Visualization of magnetic fields with cylindrical vector beams in an atomic vapor

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The atomic magnetometer based on the optically pumping or coherent resonance plays an essential role in measuring of the magnitude and direction of the magnetic field. The most common applications rely on homogeneously polarized beams and display the response to a vector magnetic field in the optical spectrum. Here, we utilize spatially varying polarization beams, so-called vector beam (VB) [1], to explore the visualization of arbitrary magnetic fields. The laser frequency is locked to the $5S_{1/2}, F = 2 \rightarrow 5P_{1/2}, F' = 1$ transition of the ^{87}Rb D1 line. A radially polarized VB that traverses an atomic vapour will generate an absorption pattern with a petal-like structure by the mediation of a transverse magnetic field (TMF). The spatial absorption pattern rotates when the transverse magnetic field's azimuthal angle is changed, while its contrast decreases when the longitudinal component of the magnetic field increases as shown in Fig. 1 (a). By analyzing the intensity distribution of the transmitted pattern, we can determine the magnetic field intensity and orientation. We also demonstrate transmitted patterns for different topological charges of the VB as shown in Fig. 1 (b), which are in agreement with the original observation of phase-dependent dark states in cold atoms [2].

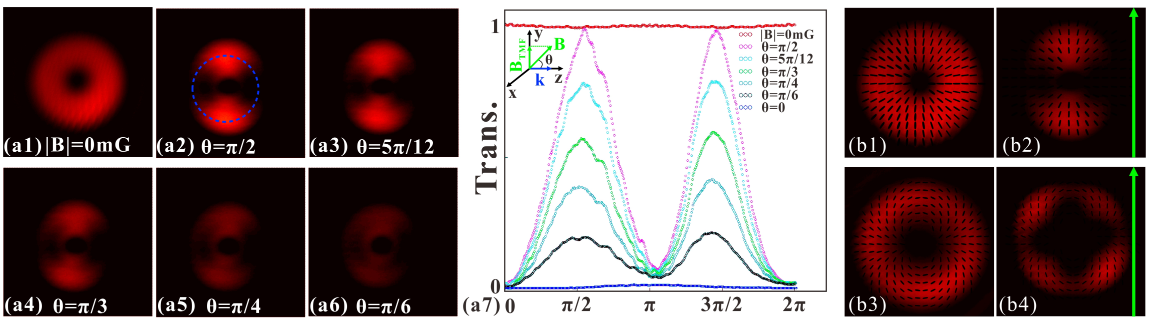

Figure 1. (a) The experimental results of the radially polarized VB in presence of the spatial magnetic field with fixed intensity ((a1): $|\mathbf{B}| = 0mG$, (a2) - (a6): $|\mathbf{B}| = 230mG$). (a7) Polar plots for different angle θ. (b) Polarization and intensity profiles for VBs with different polarization topological charges with and without TMF ($|\mathbf{B}_{\mathrm{TMF}}| = 230mG$).

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[2] N. Radwell, T. W. Clark, B. Piccirillo, S. M. Barnett, and S. Franke-Arnold, Spatially dependent electromagnetically induced transparency, Phys. Rev. Lett., **114**, 123603 (2015).