High-Energy Density Experiments

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These experiments aim to create and study warmed and hot dense matter using FLASH. The fact that the properties of the warm dense regime are difficult to calculate allows us to have impact with a straightforward experiment. For this kind of very intense radiation details of simple absorption are not easily predicted and several physical models yield results that should be measurably different. Thus we would be able to distinguish between absorption models and provide the first results of in situ measurements of a bulk quantity in the creation of warm dense matter. The various models for the absorption depend on the manner of introducing the production of bound-free transitions from a solid in this regime. The first assumes, as is common in laser-matter interaction simulations, that any conduction band electrons are essential free so that the relevant absorption processes can be described by free-free bremsstrahlung, which does not provide the 'correct' answer (i.e., the cold material absorption) in the low intensity irradiation regime, the other methods depend on detailed ionization mechanisms and population kinetics to describe the absorption. As the intensity is varied, the different models become applicable and absorption first peaks and then falls. We plan to investigate these relative changes of absorption as a function of incident intensity.

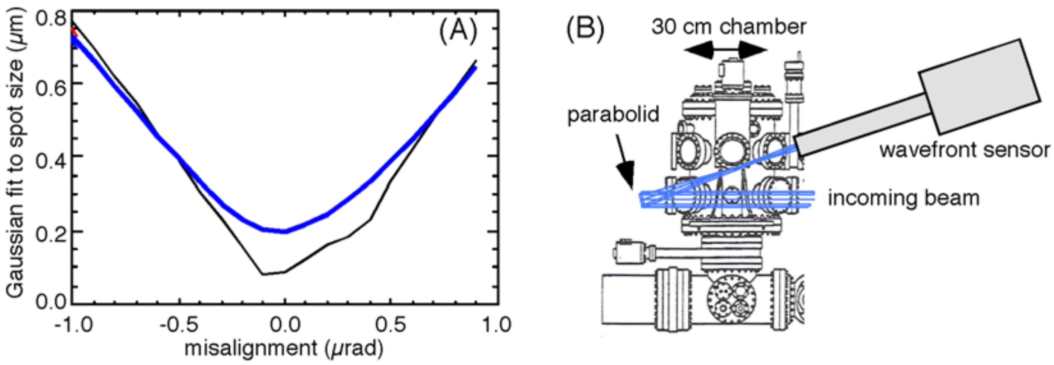

Figure 1: (A) Alignment tolerance for the tip of the optic, the tilt is similar. The thin line is based on geometrical optics, and the thick line includes dfffraction. (B) The Conceptual design of the UHV chamber the optic is mounted in a flange located 25 cm from chamber center.

To create warm or hot dense matter conditions we need to focus the FEL beam to an area two orders of magnitude smaller than for the nominal 20 microns at BL2. In an initial experiment in Nov 2005 we used 3 shifts to test if a 4-mirror optics provided by P. Zeitoun and built by Winlight, France could be used for the purpose of refocusing the FEL beam on BL2. Simulations indicated that the Winlight optic could reach a 2 micron focal spot, which was confirmed on previous bench tests. Alignment of the optics and determination of the focal spot size were to be achieved using a wavefront sensor, built by Imagine-Optic and fielded by P. Zeitoun in the framework of the EU IA-SFS program, which is a diagnostic tool for the FLASH beamlines.

The results of the tests showed that, due to several factors - the amplification of misalignment errors, the extreme sensitivity of the refocusing optic and enhanced beam movements behind the two employed optical elements - alignment using the wavefront sensor was not possible. As a result of this it was decided that we would use single optical elements to achieve both higher stability and ease the alignment procedure. However, the wavefront sensor remained the best tool to determine the spatial distribution of the focal spot.

A second experiment at BL3 employed a a multilayer-coated nearly back reflecting parabolic mirror designed to work at nominal 13.5 nm of FLASH and will have a 2 micron focus at 25 cm. The optic takes the incoming 5 mm beam and the focus will be moved out of the horizontal plane by 10 cm, which allows easier observational access to the sample surface. The focusing properties of paraboloid are show in Fig. 1 together with the general arrangement. Given the experience from the first beam time a new chamber capable of UHV operation was prepared. The chamber includes a target stage with x, y, z, rotation and a target holder for transmission for automated translations. The focusing optic stage with x, y, z, and tilt angle are also included. Next, we employed BL3, which allowed us to mount a multilayer-coated large-angle parabolic mirror inside the chamber. The samples were again relatively thin, defined as a few attenuation lengths at 13.5 nm, composed of low to mid-Z single elements or simple compounds. After consideration of the ease of fabrication and the relative rates of the surface contamination we choose to use 50 nm and 100 nm thick samples of Si_3N_4. The sample surfaces will be monitored *in situ*.

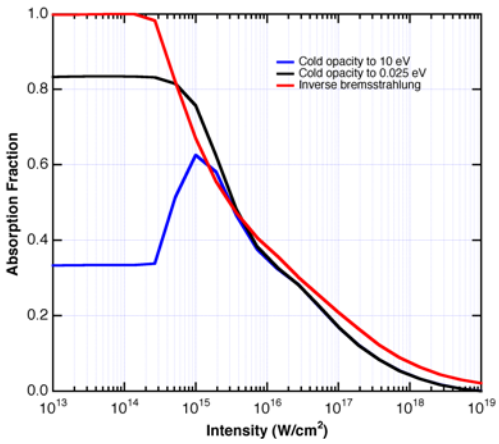

Figure 2: The Intensity of the focused FLASH source versus the absorption from a 50 nm Si_3N_4 sample.

There are three goals for the experiment. First, the measurement of the focusing of the parabolic multilayer mirror with the wave front sensor was to be used to determine the quality of the focal spot and compared to the calculation. This is first step toward achieving a strategy for obtaining high intensity VUV radiation on a sample. Second, we measure the coupling of the VUV heating source to the sample, thus obtaining, for the first time, data on sub-ps volumetrically heated heated warm and hot dense matter. This would provide initial data for calibrating the theories on the interaction of intense VUV radiation with HED matter. The absorption of the samples versus intensity is show in Fig. 2. There are three models which describe the warm dense region, i.e., the region below 10 eV, on the intensity plot. The three models cover a range of possible absorption mechanisms for the poorly understood warm dense matter region. These models are schematic and experimental data is required to distinguish amongst them and provide guidance for theoretical development. Third, we will measure emission spectra from the heated samples in the XUV range. This will provide critical information on the details of the population kinetics process in the HED matter.

These are the initial efforts for studying the HED phase space at FLASH as well as future x-ray FELs. For FLASH, we have designed, fabricated, and bench tested an optic to focus the beam to 1 micron spots, constructed the precision optics alignment stage, constructed a UHV chamber, FEL intensity transmission, reflection and scattering monitors, spectrometers and sample alignment. The equipment was employed in November and will again be implemented and improved for scheduled beam time in March.

We must also acknowledgment other support for these experiments. The calculation of the sample response to intensity FEL irradiation have been performed by several researcher at LLNL – S. Moon, H.K.-Chung, and H. Scott – and Uppsala University - M. Bergh. Further, support for instrumentation has come from J. Hajdu of Uppsala University, R. Falcone of UC Berkeley, and J. Hastings of SLAC.