1. Purpose of Experiments
Include immediate goal of the experiments, scientific importance and/or programmatic relevance. Refer to any relevant program milestones.

The purpose of this experiment is to measure the Faraday rotation in MSE optics that can affect the polarization angle measured by the MSE diagnostic system. This is a small experiment that requires only 8 to 12 Ohmic plasmas.

2. Background
Discuss Physics Basis of the proposed research. Prior results at Alcator or elsewhere, and any related work being carried out separately.

Linearly polarized light that propagates through a medium can change its polarization angle when a magnetic field is applied in the propagation direction. If a polarimetric system includes media in a magnetic field like C-Mod MSE, this effect can cause significant errors in the measurement. MSE systems in many tokamaks including C-Mod, therefore, adopt low Verdet constant (V) optical media, e.g. SFL6 (V < 0.05 rad/mT), to minimize this effect.

However, there are some possibilities in the C-Mod polarimetry that residual Faraday rotation can exist. The transmissive optics in the photoelectric modulators (PEM) are made of fused silica, which has a high Verdet constant (~ 3.84 rad/mT). The objective lens (L1), although made of SFL6, is subject to a high toroidal magnetic field in the light propagation direction. The newly installed invessel wire-grid type polarizer (WGP) is embedded in a normal high Verdet-constant glass substrate.

Spare lenses and a spare vacuum window purchased at the same time as those currently in use were tested in the lab using high field permanent magnets (0.25 T at maximum). The results showed most of the invessel components were within the specified Verdet
constant for SFL6 but some are 2 to 3 times the specified value [1]. In-vessel Faraday rotation measurement using one of the equilibrium field coils (EF4) was done during the last in-vessel calibration period. With \( B_r \sim 0.005 \) T, the total change in the polarization angle was about \( 0.01^\circ \) with large uncertainty [2].

Recent measurements utilizing the in-vessel WGP and longer data acquisition time in the normal plasma discharges at full fields show (1) a reasonably consistent rotation of measured polarization angle across all MSE channels that scales linearly with toroidal magnetic field and (2) small (less than measurement error) changes in measured polarization angle with poloidal magnetic field [3, 4]. In these measurements, however, changes in toroidal and poloidal fields are not isolated. In addition, shot-to-shot changes in the polarization direction of up to \( 0.2^\circ \) were observed in some measurements. More dedicated experiments are necessary to get definitive results.

3. Approach
Describe the methodology to be employed; explain the rationale for the choice of parameters, etc. Describe the analysis techniques to be employed in interpreting the data, if applicable. If the approach is standard or otherwise self-evident, this section may be absorbed into the Experimental Plan.

To make a polarized light source, the in-vessel WGP installed on the MSE shutter will be used, which dispenses with the use of DNB. To eliminate possible shot-to-shot changes in the polarization angles due to, for example, small variations of the shutter (WGP) orientation, a reasonably wide range of \( B_T \) or \( I_p \) ramps in a single shot is desirable. As reference shots for these, \( B_T \) and \( I_p \) flattop shots are necessary.

- Proposed plasma waveforms for the \( B_T \) ramp with constant \( I_p \): Figure 1
- Proposed plasma waveforms for the \( B_T \) flat with constant \( I_p \): Figure 2
- Proposed plasma waveforms for the \( I_p \) ramp/flat with constant \( B_T \): Figure 3

In order to reduce statistical uncertainties, shots with the same conditions will be repeated several times. The detailed shot sequence is given in Section 5.

4. Resources

4.1 Machine and Plasma Parameters
Give values or range for:

- Toroidal Field: \( 2.5 \sim 6.5 \) T
- Plasma Current: \( 0.3 \sim 1.0 \) MA
- Working Gas Species: D\( _2 \)
- Density: \( 0.8 \times 10^{20} \) \( m^{-2} \) \( \leq \) \( N_L04 \) \( \ll \) Greenwald limit
- Equilibrium configuration: 1050718004 for \( B_T \) ramp/flat shots
  1050629023 for \( I_p \) ramp/flat shots

4.2 Auxiliary Systems
RF Power, pulse length, phasing: none
Pellet Injection (species): none
Impurity blow-off injection: none
Diagnostic Neutral Beam: none
Special gas puffing: none
Non-axisymmetric Coils (Connections, Current): none
Other: none

4.3 Diagnostics
List required diagnostics, and any special setup or configuration, e.g. non-standard digitization rate.

MSE in normal operation conditions

5. Experimental Plan
Both sections must be filled in.

5.1 Run sequence Plan
Specify total number of runs required, and any special requirements, such as consecutive days, no Monday runs, extended run period – 10 hours maximum – etc.

Half a day run is expected.

5.2 Shot sequence plan
For each run day, give detailed specification for proposed shot sequence: number of shots at each condition, specific parameters and auxiliary systems requirements, etc. Include contingency plans, if appropriate.

See Table 1.

6. Anticipated Results
Discuss possible experimental outcomes and implications. Indicate if the program may be expected to lead to publications, milestone completions, improved operating techniques, etc. Indicate if the experiments are intended to contribute to a joint research effort, or an external database.

(1) Fairly definitive results about Faraday effect on the measured polarization angle by toroidal and poloidal fields separately
(2) Similar experiments can be proposed to examine the birefringence by the vacuum window by changing the torus pressure.
(3) Separate effects of radial and vertical fields still needs to be examined.

7. References
Include references both to external and internal literature or communications which bear on this proposal. See Section 2.

[1] C-Mod MSE 2004 calibration website


Figure 1. Proposed plasma waveforms for the $B_T$ ramp shots (1050718004). The blue dashed line shows the start of the Ip rampdown at 1.5 sec. The black lines are the original waveform, and the red lines represent the proposed changes.
Figure 2. Proposed plasma waveforms for the $B_T$ flat shots (1050718004). The blue dashed line shows the start of the Ip rampdown at 1.5 sec. The black lines are the original waveform, the red solid lines represent the proposed changes for the $B_T$ ramp shots (same as Figure 1), and the red dashed line in $B_T$ waveform indicates the proposed changes for the $B_T$ flat shots.
Figure 3. Proposed plasma waveforms for the Ip ramp/flat shots (1050629023). The blue dashed line shows the start of the Ip rampdown at 1.5 sec. The black lines are the original waveform, the red solid line in Ip waveform represents the proposed changes for the Ip ramp shots, and the red dashed line indicates the proposed changes for the Ip flat shots.
<table>
<thead>
<tr>
<th>shot #</th>
<th>target</th>
<th>Bt (T)</th>
<th>IP (MA)</th>
<th>other conditions</th>
<th>WGP position (cm)</th>
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<td>1</td>
<td>Bt flat</td>
<td>5.4</td>
<td>0.5</td>
<td>1050718004</td>
<td>173 (nominal)</td>
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<tr>
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<td>0.5</td>
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<td>173 (nominal)</td>
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<td>Bt ramp</td>
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<td>0.5</td>
<td>1050718004</td>
<td>173 (nominal)</td>
</tr>
<tr>
<td>4</td>
<td>Bt ramp</td>
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<td>0.5</td>
<td>1050718004</td>
<td>173 (nominal)</td>
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<tr>
<td>5*</td>
<td>Ip flat</td>
<td>5.4</td>
<td>0.8</td>
<td>1050629023</td>
<td>173 (nominal)</td>
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<tr>
<td>6</td>
<td>Ip flat</td>
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<tr>
<td>8</td>
<td>Ip ramp</td>
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<td>1.0 -&gt; 0.3</td>
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<td>173 (nominal)</td>
</tr>
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</table>

*(If time permits, do the following)*

<table>
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<th>shot #</th>
<th>target</th>
<th>Bt (T)</th>
<th>IP (MA)</th>
<th>other conditions</th>
<th>WGP position (cm)</th>
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<tr>
<td>11</td>
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<tr>
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<td>1.0 -&gt; 0.3</td>
<td>1050629023</td>
<td>173 (nominal)</td>
</tr>
</tbody>
</table>

*For Ip ramp shots, there will be trade-off between higher TF and rep rate. Some shots prior to the main Ip ramp test can be dedicated to determine appropriate TF and upper limit of Ip.*

Table 1. Shot sequence and conditions