Angle-Resolved, Polarized Raman Spectroscopy of (quasi) 2D Quantum Magnets

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The National High Magnetic Field Laboratory is supported by the National Science Foundation through NSF/DMR-2128556 and the State of Florida*

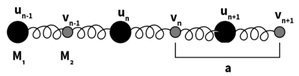
Introduction

Angle-Resolved Raman (ARPR) spectroscopy is a powerful technique to probe energies and symmetry of quasi-particle excitations in condensed matter systems. Raman scattering sensitivity to the lattice, spin, charge degrees of freedom and to electron-phonon, and spin-phonon interactions make ARPR spectroscopy an exceptional tool for studying low-dimensional quantum magnets. Here, we outline the plan for the development of an automated ARPR setup coupled to the existing 14T magneto-Raman system and then apply it to investigating selected quasi-2D quantum magnets.

Background

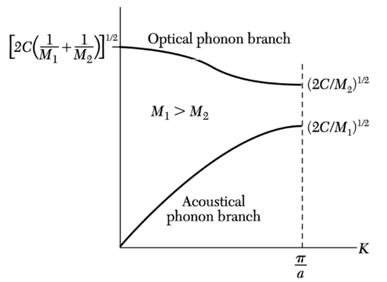
Raman Scattering

A simplified model of collective vibrations of atoms in a one-dimensional diatomic chain is presented:



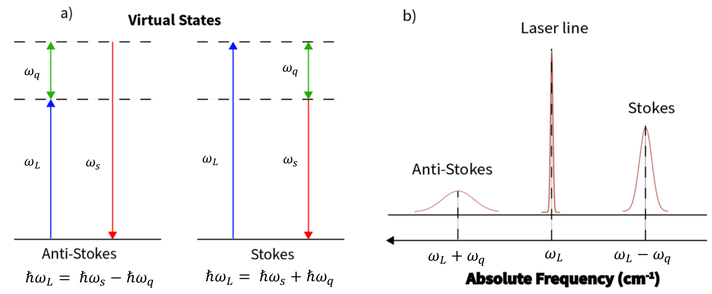
Equation of Motion:

$$M_1 \frac{d^2u_n}{dt^2} = -C(2u_n - v_{n+1} - v_{n-1})$$
$$M_2 \frac{d^2u_{n+1}}{dt^2} = -C(2v_n - u_{n+1} - u_n)$$

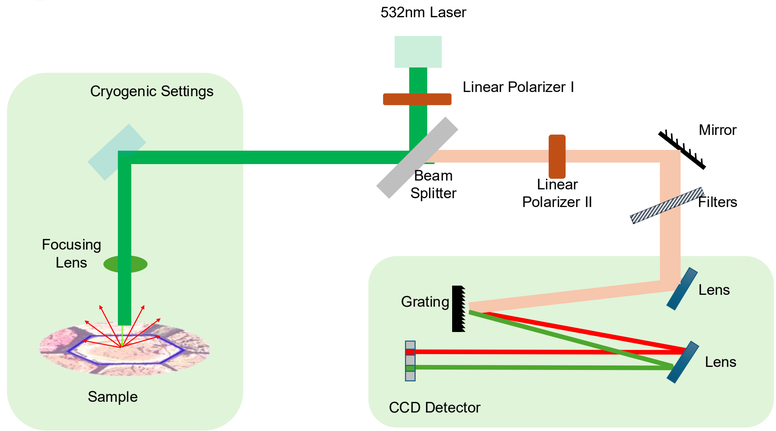


Kittel C. *Introduction to Solid State Physics*. 8th ed. Wiley; 2005.

Illustration of Stokes and Anti-Stokes scattering

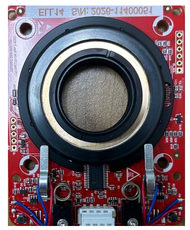


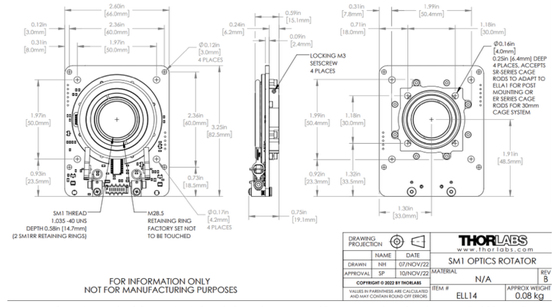
Setup



Adjustment to Setup

The polarization-control components will be motorized using ELL14 motors from Thorlabs with the control system managed by LabView.



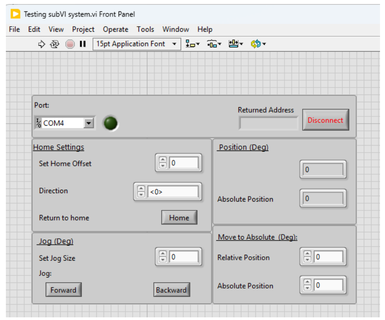


https://www.thorlabs.com/sm1-threaded-rotation-mount-with-resonant-piezoelectric-motors?tabName=Specs

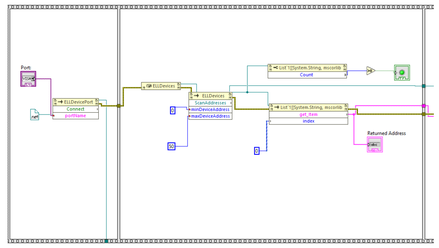
Adjustment to Setup

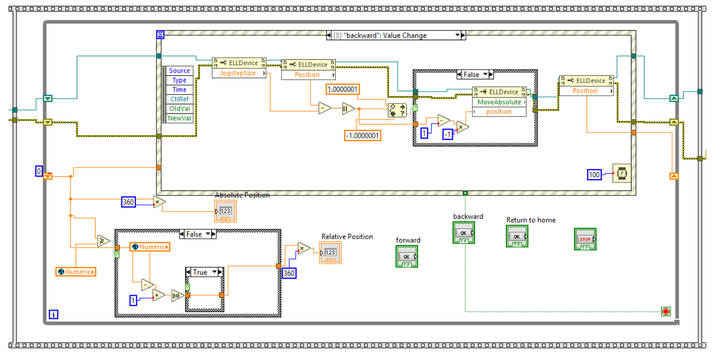
To coordinate the new polarizers with the existing setup's software, the control system must be created in LabVIEW.

Front Panel



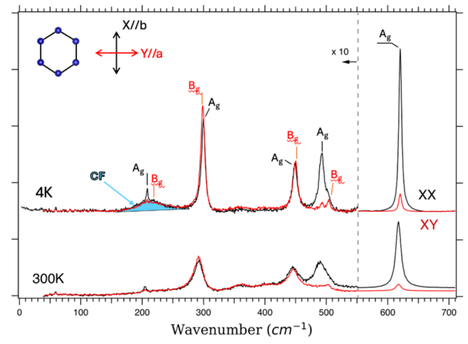
Block Diagram

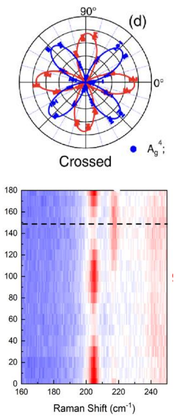




Future Analysis

The steps for analysis are demonstrated by ARPR Raman data of $Na_3Co_2SbO_6$.





$$I \propto \left| e_s^{\dagger} \cdot R \cdot e_i \right|^2$$

e_s = Polarization of scattered light
I = Intensity of light
R = Raman tensor for the given mode
e_i = Polarization of incident light

Result and Future Applications

After software developments are complete, The motors would be added to existing setup. Eventually, this technique would be applied to analyze 2D quantum magnets, where the first-order Raman scattering can give information about the dynamics present in the material.