Faraday rotation and polarization-modulated intense laser pulses in a field-ionizing gaseous medium

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As a linearly polarized light propagates in a transparent medium for a distance with the assistance of an axial external magnetic field, its plane of polarization undergoes a rotation, which is known as Faraday rotation. In our work, we investigate the propagation of an intense linearly polarized laser through an ionizing gaseous medium in the presence of an axial strong magnetic field, addressing the time-dependent modulation of laser polarization. Our simulation indicates that the laser polarization can be dramatically modulated and shows complicated temporal patterns (Lissajous curves). This striking phenomenon can be attributed to the collective movement of ionized electrons, in contrast to the traditional Faraday rotation in which the rotation angle of the laser polarization derived from the linear response of the medium is time-independent. We take the weighted average of the rotation angle over the whole pulse duration, and find that it explicitly relies on strong magnetic strength as well as the incident laser intensity. This finding has implications in strong magnetic diagnosis, laser intensity calibration, and the generation of polarization-modulated light sources.