# THE UCLA PEGASUS PLANE-WAVE TRANSFORMER PHOTOINJECTOR*

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*Abstract*

A photoinjector based on a multi-cell plane wave transformer accelerating structure has been commissioned at the UCLA Department of Physics' PEGASUS Laboratory. Design and construction of the novel structure have been previously reported [J. Rosenzweig, et al. PAC Proceedings 1997], and recent operation with a thermionic cathode is being presented at this conference [P. Frigola, et al. these proceedings]. This paper describes the planned operation of the PWT gun as a photoinjector, including design and construction details of the drive laser. Progress to date and future plans are discussed.

## THE PHOTOINJECTOR STRUCTURE

The PEGASUS Photoinjector is a novel standing-wave S-band structure based on the Plane-Wave Transformer (PWT) design [1]. The injector consists of a replaceable cathode, an initial half-cell, and ten full cells, and a final half-cell for a total length of 60 cm [2]. Each cell is, in fact, a volume separated by disks of 4.2 cm diameter in a 12 cm diameter tank (see Figure 1). The RF structure features strong (0.3) cell-cell coupling to prevent mode overlap.

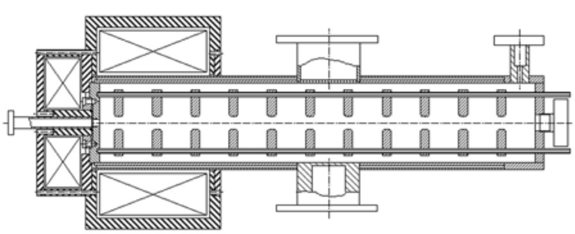

Figure 1: A cross section of the PEGASUS PWT Photoinjector showing the 11 discs forming the cells inside the tank and the solenoid surrounding the cathode region.

The peak field-gradient is designed to be 60 MV/m, and the nominal beam-energy is 17 MeV. The structure has a fill time of 2-3 µs, a shunt impedance of approximately 50 M/m, and a $Q_L$ of roughly 6000.

Due to the compact and simple design of the gun, a simple solenoid can be used for emittance compensation. Simulations indicate that the design specifications of Table 1 should be readily achievable [3].

The interchangeable cathode design allows for a variety of cathode materials to be tested including the planned use of copper, magnesium, heated $LaB_6$, and conventional thermionic emitters.

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### *Status*

The status of the PEGASUS laboratory is reviewed elsewhere [4]. To date, the PWT linac structure has been conditioned at high power (20 MW) [5], and dark-current emission has been measured with a peak energy of 15 MeV over the 4 µs RF pulse [6]. An effort to retrofit a thermionic cathode has been underway [7] in order to deliver beam for testing and preliminary measurements until a drive laser can be procured.

Table 1: Photoinjector design beam specification.

| Beam Parameter | Value |
|---|---|
| Energy | 12-18 MeV |
| Energy Spread | 0.15% |
| Emittance (norm. rms) | 4 µm |
| Charge | 1 nC |
| Bunch Length | 1 mm |

## THE DRIVE LASER

The PEGASUS drive laser, as with all photoinjector drive-lasers, must provide a sufficient number of photons with an energy above the cathode workfunction, and within a pulse-length short relative to the RF period. In practice, this implies a UV (~266 nm) laser, with ≈200 µJ of energy at the cathode, and a pulse length adjustable from about 1 to 10 ps (see Table 2). The pointing stability, energy stability and reliability have been only qualitatively considered, but should be near state-of-the-art as the design calls for an all diode-pumped system. In addition to these general requirements, the drive laser needs to be operable by non-specialists (i.e. no dedicated laser operator), and be flexible enough to allow for reconfiguration to meet new research directions (i.e. addition of a pulse shaper, diagnostics, etc.).

Table 2: The design goals of the PEGASUS drive laser.

| Laser Parameter | Value |
|---|---|
| Wavelength | 266 nm |
| Energy | > 200µJ |
| Pulse length | 1 – 10 ps |
| Repetition rate | 500 - 1000 Hz |

A future consideration for the laser system is to drive a terawatt class amplifier for short-pulse photon-electron interactions and to provide short-wavelength radiation. The above plan along with the desire to obtain as much of the laser from commercial vendors and to utilize proven technology, has lead to the selection of Ti:S as the laser medium.

### *Drive Laser Design*

Figure 2 shows a block diagram of the design for the PEGASUS drive laser. The majority of the components are commercially available. The salient components are the diode-pumped pump-lasers for both the oscillator and regenerative amplifier (regen), and the absence of any multi-pass amplifier which could degrade the beam quality and stability.

The ~100 fs pulses from the oscillator are grating stretched and then masked in order to produce a compressed pulse — after amplification — that has a minimum of residual chirp: as no pulse shaping techniques are to be employed initially, the full oscillator bandwidth is unnecessary.

The regen will likely operate at 500 Hz – 1Khz in order to improve stability, while the photoinjector RF-system will run between 1 and 10 Hz. The additional laser shots will simply hit the cathode, but not produce accelerated beam.

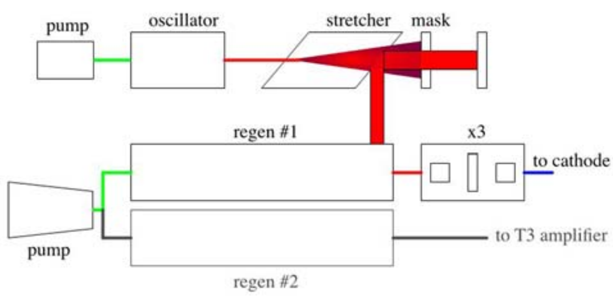


Figure 2: The design of the PEGASUS drive laser.

### *Future Work*

Near term work on the PEGASUS drive laser includes preparation of the laser room, final selection of the oscillator and frequency conversion crystals, as well as engineering of the control system interfaces. Procurement of the laser system components should occur soon thereafter.

Selection of the oscillator between the various commercial offerings is complicated by limited data on performance of these lasers in general and specifically as mode locked seeds for photoinjectors.

The laser room requires facilities upgrades including construction of an inner dust-proof room, improvement of the thermal stability (HVAC system), and general "remodeling". While the room has previously supported a drive laser, changes to the building and age have created an environment that does not meet the requirements for reliable laser operation.

## THE T$^3$ LASER

Beyond initial Photoinjector operation, beam studies, and near-term planned experiments, it is hoped to introduce a terawatt class laser into the PEGASUS lab for photon-electron interactions. One specific plan is for a Thomson source which provides modest x-ray fluxes for PEGASUS researchers and other on-campus studiers [8]. The head-on interaction of the electron beam focused to a 50 μm spot with a transversely matched laser of 1 TW (100 mJ) gives an x-ray flux of about 2 x $10^8$ photons at about 2 Å. Increasing the laser power to 2 TW and focusing the beams to a difficult to achieve 25 μm spot size, yields more than an order of magnitude more x-ray photons and two orders of magnitude improvement in the brightness. However, the head-on scattering produces long x-ray pulses. To achieve shorter pulses, 90 degree scattering will be required, with the penalty being a substantial reduction in the photon flux (down to about 2 x $10^6$ even in the aggressive case) [9].

As is indicated in Figure 2, room for a second regenerative-amplifier (regen #2) has been included in the design of the drive laser. The two regens are both pumped by the same laser, with the second regen allowing for amplification of unmasked stretched-pulses in order to produce femtosecond (~ 50 – 100 fs) pulses of sufficient energy to seed a multipass "bow-tie" amplifier. These short pulses would be transported in vacuum to near the interaction area where a vacuum compressor would be installed.

The nominal design goals for the PEGASUS T3 laser are given in Table 3, while a block diagram of the system is shown in Figure 3.

Table 3: The design goals of the PEGASUS T3 laser.

| Laser Parameter | Value |
|---|---|
| Wavelength | 800 nm |
| Energy | 100 - 200 mJ |
| Pulse length | 50 – 100 fs |
| Repetition rate | 10 Hz |

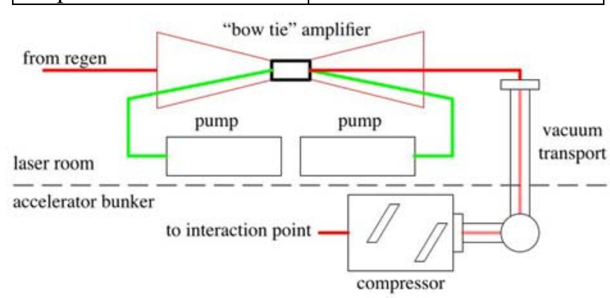


Figure 3: A simplified layout for the PEGASUS T3 laser.

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