The Ring Coupled Resonant Polarimeter, Experiment 1;

Equipment and Setup

Introduction: This experiment will attempt to non-invasively measure the longitudinal spin polarization of a bunched electron beam using a ring-coupled TE_{011} cavity, a sensitive I/Q receiver, and an oscilloscope.

There are four components that will be used to make the measurement;

1. A ring coupled cavity,
2. A filter/pre-amplifier,
3. An I/Q receiver,
4. An oscilloscope.

There are three additional items that could be useful for troubleshooting and for measuring the sensitivity of the experimental set-up and instrumentation prior to in-beam experiments. These are;

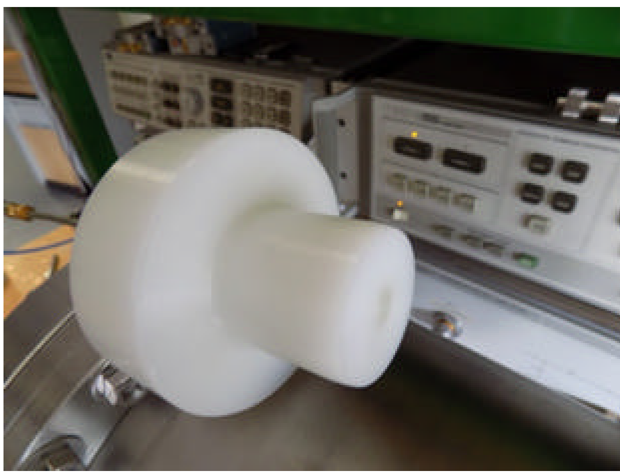
5. A test antenna,
6. An I/Q modulated signal transmitter,
7. A step attenuator (HP 8495b 0-70dB step attenuator or similar).

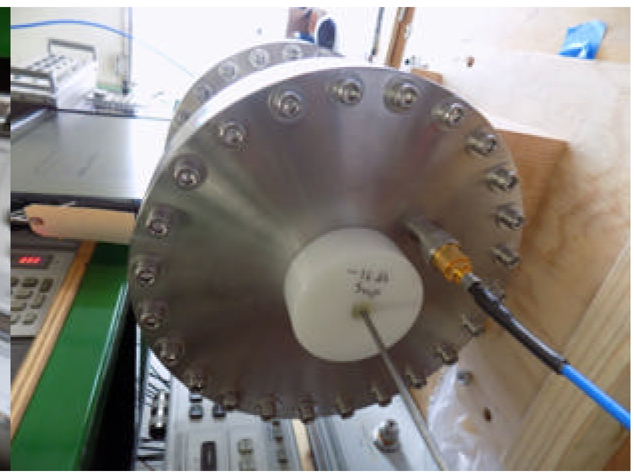
Items 1,2,3,5 and 6 have been provided by Electrodynamic, 4 and 7 are likely on location at JLAB.

The Measurement Layout: The cavity will be installed on the beamline so that the beam passes through its ring coupler. The filter/pre-amplifier will be connected to the cavities output connector. A length of coaxial cable will separate the accelerator tunnel from the measurement area and connects the filter/preamplifier's output (in the tunnel), to the I/Q receiver's input (in the measurement area). A 499 MHz accelerator clock signal is provided to the I/Q receiver's LO input. An oscilloscope in the measurement area is connected to monitor the receivers RSSI port and to the I+ and Q+ outputs. The receiver's outputs are differential, so for improved common mode noise rejection the oscilloscope can be set-up differentially and also use the I- and Q- outputs, but for validation on the bench top, monitoring two single sides of the differential output with the oscilloscope is visually equivalent to differential measurements. The oscilloscope is triggered from the Pockels cell signal, with a time base that captures at least a wavelength of the Pockels cell frequency.

Pre-Experiment Setup and Validation: Before the cavity is installed on the beamline, the experimental setup can be tested and troubleshot using components 5, 6, and 7. This is done by inserting the test antenna into the cavity's bore and transmitting a phase modulated signal into the cavity using the transmitter. The overall sensitivity of the experimental system can be determined by attenuating this signal until the detected phase modulation on the oscilloscope vanishes.

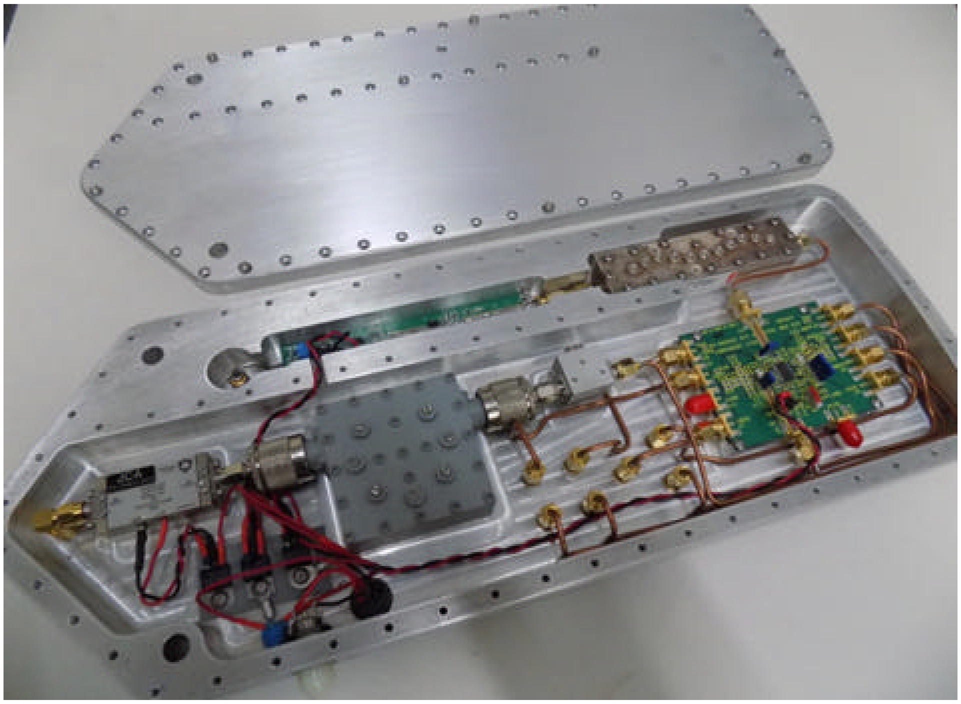
The Test Antenna: The test antenna is a small magnetic field loop coupler imbedded in a polyethyleyne plug. Inserting this antenna into the cavities 2 ¾ beam tube allows one to make a transmission measurement of the cavity, and to drive the cavity with the transmitter while the receiver is attached to the cavities end wall antenna. The test antenna is undercoupled while the cavities end wall antenna is a near match to the cavity mode. An S21 measurement using a network analyzer should show a -16 db coupling on resonance (between the test antenna and the cavities end wall antenna).



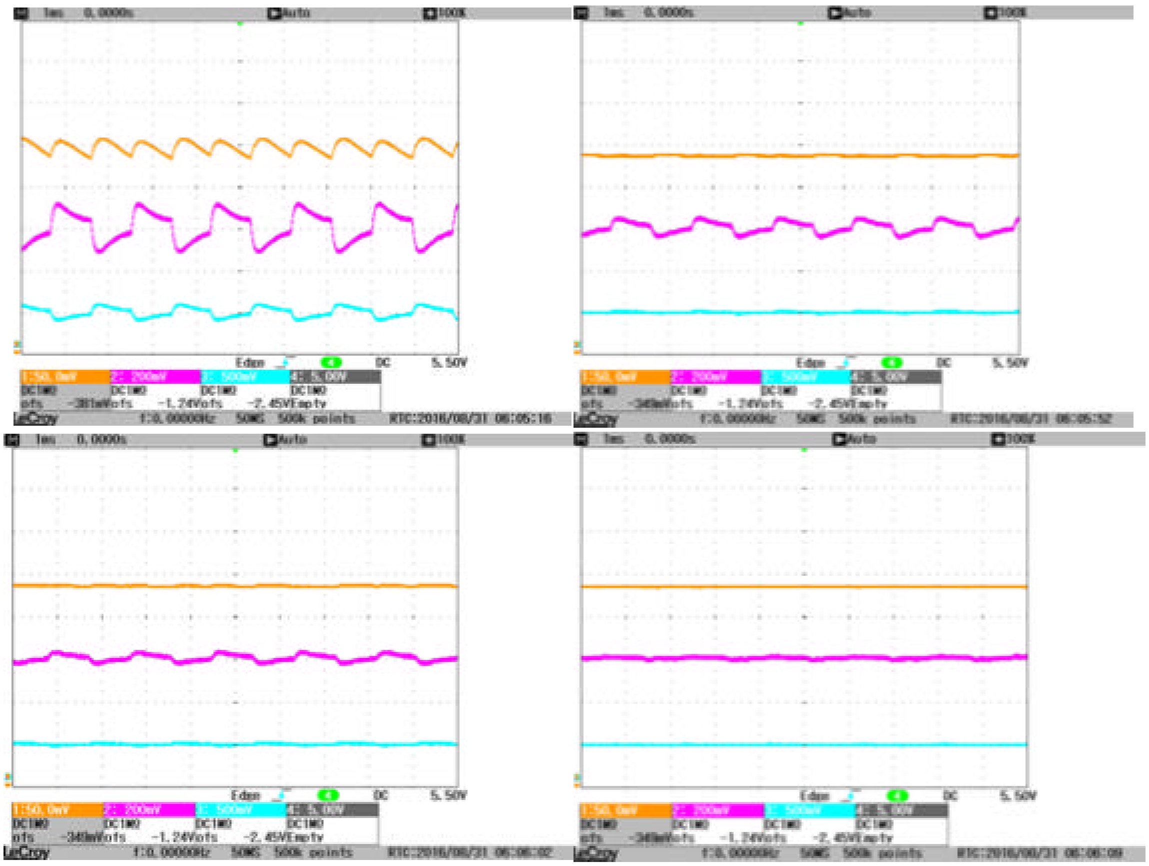


The Transmitter: The transmitter was developed to test the receiver and cavity on the bench, without a beam. The transmitter emulates the expected cavity response to the alternating longitudinal polarity of the beam by producing a 2495 MHz signal that is phase modulated in 180 degree steps at 500 Hz. 500 Hz is the center of the Pockels cell's range (0 to 1kHz). When -10 bBm of 499 MHz is input into the transmitter, it is frequency multiplied X 5, phase modulated and internally attenuated producing -43 dBm at the transmitters output connector. For troubleshooting the experimental system, the transmitter can be connected directly to the receiver, connected to the receiver through a variable or step attenuator, or connected to the test antenna to drive the cavity. Using a variable attenuator to decrease the power transmitted into the cavity by the test antenna allows one to test the sensitivity of the system, prior to the cavities installation on the beamline.

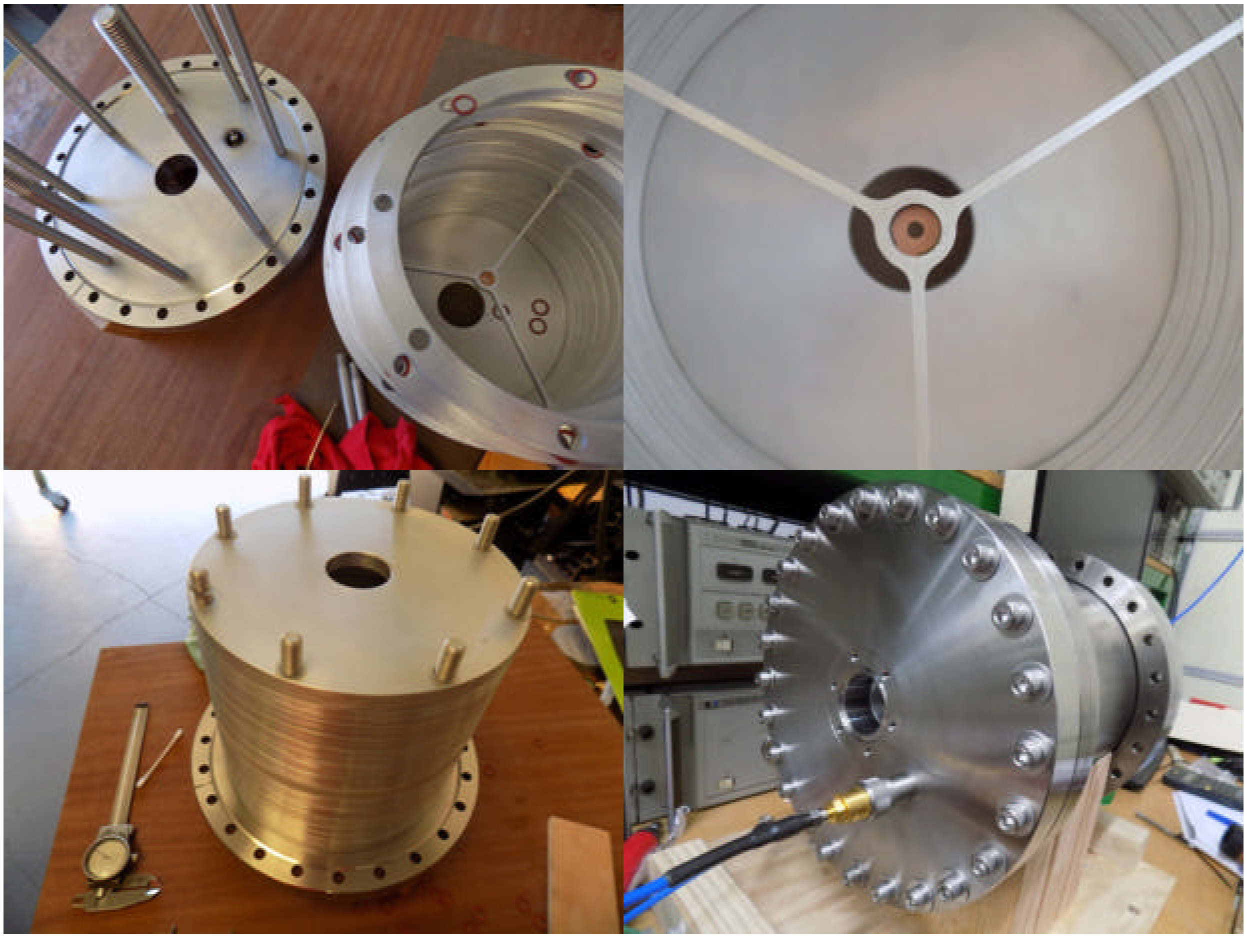
The Receiver: The receiver was developed to measure a 2495 MHz signal coupled from the ring coupled cavity polarimeter, amplify it, and compare it's phase to the accelerators 499 MHz sinusoidal clock. Because the clock signal is continuous and the cavity signal changes phase 180 degrees when driven by electron bunches of different polarities, the I/Q receiver's output with flip with longitudinal bunch polarization.



Benchtop Measurements: Using the hardware above (except for the filter/pre-amp that was not yet constructed), the receiver and cavities pre-experimental performance was tested using the transmitter, the test antenna, a step attenuator and the receiver. The transmitter's 2495 MHz sinusoidal source is internally phase modulated 180 degrees at 500 Hz. This signal was attenuated before entering the test antenna that is inserted into the bore of the cavity. The four plots below show the measured phase while the input is modulated at 500Hz and attenuated to -100 dbm, -110 dbm, -120 dbm and -130 dbm. The yellow trace is the received signal strength indicator (RSSI) that is AC coupled. A measurement of RF power can be made using the offset level, the number in the lower left (yellow) box on the oscilloscopes screen. The receiver is able to make phase measurements below the minimum RSSI voltage that functions to about -110 dbm. The receivers performance improves when the I/Q modulation is 1 kHz, near the top end of the Pockels cells operating frequency.



The Cavity: The ring coupled cavity was constructed to resonate its TE_{011} mode at 2495 MHz, and to suppress TM modes that could be driven by the beams charge. The TE_{011} mode has fields that are orthogonal to, or insensitive to the beams charge. Rather being driven by the passing charge, this mode is driven by current induced in the copper ring by the magnetic field of the passing electron bunch (Lenz's law). The cavity is constructed from a stack of rings, eight threaded posts, and Teflon spacers. The TE_{011} mode has purely azimuthal wall currents, so this mode is unaffected by the segmentation of the cavity, while the TM modes, the modes usually driven by the passing charge, are suppressed by it. The cavity is built onto a 10" Conflat flange and has its antenna on the cavities end wall. Connection to the coaxial vacuum feedthrough allows the excitation of the TE_{011} resonance to be measured externally.



The center frequency of the TE_{011} mode can be tuned with by very slightly tightening or loosening the nuts on the eight threaded rods; compression of the cavity stack increases its resonant frequency, while loosening the nuts lowers the resonant frequency. This was done prior to shipping while using a network analyzer's transmission measurement from the test antenna to the cavity antenna. The cavity was shipped tuned to 2495 MHz, having an unloaded Q of 15,000. A heating blanket and temperature controller could be used to adjust and maintain the center frequency if desired.