Experimental validation of Mueller-Stokes theory and investigation of the influence of the Cotton-Mouton effect on polarimetry in a magnetized fusion plasma

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Abstract. Mueller-Stokes theory can be used to calculate the polarization evolution of an electromagnetic (EM) wave as it propagates through a magnetized plasma. Historically, the theory has been used to interpret polarimeter signals from systems operating on fusion plasmas. These interpretations have mostly employed approximations of Mueller-Stokes theory in regimes where either the Faraday rotation (FR) or the Cotton-Mouton (CM) effect is dominant. The current paper presents the first systematic comparison of polarimeter measurements with the predictions of full Mueller-Stokes theory where conditions transition smoothly from a FR-dominant (i.e. weak CM effect) plasma to one where the CM effect plays a significant role. A synthetic diagnostic code, based on Mueller-Stokes theory accurately reproduces the trends evident in the experimentally measured polarimeter phase over this entire operating range, thereby validating Mueller-Stokes theory. The synthetic diagnostic code is then used to investigate the influence of the CM effect on polarimetry measurements. As expected, the measurements are well approximated by the FR effect when the CM effect is predicted to be weak. However, the code shows that as the CM effect increases, it can compete with the FR effect in rotating the polarization of the EM-wave. This results in a reduced polarimeter response to the FR effect, just as observed in the experiment. The code also shows if sufficiently large, the CM effect can even reverse the handedness of a wave launched with circular polarization. This helps to understand the surprising experimental observations that the sensitivity to the FR effect can be nearly eliminated at high enough $B_T = 2.0$ T. The results also suggest that the CM effect on the plasma midplane can be exploited to potentially measure magnetic shear in tokamak plasmas. These results establish increased confidence in the use of such a synthetic diagnostic code to guide future polarimetry design and interpret the resultant experimental data.

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