Pockels Cell Incorporation For CESR

Nicholas M. Brown
Mentors: Suntao Wang, Michael Ehrlichman

Abstract:

The goal of this project was to incorporate a device called a pockels cell into a bunch purity monitor. A custom built circuit was used to amplify the signal from a photo detector illuminated by a laser, whose beam was modulated by the pockels cell, in order to view how well the pockels cell works. The results show that the pockels cell, when paired with a polarizer, does perform as expected. However, the technology available operates too slowly to demonstrate that it can perform at the 2ns speed required for use at CESR.

Introduction:

The beam used in CESR is made up of packets of electrons called bunches, that travel through the storage ring (CESR) at nearly the speed of light. The bunches emit radiation when they pass through a bend; most of which is in the form of x-rays, but some is in the form of visible light. A series of tubes and mirrors allows us to view and record this light with a detector in an adjacent room without disturbing the beam itself [1]. This bunch purity monitor is envisioned as a very crucial element in many user experiments, particularly ones where the timing of bunches is critical. Ideally, there should not be any particles between bunches. This monitor is in place to eliminate any doubt, or bring to light any problems with bunch purity.

A pockels cell [2] is a device that allows the user to rotate the polarization of light. Inside, there is a crystal that changes the light's polarization based on the orientation of its axis. When given a voltage, the pockels changes the optical axis of the crystal, and when paired with a polarizer, should act like a shutter for the photo detector.

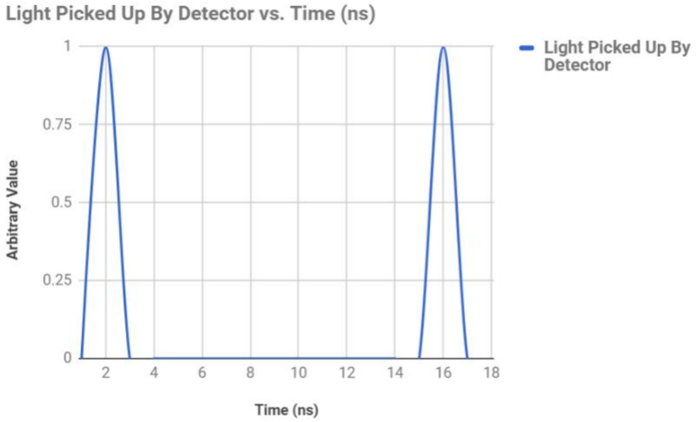

Figure 1: What the detector would pick up in a perfect beam, without distortion

The problem at hand is that as a bunch passes the detector, the light it emits is so bright that it overwhelms the image of the adjacent space. Much like if you were to look directly at the sun and look away, it takes a moment for your eyes to readjust. Figure 1 shows an example of results from a perfect beam, if this issue didn't exist with a CHESS-U beam. The spikes shown are two different hypothetical bunches passing the detector, spaced 14ns apart. This time scale was the goal in our attempt to operate the pockels cell. However, a beam can have bunches spaced as close as 2ns apart, and if the pockels can function that quickly, it could be utilized with any beam.

To use the pockels cell, an amplifier [3] and pulse generator [4] are necessary. The user controls the frequency and pulse characteristics with the pulse generator, and the voltage applied (voltage bias) to the pockels with an amplifier.

Design:

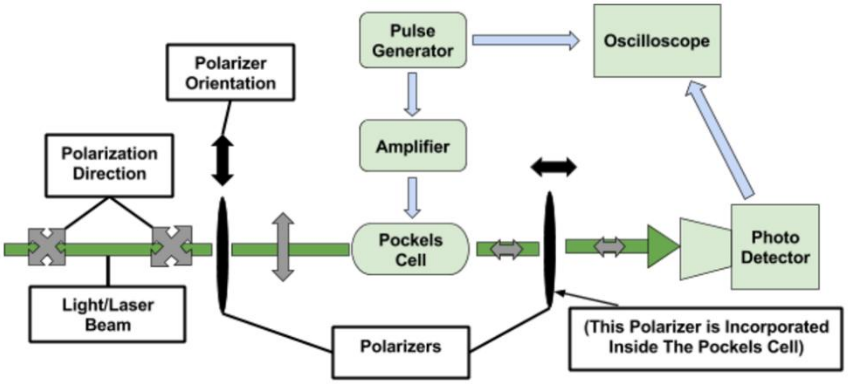

Figure 2: Bunch Purity Monitor Layout

Using an oscilloscope [5], the signal sent to the amplifier, and the signal picked up from the photo detector can be viewed clearly by the user. As shown in figure 2, there are two polarizers in place, one on either side of the pockels cell. A polarizer acts like a gate; when light flows polarized perpendicular to the polarizer, it blocks the light completely. When the polarizations are in the same direction, the light can pass through unaffected. The first polarizer gives the pockels a controlled input polarization, giving the pockels a “clean” beam to work with. The second is built inside of the pockels, and acts as the final gate before the photo detector. The grey arrows shown in figure 2 demonstrate an example of what the light polarization would look like when all the light is passing through to the detector.

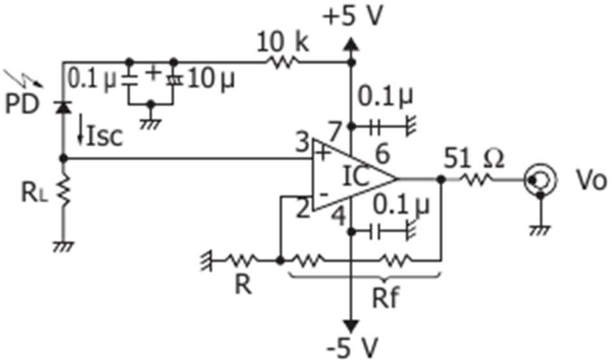

Figure 3: High Speed Photo Detector Circuit Diagram [6]
IC: Op Amp [7]
PD: Photo Detector [9]
Rf & R: 270ohm Resistor
Rl: 50ohm Resistor

A large portion of this project was spent building a custom circuit. Shown in figure 3, this circuit utilizes an op amp to amplify the signal from the photo detector. This design was chosen to characterize the detector, to see how well it could pick up a signal, and how fast it could operate compared to other photo detectors available at the lab. To test the functionality of the circuit, a high-speed LED transmitter [8] was used; one built for fiber optic communication systems, because the response time of this transmitter was much shorter than that of the photo detector [9].

Test/Results:

Once completed, the circuit was compared to the two other photo detectors available in the lab, and it was found that the custom circuit picked up the signal from the LED much faster than the others. The InGaAs (indium gallium arsenide) photo detector didn't pick up the signal at all, for it was built for infrared wavelengths, and the silicone detector did pick up the signal, but its response time was much slower than the circuit's. The circuit was then mounted down in the L3 experimental station where the pockels cell is located, and while CESR is shut down for maintenance, a continuous wave helium neon laser was used to complete our tests. The tests included manipulating the voltage bias, and collecting data on pulse maximum and minimum values, rise and fall times, but particularly pulse width and amplitude (figure 4).

To get an optimal view of the pulse, the first polarizer needed to be perpendicular to the polarizer in the pockels cell. This was done by making sure the amplifier was off, and adjusting the polarizer until no light exited the pockels.

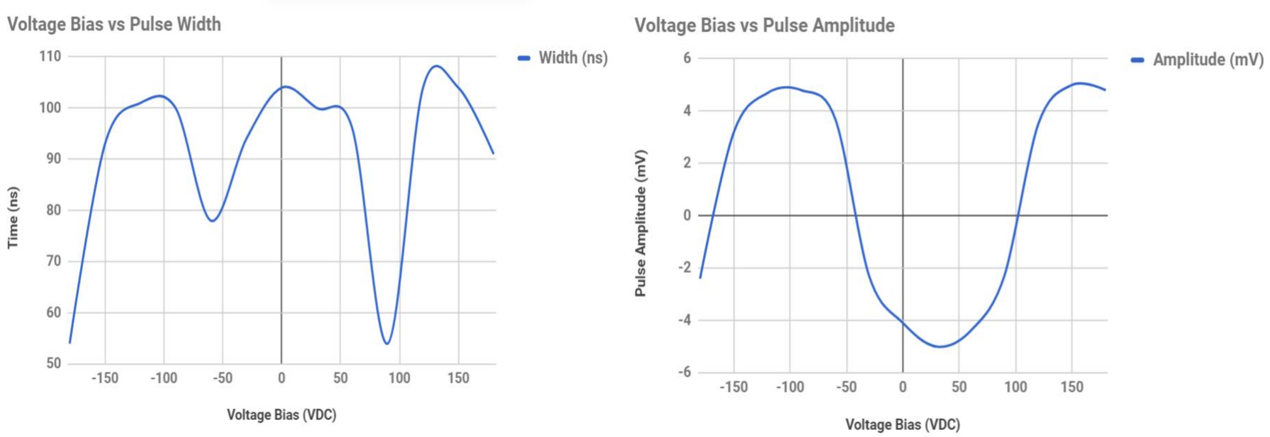

Figure 4: Voltage Bias vs Pulse Width and Amplitude

The pockels cell manual [1] states that for the wavelength of light emitted by the laser [10], the half-wave voltage (bias required by the pockels to change the lights polarization by 90 degrees) is 140VDC. As evident in figures 5 and 6, 180 VDC shows a higher pulse amplitude. This increase in amplitude displays a more powerful modulation when the pulse minimum value is at zero. Therefore, the true half-wave voltage is at 180 VDC.

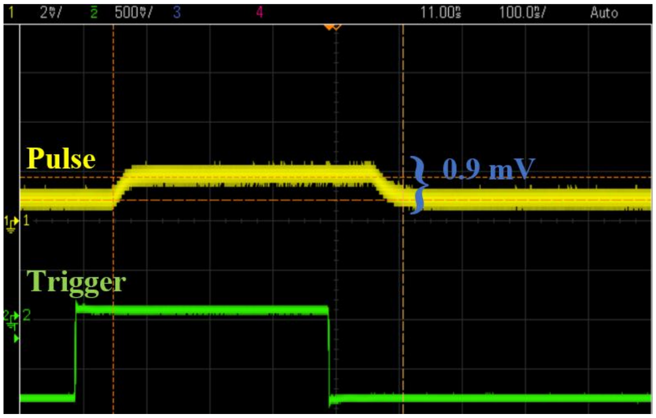

Figure 5: Pulse at 140 VDC

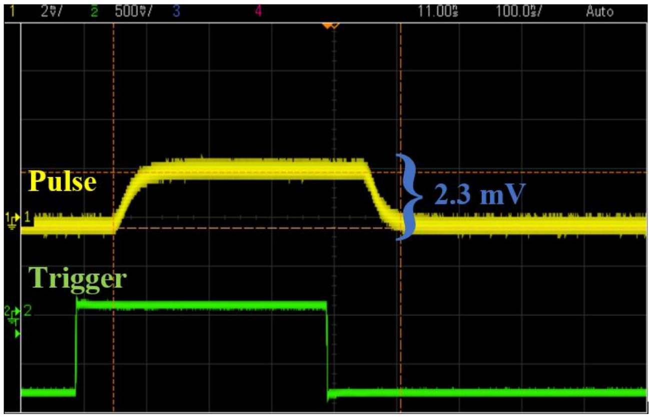

Figure 6: Pulse at 180 VDC

Thus, 180VDC is the optimal voltage bias for using the pockels cell. However, it was found that the custom built circuit was not fast enough to look at a signal comparable to the CESR beam. So, the testing continued, comparing the silicone detector and the circuit by using the laser instead of the LED transmitter. As shown in figures 7 and 8, the results are almost identical. The silicone photo detector [11] signal shows a little less noise, but has identical pulse width. However, the pulse amplitude of the custom circuit is 1.1 mV higher than that of the silicone photo detector Since both signals are unequilibrated, this means that the circuit can pick up weaker signals. This could be useful for many applications, but for the purpose at hand, the lower noise from the silicone detector proves itself more applicable, even though it also does not operate fast enough.

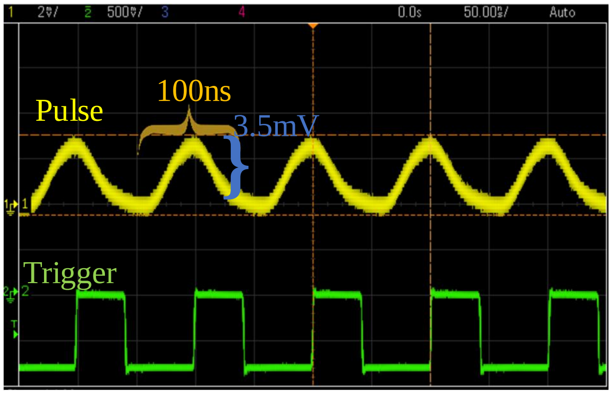

Figure 7: Silicone Photo Detector @ 10MHz

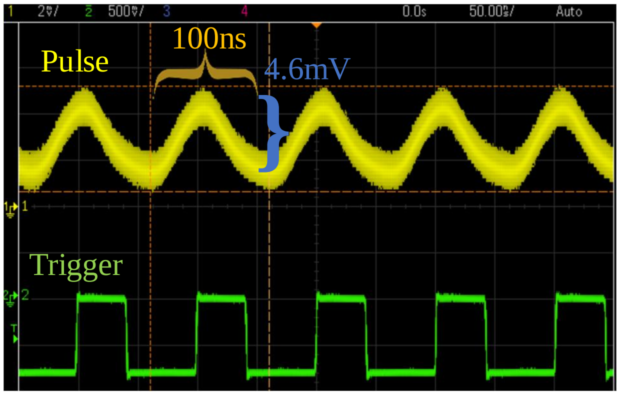

Figure 8: Circuit Photo Detector @ 10 MHz

This project demonstrated the limits that the photo detector can reach. At the speed of 10 MHz (figure 9), the photo detector can't equilibrate. The rise time of the photo detector can be up to 30 ns, meaning that when the trigger falls, the photo detector is still rising, never displaying the full modulation from the pockels cell. At the slower speed of 1 MHz (figure 10), a clear view of the rise and fall times of the pulse are displayed. With a faster photo detector, we can determine if the pockels cell is able to function as viewed in figure 10 at the 2ns time scale required by CESR.

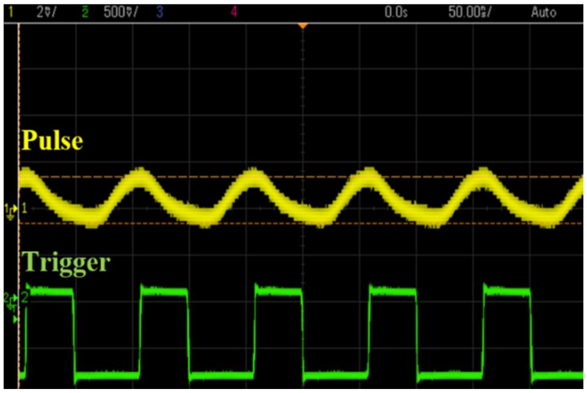

Figure 9: Silicone Photo Detector @ 10 MHz

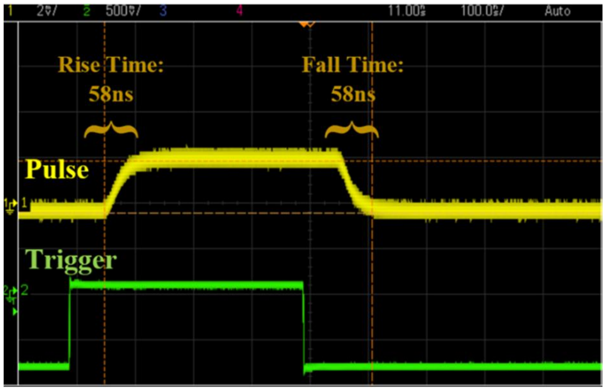

Figure 10: Silicone Photo Detector @ 1 MHz

Conclusion:

Our results show that the pockels cell does work, and could very well serve its intended purpose. Unfortunately, because both the custom circuit and the available photo detectors did not operate at a small enough scale to view the pockels effects at the 14ns period required for the CHESS-U beam, the project will need more work. However, knowing that it can indeed act as a shutter is a big step forward.

The next step in this project should be to obtain a photo detector that is specified to work much faster than the present detectors, and see if any modulation can be viewed at that scale. If that is successful, perhaps modulation can be seen with a 2ns period. At that point, we will have a bunch purity monitor that can be used with any beam here at CESR.

Acknowledgements:

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