experiments as it permits high-speed scanning over a given time delay electronically without a mechanical delay line.

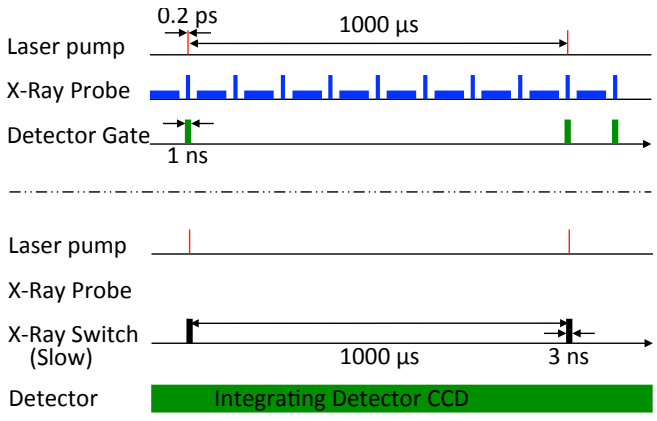

Figure 4. Conventional method of pumping with kHz repetition rate. Only 0.1% of X-ray pulses can be used.

The charts in Figure x and Figure y highlight the true advantage of using the high repetition rate IMPULSE™ laser by showing a comparison between the conventional slow kHz and the fast MHz detection schemes. The synchrotron produces X-ray pulses at 1 MHz. Using the conventional slow kHz laser, only every 1/1000th of the X-ray pulses can be used.

With the IMPULSE™ running at MHz repetition rates, every X-ray pulse can be used.

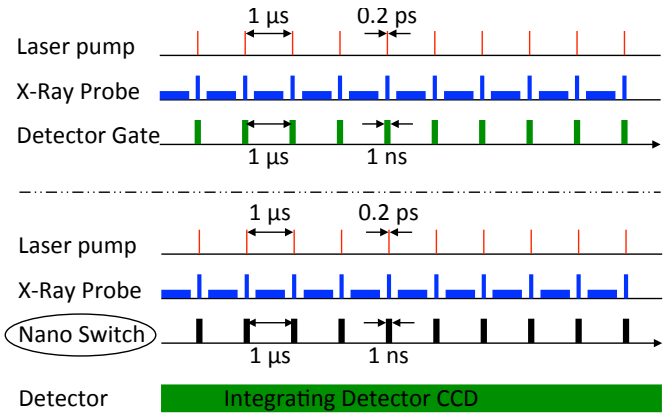

Figure 5. Fast Scheme: Pumping with MHz repetition rate. Every X-ray pulse can be used.

IMPULSE™ represents a new laser design delivering ultra short pulses (<< 1ps) with high average power (20W) and a very flexible repetition rate all in one box. Fiber technology enables the system to be stable and require little to no intervention in typical beam line environments. The option for stable synchronization to external sources enables new beam lines like the one at BESSY to perform ultrafast X-Ray diffraction and absorption investigations using pump/probe techniques on the sub-picosecond time scales. Observations of structural changes of materials using X-ray diffraction, absorption, reflectometry, and scattering is one of the motivations for this new beam line.

Please contact us at sales@cmxr.com to learn more about the Model IMPULSE™ Yb-doped fiber oscillator/amplifier and the PhaseShifter version of Model IMPULSE™

References:

Synchrotron-based ultrafast x-ray diffraction at high repetition rates. H. Navirian, R. Shayduk, W. Leitenberger, J. Goldshteyn, P. Gaal, and M. Bargheer. Rev. Sci. Inst. **83**, 063303 (2012)

Clark-MXR, Inc.
clark-mxr.com

Clark-MXR, Inc.

7300 West Huron River Dr.

Dexter, MI 48130 USA

Phone: 001-734-426-2803 Fax: 001-734-426-6288