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TMO - A NEW SOFT X-RAY BEAMLINE AT LCLS II*

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Abstract

LCLS is building 4 new soft X-ray beamlines with the LCLS-II upgrade. The TMO (Time resolved Molecular Optical science) beamline aka NEH 1.1 will support many experimental techniques not currently available at LCLS. The beamline hinges around 2 main end stations, LAMP a multi configurable end station and DREAM, dedicated to COLTRIM type of experimentation. Both the existing LAMP as well as the newly built DREAM end-station will be configured to take full advantage of both the high per pulse energy from the copper accelerator (120 Hz) as well as high average intensity and high repetition rate (up to 100 kHz) from the superconducting accelerator. Each end station will have its own focusing optic systems (KB Mirrors) which can focus the beam down to 300 nm, and have laser pump probe experiments capability. Very demanding requirements for IR and X-ray overlap as well as beam stability, make the TMO beamline a major engineering challenge. The main components of the beamline (KB optics, DREAM end stations and diagnostics components) are built on granite stands. The building structure is being reviewed for thermal stability. First light on TMO is expected in February 2020.

SCIENCE DRIVERS

TMO stands for Time resolved Molecular Optical science instrument

LCLS-II will be a transformative tool for energy science, qualitatively changing the way that X-ray imaging, scattering and spectroscopy can be used to study how natural and artificial systems function. It will enable new ways to capture rare chemical events, characterize fluctuating heterogeneous complexes, and reveal quantum phenomena in matter, using nonlinear, multidimensional and coherent X-ray techniques that are possible only with X-ray lasers. This facility will operate in a soft X-ray range (250 eV to 1.5 keV), and will use seeding technologies to provide fully coherent X-rays in a uniformly spaced series of pulses with programmable repetition rate and rapidly tuneable photon energies.

NEH beamline 1.1 aka TMO will support many experimental techniques not currently available at LCLS. High operational efficiency will be achieved through utilization of 2 fixed endstations. Stable beam trajectories will be provided through streamlined X-ray alignment to the fixed interaction points. Delivering the beam to only a few fixed locations will optimize optical laser experiments and setups.

END STATIONS

The beamline hinges around 2 main end stations; LAMP a multi configurable end station and DREAM, dedicated to COLTRIM type experimentation.

Both the existing LAMP as well as the newly built DREAM end-station will be configured to take full advantage of both the high per pulse energy from the copper accelerator (120 Hz) as well as high average intensity and high repetition rate (up to 100 kHz) from the superconducting accelerator.

The new DREAM endstation will house a well-defined geometry and COLTRIMS type spectrometer as a standard configuration to accommodate extreme vacuum, sub-micron focus spot size, and target purity requirements dictated by the pump-probe class of coincidence experiments, while ac-cumulating data on the event-by-event basis at the rep rates in excess of 100 kHz fully utilizing the LCLS-II capabilities. Photon fluency in DREAM will reach over 1021 photons/cm2 with superconducting Linac X-rays, while with copper accelerator it will be over 1022 photons/cm2 at 120 Hz.

The LAMP endstation will be part of the Next generation Atomic, Molecular, and Accelerator Science and Technology Experiments (NAMASTE) and it will be optimized for performing high energy, high resolution, time, but also angular-resolved photoelectron spectroscopic measurements. NAMASTE will accept highly standardized modular endstations.

Pump-probe timing resolution of X-ray with optical laser pulses goal is sub 10 fs for both end-stations. Optical laser peak field power density will be over 1015 W/cm2 (of 800 nm) on target.

FOCUSING OPTICS

Each endstation will have its own focusing optic systems (KB Mirrors). The focus size in LAMP will be around 5µ and down to 300 nm in the DREAM end station. Both end station will have laser pump probe experiments capability. The KB mirrors will be used in “series”. The focal point of the first set of mirrors for the LAMP end station being used as the source point for the second set of KB mirrors for the DREAM endstation. Only the first set of KB mirrors will be bendable to adjust focus in either endstation.

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BEAMS STABILITY AND OVERLAP

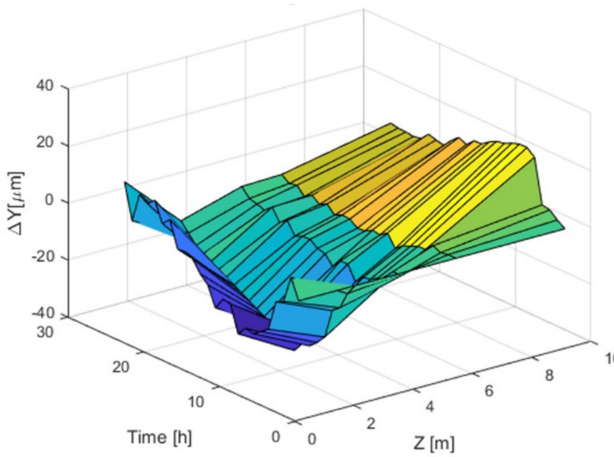

Figure 1: Floor motion measurements.

Very demanding requirements for IR laser and X-ray overlap as well as beam stability, make the TMO beamline a major engineering challenge. In the DREAM endstation we will need to overlap a 300nm X-ray focus to a 5μ IR laser focus. For this reason all the main components of the beamline (KB optics, end stations and diagnostics components) are built on common granite stands.

The thermal stability of the building itself has a direct impact on beam stability. External shifts of temperature have directly been measured as floor deviation in the sub-basement of the building where the beamline is installed. Variations of up to 30μ have been measured on the floor flatness and horizontality. In order to meet our very demanding requirements the part of the building that is directly exposed to climate and solar radiation is being thermally insulated to reduce thermal expansion of the walls.

Figure 1 shows the motion measurements of the hutch floor as a function of day time over a typical 24h period.

VACUUM REQUIREMENTS

The large range of vacuum pressure used in the 2 main end stations requires sophisticated pumping options and numerous differential pumping systems between the essential elements of the beam-line. The LAMP endstation will work at levels of up to 10-5 torr, while the DREAM endstation will continuously work in the low 10-11 torr range as shown in Figure 2 vacuum profile.

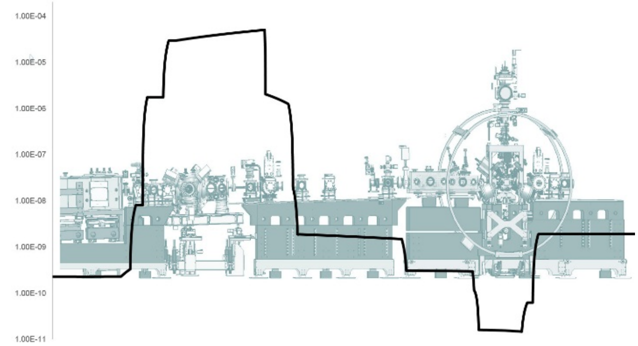

Figure 2: TMO Vacuum profile.

BEAM DIAGNOSTICS DEVICES

A whole battery of diagnostics are installed along the X-ray beam line. These include the following:

-Profile monitors to look at beam profile and position.

-Fluorescence intensity monitors. These will look at the pulse by pulse intensity of the beam by looking at the fluorescence induced by the x-ray beam on the surface of the KB mirrors.

-Wavefront sensors. Each endstation focus spot will be analysed and controlled for quality (astigmatism) and size of the focus. Focus quality and size will very much be driven by the bending and position of the optics.

-Arrival time monitors. These will monitor the synchronization of the IR pumping laser to the X-ray beam to sub 10 fs level.

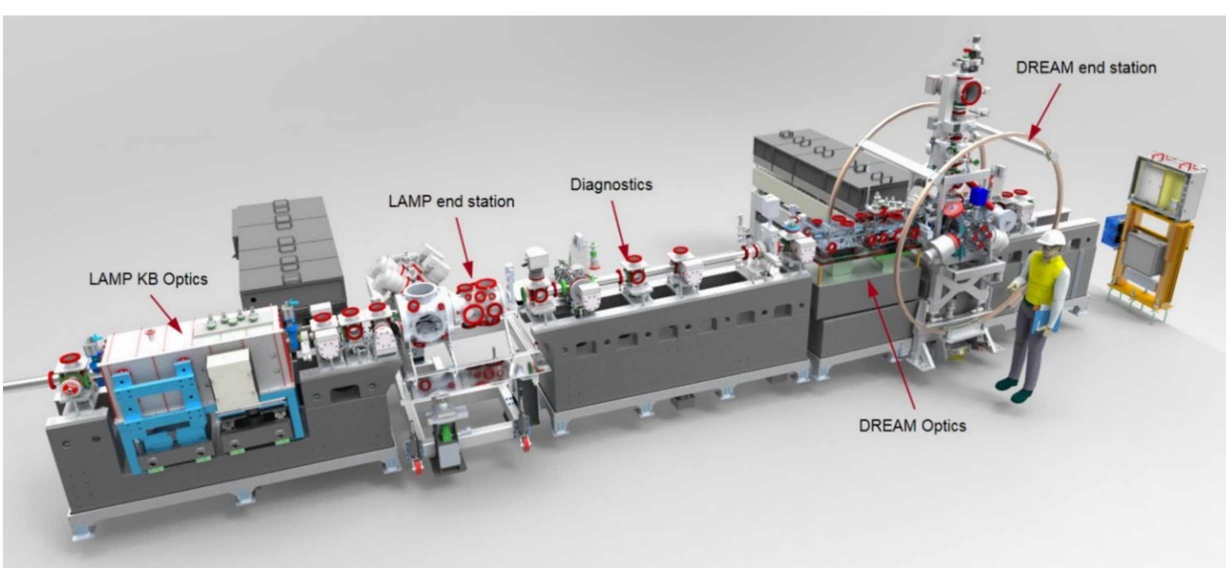

Figure 3: The TMO Beamline in its preliminary design phase.

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BEAM CONTAINMENT

A number of components along the beamline provide for beam containment requirements.

These include the following:

-Solid and gas beam attenuators

-Collimators

-Slits systems

-Beam stoppers

-Safety beam dump for personnel protection

CONCLUSION

The TMO beamline is in its preliminary design phase (see Figure 3) and following a very bold schedule. The high average intensity and high repetition rate capability will open the door to new type of experiments not possible to today. It will be the first beamline of the LCLS II project to take beam. First light is expected in February 2020.

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