MOLLER New RTP HV Driver – Requirement Document

Joe Grames, Paul King, Caryn Palatchi, Kent Paschke, Riad Suleiman

December 12, 2022

The probability of interaction of electrons with their spin aligned along the momentum direction (positive helicity) with matter (e.g., atomic electrons in the hydrogen atom, as in MOLLER experiment) is different than that of the interaction of electrons with negative helicity where the spin direction is opposite to the momentum direction. Since under parity asymmetry (or mirror asymmetry or space inversion) a positive helicity electron becomes a negative helicity electron, the fact that the probability of interaction is different is called parity violation. The helicity of the electron beam is reversed (or flipped) by changing the circular polarization of the laser light used to generate the electrons from the photocathode. By flipping the laser circular polarization from right-handed to left-handed, the helicity of the electron beam is reversed. At CEBAF, we are using a Rubidium Titanyl Phosphate (RTP) Pockels cell to achieve this fast reversal, planned to at 2 kHz. A Linearly polarized laser light passing though the RTP crystals becomes right-handed or left handed circularly polarized light depending on the HV applied to the RTP cell. The ultimate goal is to achieve a perfect polarization flip while keeping all other properties (like charge and position) of the electron beam unchanged. This is achieved by carefully aligning the cell and also making sure any information that gives the real helicity is isolated from the outside world. The leakage of the real helicity signal (e.g., changing the electrical ground level) can be picked up by other devices used by the beam or the experiment and gives a false difference in the interaction of the polarized beam.

The RTP cell and its HV driver are the most critical part of any parity violation experiment. Thus, very careful work goes into the design and operation of the cell. The RTP cell is made up of two crystals, transversely oriented, with 4 electrodes, 2 of which have a common ground, and use 2 HV's in switching states. The RTP cell differs from commercial cells in that, in addition to electrodes, it also has grounded side panels, and the bottom electrodes, rather than having a common ground, can be set independently. Thus, the cell has 8 HV's: 2 crystals x 2 plates/crystal x 2 helicity states = 8 as illustrated in Figure 1.

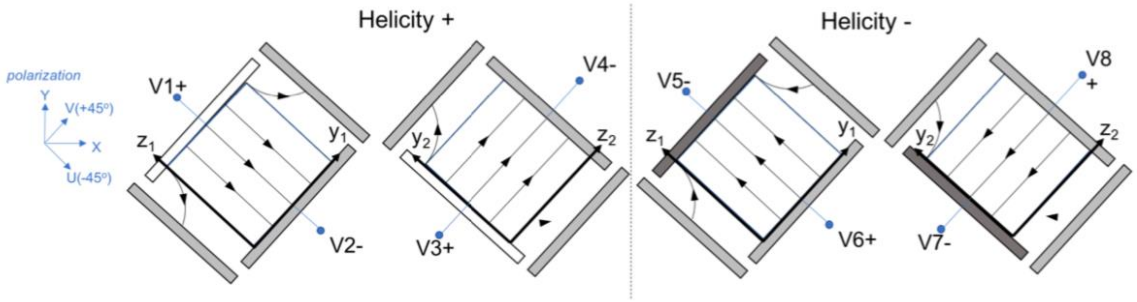

Figure 1: The RTP Cell HV scheme.

Functional requirements for HV Driver:

1. Disabled state: The driver should have an OFF state in which the driver does not process the real-time helicity signal (or, process only in an entirely electrically isolated system). In this state, the voltages should be set to zero.
2. Real-time helicity: The driver should be controlled between two setpoints using the real-time helicity signal.
3. Electrical isolation: Great care is required to maintain security of the real-time helicity signal. The HV driver should be electrically isolated in the same manner as the helicity generator board.
4. Fast HV Switching: The driver should change HV setpoints at 2kHz.
5. Rise time: HVs should reach setpoint with 1 µsec.
6. Precision: Bit resolution in should be at least 0.1 V.
7. Dynamic range: Each HV output should span +/-8000 V
8. Stability: The HV vs setpoint should be stable within 1% at time scales of 1 week or more.

RTP Crystal Properties:

The RTP cell is made up of two crystals as shown in Figure 2.

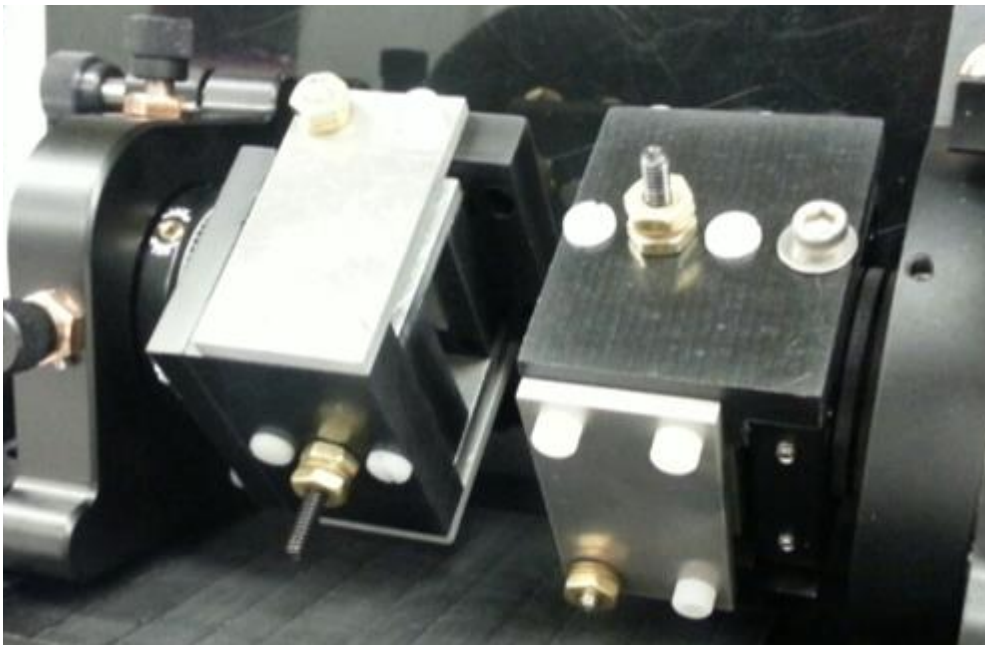

Figure 2: RTP Cell with two crystals.

HV Drivers:

1. Existing Dragon LED 8HV System: this is HV driver in used right now at CEBAF. It was designed and built by Caryn Palatchi (UVa). Figures 3 and 4 show the RTP cell and its HV driver.

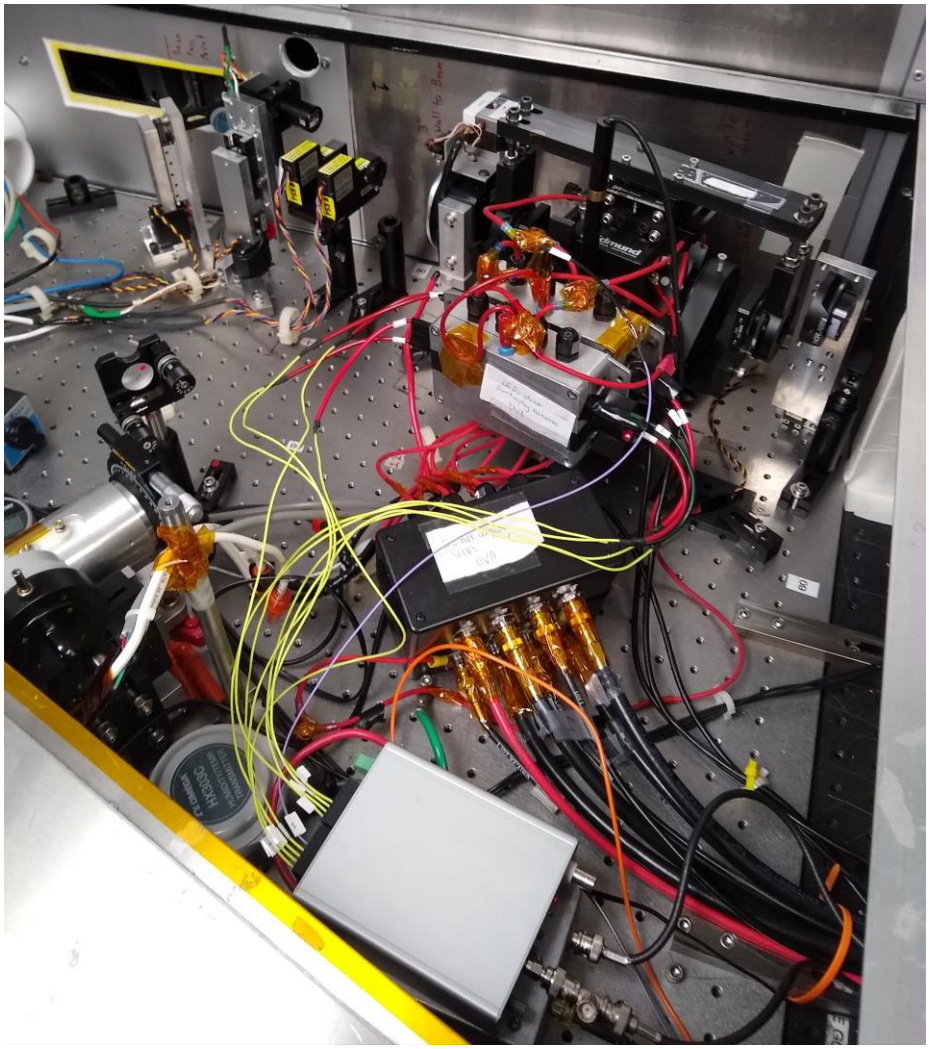

Figure 3: The RTP installed at CEBAF laser table with its HV connections.

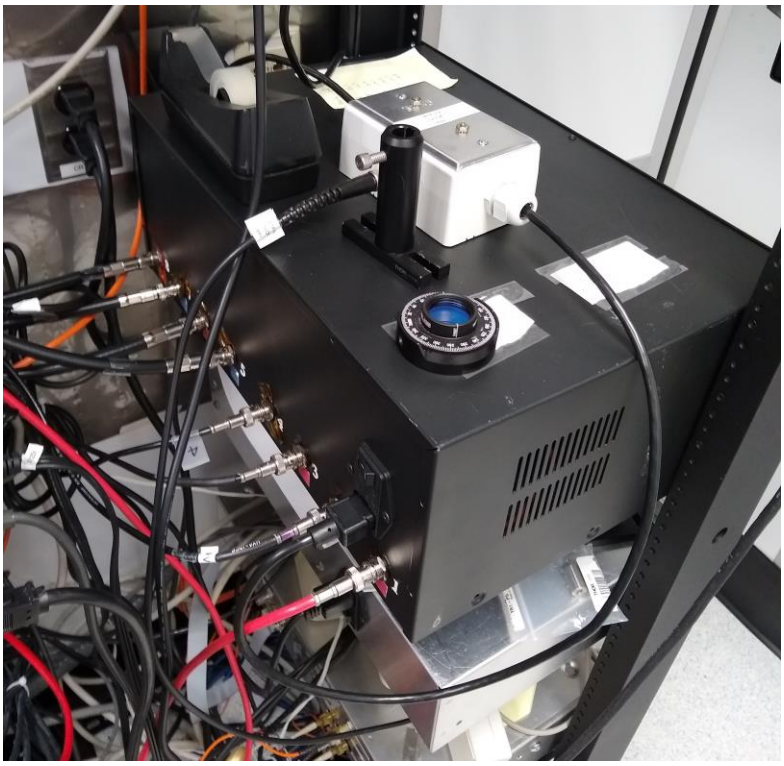

Figure 4: RTP HV driver used at CEBAF laser table.

2. 2019 Design: a protype was designed and built at Jefferson Lab. However, there were issues with isolation and overheating when running at 2 kHz HV reversal.

3. 2023 New Design: the new design should build on the first two designs but use solid-state

More technical details about the RTP Cell HV drivers can be found here:

https://wiki.jlab.org/ciswiki/index.php/New_RTP_HV_Driver

Control System:

I. Real time helicity signal: the driver receives a TTL signal.
II. The 8 HV setpoint are controlled by 0-5V DAC (18bit).