DCS Laser Shock Capabilities for Run 2023-1

UV Drive Laser Capabilities

1) The pulse energy on target is expected to be 80 J for the both the 5 ns and 10 ns pulses.

2) Standard pulse shapes are listed in the table below. All but 'Pulse Shape #4' are designed to hold a constant stress in a Kapton ablator for a given duration and stress level. To accommodate non-standard pulse shapes (even if used in previous runs), initiate the request to your DCS point-of contact at least 2-months in advance.

Standard DCS laser pulse shapes	
Pulse Shape	**Description**
10 ns Flat - T100, T90, T80, T70	Flat 10ns UV Output at Rod Transmissions of 100%, 90%, 80%, and 70%
10 ns Down - T100, T90, T80, T70	Slightly down-ramped UV output after initial 100% step, to maintain constant stress in Kapton below ~1.25 TW/cm2, Rod Transmissions of 100%, 90%, 80%, and 70%
5ns Flat - T100, T90	Flat 5ns UV Output at Rod Transmissions of 100%, 90%
Pulse Shape #4	15 ns duration, ramp (13 ns) and hold (2 ns)

3) The 250 µm DPP continues to be offered. Using the 500 µm DPP and 5 ns pulse, the highest achievable stress in Kapton is approximately 125 GPa. For stresses higher than this, the 250 µm DPP must be used. For shot planning, the intensity of the laser on target is approximately 3.5x brighter with the 250 µm DPP than the 500 µm DPP. It is important to note that our most common interferometry window, LiF, becomes opaque between 200 and 220 GPa. An appropriate alternative window material should be chosen for configurations that would produce >200 GPa in LiF.
   a. The 250 µm DPP requires narrower field-of-view optics for line VISAR than the 1 mm DPP. The 500 µm DPP can work with either configuration. The same is true for VISAR VPFs, but this change is at the user's discretion. Generally, plan for a 1 hour reconfiguration time when changing DPPs, but if you can keep the same magnification and VPFs, it *may* be faster.
   b. We have found that gold mirrors work better than aluminum mirrors for stresses above 180 GPa in LiF. With gold mirrors, we have measured the particle velocity up to 250 GPa in LiF (with extremely low signal level).
   c. To avoid probing areas contaminated by edge waves or by reverberation from the ablator/target interface, typical x-ray probe times are ~1 ns or less (depending on the ablator and target thicknesses, stress, etc.). Please keep these constraints in mind when designing your experiment and ask for assistance from your DCS point-of-contact in selecting target/timing parameters, as needed.

4) For 10 ns and 5 ns-duration flat pulse shapes, on top of the UV attenuation in 10% increments using beamsplitters, we can achieve finer granularity in UV energy selection through attenuation at the Rod amplifier. For 10 ns pulses, we can attenuate an additional factor of 90%, 80%, or 70% on top of the beamsplitter attenuation, and for the 5 ns pulse, we can attenuate by an addition 90% on top of the beamsplitter attenuation. For example, to reach a level of 63% of the total output energy, we could use the 70% transmission attenuator and 90% rod attenuation. The increments are limited to these options because each setting requires a new input pulse shape to achieve the flat UV output. Thus, arbitrary adjustment is not currently offered. If an intermediate level is desired, please discuss this with your DCS point-of-contact well in advance of your beamtime.
    a. Please specify the rod attenuation level and UV beamsplitter attenuation separately in the shot matrix, in the respective columns.
    b. To minimize the uncertainty in pulse energy and pulse shape:
        i. Use beamsplitter attenuation in preference to rod attenuation when possible.
        ii. When combining rod attenuation with beamsplitter attenuation, give preference to the beamsplitter for providing the larger portion of the attenuation (e.g, use 70% transmission attenuator + 90% rod attenuation rather than 90% transmission attenuator + 70% rod attenuation).

5) 1 mm Spot Size (1 mm DPP) for 10 ns pulse shape, Attenuators #7-10
    a. For achieving stress levels resulting from the 500 µm spot size with attenuator #2, but with finer stress adjustment, the 1 mm DPP may be used. For guidance on the relative stress levels using the 1 mm DPP vs the 500 µm DPP, see the table below, showing the peak particle velocity at the Kapton/LiF interface, after the shock exits the 75 µm-thick Kapton ablator.
    b. Using attenuator #6 and below with the 1 mm DPP, the wave profile at the Kapton/LiF interface significantly deviates from a flat temporal profile, so these are not offered at this time.
    c. 75 µm Kapton should be used as the ablator for stresses in this range – for both the 1 mm DPP and the 500 µm DPP with attenuator #2. With 50 µm Kapton, the wave profile exiting the Kapton may vary considerably with small changes in the UV pulse energy, and a two-wave structure is often observed. With 75 µm Kapton, a smoother profile develops before exiting ablator.

6) As in previous runs, the 500 µm DPP may be used with the 10 ns pulse shape and attenuators #2-10. It may also be used with the 5 ns pulse shape and attenuators #5-10. Again, a 75 µm Kapton ablator should be used for the 10ns pulse shape with attenuator #2.

Expected Particle Velocities in LiF

To assist with selecting the right configuration for your shots, the table below lists the measured particle velocities of a mirror at a Kapton/LiF interface for targets composed only of Kapton ablators glued to LiF windows. The table is in order of descending velocity for each DPP, beginning with the highest measurable velocity with this sample configuration (at about 250 GPa in the LiF). We have not successfully measured the interface velocity at stresses greater than 250 GPa in the LiF. The configurations producing stresses above this (i.e. the 250µm DPP with > attenuator 8 with 10 ns pulse duration or any configurations with the 250µm DPP and 5 ns pulse duration) are available but have not been characterized through these measurements. Repeated measurements in the table are due to variation in the energy on target.

Phase Plate	Attenuator (#)	Pulse Duration (ns)	Kapton Thickness (µm)	Energy On Target (J)	Peak Particle Velocity at Kapton/LiF interface (km/s)
250 µm	9	10	50	--	No VISAR signal at this stress and above
250 µm	8	10	50	60.4	6.7
250 µm	7	10	50	53.1	6.44
250 µm	6	10	50	45.5	6.08
500 µm	10	5	50	78.1	5.63
500 µm	9	5	50	66.8	4.99
500 µm	8	5	50	60.2	4.83
500 µm	7	5	50	51.5	4.52
500 µm	6	5	50	46.8	4.42
500 µm	5	5	50	37.0	3.95
500 µm	10	10	50	75.5	3.92
500 µm	9	10	50	67.4	3.64
500 µm	8	10	50	61.2	3.48
500 µm	7	10	50	53.1	3.23
500 µm	6	10	50	45.5	3.09
500 µm	6	10	50	48.4	3.11
500 µm	5	10	50	37.9	2.75
500 µm	4	10	50	30.2	2.23
500 µm	3	10	75	22.4	1.77
500 µm	2	10	75	14.9	1.42
1 mm	10	10	75	78.7	1.69
1 mm	10	10	75	75.5	1.65
1 mm	9	10	75	69.7	1.57
1 mm	9	10	75	67.1	1.51
1 mm	8	10	75	62.5	1.47
1 mm	7	10	75	54.4	1.36
1 mm	6	10	75	46.3	1.22

Velocity Diagnostics:

1) Line VISAR: Dual VPF, single axis
   - VPF: 2.068, 1.160 km/s (standard). Expect 30 min to change.
   - Available etalons (VPF in km/s): 0.992, 0.9927, 1.1597, 1.160, 1.4465, 1.653, 1.653, 2.068, 3.622, 5.176, 8.939, 12.7515, 22.2026
     - Users may request combinations of these etalons for lower VPF
2) Single Point VISAR: As in previous runs. 100 µm spot size. Dual VPF
   - VPFs: (standard) 1555.13 km/s and 748.01 km/s

X-ray capabilities

X-ray Beam Size

The X-ray spot size is 70 µm H x 30 µm V (FWHM), measured perpendicular to the beam (i.e., not on the angled target surface). The beam will be expanded horizontally due to the incidence angle. The typical grazing angle (x-ray beam to sample surface) is 38°, expanding the horizontal beam size on target to 115 µm FWHM. If the target is rotated, such that the laser remains off the sample normal by 7 degrees in the opposite direction (i.e. grazing angle = 52°), the horizontal beam size is 89 µm. The 38° grazing angle configuration is standard, due to lower interference of the VISAR optics with the XRD cone, but a 52° incidence angle is available on request (and is recommended for shots with the 250 µm DPP).

X-ray Diffraction configuration

The detector mount puts the beam vertically off-center by ~7 mm, yielding an asymmetric q-range, and the minimum detector distance is approximately 97 mm. For the 23.6 keV beam, with the detector at 97 mm, this corresponds to a maximum scattering vector of 8.7 $Å^{-1}$ on one side and 7.7 $Å^{-1}$ on the other.

Standard XRD beam configuration uses the U17.2 undulator (23.6 keV) with a multilayer monochromator to isolate the first harmonic and narrow the bandwidth. A 36 keV configuration is available (using the 5^{th} harmonic of the U27). Generally, the 23.6 keV configuration provides the best signal for most targets, even high-Z targets (due to the target thickness limitations from the pulse duration and spot size). However, if higher-q data is required, the 36 keV configuration is appropriate.

Extended X-ray Absorption Fine Structure (EXAFS) configuration

EXAFS measurements on dynamically compressed materials can be performed at the DCS for materials with absorption edges ranging from 9 keV to 13 keV. The x-ray beam is configured using the U27 undulator with ~10^9 photons/bunch. Flat-plate HOPG is used as the dispersive spectrometer element and a Rayonix SX165 is used as the detector. The detector is placed at a horizontal distance of ~2.45 m from the spectrometer. The energy resolution ($\Delta E/E$) is ~0.1%. EXAFS oscillations can be observed up to ∼350 eV to 550 eV beyond the absorption edge, depending on the material.

Detector

The Rayonix SX165 detector has an active area diameter of 161.8 mm. The minimum target to detector distance for XRD is approximately 95 mm.