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Physics Requirements for the XTOD Total Energy Measurement System

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Brief Summary: This document provides general physics requirements for the XTOD Total Energy Measurement System. The Total Energy Measurement System is located downstream of the Attenuator and provides an accurate, although intrusive, measure of the FEL pulse energy based on the temperature rise produced in a known quantity of matter after interaction with an FEL pulse. This detector will be used during commissioning and operations to accurately measure the FEL pulse energy and to cross-calibrate other detectors.

Change History Log

Rev Number	Revision Date	Sections Affected	Description of Change
000	2006/7/18	All	Initial Version

1. Introduction

The XTOD Total Energy Measurement System will be located in the Front End Enclosure (FEE), downstream of the Attenuator and Spectrometer and upstream of the Direct Imager. The Total Energy Measurement System measures ***u***, the FEL pulse energy, pulse-to-pulse, by measuring the temperature rise in a known quantity of matter after it interacts with an incident FEL pulse.

The System will employ an absorbing material, weakly coupled to a heat sink. When struck by an FEL pulse, sensors monitor the temperature rise and fall in the absorber as the heat (slowly) flows out through the weak thermal link. If the rate of heat loss is low enough, the FEL pulse energy deposited can be found from the net temperature rise of the absorber and its heat capacity.

The absorbing material must be thick enough to absorb substantially all of the FEL pulse energy, yet not suffer damage nor lose sensitivity when absorbing a fully-saturated FEL pulse. As a result, it is an "intrusive" measurement system. Ideally, the entire FEL beam is absorbed in the System.

The choice of absorber could be FEL photon energy dependent. For example, a 1 mm thick Si absorber would work well at 8.265 keV, while a 1 mm thick Be absorber would work well at 826 eV.

The absorber, and the underlying materials, should be made of low-Z materials, thin enough so as not to absorb significant amounts of the spontaneous radiation energy, which could obscure the FEL signal. Additional sensors, located surrounding those centered on the FEL, could be used to estimate the spontaneous contamination in each pulse.

The Total Energy Measurement System will be used during commissioning and operations to accurately measure the FEL pulse energy and to cross-calibrate other detectors, e.g. the Gas Detectors.

2. Fundamental Requirements

2.1. Survivability under FEL Irradiation: Portions of the Total Energy Measurement System will be directly illuminated by the incident FEL beam. These components shall be designed to sustain such irradiation indefinitely without damage, under all relevant FEL conditions.

2.2. Dynamic Range and Sensitivity: The Total Energy Measurement System will provide a beam-pulse-synchronous measurement of ***u***, the total energy in the FEL pulse, for FEL pulse energies between 1 μJ to 10 mJ.

2.2.1. Operation With and Without the Attenuator: The System shall be designed for direct use with pulse energies of up to 2 mJ, without the Attenuator system, or any other attenuation device. However, for use between 2 mJ and 10 mJ, the Attenuator, or another attenuation device, may be used to reduce the incident FEL pulse energy.

2.3. Range of Validity: The range of conditions under which the Total Energy Measurement System output signal is representative of the total energy in the FEL fundamental shall be determined in advance. Relevant determining conditions include: the photon energy and degree-of-saturation of the FEL beam, the average bunch charge of the electron beam, the aperture defined by the Slit System and the setting of the Attenuator. Utilizing this range-of-validity information, perhaps with the aid of the Control System, misinterpretation of the System output signal can be avoided.

2.4. Absolute Accuracy: The absolute accuracy of the total pulse energy measurement must be within ± 10% at 10 mJ and within ± 25% at 10 μJ.

2.4.1. Energy Fraction Absorbed: A fraction of the incident FEL pulse total energy is absorbed in the Total Energy Measurement System. A first-principles knowledge of that absorbed fraction, as a function of FEL photon energy, is essential to determination of the absolute accuracy of the system, and shall be derived.

2.5. Field of View: The system should be sensitive to FEL beam pulses located anywhere within a diameter of 3 mm centered on the ideal FEL beam axis.

2.6. Field of Regard: Means must be provided to remotely reposition the axis of the detector sensitive area to any transverse location within at least ± 5 mm of the survey-defined FEL beam axis.

2.7. Repeatability: At a pulse energy of 200 μJ, individual measurements must be repeatable to within ± 1%, on both a short-term and long-term basis.

2.8. Output Readout Rate: The Total Energy Measurement System shall provide measurements of the total FEL pulse energy for every pulse, at pulse rates up to and including 10 Hz. Operation up to 120 Hz is desirable.

2.9. Stay-Clear Area: The Total Energy Measurement System must be designed such that, when not in operation, it can be remotely commanded into a configuration that does not obstruct radiation within the stay-clear zone defined by the XTOD Fixed-Mask clear aperture.

2.10. Periodic In Situ Recalibration: Periodic examination of the Total Energy Measurement System sensitivity and calibration may be essential. An in situ method shall be developed to accomplish this.

3. Other Requirements

3.1. The Total Energy Measurement System design shall adhere to all elements of PRD 1.5-002, *XTOD Mechanical-Vacuum Systems*.

3.1.1. In particular, the Vacuum System requirements referenced in Section 2.1 and its supporting documents shall be followed. Permitted systems use of only metallic and ceramic materials and generally must avoid the use of elastomers and organic materials.

4. Controls

4.1. The Control System for the Total Energy Measurement System shall be EPICS. The gain settings, clear-aperture configuration and sensor position shall be remotely controllable. The measured value of the total pulse energy in each FEL pulse shall be available as a beam-synchronous EPICS process variable for archival and display purposes, at up to the maximum rate stated above.