Tata Institute of Fundamental Research
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Internal Seminar

Optical Magnetometry: Detection of weak magneto-optical rotation using weak-measurement technique

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Optical magnetometry is a technique of using linear polarized light beam to detect magnetic field in an atomic medium, using the principle of resonant magneto-optical or Faraday rotation. The technique is fast gaining significance in a variety of fundamental and applied research activities due to its unprecedented measurement sensitivities comparable to SQUID, which required cryogenic refrigeration.

The sensitivity of optical magnetometer, δB_z, to longitudinal magnetic field,

$$\delta B_z = \left(\frac{\partial \emptyset}{\partial Bz}\right)^{-1} \delta \emptyset$$

depends on the slope of magneto-optical rotation with respect to longitudinal magnetic field and least optical rotation that can be measured. The conventional balanced polarimetry technique's sensitivity is limited by photon-shot noise, which can be improved by using frequency and amplitude modulated light beam. But instead we introduce a new method, Weak Measurement (WM) technique to increase the sensitivity. The weak measurement technique is an optical analogue of the weak value concept introduced by Aharonov et al. in 1988 using the Stern-Gerlach device and it consist of three stages, pre-selection of polarization state of light beam, weak interaction between an uni-axial crystal (Soleil-Babinet Compensator (SBC), variable phase-retarder) and light beam leading to polarization gradient across the beam cross-section and finally post-selecting orthogonal polarization state w.r.t initial state. The smallest weak optical rotation we measured in our lab is 12.7 µrad, three times less than the theoretical photon short noise limit of 46 µrad using the balanced polarimetry technique. The weak measurement technique opens a new way of measuring small optical rotation, replacing SBC with wave-plates like QWP and HWP may give higher/controllable slope than we have today.

In future the achieved sensitivity B_z can be further reduced to ~pT by going to non-linear magneto-optical rotation regime using spin exchange relaxation-free (SERF) configuration.

Thursday, Sep 27th 2018

4:00 AM (Tea/Coffee at 9:30 AM)

Seminar Hall, TIFR-H