**Magneto-Raman Spectroscopy on Correlated Electron System -RuCl3**

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**Introduction**

One of the very elusive and intriguing states of matter is a quantum spin liquid (QSL) where quantum fluctuations hinder long range order at low temperatures. Recently, it was suggested that a two-dimensional QSL might manifest in a spin-orbit coupled Mott insulator such as -RuCl3 with honeycomb lattice [1]. Optical spectroscopy and Raman scattering studies on -RuCl3 performed at low temperatures identified elementary excitations due to electronic correlations and spin-orbit coupling [2]. In particular, low temperature Raman scattering revealed a broad continuum of magnetic scattering at very low energies (below 25 meV) which was found to persist at temperatures much higher than the magnetic ordering temperature suggesting the presence of frustrated magnetic interactions [2]. Furthermore, specific heat and magnetic susceptibility measurements also found evidence for unconventional magnetism driven by spin-orbit coupling and electronic correlations [3]. The observations appear to be consistent with theoretical expectations for Heisenberg-Kitaev model for QSL [4].



**Experimental**

Magneto-Raman spectroscopy was performed on a single crystal of -RuCl3. The Raman spectra were measured in a backscattering Faraday geometry using a 532 nm laser excitation. The collected scattered light was guided via an optical fiber to a spectrometer equipped with a liquid-nitrogen-cooled CCD camera. The sample was placed on X-Y-Z actuator to obtain the best alignment as well as for position selectivity. Raman spectra were collected for over long acquisition times at temperature of 6 K and magnetic fields from 0 T to 17 T in steps of 1 T.

**Results and Discussion**

The plot of Raman spectra of RuCl3 as a function of magnetic fields up to 17 T at temperature of 6 K is shown in the **Fig. 1**. The three phonon modes were observed with reasonable signal-to-noise ratio within the energy range of 200-400 cm−1 in agreement with previous report at zero magnetic field [2]. Although the changes in the measured spectra with the application of magnetic fields up to 17 T are small, the A1*g* phonon at about 312 cm−1 seems to lose intensity with increasing magnetic field.

**Fig. 1.** Plot of Raman spectra of -RuCl3 at the temperature of 6 K in magnetic fields up to 17 T. The observed phonon modes are in agreement with the literature [2]. Inset shows the comparison of intensity of phonons at 0 T and 17 T.

**Conclusions**

Magneto-Raman spectroscopy on the QSL compound RuCl3 was successfully performed at temperature of 6 K and magnetic fields up to 17 T. Although there appears to be a small change in the intensity of *A1g* phonon, the changes due to rotation of polarization at magnetic fields could not be fully eliminated. Therefore, further measurements will be performed using a direct optics probe with no optical fibers in the magnetic fields to obtain unambiguous results.

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**References**

[1] Plumb, K.W., *et al*., Phys. Rev. B, **90**, 041112 (2014).

[2] Sandilands, L.J., *et al*., arXiv:1503.07593 and Phys. Rev. Letters **114**, 147201 (2015).

[3] Sears, J.A., *et al*., Phys. Rev. B, **91**, 144420 (2015).

[4] Kim, H.-S., *et al*., Phys. Rev. B, **91**, 241110 (2015).