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Development of diamond-based diagnostics for next-generation XFELs

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FELs deliver rapid pulses on the femtosecond scale, and high peak intensities that fluctuate strongly on a pulse-to-pulse basis. The fast drift velocity and high radiation tolerance properties of chemical vapor deposition (CVD) diamonds make these crystals a good candidate material for developing a high frame rate pass-through diagnostic for the next generation of XFELs. We report on two diamond based diagnostic systems being developed by a collaboration of a UC campuses and National Laboratories supported by the University of California and the SLAC National Laboratory.

For the first of these diagnostic systems, we have developed a new approach to the readout of diamond diagnostic sensors designed to facilitate operation as a passthrough detection system for high frame-rate XFEL diagnostics. Making use of the X-ray Pump Probe (XPP) beam at the Linac Coherent Light Source (LCLS), the performance of this new diamond sensor system has been characterized and compared to that of a commercially available system. Limits in the magnitude and speed of signal charge collection are explored as a function of the generated electron-hole plasma density and compared to results from a TCAD simulation.

A leading proposal for improving the efficiency of producing longitudinally coherent FEL pulses is the cavity-based X-ray free electron laser (CBFEL). In this configuration, the FEL pulses are recirculated within an X-ray cavity in such a way that the fresh electron bunches interact with the FEL pulses stored in the cavity over multiple passes. This creates a need for diagnostics that can measure the intensity and centroid of the X-ray beam on every pass around the recirculatory path. For the second of these diagnostic systems, we have created a four-channel, position-sensitive pass-through diagnostic system that can measure the intensity and centroid of the circulating beam with a repetition rate in excess of 20 MHz. The diagnostic makes use of a planar diamond sensor thinned to 43 μm to allow for minimal absorption and wave-front distortion of the circulating beam. We also present results on the response and position sensitivity of the diagnostic, again measured using the LCLS XPP beam.

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