FLAT LONG PULSE TRAIN FORMATION USING MULTI-PASS STRUCTURE

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Abstract

Flat long pulse train is part of the requirements for International Linear collider. Here in Fermi lab the constrction of ILCTA at New Meon Lab will present the similar requirements (3MHz, 2810 Pulses, 5Hz) for the laser systems. In this paper we will report the effort to develop a new multi pass (MP) cavity based on Nd:YLF crystal end-pumped by diode laser. It takes a seed (1052 nm, 4-5ps) from a commercial CW mode locked laser (GE-100 from TBWP) and has a gain of 1000 or more. So far we already tested up to 1000 pulses with 1μs spacing and the pulse train amplitude fluctuation is less than 5% throughout the whole duration. We attribute this to the high optical to optical conversion efficiency achieved using Nd:YLF crystal inside the Multi-pass structure. We will also discuss the implementation of the new pulse picker unit after the MP strcuture. We will also discussed about improvement of the overall pulse quality after the insertion of another pulse picker.

INTRODUCTION

The laser system for the Fermilab-A0 photoinjector has been recently upgraded in order to improve the reliability of the system and to reduce amplitude fluctuations. [1] The stability of the current laser system is greatly improved compared to the previous version. However one of the remaining problem is the lack of the capability to form a flat long pulse train (up to 3000 pulses), which is one of the essential upgrades required at New Muon Lab. The requirement for long pulse train comes from the high quality factor of the superconducting TESLA cavity. With the high cavity Q the storage time of the radio frequency (RF) fields will be able to sustain more than several hundred microseconds. In this situation the duration of laser pulse train need to be at the same magnitude in order to operate the cavity at the maximum efficiency.

I. Will et al upgraded a laser system for TESLA test facility (TTF) at DESY. [2] The upgraded laser system has the capability to output the required long pulse train structure. The whole laser system is based on Master Oscillator Power Amplifier configuration. The master oscillator is able to output pulse with the repetition of 81.25MHz. each of the pulse is about 280 nJ and the suitable pulse train structure can be picked up using pulse picker. Afterwards the train structure will be amplified by 2 stage power amplifier which will boost the energy to the desired level. In current A0 configuration a commercial available laser (GE-100 from TBWP Inc) is used as a seed laser. This laser can also be locked to master frequency. However a major difference between our seed laser and the home made system TTF seed laser is the energy per pulse. In our case the energy per pulse is about several nJ. This is about 2 order of magnitude less than the TTF seed laser. In this situation it will be very difficult to use the same strategy, i.e, one pass amplifier to achieve the similar energy level.

In this paper we will describe first describe the effort to switch from a flashed lamp pumped MP structure to a more efficient diode laser pumped MP structure. Then we will discuss our initial effort to use new Multi-pass structure to achieve a flat long pulse train structure. Long pulse train up to 1000 pulses with 1 μs is tested. The flatness is dramatically improved compare to previous results. We will also dicuss the improvement we achieved by putting another pulse picker after the our MP strcture.

EXPERIMENT

The current A0 injector drive laser also uses MP structure with Nd:Glass rod as the gain material. And the system is pumped with flash lamp. It's capable of delivering only up to 400 relatively flat top pulse trains. One of the main problems is the overall low efficiency of the Nd:Glass rod amplifier. We decided to use Nd:YLF crystal pumped by the diode laser. The layout of the

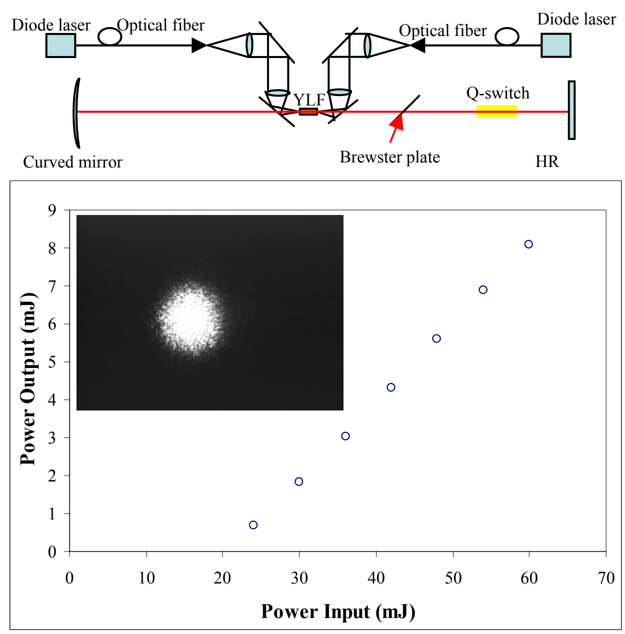

Figure 1: Top sketch is the layout of the end pumped 1053 nm Nd:YLF multi-pass structure. The red beam is the optical axis of the whole structure. Bottom plot shows measured output energy vs. the pump energy by switch the HR mirror to a output coupler with 90% reflection. The inset shows the spatial profile from our TEM_{00} mode captured using a CCD camera.

newly constructed MP cavity is shown at the top of figure 1. The active laser medium is a 4-mm diameter and 10mm long Nd:YLF rod. Both ends are AR coated for both 805 nm and 1053 nm. The focused pump beam formed a circular symmetric spot at the input surface of Nd:YLF rod with a pump beam cross section of < 1mm full width half maximum (FWHM) over the entire crystal length. The cavity length is about 1.5m. The red arrow on the sketch shows the direction that the seed laser is coupled into the cavity. Afterwards the beam will travel inside the cavity and being kicked out along the same path after certain round trips. The diode laser used here is from Dilas Inc. In order to test the alignment of the cavity itself we did a test with 10% output coupler instead of HR mirror. Results are shown at the bottom of figure 1. The whole cavity begins to lase at a pretty low threshold, which is an indication of successful cavity alignment.

After the successful alignment of the MP structure the seed laser pulse is coupled into the MP structure using a Q-switch unit. The results are shown at the bottom plot of figure 2. The distance between each pulse is 1 μs and the whole duration is about 1ms. The red trace is the output from the new MP structure. The energy of each pulse is about 2 μJ. The RMS value of peak amplitude variation is less than 5%. The top plot is the oscilloscope trace from the old flash lamp pumped system.[3] We can see the dramatic improvements of the performance using the new MP structure. This is attributed to the big boost of the optical to optical differential efficiency after the upgrade. A very rough estimation is more than 15% in current configuration. A 3MHz pulse train with a duration of 1ms is currently under test. It's worth to mention that in Ref. 2 the thermal lensing is a common difficult faced by the Nd:YLF system. In our configuration we actually pick up the 1MHz pulse train before our MP structure. That will

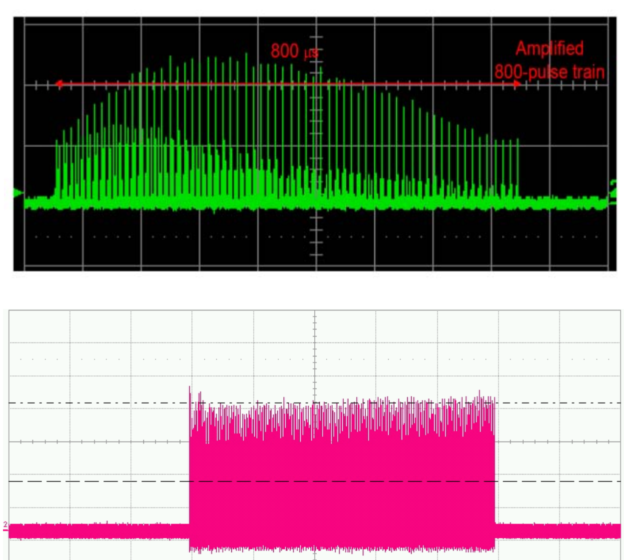

Figure 2: Top plot is the 800 amplified pulse train using the flashed lamp pumped MP cavity and the bottom plot is the 1000 amplified pulse train with the upgraded diode pumped MP structure.

help us to reduce the optical power needed for the Nd:YLF crystal. Thus the thermal lensing effect will be greatly reduced in our case.

However our current MP configuration still has its own shortcomings. One of the problems we face is the pre or post pulse structure with the primary pulse. The green trace shown in the top of the fig.3 is the typical UV diode signal after the frequency doubling and quardrupling.In this case a pre-pulse is shown. This is caused by the fact that the length of our current MP structure is pretty short. The round trip time for a pulse is in the order of 10 ns in this case, which is very closed to the turn-on/turn-off time of our Q-switch unit inside the MP structure. Now problem arises when we try to kick the pulse out of the cavity. If we turn on Q-switch too early the polarization of amplified pulse will be rotated inside Q-switch before getting to Brewster plate therefore there'll be a pre-pulse in front of the main pulse. If we turn off Q-switch too late the polarization of the amplified pulse will not rotate enough, some portion of the pulse will travel through the Brewster plate and travels inside the cavity for one more round trip, which means that this portion will be amplified by MP structure again before being kicked out from the cavity. So even if the leak through portion is

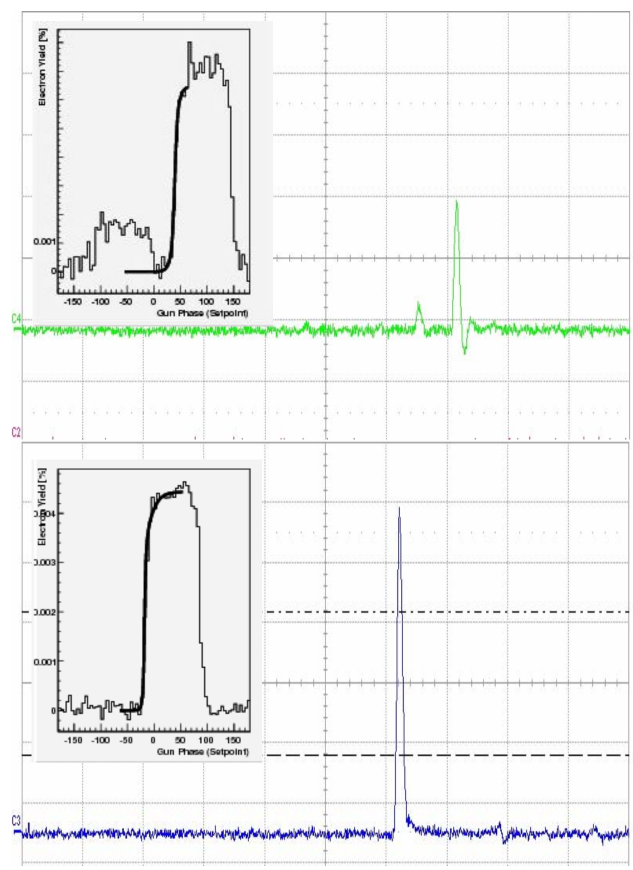

Figure 3: Top plot is the typical UV pulse before the insertion of pulse picker after the MP pulse and the bottom plot is the typical UV pulse with the insertion of pulse picker. The inset in both plot is the charge vs Gun RF phase for each different pulse.

relatively small compare to the main peak, the ratio will be much close after that additional trip. This unwanted pulse can be seen clearly when we do the charge scan vs the gun RF phase. The inset is a typical phase scan with a presense of a pre-pulse. One of the solutions is the rebuild of MP structure with much long cavity length, at least 3 meters in our case. This will need to interrupt the current operation of the A0 photo injector. In order to solve the problem another pulse picker is inserted after the current MP structure. So now the Q-switch unit inside the MP structure can be open as late as possible to prevent the pre-pulse and the pulse picker after the MP structure is used to eliminate the post-pulse. The converted UV trace is shown at the bottom of Fig. 3. The pulse is very clean compare to previous situation. And the phase scan with the current UV pulse is shown in the inset of bottom plot, which resolve no other structure except the main peak.

CONCLUSION

Flat long pulse train is one of the requirements for planned ILC test facility in FNAL. In this paper we describe the effort to form a flat long pulse train using a MP structure. New MP structure is designed and build using Nd:YLF crystal pumped with a set of diode lasers. The initial test with 1MHz pulse train with the duration of 1 ms shows dramatic improvement compare to the previous result. The amplitude variation is less than 5% rms throughout the whole long pulse train. This is due to the improvement of high optical to optical conversion efficiency achieved using Nd:YLF crystal inside the Multi-pass structure. However the current design of the MP cavity leads to an unwanted side peaks on the pulse structure. At the end portion we will discuss the cause and solutions for this problem.

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