LCLS INJECTOR DRIVE LASER*

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Abstract

Requirements for the LCLS injector drive laser present significant challenges to the design of the system. While progress has been demonstrated in spatial shape, temporal shape, UV generation and rep-rate, a laser that meets all of the LCLS specifications simultaneously has yet to be demonstrated. These challenges are compounded by the stability and reliability requirements. The drive laser and transport system has been installed and tested. We will report on the current operational state of the laser and plans for future improvements.

LCLS INJECTOR DRIVE LASER SYSTEM REQUIREMENTS

The Injector Drive Laser is the significant part of the LCLS machine, which to a great extent defines the quality of the electron beam produced by the injector. In order to meet the injector electron beam specifications [1] the requirements on the laser beam irradiating the photocathode were defined as given in Table I.

LCLS INJECTOR DRIVE LASER SYSTEM DESCRIPTION

The Drive Laser system has been purchased from Thales Lasers S.A. It is a custom made Chirped Pulse Amplification system containing a Femtolasers™ Synergy oscillator, stretcher, regenerative amplifier, two multipass amplifiers, compressor, UV conversion unit and two pump lasers. Temporal pulse shape is controlled by an Acousto Optic Programmable Dispersive Filter (Dazzler™) located after the stretcher.

Laser output energy exceeds 2.5mJ. Taking into consideration the losses in the beam transport system, this allows delivery of 400 μJ on the photocathode. The Laser output energy is controlled by rotating the waveplate inside the UV conversion unit. This allows the amplifiers before the UV generator to run in thermal equilibrium, regardless of the requested energy.

The laser system has the ability to generate laser pulses up to the 120Hz. The pulse repetition rate of the Laser system is controlled by a Pockels cell after the regen amplifier (Pulse Picker). This also allows rep-rate to be changed without upsetting the thermal equilibrium of the regen cavity.

The beam from the Laser Bay is guided down to the RF gun region, which is housed in the tunnel, through the UV beam vertical transport tube. The length of the beam path exceeds 8 m. The transport tube carrying the UV beam is under vacuum in order to avoid beam distortion.

UV launch system diagnostics are located at the gun site in the tunnel to monitor UV pulse energy, transverse spatial profile and position of the beam on the photocathode. This relies on a "virtual cathode" at an equivalent image plane to the cathode.

Table 1: LCLS drive laser specifications and tolerances

Parameter	**Nominal Spec**	**Tolerance**
Central Wavelength	255nm	
Pulse Energy	>0.4mJ, continuously adjustable	<2% RMS variation (shot-to-shot)
Fluence Profile (spatial)	Uniform	<20% (peak-to-peak) on single pulse
Spot Radius	Adjustable from 0.6mm to 1.5mm	<4% (Shot-to-shot)
Profile Centroid Stability	<10% radius (RMS)	Shot-to-shot
Repetition Rate	120Hz, 60Hz, 30Hz, 10Hz, 1Hz single shot	
Power Profile (temporal)	Uniform	<8% peak-to-peak over flattop on single shot
Profile Rise/Fall time	1.0ps (10% to 90%)	
Profile FWHM	10 psec (adjustable from 5 to 20 psec)	< 2 % RMS (over multiple shots)
Timing Jitter (with respect to the external RF source)	< 0.5 psec (shot-to-shot)	

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The optical transport system includes UV beam steering stabilization apparatus, which provides beam positioning stability on the photocathode with the 0.06mm accuracy. The signal from the camera is analyzed to determine the centroid position of the beam, the computer then drives the appropriate mirror to keep this position constant.

Beam steering stabilization apparatus consists of two loops: the first - stabilizes the beam position at the output of the transport tube and compensates for the relative shift of the laser bay and tunnel setups, the second – on the cathode. The second beam steering stabilization loop is driven by the signal from the virtual cathode camera. This loop also implements beam steering over the photocathode in search of the electrical center of the gun. The beam pointing stability tests of the system showed that the use of the first steering stabilization loop was not necessary due to negligible shift of the laser bay vs. tunnel setup. Using only the second loop we could achieve the beam stability requirements.

LCLS INJECTOR DRIVE LASER PERFORMANCE

The Drive laser system was installed in July 2006. After the start of injector commissioning in April 2007 the system is operational 24/7 except several short periods of downtime.

The laser meets all the requirements except the most challenging ones: temporal and spatial shape. The example of the temporal pulse shape taken with the single and multi shot cross-correlator and the streak camera is shown on Fig. 1. The modulations in the laser beam temporal profile were caused by the birefringent Lyot filter in the regenerative amplifier cavity. We believe that this problem could be eliminated by removing the Lyot filter and implementing another spectrum selection which consists in using end cavity mirrors with special coatings.

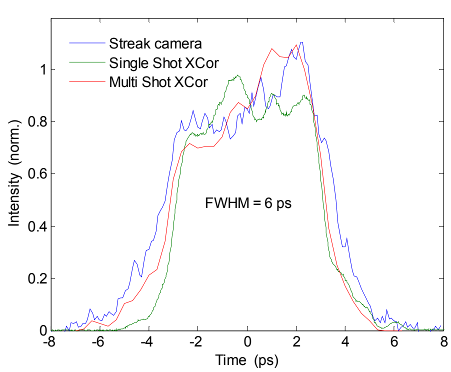

Fig. 1 Laser Pulse Temporal Shape

Spatial beam shape out of the laser is close to Gaussian. It was planned to convert the spatial shape to a flat top by using an aspheric beam shaper (Newport Corp product) [2] and imaging the shaper output to the photocathode with adjustable magnification. But achieving a flat-top spatial beam profile using this Newport shaper presented certain problems. The shaper has very high requirements to the quality of the input beam and to the accuracy of alignment. The shaper (see Fig. 2) did not provide better beam quality than simply clipping the beam with the hard-edge aperture (see Fig. 3). Eliminating the beam shaper significantly reduced alignment sensitivity while providing flexibility in spatial profile versus energy on target.

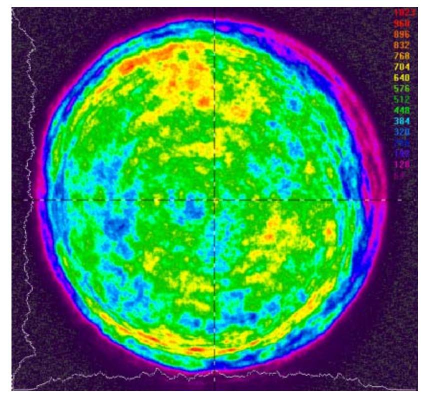

Fig. 2 Laser Beam after Newport Shaper

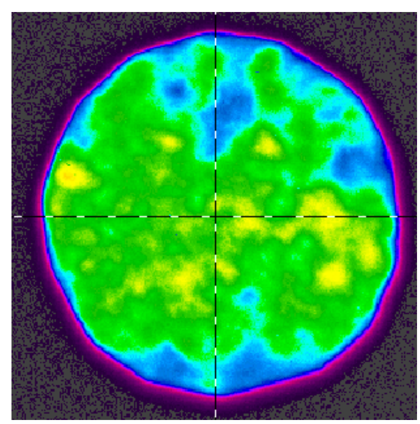

Fig. 3 Laser beam after the clipping aperture

PLAN FOR FUTURE IMPROVEMENTS

In addition to the future work on the temporal shaping mentioned in the previous section we are working on decreasing the losses in the beam transport system. Presently the beam transport system is experiencing about 60% losses (downstream of the clipping aperture). We expect significant improvement of this number in the new optical system, which will be installed during September 2007 downtime. Using the aperture instead of the shaper removes the requirements to the size of the input beam and allows eliminating one stage of the relay imaging in the present system. Replacement of the fused silica lenses by the CaF_2 ones will diminish losses in the transmissive optics.

Another significant source of losses is contamination of the transport tube windows in the presence of the UV beam due residual hydro-carbons in the tube. Our downtime plan includes glow discharge cleaning of the transport tube to reduce the contamination and slow the buildup on the windows.

We also plan to install an active steering stabilization loop on the laser beam upstream of the clipping aperture. This will increase the stability of the spatial shape and allow changes to be made using the control system. When commissioning begins again, we expect to be able to perform all normal operation of the laser remotely using the LCLS control system.

REFERENCES

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[2] Jefferson, C. M.; Hoffnagle, John A. "An achromatic refractive laser beam reshaper", Laser Beam Shaping IV. Edited by Dickey, Fred M.; Shealy, David L. Proceedings of the SPIE, Volume 5175, pp. 1-11 (2003).

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