SLAC-PUB-5950
October 1992
(A)

A TI:SAPPHIRE LASER FOR THE NEW POLARIZED ELECTRON SOURCE*

Josef Frisch, Mike B. Woods, Max Zolotorev
Stanford Linear Accelerator Center
Stanford University
Stanford CA 94305 USA

Abstract

The SLAC polarized electron source uses a laser driven photo cathode gun. We have developed a Titanium Sapphire laser at SLAC to replace the dye laser currently used for the source. The new laser is designed to operate at wavelengths between 750 and 850 nm while producing 400mJ of energy in 1.6 ns pulses at 120 Hz. Installation on the accelerator is expected in January of 1993.

System requirements

The polarized electron source for the Stanford Linear Accelerator uses a semiconductor (GaAs) photo cathode. Currently the light source for this photo cathode is a dye laser that operates at a wavelength of 710nm. . We are replacing this laser with a Titanium doped sapphire laser in order to operate at 765nm to provide higher electron polarization with GaAs cathodes, and possibly 800-850nm for use with very high polarization strained lattice cathodes. A prototype for the new laser has been constructed and the final system is nearing completion. Installation on the accelerator is expected near the end of 1992.

TABLE 1.
System Specifications

Wavelength range	750-850nm
Wavelength tuning	Discrete tuning OK
Pulse repetition rate	2 pulses, 62ns separation, 120Hz
Pulse shape	Near rectangular, 1.6ns FWHM
Pulse timing jitter	<50 psec RMS
Transverse mode shape	TEM_{00}
Pulse energy	400mJ
Energy Stability	<3% RMS
Pointing Stability	<1% beam divergence angle
System Reliability	>10,000 Hour operational lifetime

* Work supported by US Department of Energy contract DE-AC03-76SF00515

System Design

No commercial lasers were available that met these specifications so a system was constructed at SLAC. Several laser materials were considered. Dyes were rejected due to the difficulty of achieving the required high peak powers with good transverse mode properties, and due to limited lifetimes at the required wavelengths. Alexandrite ($Cr^{+3}:BeAl_2O_4$) was rejected as its low gain at the longer wavelengths required makes it difficult to operate[1]. LiCAF[2] ($Cr^{+3}:LiSrAlF_6$) has poor thermal conductivity and is difficult to operate at high repetition rates. We also considered it to be too new and untested for this application. Ti:Sapphire[3] ($Ti^{+3}:Al_2O_3$) was chosen as the laser material.

Ti:Sapphire is difficult to pump directly with flash lamps due to its short excited state lifetime (4.2ms) and its fairly narrow absorption band. The only reasonable option for pulsed laser pumping of Ti:Sapphire is a frequency doubled Nd:YAG laser. With output energy requirements of a few hundred microjoules, pump energies of a few millijoules are required. Of the available options: flashlamp, arclamp, and diode pumping, only flashlamp pumped lasers are available commercially with sufficient output energy. Commercial flashlamp pumped Nd:YAG lasers are generally only available at repetition rates of 60Hz and lower. We therefore use 2 60Hz lasers operating interlaced as the pump source. Each of the YAG pump lasers produces approximately 20mJ of 532nm light in 6ns FWHM pulses. We use 2 Ti:Sapphire oscillators to produce the required double pulse structure. The overall schematic is shown in Fig. 1.

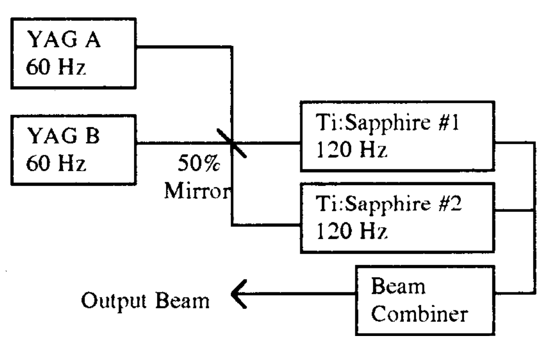

Fig. 1 Overall system schematic

Presented at the Linac '92 Conference, Ottawa, Canada, August 24-28, 1992

The beam combiner uses a polarizer and Pockels cell to combine the pulses from the Ti:Sapphire oscillators and equalize the pulse amplitudes. Downstream of the beam combiner, the optical system duplicates the existing SLAC polarized light source system for beam intensity and polarization control.

Ti:Sapphire cavity design

We use a technique knows as Cavity dumping[4] to produce pulses whose length is equal to the 1.6ns round trip cavity length. After the pump pulse, the intra-cavity power is allowed to build up to maximum and then a Pockels cell is used to change to polarization of the light so that it is transmitted through the output polarizer. The build up time in the cavities is controlled by Q-switching (applying high voltage to the Pockels cell to prevent lasing) after the YAG pump pulse. This allows one of the cavities to have its output delayed by the required 60ns relative to the other. A schematic of the timing for the cavities is show in Fig. 2.

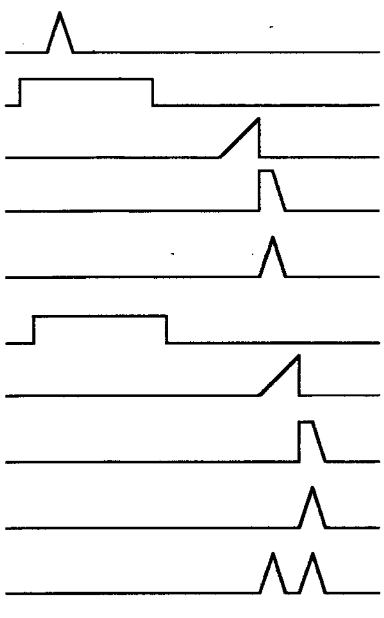

Fig. 2 System pulse timing.

The design of the Ti:Sapphire cavities was motivated by the requirements for a 1.6ns pulse length with very small timing jitter and good intensity stability. As the photocathode does not require a narrow linewidth (a few nanometers is acceptable), only a simple tuning system was used. In this laser, as in most solid state lasers, increasing the pump energy density improves both the efficiency and stability, with optical damage limiting the maximum pump density. The cavity design uses high damage threshold materials. A schematic of the cavity is shown in Fig. 3.

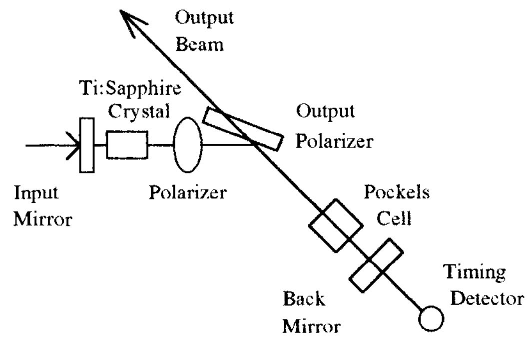

Fig. 3 Ti:Sapphire cavity design

The input mirror is designed to transmit the 532nm pump beam and reflect the lasing beam. The Ti:Sapphire crystal has anti-reflection coated faces perpendicular to the beam. We used a rectangular instead of Brewster angle crystal both to simplify the cavity geometry. We plan to experiment with Brewster cut crystals in the near future.

We use Brewster angle, multilayer dielectric polarizers because of heir high damage threshold. The use of one polarizer in transmission, and one in reflection produces a bandpass filter. With no additional tuning elements, the bandwidth of the laser is 5nm. A multi-order waveplate can be placed between the polarizers to decrease the system bandwidth.

The Pockels cell uses a single KD*P crystal with Sol-Gel coatings for high damage threshold. The cell is driven with a fast high voltage driver constructed at SLAC. The driver uses a FET driving planer triode to provide the 1800 Volt, 150ns long, 10ns rise and fall time pulse for Q-switching. The cavity dumping pulse is a 2400 Volt, 750 picosecond edge produced by an avalanche transistor and planar triode

The Ti:Sapphire cavity has an optical length of 25cm, and uses a flat mirror and a 2 meter concave mirror. This produces a mode radius of 0.4.25 mm at the Ti:Sapphire crystal. These mirror curvatures were chosen to provide a stable cavity without producing a small mode size (which could lead to optical damage) anywhere in the cavity.

Operating Conditions

The pump beam optics are set for a far field image from the pump lasers in order to provide a Gaussian transverse mode. The pump beam mode radius is 0.3mm, chosen to provide approximately 2.1 J/cm^2 pump energy density at the nominal pump energy of 3 mJ.

With the Q-switch and cavity dump disabled, the time to for the oscillator to build up to 10 percent of full power after the pump pulse is shown in Fig. 4. The decay time for light in the cavity is approximately 30 ns.

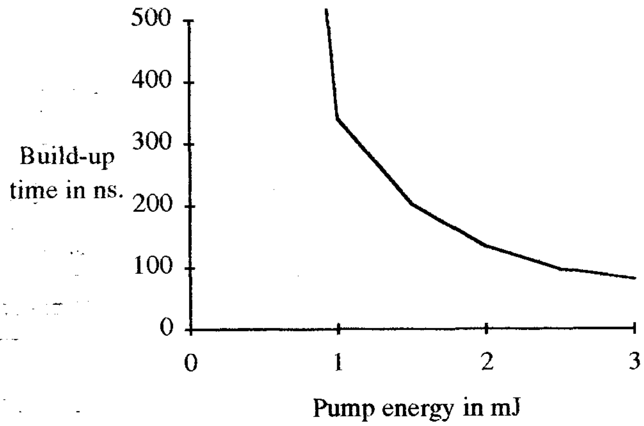

Fig. 4 Optical power build-up time in Ti:Sapphire cavity.

The time for firing the cavity dumper is fixed by the accelerator beam time. The buildup time of the Ti:sapphire laser pulse must be adjusted so that the dumper fires at the peak of the intra-cavity power. This both provides both maximum output power and optimum stability. Drifts in the output power and steering of the pump beams cause changes in the build up time for the Ti:Sapphire laser pulses. We use a feedback system which adjusts the timing of the Q-switches to stabilize the buildup time of the lasers. As the drifts in the pump beams and oscillator cavities are independent, we use 4 independent feedback loops.

System Performance

A prototype laser system consisting of a single pump laser and single oscillator has been constructed. This system has operated for several months. The measurements described below refer to this prototype system. The final version of the system, when completed, is expected to have similar performance.

The output pulse shape, measured with a 50 psec risetime vacuum photodiode and sampler is shown in figure 5. The output pulse energy is typically 400 mJ.

The prototype system has been operated at wavelengths of 765nm and 718nm. The optical bandwidth is approximately 5nm FWHM. As the gain peak of Ti:Sapphire is somewhat longer than 800nm, no difficulties are expected in reaching the full design wavelength range.

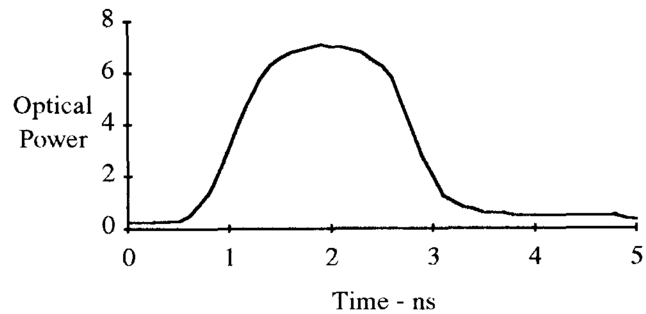

Fig. 5. Output optical pulse shape

The 750 psec. risetime of the pulse is determined by the risetime of the cavity dump pulse generator and the time for the electrical fields to penetrate the pockels cell material. The 1.6 nanosecond pulse width is determined by the optical cavity round trip length. The fall time of the pulse approximately matches its risetime. The measured timing jitter of the rising edge of the pulse is approximately 30psec, most of which is probably measurement noise.

The pulse to pulse energy stability is typically 3% RMS. This is dominated by changes in the Ti:Sapphire gain (caused by changes in pump energy or position) causing the Q-switched pulse to move in time with respect to the cavity dump pulse. The output transverse mode shape is TEM_{00} and the pointing stability meets the 1% of divergence angle specification.

The final, dual pump laser, dual oscillator, 120 Hz, double pulse system is nearly completed. It is expected to be installed on the accelerator in January of 1993.

References

[1]Richard C. Sam, Jen-Jye Yeh, Kendrik R. Leslie, William R. Rapoport, "Design and Performance of a 250 Hz Alexandrite Laser", IEEE J. Quantum Electron., V -24, No-6, (1151-1166) 1988

[2]Lloyd L. Chase, Stephan A. Payne, "New Tunable Solid-State Lasers",Optics and Photonics News, (16) Aug. 1990

[3]Antonio Snachez, Alan J. Strauss, Roshan L. Aggarwal, Robert E. Fahey, "Crystal Growth, Spectroscopy, and Laser Characteristics of $Ti:Al_2O_3$ " IEEE J. of Quantum Electron., Vol 24, No. 6, (995-1002) 1988

[4]Walter Koechner, "Solid-State Laser Engineering", Springer-Verlag, (441-445) (1976).