ESF short Visit - Report

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Part One

Raman scattering from an ideal spin 1/2, Kagome compound

Experiment goals

The goal of the experiment is to measure the Raman spectrum in different directions and different polarization of the new compound Cu(1,3-benzenedicarboxylate) (blue Kagome, henceforth). The spectrum will be analyzed in the search of several features:

- magnon Raman scattering. This can serve for the determination of the values of the exchange interaction in different directions.
- The phonon spectrum. The aim is to see if there are any changes from room temperature to low temperatures.
- asymmetric phonon line shapes. These may be due to the Fano effect, which is due to the interaction of the phonon with continuous spectrum of excitations of presumably magnetic origin.

Experimental setup

The spectrum was measured using the JY-LabHR micro-Raman system. Because the crystals are quite small (dimensions of about $0.5\times0.5\times0.1$ mm) The measurement of the ac plane is possible only using a microscope. Furthermore the micro-Raman system gives good SNR in relatively short measurement time. The disadvantages are low resolution, and low sensitivity to low signals at high shifts. Another disadvantage is that the measurement is limited to shifts greater than $100cm^{-1}$.
The laser was a 532nm DPSS laser with output power of about 5mW. To prevent damage to the sample when using a high magnification microscope lens, a neutral density filter was used to reduce the incident power to about 0.5mW. The laser light was focused on the sample using a $\times50$, long working distance, microscope objective. Backscattered light was collected using the same lens. The first filtration stage was a notch filter with less than $100cm^{-1}$ width. The second stage was an 1800grooves/mm holographic grating. The entrance slit was opened to 100μm. The range of the measurement was $100cm^{-1}-4000cm^{-1}$. This range required 12 measurements windows. For each window the exposure time was 1000sec and the measurement was averaged over 3 runs. The total measurement time of a single spectrum was therefore 10 hours.
The determination of the exposed plane of the crystal is done by looking for a 120° angle between sides. These angles are visible in the ab plane. This is shown in Fig. 1.

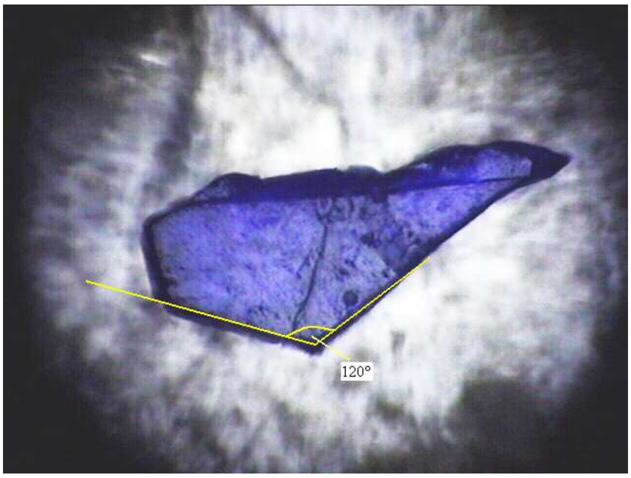

Figure 1: An image of a blue Kagomé with the ab plane faces up

Results

The following figures (Fig.2 and Fig.3) show full spectra in two different directions and two temperatures as indicated in the figures. These spectra were corrected for a wave-number dependent background of the spectrometer. In order to see the details, the full spectrum should be divided into several windows. This is not shown in this short report.

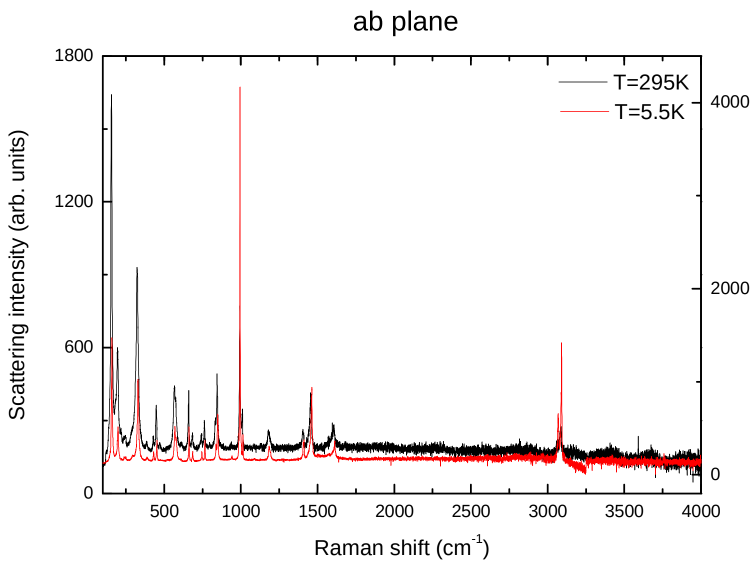

Figure 2: ab plane full spectrum at 295K and 5.5K

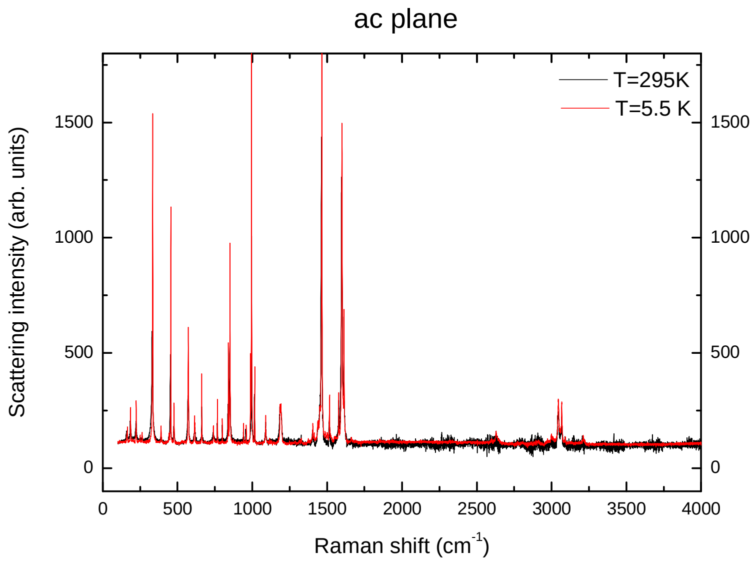

Figure 3: ac plane full spectrum at 295 K and 5.5 K

Discussion

A view of the results in light of the initials goals

<u>Magnon Raman peak</u>

- The spectrum taken does not show any sign of such a peak. It is most probable that the value of the superexchange interaction is as low as few degrees of Kelvin. In such a case, the expected magnon peak is at few 10cm^{-1} at most. When using the LabHR spectrometer it is not possible to measure at this low range. Dedicated experiments in the low energy regime are under preparation. As they require low frequency resolution they need a time consuming fine adjustment of the scattering geometry.

<u>Phonon at different temperatures</u>

- There are several peaks that appear in the room temperature data but not at low temperatures. These maybe forbidden transitions presumably enhanced by thermal fluctuations.

<u>Asymmetric phonons</u>

- There are 3 asymmetric peaks (at 750cm^{-1} ,2630cm^{-1} and 3211cm^{-1}) which may be related to the Fano effect.

Analysis of the number of the Raman active modes and their selection rules for the blue kagomé.

In this short visit I learned how to use the results of group theory to count the number of allowed modes and their selection rules. This was applied to the Kagomé system.

The result is that there are 122 Raman active modes, 78 of them are expected to appear in the ab-plane and 70 are expected to appear in the ac-plane.
The number of observed mode is less than half of the expected. This might be attributed to the fact that due to time constraint not all scattering geometries could be probed.

Conclusion

The preliminary results show that the blue Kagome has a rich Raman spectrum that needs to be studied carefully. The measurement presented here may serve as a general guideline for the preparation of future measurements, especially in the low frequency regime and in the vicinity of the 750cm^{-1} ,2630cm^{-1} and 3211cm^{-1} asymmetric lines.
Future collaboration is planned in making the necessary measurements and analyzing the results.

Part Two

Raman Scattering from anitferromagnetic CLBLCO film

Background

In this experiment we want to look on the Raman spectrum of a film of the antiferromagnetic compound $(Ca_xLa_{1-x})(Ba_{1.75-x}La_{0.25+x})(Cu_3)O_y$ (acronym CLBLCO) This antiferromagnetic compound is the parent compound of the CLBLCO high temperature superconductor. From a careful study of the phase diagrams and other properties (such as staggered magnetization and anisotropy) of the different varieties (meaning different x) of CLBLCO it has been suggested that $T_c^{\max} \propto J$ ($T_c^{\max}$ being the maximal transition temperature to the superconducting state and J is the Heisenberg coupling constant). It is known that J can be measured using Raman scattering by finding the two-magnon Raman peak, $\omega_{2magnon}$, and using $J = \frac{\omega_{2magnon}}{\sim 3}$.
We wish, therefore to examine the magnetic spectrum of the different x content CLBLCO's and look for correlations between the magnon Raman peak and Tc

Experiment goals

1. Measure the Raman spectrum of a film of CLBLCO and a crystal, compare the results and answer the question "Is it possible to do reliable Raman scattering on films?"
2. Measure the Raman spectrum of the CLBLCO film at higher energies in order to detect the two-magnon peak and extract the value of J .
3. Measure the optical phonons and identify them.

Results

To address goal number 1 we measured both a crystal and a film, the result is shown in Fig. 4

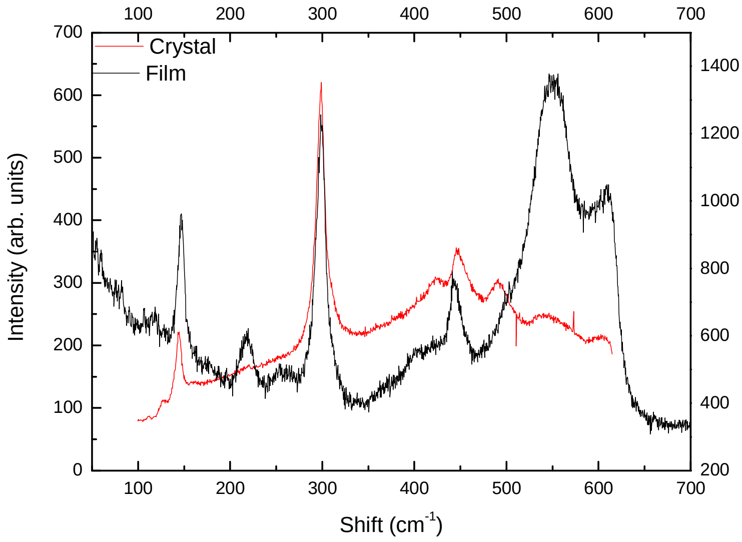

Figure 4: Optical phonons of a crystal and a film of CLBLCO

The two spectra have enough in common to suggest that the film is a good form of CLBLCO.

To address the second experimental goal, Figure 5 shows the magnon Raman peak at about 2500 cm^{-1}

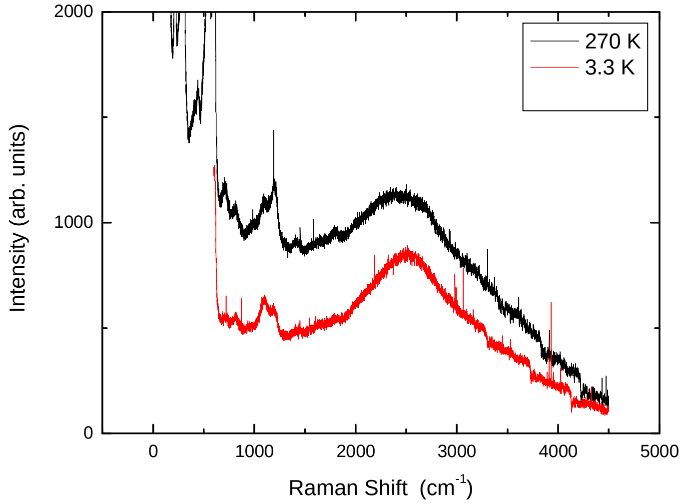

Figure 5: Two magnon Raman peak in CLBLCO (x=0.1).

To address the third goal the optical part of the spectrum was studied for different polarizations, and compared to known results from YBCO [Liu *et. al* PRB **37** 7973 (1988)] . This is shown in Fig. 6

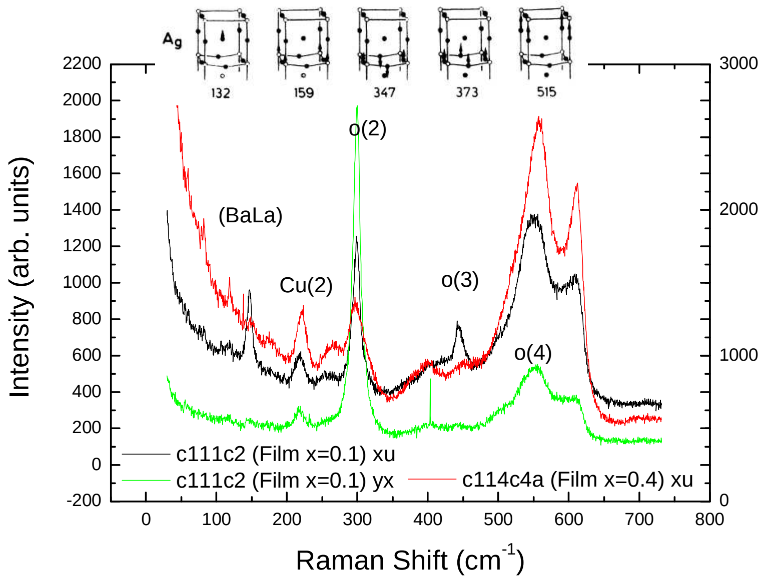

Figure 6: Optical modes in CLBLCO.

Conclusions

It is possible to get good Raman spectra from films of the CLBLCO system.
It is possible to identify the two magnon Raman peak from such films. From the two-magnon Raman peak of the x=0.1 film we find that $J = 1190 \pm 50$K in good accord to previous values (based on calculations or indirect measurements).
All 5 optical modes for the $\vec{k} \parallel \hat{c}$ configuration were observed for the x=0.1 sample.
It is desirable to continue this study and measure other x values of this compound.
Future collaboration is planned in preparing more samples, making the necessary measurements and analyzing the results.