The Vulcan 10 PW OPCPA project

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Introduction

In 2006 the Vulcan laser facility was awarded a Facility Development Grant for Phase 1 of the Vulcan 10 PW OPCPA project. This project is concerned with the upgrade of the Vulcan facility to deliver 10PW of power using the Optical Parametric Chirp Pulse Amplification (OPCPA) technique[1-2]. The project builds on the work conducted at the CLF in large scale OPCPA in recent years[3]. It will enhance the capability of the Vulcan laser to produce pulses with 300 J in 30 fs with focused intensities 10^{23} Wcm^{-2}. This upgrade is a five year project that has been planned in two phases, with phase 1 fully funded. Phase 1 has duration of two years and in this period the new front end of the 10 PW facility will be developed. This Front End will be independent from the existing Front End of the Vulcan laser and its development will have no impact on Vulcan operations. It will produce pulses centred at 900 nm with sufficient bandwidth to support a <30 fs pulse and an energy up to the joule level. As part of phase 1 of the project we will address some of the technological risks associated with phase 2 of this project.

The second phase, of duration three years, would impact Vulcan operations and provides both high energy amplification and the associated compression / target interaction equipment to enable user experiments.

Methodology

The proposed scheme for the 10 PW OPCPA facility is shown in Figure 1. In phase one we will generate an ultra broad band seed at 900 nm, using one of four possible schemes described elsewhere in this CLF annual report[4]. This seed is generated in a LBO OPA amplifier by combining a broadband seed centered at 710 nm with a pump centered at 400 nm. It is the idler at 900 nm that we will use. Both pump and signal are optically synchronized as they have been generated by spectrally dividing a 300 nm broadband source. The seed and pump signals are set to be ~ps, as using a short pump pulse limits the duration of parametric fluorescence generated on the OPA. The energy of this seed pulse should be larger than 100 µJ to ensure the required level of contrast. The optical pulse contrast is a key parameter for the 10 PW OPCPA project. With high intensities it is of paramount importance to ensure that there will be no early target breakdown. The µJ pulse will be then stretched to ~ 3ns and will be further amplified to the J level in two OPCPA stages using LBO as the non linear medium. The pump pulse used on these stages will have a square temporal profile and spatial top hat profile.

In phase 2 the pulse will be amplified further to energies around 500 J using two large aperture OPCPA stages with

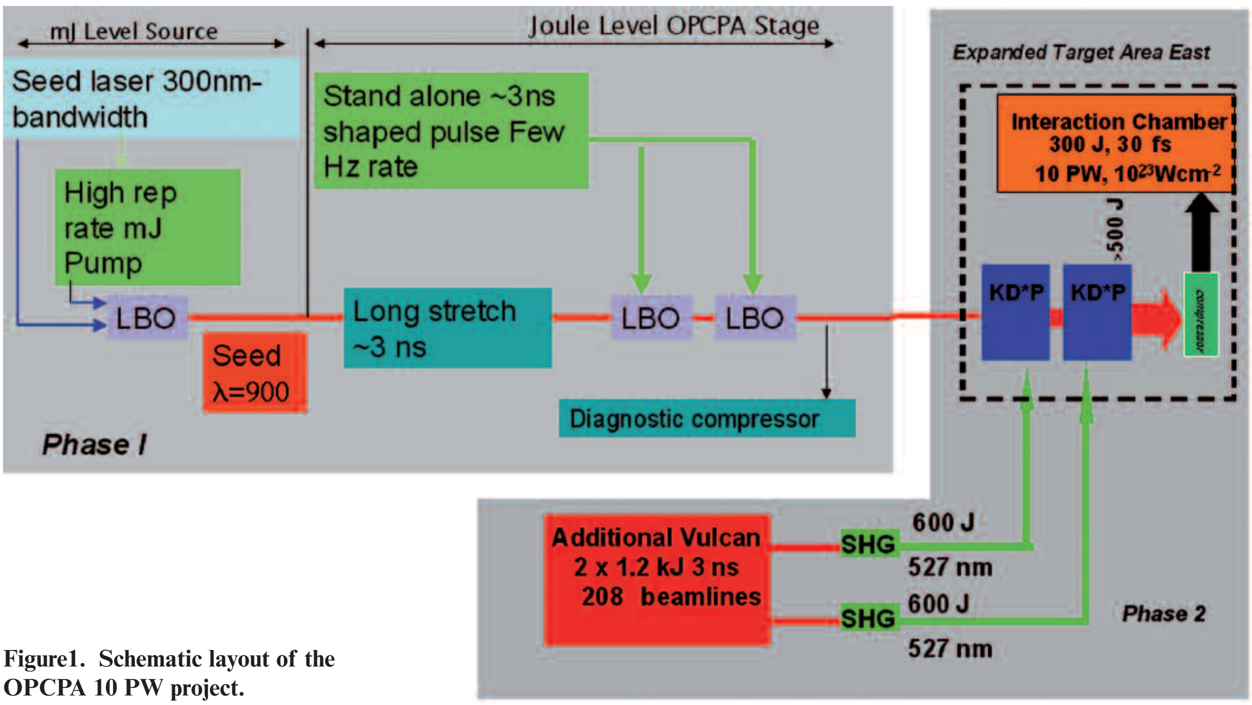

Figure1. Schematic layout of the OPCPA 10 PW project.

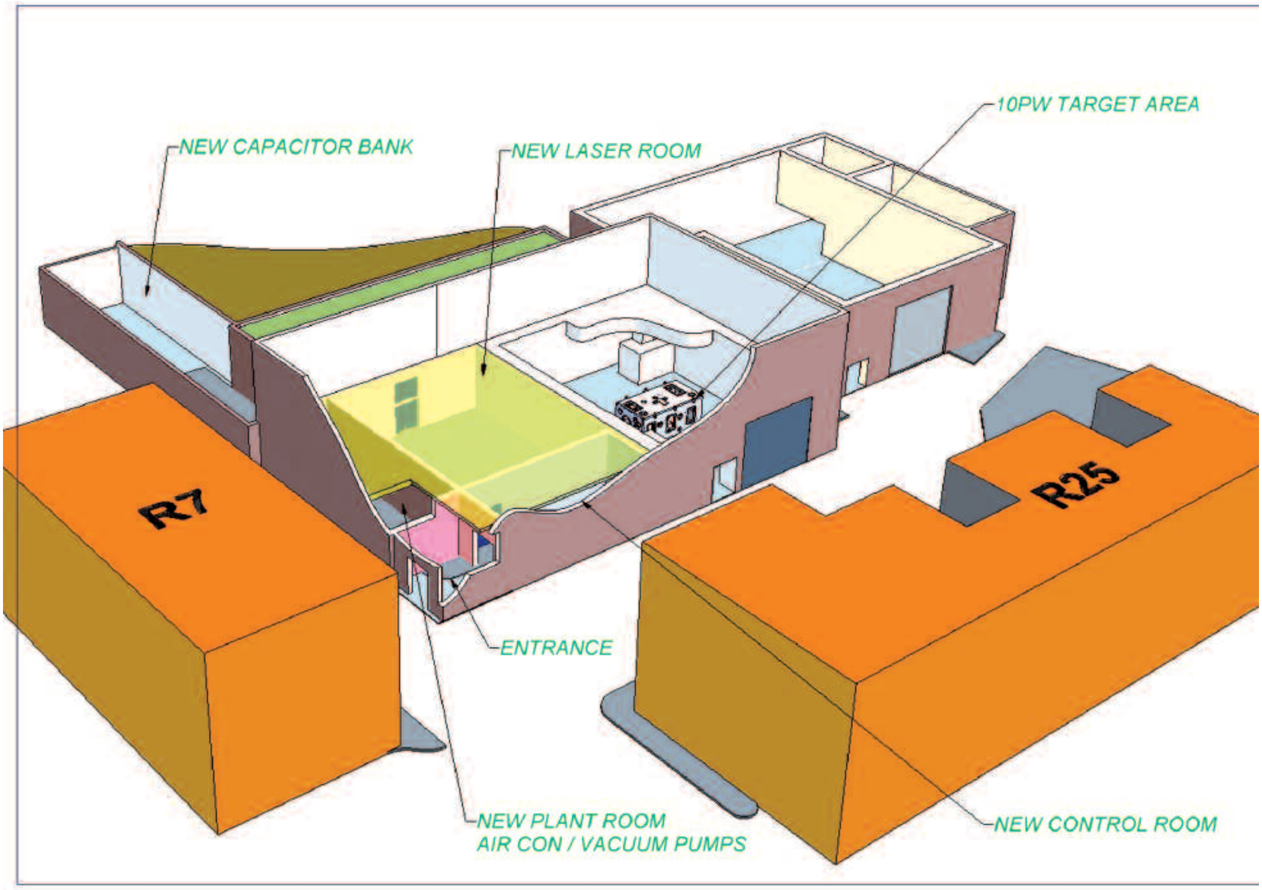

Figure 2. Schematic of R1 building extension.

DKDP as the nonlinear medium because of the large beam diameters required at this point. This second phase requires an increase on the amplification capabilities of the existing glass amplifier chain. The addition of further amplifiers will take the possible output on two beam lines to 1.5 kJ at 1053 nm in 3 ns. This will provide the required 600 J in the second harmonic to pump each of the OPCPA stages. The second requirement for the pump pulse is the ability to have temporal control of its shape. Therefore a new long pulse shaping system will be the seed for the long pulse in the Vulcan laser [5]. The final pulse compression to 30 fs will be achieved using a compressor designed to take advantage of the recent developments in grating technology. The pulse will be delivered in a new interaction chamber in an appropriately shielded target area.

The OPCPA project will require a substantial extension to the existing building to accommodate both a new laser area and an interaction area. As part of phase one we need to look at the building modifications required to accommodate the new facility. One very attractive solution for the new area would be to use the current TAE area as the new 10 PW OPCPA target area. The current R1 building would need to be extended as well as creating a second floor above the existing TAE and TAW as shown in Figure 2. We aim to have a design for the facility building that will allow an accurate costing to be made as part of phase 1. We also have initiated a consultation with the user community to define the possible beam combinations for the new 10 PW area.

One of the key technological issues for phase two is the provision of large aperture gratings at low line density for the pulse compression. The possible schemes for the pulse compression would require gratings at 1 m diameter with line densities from 900 l/mm to 1200 l/mm operating at ~900 nm center wavelength. The pulse compressor needs to have a large bandwidth to ensure a compressed pulse of 30fs. This type of gratings does not currently exist, as part of phase 1 we will conduct grating design feasibility studies to look at some key grating parameters in conjunction with two grating manufacturers.

Further more phase two will require discs amplifiers with square discs. This is a new type of technology to the one currently being used in Vulcan, it presents benefits in that it reduces stresses in the glass, so opening up the potential active area and improved efficiency. It requires that during phase one we acquire experience in the building and operation of these new amplifiers. Phase 1 is due to be completed on December 2008, this will provide an operational independent Front End that will deliver <20 fs pulses with 1 J of energies.

References

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