Laser diode floating zone growth of ultrahigh-purity crystals for Skyrmion Qubits

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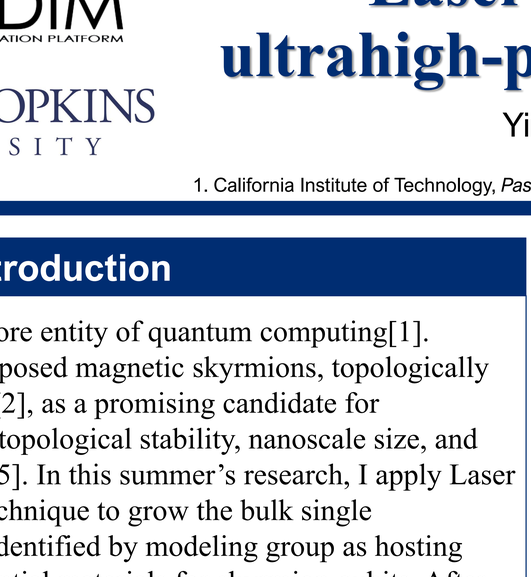
Introduction

A quantum bit, or qubit, is the core entity of quantum computing[1]. Recently, theoreticians have proposed magnetic skyrmions, topologically protected swirling spin textures[2], as a promising candidate for macroscopic qubits due to their topological stability, nanoscale size, and helicity-based characteristics[3-5]. In this summer's research, I apply Laser Diode Floating Zone (LDFZ) technique to grow the bulk single crystals:$Gd_3Ru_4Al_{12}$, which is identified by modeling group as hosting nanoskyrmions, to develop potential materials for skyrmion qubits. After crystal growth, X-Ray Diffraction (XRD) methods were used to characterize the crystal's structure properties.

Methods

Arc-melting → Laser diode floating zone(LDFZ)

Arc melting was used to synthesize homogenous buttons of metallic materials. These buttons were then arc melted together to create rods for subsequent floating zone growths

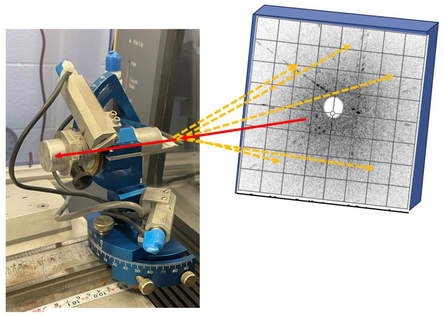


Single crystals were grown using a laser diode floating zone(LDFZ) furnace. In the floating zone technique, two rods of matching composition($Gd_3Ru_4Al_{12}$)are melted using the laser heating source, joined together to form a molten zone, and then translated downwards to precipitate crystalline material on the bottom (seed) rod.

Results

The structure properties of grown single crystal $Gd_3Ru_4Al_{12}$ are characterized by Laue backscatter diffraction and X-ray powder diffraction method.

Laue backscatter diffraction



The crystal orientation and quality are determined by Laue backscatter diffraction.
The grown crystal is exposed to X-rays, which interact with the periodic atomic planes of the crystal and produce a pattern of diffraction spots on a detector, shown as the lattice points

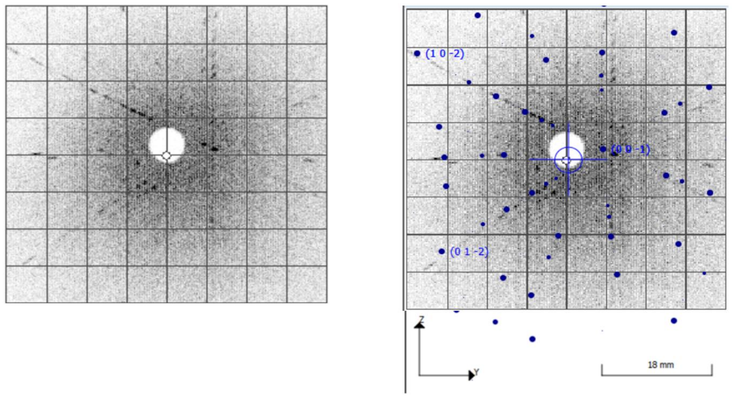


Figure1: Laue backscatter diffraction result of grown $Gd_3Ru_4Al_{12}$ crystal at <001> plane. The detected black dots were aligned with simulated lattice points(blue dots) confirmed that we grew the single crystal $Gd_3Ru_4Al_{12}$ as designed

Powder X-rav diffraction

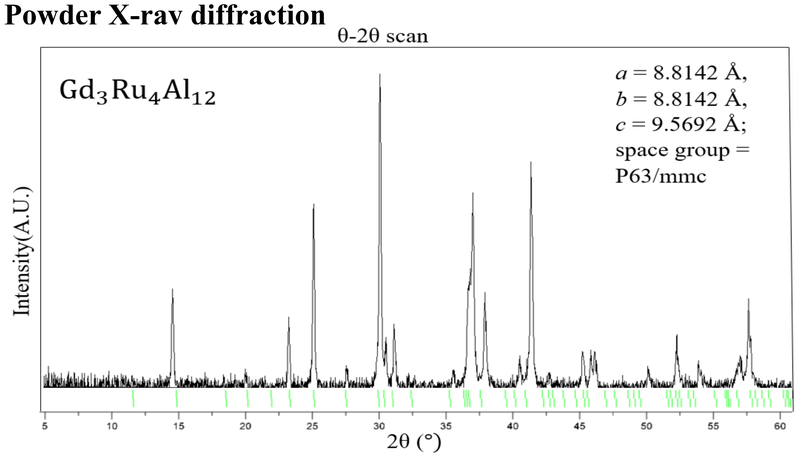


Figure2: the powder X-ray diffraction pattern of grown $Gd_3Ru_4Al_{12}$ single crystal. The peak positions and intensity are aligned with the positions calculated from ICSD file and confirmed the crystal's lattice constant and space group

Conclusions

$Gd_3Ru_4Al_{12}$ bulk single crystal were successfully synthesized by arc-melting and LDFZ. The XRD characterizations by Laue Diffraction and θ-2θ scans also confirmed the grown crystal structures as designed

Future Work:

- The magnetic and magneto-transport properties of grown crystals will be investigated using PPMS and MPMS.
- Grown single crystals will be cut and polished for further measurement

References

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