Rabi amplitude nulling for laser beam attitude measurements (RANBA)

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One of the key challenges in vector magnetometry is maintaining consistent directional measurements despite sensor orientation drift. This issue can be addressed by referencing the sensor axes to the attitude of a laser beam. In this work, we demonstrate RANBA to reference an atomic magnetometer frame to a laser beam. This novel technique determines the attitude of a probe beam by identifying the DC magnetic field directions that null the Faraday rotation signal during Rabi oscillations between the hyperfine transitions of ^{87}Rb vapor. We demonstrate proof-of-concept measurements that determine laser beam attitude with a precision of 0.014°, consistently agreeing across different hyperfine transitions and microwave driving fields ($\vec{\mathcal{B}}_{\mu\mathrm{w}}$). Furthermore, we theoretically investigate sources of systematic error and show that in experimental realizable regimes that this technique could be accurate to within 0.003°. At this level of accuracy, RANBA could be useful for vector gradiometry calibration, high-accuracy spatial magnetic field maps, and referencing magnetic fields to non-magnetic objects.

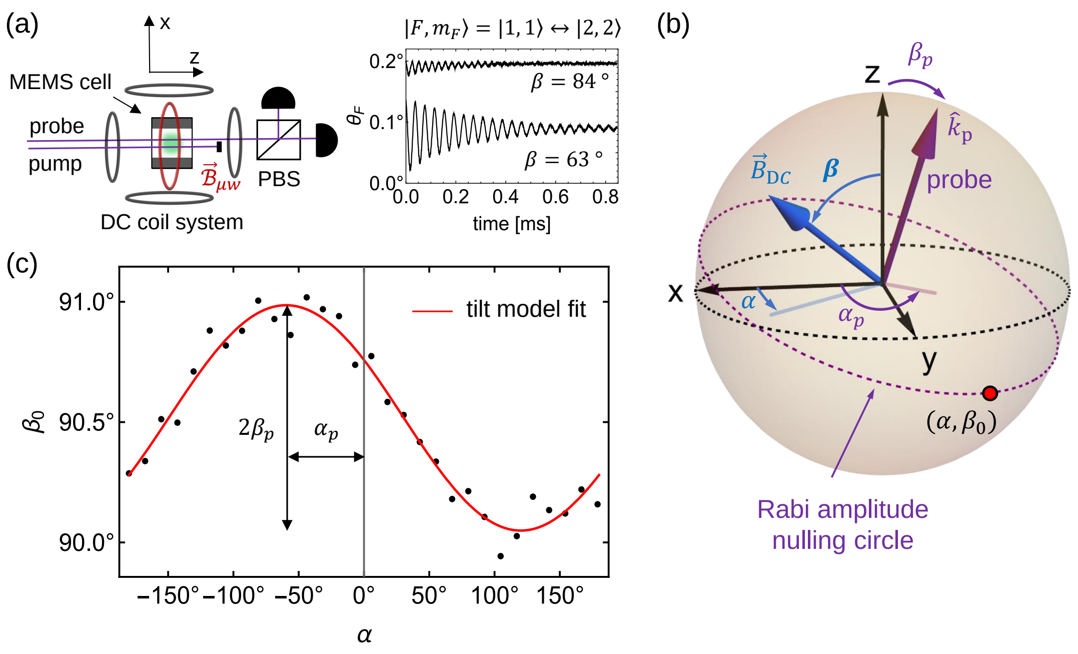

Figure 1. (a) Experimental setup (left) for detecting microwave-driven Rabi oscillations between the hyperfine manifolds of ^{87}Rb (right). (b) Schematic of the magnetic field $\vec{B}_{\mathrm{DC}}$ and the probe beam within the DC coil system frame. Rabi oscillation signals null when $\vec{B}_{\mathrm{DC}} \perp \hat{k}_p$. (c) Measured nulling circle points. Amplitude and offset of the probe tilt model gives the polar and azimuthal directions of the probe beam in the coil system frame.