4 High Power Laser System

4.1 System description and specifications

The high-power laser system (HPLS) will utilize the Chirped Pulse Amplification (CPA) technique [ref Strickland, Mourou]. The technique is illustrated in Fig XXX. An ultrashort, low-energy laser pulse is stretched in time, amplified up to the required energy, and then compressed back. This way, the peak-fluence of the pulses is kept below the damage threshold of the amplifying media. The result is high-peak power, fs-scale duration laser pulses.

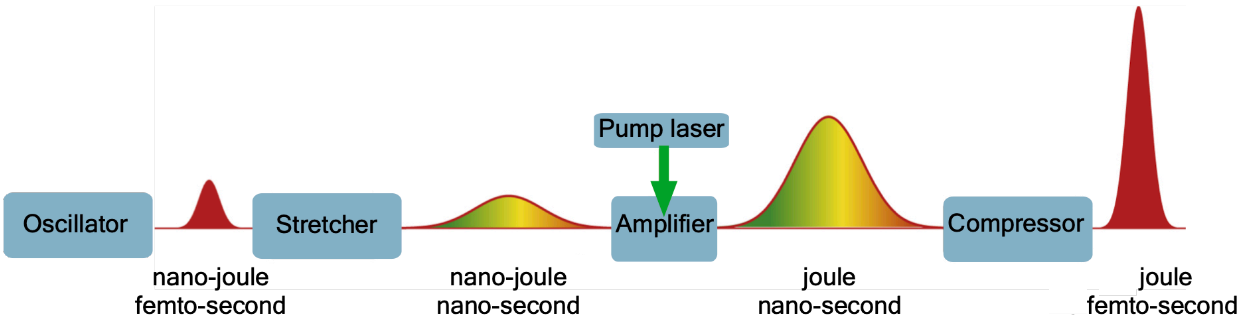

Fig. XX Illustration of the Chirped Pulse Amplification technique

Out experimental strategy is to implement the HPLS in two stages. “Stage 0” will be a commercial 20 TW laser, in which the beam aperture is no-larger than 50 mm. With this aperture, the beam can be propagated with off-the-shelf optics, dramatically reducing the overall cost. For the “Stage 1” upgrade, we will install an extra amplifier, and replace the optical compressor, beam transport and focusing optics to accommodate the larger aperture beam.
A photograph a typical 20 TW, high contrast HPLS is shown in figure XX.

The key specifications of the two HPLSs are listed in the table below.

	Stage 0	**Stage 1**
Central wavelength	800 nm ±5 nm	800 nm ±5 nm
Pulse energy	0.7 J	7 J
Pulse duration	≤ 30 fs	≤ 30 fs
Peak power	20 TW	200 TW
Spectral bandwidth	≥ 30nm FWHM	≥ 30nm FWHM
Beam aperture	50 mm	150 mm
Beam quality Strehl ratio	≥ 0.6	≥ 0.6
Energy stability (rms 5 hrs)	<2.5%	<2.5%
Pointing stability	≤ 20 μrad	≤ 20 μrad
Pre-pulse contrast	>10^{10}:1 (at 100 ps)	>10^{12}:1 (at 100 ps)

Table XX: Key specifications of the HPLSs.

Fig. XX: A photograph of a typical 20 TW, high-contrast HPLS.

4.2 Optical layout and components

Front End

An optical layout of a typical high contrast HPLS is shown in figure XX. The laser chain starts with a commercial femtosecond oscillator which delivers a ~75 MHz pulse train. Each of these pulses is a few-fs long with a few-nJ in energy. The system picks one of these pulses at a rate of 10 Hz, and amplifies it to about 1 mJ. This part of the system is known as the "Front-end". Different amplification technologies may be employed here. They differ in their cost, reliability, and achievable "pulse contrast"; i.e. the light intensity level which precedes the main laser pulse. Our front-end will be based on either "Non-linear pulse cleaning" [ref], or on "Short-pulse optical parametric chirped pulse amplification" [ref], both of which have proven to provide excellent contrast.

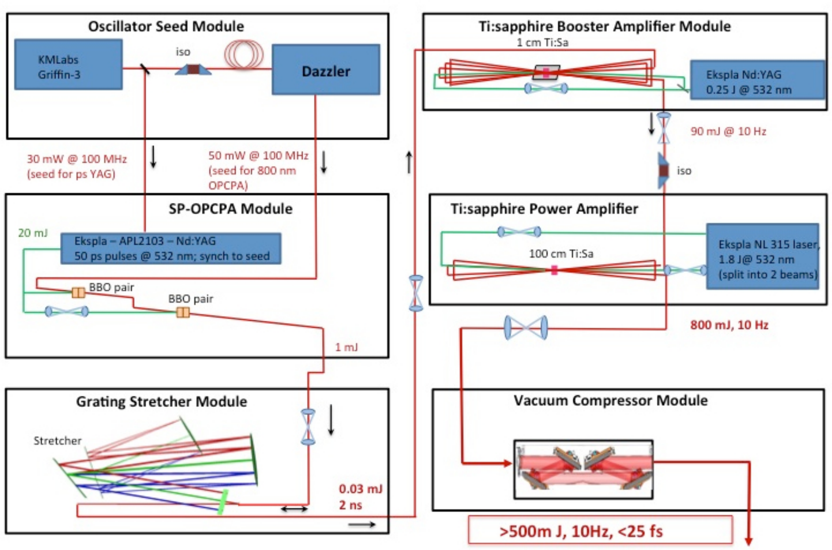

Fig. XX: A typical optical layout of a high contrast HPLS.

Optical Pulse stretcher

Following the front-end, the pulses are sent into a grating-based pulse stretcher. There they are steered to hit an all-reflective ~1500 lines/mm grating four times. The stretcher bandpass is set to about 100 nm to avoid clipping effects that would reduce pulse contrast.

Multi-pass 10 Hz Ti:Sapphire Power Amplifier

Following the stretcher, the pulses have approximately 0.3 mJ of energy. These pulses are spatially filtered and amplified in three amplification stages. Each stage consists of a Ti:Sapphire crystal pumped with ns-long green (532 nm) laser pulses. Following each stage, the beam is expanded to remain below the damage threshold of the following optics in the optical chain.

Optical pulse compressor

The fully amplified pulses will be expanded and sent through a window into an optical pulse compressor which operates under vacuum. The compressor design is based on two large gold-coated diffraction gratings.

4.4 Optical diagnostics suite

Laser pulses will be characterized on-shot using the following instruments:

- Energy measurement using an energy meter,
- Spectral phase measurement using a Self-Referenced Spectral Interferometry,
- Pulse duration measurement using an autocorrelator,
- Wavefront measurement using a Shack–Hartmann sensor,
- Optical spectrum measurement using a ccd-spectrometer, and
- Pointing stability measurement using a far-field imaging system.

4.5 Beam transport and final focusing

Following the pulse compressor, the beam will be propagated to the interaction chamber under vacuum on 75 mm (Stage 0) or 150 mm (Stage 1) diameter mirrors. The final optics, will consists of two folding mirrors and a focusing off-axis parabolic mirror. Each of these optics will be motorized in 5 axes, to allow steering the focal position in space. A motorized, in-vacuum microscope will be used for aligning these optics and for characterizing the focal spot size under low laser power.

4.6 Environmental requirements

The laser will be installed in a room or under a hood, which operates with at least a class 100,000 clean room spec (Class 10,000 preferred). A ± 1.0˚ C temperature stability is required in the laser lab with humidity held to < 60%, noncondensing.

Typical operation requirements consist of few 3-phase outlets at 30 Amps and about 20 l/min of chilled house water.