Development of Laser Optics for the AWA Photocathode*

J. Norem, and W. Gai
Argonne National Laboratory, Argonne, IL 60439

I. INTRODUCTION

The photocathode electron source for the Argonne Wakefield Accelerator is being designed to produce a number of short (10 psec), 100 nC bunches per rf pulse.[1] Possible sources of fluctuations in the position and energy of these bunches are variations in the initial intensity, position and profile of the bunches which are amplified by wakefields. Since high pulse power lasers have historically produced large fluctuations in pulse to pulse energy and transverse beam profiles, we have been concerned about the stability of the RF photocathode as an injector for the linac. Unfortunately, there is no commercial devices will minimize those fluctuations. In order to minimize these problems, we have designed and begun to test systems which should reduce the initial fluctuations of the beam by stabilizing the laser pulse energy and beam profile.

The pulse to pulse energy fluctuation reduction device (noise eater) is a feedforward system, as shown schematically in Figure 1. The transmission of a polarized beam through the Pockels cell and analyser depends on the voltage applied on it. A fraction of the laser pulse incident on a vacuum photodiode will generate a voltage pulse on the Pockels cell. The amplitude of voltage will depend on the total number of the incident photons and bias voltage applied on the diode. If the transmission coefficient of the Pockels cell has negative slope vs applied voltage, it could stabilize the incoming laser pulses under conditions described below.

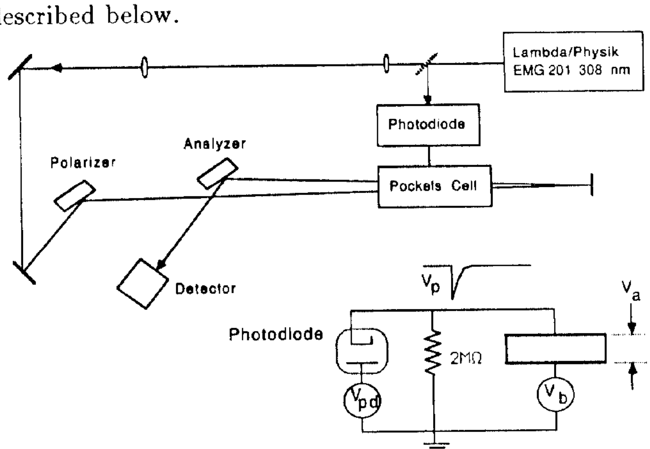

Figure 1. A schematic of the noise eater.

Fluctuations in the transverse profile of the laser will be magnified by the electron beam due to wake fields in the linac. This effect causes unstable electron beam positions in the wake field accelerator sections where further transverse amplification can occur. These fluctuations are stabilized by scattering the beam into small angles which is uncommon in classical optics.

II. PRINCIPLE OF THE NOISE EATER

The transmission coefficent of polarized light thru the Pockels cell and analyser vs applied voltage V_a is given by the expression[2]

$$T = T_a \cos^2\left(\frac{\pi}{2}\frac{V_a}{V_{1/2}}\right) \qquad (1)$$

where $V_a = V_b + V_p$ and $V_p = Q/C$ is induced voltage from photodiode with $Q = Q(I_{in}, V_{pd})$ the charge of total photo electrons, C is the capacitance, and $V_{1/2} = \lambda/2n_0^3 r_{63}$. Thus the transmission depends nonlinearly on the applied voltage as well as the wavelength, λ, refractive index, n_0, and electrooptic coefficient of the media, r_{63}. Single or double pass operation can be used, with two passes requiring half the applied voltage.

Attenuation of light in a medium is described by $dI(z)/dz = -[\alpha + \beta I(z)]I(z)$, where α and β are the one and two photon absorption coefficients.[3] If reflections are neglected, the transmission is the product of the linear and nonlinear terms, $T_a = T_l T_{nl}$. With short pulses and high powers, the aperture (and cost) of the Pockels cell must be large enough to minimize two photon absorption, which can become significant at power levels of $100 - 500$ MW/cm^2. Laser power density can reach damaging levels if the beam is inadvertently focused near the Pockels cell.

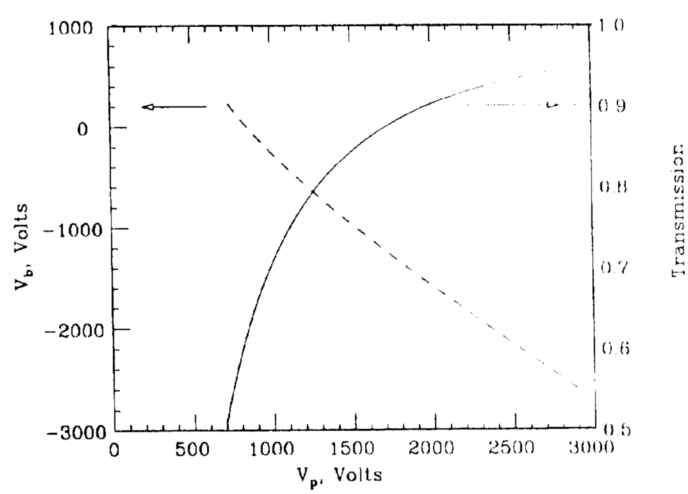

Fig 2 Transmission of the noise eater as a function of V_p and V_b neglecting attenuation effects for a single pass Pockels cell at 248 nm. A double pass device requires half the voltage.

For an incoming laser pulse with intensity I_i, the transmitted intensity $I_o = TI_i$, then the operating point will be

*Work supported by the US Department of Energy, Offices of High Energy and Nuclear Physics, including Contract W-31-109-ENG- 38.

0-7803-0135-8/91$01.00 ©IEEE

where

$$\frac{\delta I_o}{I_o} = \frac{\delta T}{T} + \frac{\delta I_{in}}{I_{in}} = 0. \qquad (2)$$

For the purpose of noise eater under the ideal situations, one would like to have $\delta I_o = 0$ for $\delta I_{in} \neq 0$, which yields the condition for stabilization

$$\delta V_a = \frac{2V_{\lambda/2}}{\pi}\frac{\delta I_{in}}{I_{in}} \cot\left(\frac{\pi}{2}\frac{V_a}{V_{1/2}}\right). \qquad (3)$$

One can satisfy the above equation in many ways. If the bias voltage on the Pockels cell and the pulse voltage are free variables, it is possible to find solutions where the transmission of the system can be high, although at the expense of high V_p and V_b, see Figure 2. This also requires small capacitances high photodiode biases, V_{pd}.

III. EXPERIMENT

The test assembly is shown schematically in Figure 1. The Pockels cell used was a Model QX1020, with a $V_{\lambda/2}$ = 4.16 kV at 633 nm, a capacitance of 7.3 pF, and a hard aperture of 9 mm, and was composed of 95% KD*P.[4] Plate polarizers used dichroic coatings on fused silica, tuned for 308 nm. Polarizers are being developed which can transmit 97%, reflect 99% and withstand high laser powers.[5] The vacuum photodiode used was a Hamamatsu R1193-02 with a Sb-Cs photocathode and a capacitance of about 2 pF. The short (15 cm) cable connecting the photodiode and Pockels cell contributed about 15 pF to the total capacitance of 25 pF. The laser used in the test was a Lambda Physik EMG201, operating at 308 nm, and had a pulse length of about 25 ns. Pulse energies were measured with a Molectron J25 probe and a silicon photodiode operated with no external bias, the pulse to pulse fluctuations of the laser varies but is about 5%.

The voltage induced by the vacuum photodiode on the Pockels cell is shown in Figure 3, for $V_{pd} = 500 - 2500$ V. At low incident pulse energies the induced voltage is independent of bias, however, for high energies space charge effects limit the photocurrent and the induced voltage is proportional to $V_{pd}^{3/2}$ due to Childs Law. The operating point during these tests was $V_p \sim 500$ V from 0.0002 mJ of laser light with $V_{pd} = 2500$ V. It is possible to work near the nonlinear regime of the vacuum photodiode, where the photon induced current is very close to space charge limited. Since the photodiode capacitance is small, it is possible to increase the voltage of this system by increasing the number of photodiodes.

A preliminary experiment was conducted to investigate the system as described above. The laser we used had a large and irregular emittance and a comparatively stable beam, and the laser intensity used was low, thus giving a large signal to noise ratio when the beam intensity was measured with detectors more suitable for high intensity pulses. Nevertheless we have observed that transmission is sensitive to pockels cell voltages, and with $V_{pd} \sim 2100$ V, transmitted intensity first increases then stays constant then decreases with increases in the total beam power, demonstrating the basic operation. More precise measurements are under the way to determine the limitations of noise reduction device for pulsed power UV lasers.

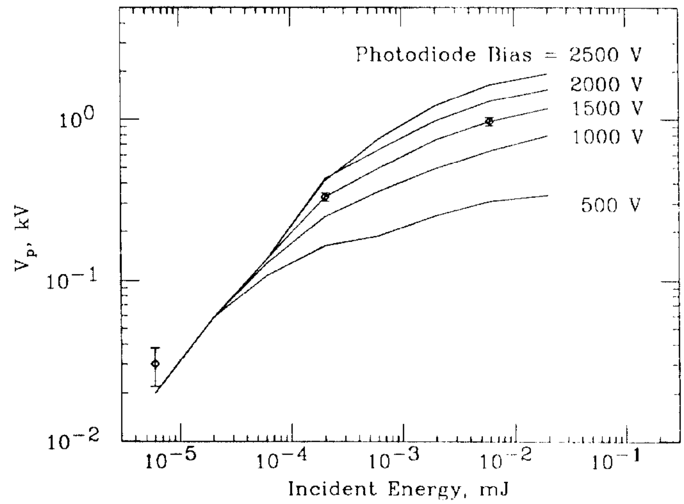

Fig 3 Voltage V_p as a function of light intensity, with $C = 25$ pf.

IV. SMALL ANGLE SCATTERERS

We are planning the use of components which will diffuse the light at small angles. In order to insure that the distribution of the light at the photocathode is as uniform as possible. Since most diffusers are composed of surfaces which have sharp discontinuities and small angle structures, most commercial diffusers scatter into large angles.[6] We have produced surfaces which scatter into small angles by 1) fire polishing and 2) etching rough ground surfaces. Fig . shows a microphotograph of a fused quartz surface produced using 1200 abrasive, and etching with HF for roughly 50 hrs. This surface scatters UV with $\sigma_\theta \sim 1°$.

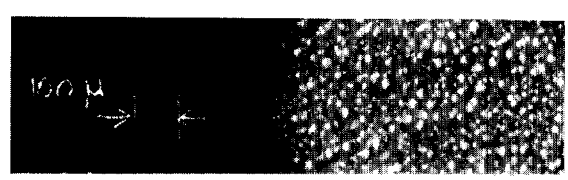

Fig. 4. Microphotograph of the etched surface.

V. SUMMARY

We have designed and constructed a noise eater to reduce the fluctuations of a UV laser. Preliminary experimental data demonstrate that the system works, though with large signal to noise due to problems in the test assembly that should not occur in the final device. Further experimental study should show the limits of this system.

We have also investigated the scattering effects of a variety of different surfaces.

VI. ACKNOWLEDGEMENT

We would like to thank M. Pellin and C. Young of ANL-CHM for their assistance and the use of their laser and Bill Partlo of the University of California - Berkeley for helpful discussions.

VII. REFERENCES

1. M. Rosing et al this conference

2. W. Koechner, Solid State Laser Engineering, Springer Verlag, New York, (1976)

3. M. J. Weber CRC Handbook of Laser Science and Technology, Vol III: Optical Materials, CRC Press, Inc., Florida, (1986)

4. Cleveland Crystals, Highland Heights, Ohio, 44143

5. T. Kardos, Broomer Research Inc, Islip, New York 11751

6. J. M. Elson and J. M. Bennett, J. Opt. Soc. Am. **69**, (1979), 31